Investigating prevention, diagnosis and impact of surgical site infection

Dr Ross Lathan

MBChB, PGCertHPE, FHEA

Being a thesis submitted for the award of Doctor of Medicine (MD);

The University of Hull and The University of York

Hull York Medical School

September 2025

1 ABSTRACT

Surgical site infection (SSI) is the most common healthcare-associated infection, affecting up to 40% of surgical procedures depending on patient, operation, and specialty. Prevention and early recognition are essential to reducing morbidity and improving quality of life. Remote assessment offers opportunities to detect infections earlier, minimize patient travel and costs, and lessen environmental impact.

This thesis addresses the problem through a series of seven studies. Surveys of UK vascular surgeons and international practice reveal wide variation in SSI prevention across multiple domains, highlighting the absence of consensus. A systematic review of diagnostic test accuracy studies demonstrates that while remote assessment shows good screening potential for SSI (sensitivity 87.9%, specificity 96.8%), no research has assessed combined use of wound images and patient-reported data.

Building on these findings, a novel remote diagnostic tool—the ASSIST measure—was developed and validated. This 11-item instrument achieved excellent diagnostic accuracy (sensitivity 97.9%, specificity 92.5%, AUC 0.997). Subsequent studies quantified the impact of SSI on healthcare resources, showing a 62.5-fold increase in carbon emissions for patients with SSI compared to those without (643.8±1,276.4 vs 10.3±24.3 kgCO2e, $p<0.001$). Financial costs were similarly disproportionate (£8,355.08±18,144.84 vs £61.10±133.67 per patient, $p<0.001$). Implementing remote assessment in place of in-person review reduced emissions by 30.8±26.2 kgCO2e per patient (71.0% relative reduction, $p<0.001$) and lowered per-patient costs by £77.58 (87.0% relative reduction, $p<0.001$).

In conclusion, this thesis demonstrates significant variability in SSI prevention practices and the urgent need for evidence-based recommendations. The ASSIST measure shows high diagnostic accuracy and the potential to markedly reduce both financial and environmental burdens, supporting broader healthcare goals such as Net Zero 2045 and Darzi recommendations. Future work should assess this approach across other specialties and optimize remote delivery technologies.

2 PRESENTATIONS

Lathan R, Daysley H, Ravindhran B, Lim A, Cutteridge J, Sidapra M, Long J, Hitchman L, Beltran-Alvarez P, Carradice D, Smith G, Chetter I. "Environmental and Financial Cost of Surgical Site Infection by Severity following Lower Limb Vascular Surgery". *In* Vascular Societies ASM 2024, Brighton, UK, 27th November 2024.

Lathan R, Hitchman L, Walshaw J, Ravindhran B, Carradice D, Smith G, Chetter I, Yiaseidou M. "Postoperative Remote First Care for Financially and Environmentally Sustainable Healthcare in Surgical Site Infection" (Poster). *In* the Infection Prevention Society's Annual Conference 2024, Birmingham, UK, 24th September 2024.

Lathan R, Hitchman L, Ravindhran B, Sidapra M, Walshaw J, Lim A, Long J, Totty J, Smith G, Chetter I. "Validation of a combined clinician-patient reported diagnostic measure for identifying surgical site infection." *In* the Vascular & Endovascular Surgery Society Winter Meeting 2024, Sun Valley, Idaho, USA, 20th January 2024.

Lathan R, Hitchman L, Ravindhran B, Sidapra M, Walshaw J, Lim A, Long J, Totty J, Smith G, Chetter I. "ASSIST: Validation of a Novel Remote Outcome Measure for Diagnosis of Surgical Site Infection." *In* the Surgical Research Society Annual Meeting (ASiT session) 2024, Cambridge, UK, 12th January 2024.

Lathan R, Walshaw J, Hitchman L, Ravindhran B, Carradice D, Smith G, Chetter I, Yiaseidou M. "Telemedicine for Sustainable Follow-up: A Cost-Emissions Evaluation using a Hybrid Life-Cycle Assessment Approach to Carbon Footprint Analysis. *In* the Vascular Societies ASM 2023, Dublin, Republic of Ireland, 22nd November 2023.

Lathan R, Sidapra M, Yiasemidou M, Long J, Totty J, Smith G, Chetter I. "Telemedicine for the Diagnostic of Surgical Site Infection: A Systematic Review and Meta-Analysis" (Poster). *In* the Vascular Annual Meeting (VAM) 2023, Washington, District of Columbia, USA, 16th June 2023.

Lathan R, Walshaw J, Kwan JY, Hitchman L, Ravindhran B, Carradice D, Smith G, Chetter I, Lockwood S, Yiasemidou M. "Telemedicine for Sustainable Follow-Up: A Pilot Evaluation of the Hybrid Life-cycle assessment approach to carbon footprint analysis" *In* Association of Surgeons of Great Britain and Ireland (Sustainable Surgery Session) 2023, Harrogate, UK, 17th May 2023.

Lathan R. "Prevention of Surgical Site Infection: An International Pan-Surgical Survey of Practice." *In* the Vascular Societies ASM (Dragon's Den Session) 2022, Brighton, UK, 24th November 2022.

Lathan R, Yiasemidou M, Long J, Mohamed A, Hitchman L, Ravindhran B, Sidapra M, Carradice D, Smith G, Chetter I. "Prevention of Surgical Site Infection in Vascular Surgery: A National Survey of Practice." *In* the Vascular Societies ASM (Sol Cohen Prize Session) 2022, Brighton, UK, 24th November 2022.

Lathan R, Sidapra M, Yiasemidou M, Long J, Totty J, Smith G, Chetter I. "The Diagnostic Test Accuracy of Remote Follow-up for Detecting Surgical Site Infection." *In* the European Society of Vascular Surgery Conference 2022, Rome, Italy, 20th September 2022.

Lathan R, Sidapra M, Yiasemidou M, Long J, Totty J, Smith G, Chetter I. "The Diagnostic Test Accuracy of Remote or Virtual Follow-up for Detecting Surgical Wound Infection." *In* the Yorkshire Vascular Forum 2022, York, UK, 24th June 2022.

3 PUBLICATIONS

Lathan R, Hitchman L, Walshaw J, Ravindhran B, Carradice D, Smith G, Chetter I, Yiasemidou M. Postoperative Remote First Care for Financially and Environmentally Sustainable Healthcare. *Nature Partner Journals Digital Medicine.* 2025. *In press.*

Lathan R, Hitchman L, Walshaw J, Ravindhran B, Sidapra M, Lim A, Long J, Totty J, Carradice D, Smith G, Chetter I. ASSIST: Development of a Simplified Clinician-Patient Hybrid Reporting Outcome Measure for Remote Diagnosis of Surgical Site Infection. Int Wound J. 2025;22(4):e70234. DOI: 10.1111/iwj.70234.

Lathan R, Daysley H, Ravindhran B, Lim A, Cutteridge J, Sidapra M, Long J, Hitchman L, Beltran-Alvarez P, Carradice D, Smith G, Chetter I. Environmental and financial cost of surgical site infection by severity following lower limb vascular surgery. *BJS Open.* 2025, 7;9(3):zraf015. DOI: 10.1093/bjsopen/zraf015

Lathan R, Hitchman L, Walshaw J, Ravindhran B, Carradice D, Smith G, Chetter I, Yiasemidou M. Telemedicine for sustainable postoperative follow-up: a prospective pilot study evaluating the hybrid life-cycle assessment approach to carbon footprint analysis. *Frontiers in Surgery.* 2024; 11. DOI: 10.3389/fsurg.2024.1300625

Heinz J, **Lathan R**, Walshaw J, Kwan JY, Long J, Carradice D, Totty J, Kontouli KM, Lainas P, Hitchman L, Smith G, Huo B, Guadalajara H, Garcia-Olmo D, Sharma D, Biyani CS, Tomlinson J, Loubani M, Galli R, Chetter I, Yiasemidou M. PRESS Survey: PREvention of surgical site infection – a global pan-specialty survey of practice protocol. *Frontiers in Surgery.* 2023; (10). DOI: 10.3389/fsurg.2023.1251444

Lathan R, Sidapra M, Yiasedmidou M, Long J, Totty J, Smith GE, Chetter I. Diagnostic accuracy of telemedicine for detection of surgical site infection: a systematic review and meta-analysis. *Nature Partner Journals Digital Medicine*. 2022; 5(1):108. DOI: 10.1038/s41746-022-00655-0

Lathan R, Sidapra M, Yiasedmidou M, Long J, Totty J, Smith GE, Chetter I. The diagnostic test accuracy of telemedicine for detection of surgical site infection: a systematic review protocol. *PLOS one.* 2022;17(11):e0263549. DOI: 10.1371/journal.pone.0263549

Lathan R, Yiasemidou M, Long J, Mohamed A, Hitchman L, Ravindhran B, Sidapra M, Smith G, Chetter I. A survey of surgical site infection prevention practice in UK vascular surgery. Journal of Vascular Societies Great Britain and Ireland. 2022. DOI: 10.54522/jvsgbi.2022.030

4 FUNDING AND AWARDS

Lathan R, Hitchman L, Walshaw J, Ravindhran B, Carradice D, Smith G, Chetter I, Yiaseidou M. Infection Prevention Society Annual Conference 2024 Best Oral Poster: "Postoperative Remote First Care for Financially and Environmentally Sustainable Healthcare in Surgical Site Infection." 24th September 2024.

Lathan R. Medipex NHS Innovation Awards 2024; Delivering Benefits Through Diagnosis and Screening (Finalist): Validation of a Novel Remote Diagnostic Measure for Identifying Surgical Site Infection. 13th March 2024.

Lathan R. Journal of Wound Care Awards 2023: Innovation in SSI Silver Award: Validation of a Novel Remote Diagnostic Measure for Identifying Surgical Site Infection. 23rd February 2024.

Lathan R, Hitchman L, Ravindhran B, Sidapra M, Walshaw J, Lim A, Long J, Totty J, Smith G, Chetter I. Surgical Research Society ASiT Prize: "ASSIST: Validation of a Novel Remote Outcome Measure for Diagnosis of Surgical Site Infection." 12th January 2024.

Lathan R, Walshaw J, Kwan JY, Hitchman L, Ravindhran B, Carradice D, Smith G, Chetter I, Lockwood S, Yiasemidou M. Association of Surgeons of Great Britain and Ireland Short Paper of Distinction: "Telemedicine for Sustainable Follow-Up: A Pilot Evaluation of the Hybrid Life-cycle assessent approach to carbon footprint analysis", 17th May 2023.

Lathan R. Journal of Wound Care Awards 2023: Innovation in SSI Gold Award: Development of a Novel Remote Diagnostic Measure for Identifying Surgical Site Infection. 24th February 2023.

Lathan R, Smith G, Chetter I, Yiasemidou M. Rosetrees Trust & Royal College of Surgeons Recovery Scheme: Postoperative Remote First Care for Financially and Environmentally Sustainable Healthcare (£5,000). 5th January 2023. Lead Applicant.

Lathan R. Vascular and Endovascular Research Network (VERN) Dragons Den Prize: PRESS – Prevention of Surgical Site Infection: An International Pan Specialty Survey of Practice (£3,000). 24th November 2022. Lead applicant.

Lathan R. Medipex NHS Innovation Awards 2022; Delivering Benefits Through Diagnosis and Screening (Finalist): Development of a Novel Remote Diagnostic Measure for Identifying Surgical Site Infection. 12th October 2022.

Lathan R, Totty J, Long J, Smith G, Chetter I. NIHR Surgical MedTech Co-operative Proof of Concept Funding Award: Validation of a mixed digital reporting outcome measure for surgical site infection diagnosis (£10,000). 6th July 2022. Lead applicant.

Lathan R, Sidapra M, Yiasemidou M, Long J, Totty J, Smith G, Chetter I. Yorkshire Vascular Forum Paper Session Prize: The Diagnostic Test Accuracy of Remote or Virtual Follow-up for Detecting Surgical Wound Infection. 24th June 2022.

Lathan R, Long J, Johnson G, Burns P, Adams K, Totty J, Nandhra S, Wall M, Smith G, Chetter I. Healthcare Infection Society Major Research Grant: The DRESSINg Trial (£98,998). 4th April 2023. Lead applicant.

5 TABLE OF CONTENTS

6 LIST OF FIGURES

7 LIST OF TABLES

8 ACKNOWLEDGEMENTS

I would like to thank all the individuals who made this work possible through their support, contribution and advice in one form or another. Most importantly, I extend thanks to every participant who chose to contribute to this research, without whom, none of this would be possible.

I would like to express my deepest gratitude to my supervisors, Professor Ian Chetter and Mr George Smith, for granting me the research fellowship that enabled this journey. From taking me on with no prior experience to fostering my interest in academia, their guidance, patience, and encouragement have shaped both my professional and personal growth.

I am indebted to Professor Daniel Carradice, whose unwavering encouragement to explore new frontiers, openness to alternative perspectives, and thorough feedback on countless paper revisions has been invaluable. I would also like to thank Mr Joshua Totty, whose example I followed closely; his precise and thoughtful advice has been truly pivotal. I am equally grateful to Judith Long, whose dedication as research manager underpins all the department's work — her support has been integral to every success.

To my peers and colleagues — Louise Hitchman, Bharadhwaj Ravindhran, Misha Sidapra, Sean Pymer, Jonathon Prosser, Arthur Lim, Abduraheem Mohamed, Claire Acey, Josephine Walshaw and Marina Yiasemidou — thank you for being instrumental in completing projects, sharing knowledge, and making the process enjoyable.

I am also indebted to the Academic Vascular Nurses — Josie Hatfield, Tracey Roe, Anna Firth, Louise Mclean, Amy Keld, and Helen Gray — whose tireless support and care for countless patients has been inspiring.

I am deeply grateful to the consultant body of the Vascular Department in Hull Royal Infirmary, namely Mr Johnson, Mr Renwick, Mr Lonsdale, Mr Mekako, Mr Kapur, Mr Akomolafe, and Mr Sultan in addition to those already mentioned — for their expertise, collaboration, and for my education in vascular surgery.

I would also like to thank each of the funders; the Vascular and Endovascular Research Network, National Institute for Health and Care Research, Rosetrees Trust, Royal College of Surgeons, Healthcare Infection Society and Hull University Teaching Hospitals NHS Trust, for enabling the infrastructure to complete this research.

To my Mum and Dad, whose kindness, wisdom, and unwavering support in every endeavour have shaped who I am today — what you have given me cannot be put into words and I am incredibly grateful for everything you have done.

I would like to thank my younger sister, Corin, who may have followed me into the path of medicine, but whose brilliance I will always look up to and aspire towards.

Finally, to my fiancée Lauren, who has stood by my side through every late night, every long shift, and every stress over journal submissions and conference presentations. Her patience, love, and belief in me have made this journey possible. I am eternally grateful and thankful for you.

9 AUTHORS DECLARATION

I confirm that this work is original, and that if any passage(s) or diagram(s) have been copied from academic papers, books, the internet or any other sources these are clearly identified by the use of quotation marks and the reference(s) is fully cited. I certify that, other than where indicated, this is my own work and does not breach the regulations of HYMS, the University of Hull or the University of York regarding plagiarism or academic conduct in examinations. I have read the HYMS Code of Practice on Academic Misconduct, and state that this piece of work is my own and does not contain any unacknowledged work from any other sources. I confirm that any patient information used to produce this piece of work has been appropriately anonymised.

11 CHAPTER 1: INTRODUCTION

11.1 Wounds and wound healing

11.1.1 Anatomy of skin

The skin is the largest organ of the human body, constituting approximately 15% of total body weight and serving as a complex, multifunctional barrier between the internal environment and external stimuli[4,5]. It plays critical roles in protection, thermoregulation, immune response, sensory perception, and biochemical synthesis (e.g., vitamin D production). The skin is composed of three primary layers: the epidermis, dermis, and hypodermis, each with distinct structural and functional characteristics[6].

11.1.1.1 The Epidermis

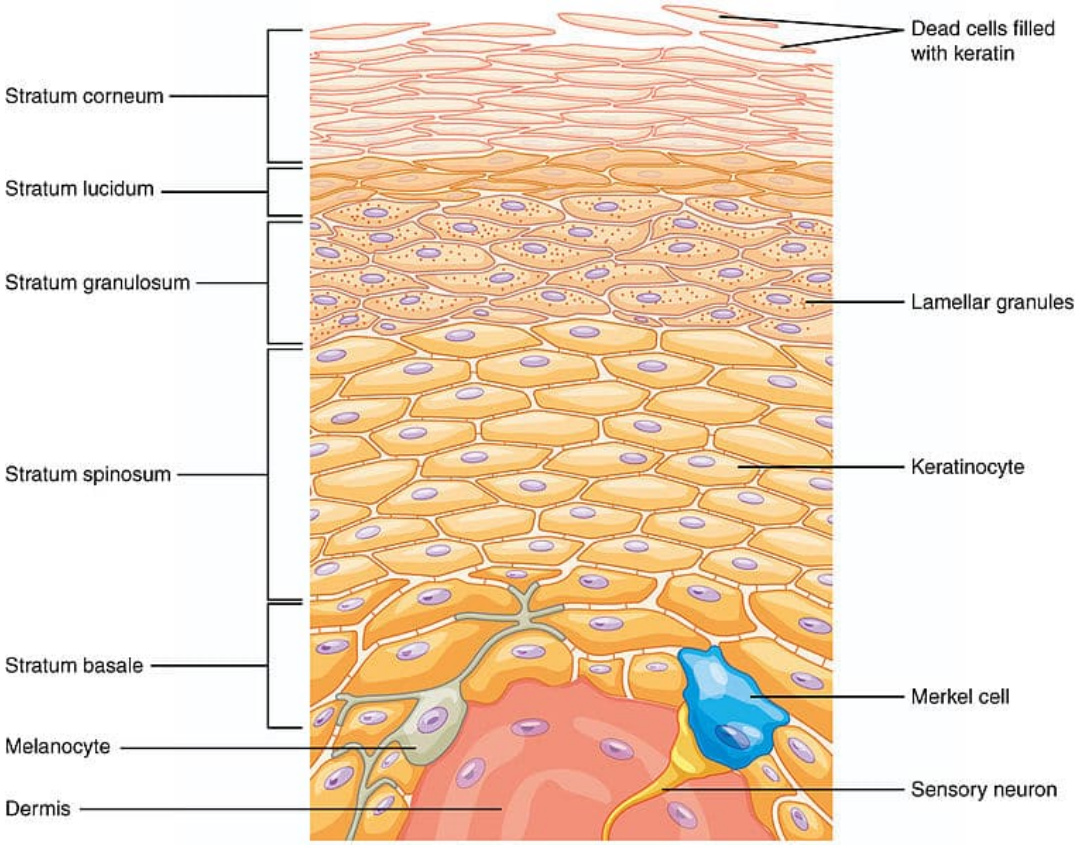


Figure 1:Layers of the epidermis[2]

The epidermis is the outermost layer of the skin, primarily composed of keratinized stratified squamous epithelium. It is avascular and relies on diffusion from the underlying dermis for nutrient exchange. The primary function of the epidermis is to provide a protective barrier against pathogens, dehydration, and mechanical stress[4].

The epidermis consists of several specialised cell types:

11.1.1.1.1 *Keratinocytes*

The predominant cell type, up to 95% of epidermal cells and originating from basal stem cells in the stratum basale. These cells undergo terminal differentiation and keratinisation, producing keratin filaments, which enhance mechanical resilience[4,7]. They also synthesis lipid lamellae, which contribute to the permeability barrier[4,7].

11.1.1.1.2 Melanocytes

Melanocytes comprise 5-10% of the epidermis and are derived from neural crest cells and located in the stratum basale. These cells synthesize melanin within melanosomes, which are transferred to keratinocytes for UV protection[7,8].

11.1.1.1.3 Langerhans Cells

These are dendritic antigen-presenting cells (APCs) originating from bone marrow making up around 3-8% of epidermal cells. They are predominantly found in the stratum spinosum, where they initiate immune responses by presenting antigens to T lymphocytes[4,9].

11.1.1.1.4 Merkel Cells

Merkel cells are the rarest cell type within the epidermis (<1%), and are mechanoreceptors associated with slow-adapting type I sensory fibers. They are primarily located in glabrous skin (e.g., fingertips) and involved in fine-touch discrimination[4,10].

The epidermis consists of five distinct layers, arranged in a differentiation gradient each containing varying concentrations of the specialised cell types**:**

11.1.1.1.5 Stratum Basale

This is the basal layer, a single layer of columnar basal keratinocytes, attached to the basement membrane via hemidesmosomes. It houses epidermal stem cells, which continuously divide to replenish the epidermis, also containing melanocytes and merkel cells (slowly adapting nerve cells detecting fine touch)[4,11].

11.1.1.1.6 Stratum Spinosum

This is the prickle cell layer. It contains several layers of polyhedral keratinocytes connected by desmosomes, forming a spiny appearance under a microscope[4,11]. The stratum spinosum produces cytokeratins, K1 and K10, contributing to epidermal structure[12].

11.1.1.1.7 Stratum Granulosum

The stratum granulosum is a granular layer, characterised by keratohyalin granules, rich in filaggrin and loricrin, which aggregate and bind keratin filaments[13]. Lamellar bodies secrete ceramides, cholesterol, and free fatty acids, forming the lipid barrier[4,14].

11.1.1.1.8 Stratum Lucidum

Stratum Lucidum is a clear layer, only found in thick skin such are palmar and plantar skin, it consists of flattened, enucleated keratinocytes. This layer increases mechanical resilience in high-friction areas[4].

11.1.1.1.9 Stratum Corneum

Stratum corneum is composed of flattened, anucleate corneocytes embedded in a lipid matrix. It forms a hydrophobic barrier, crucial for preventing transepidermal water loss and microbial invasion[15,16].

11.1.1.2 The Dermis

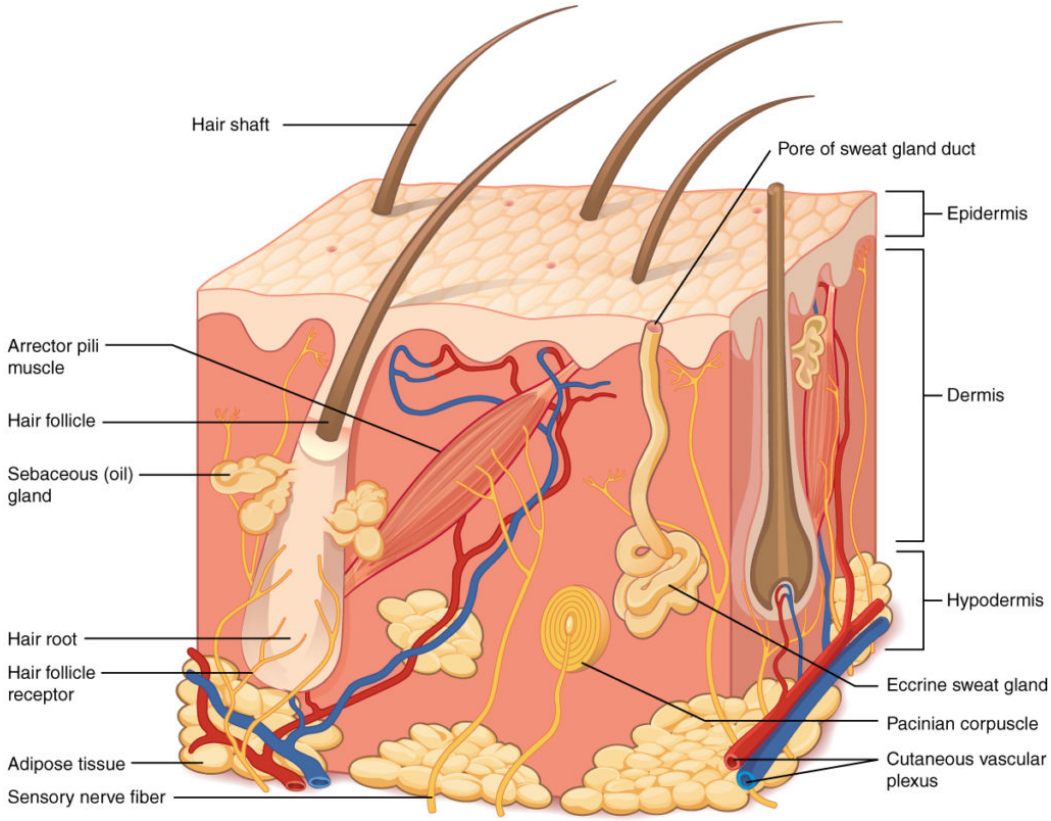


Figure 2: Dermal structure and anatomy[3]

The dermis lies beneath the epidermis and is a fibrous layer consisting of connective tissue, providing mechanical strength, elasticity, and thermoregulation. It is richly vascularized and contains fibroblasts, immune cells, sensory receptors, and adnexal structures (hair follicles, sweat glands, sebaceous glands)[4,17].

Layers of the dermis can be divided into papillary and reticular layers, depending on their location and contents:

11.1.1.2.1 Papillary Dermis

This layer is the most superficial within the dermis and is composed of loose connective tissue with a high density of capillaries, nerve endings (including meisseners corpuscles, rapid acting nerve cells detecting light touch) , and immune cells[4]. It contains dermal papillae, which interdigitate with the epidermis, enhancing nutrient exchange and mechanical adhesion[17].

11.1.1.2.2 Reticular Dermis

The deeper reticular dermis is composed of dense irregular connective tissue, rich in collagen type I and elastin fibres. This provides mechanical support and tensile strength, essential for wound healing and skin elasticity[4,17].

Additionally, several key cellular components are comprised within the dermis, including fibroblasts, immune cells and extracellular matrix (ECM):

11.1.1.2.3 Fibroblasts

Fibroblasts are the main cells of the dermis. They synthesize collagen (type I and type III), elastin, and glycosaminoglycans (GAGs). Their role is to regulate ECM remodelling and wound healing[17,18].

11.1.1.2.4 Immune Cells

The dermis harbours mast cells, macrophages, and dermal dendritic cells, which mediate innate and adaptive immune responses[18,19].

11.1.1.2.5 Extracellular Matrix

ECM is composed of collagen (type I and type III), elastin, proteoglycans, and glycoproteins. It provides mechanical support and anchors cellular components in the dermis[20,21].

11.1.1.3 The Hypodermis

The hypodermis (subcutaneous tissue) is composed of adipose tissue and loose connective tissue, serving as an energy reservoir, insulator, and shock absorber[22]. It contains blood vessels, lymphatics, and nerves that supply the dermis and epidermis, including Pacinian corpuscles (detecting deep pressure and vibration) and Ruffini endings (detecting skin stretch[4].

11.1.2 Definition and Classification

A wound is a disruption of the structural and functional integrity of the skin and underlying tissues, resulting from trauma, pathological processes, or surgical intervention. Wounds can be limited to the epithelium or extend deeper into the dermis or subcutaneous tissues which may include vessels, nerves, muscles, organs and bones[23]. The resultant impact of a wound disrupts cutaneous homeostasis, leading to loss of barrier function, vulnerability to

microbial invasion, fluid imbalance and thermal dysregulation[6]. Wounds can be classified based on their aetiology, healing trajectory, and microbial contamination status, each of which influences clinical management and prognosis.

11.1.2.1 Classification of Wounds

11.1.2.1.1 Aetiological Classification

- Traumatic Wounds: Result from external mechanical forces, such as abrasions, lacerations, contusion, punctures, and crush injuries[24].
- Surgical Wounds: Incisions made under controlled conditions, which may be closed and heal by primary intention, or left open to close by secondary intention. Wounds may also undergo tertiary intention, or delayed primary closure[25].
- Pathological Wounds: including arterial or venous insufficiency, diabetes mellitus, prolonged pressure damage, and burns (which result from thermal, electrical, chemical and radiation sequelae)[26,27].

11.1.2.1.2 Healing Classification

Wounds may also be classified by their trajectory, which correspond with progression through in wound healing phases:

- Acute wounds progress through the four phases of wound healing (haemostasis, inflammation, proliferation, and remodelling) in a timely manner, usually resulting in restoration of anatomy and function within 30 days depending on wound type, size and patient factors[28,29].
- Chronic wounds exhibit prolonged inflammatory responses, impaired angiogenesis, and defective matrix remodelling, often due to ischemia, infection, or metabolic disorders. Wounds which persist beyond 6 weeks are often classified as chronic[28].

11.1.2.1.3 Microbial Contamination Classification

Surgical wounds can be classified by their degree of contamination, defined by the Centres for Disease Control and Prevention (CDC), *table 1*[30].

Table 1: CDC surgical wound classification[30]

Wound category	Definition
Clean	An uninfected operative wound without inflammation. Respiratory, alimentary, genital or uninfected urinary tracts are not entered.
Clean-contaminated	Operative wounds in which the respiratory, alimentary, genital or urinary tracts are electively entered, without unusual contamination.
Contaminated	Operations with major breaks in sterile technique or gross spillage from the gastrointestinal tract, and incisions in which acute, non-purulent inflammation is encountered.
Dirty	Old traumatic wounds with retained devitalised tissue or those that involve existing clinical infection or perforated viscera.

11.1.3 Stages of wound healing

Acute wound healing is a highly coordinated biological process through which the body restores damaged tissue integrity and function following an injury. The healing of acute wounds typically progresses through four well-defined stages: haemostasis, inflammation, proliferation, and remodelling (maturation). Each stage involves complex cellular and molecular activities aimed at achieving tissue repair and restoring homeostasis. The proper progression through these stages is essential for optimal healing, and deviations can result in delayed healing or pathological scarring[31].

11.1.3.1 Haemostasis

Immediately following tissue disruption, haemostasis acts to prevent exsanguination and initiate the wound healing cascade. Blood vessels constrict to minimize blood loss mediated by endothelial cell injury and the release of vasoconstrictors serotonin and thromboxane A2[32].

Platelets are activated upon encountering exposed collagen at the injury site and adhere to the wound bed. Activated platelets release various growth factors, including platelet-derived growth factor (PDGF), transforming growth factor-beta (TGF-β), and vascular endothelial growth factor (VEGF), which help recruit additional platelets and stimulate subsequent wound healing stages. These growth factors also contribute to chemotaxis of inflammatory cells and fibroblasts in later stages[33]. Further blood loss is then prevented through the activation of the intrinsic and extrinsic coagulation cascades, which results in the conversion of fibrinogen into fibrin, *figure 3*[33,34].

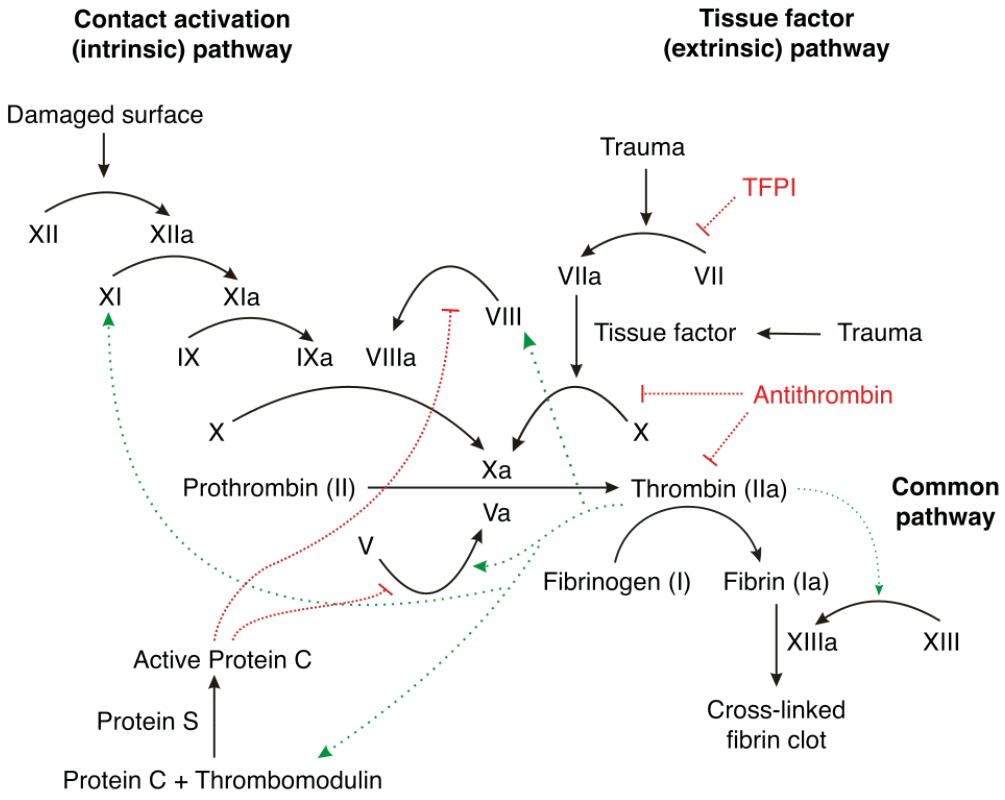


Figure 3: The coagulation cascade[1]

11.1.3.1.1 The intrinsic pathway

Endothelial damage exposes subendothelial collagen to blood, causing the activation of factor XII. Activated factor XII begins the cascade of activation of factor XI, followed by factor IX and resulting in the activation of factor X. Factor Xa signifies the beginning of the common pathway[34].

11.1.3.1.2 The extrinsic pathway

Endothelial damage causes the release of tissue factor which activates factor VII. In turn activated factor VII results in the activation of factor X. The common pathway then begins[34].

11.1.3.1.3 The common pathway

Activation of factor X occurs at the end of both the intrinsic and extrinsic pathway. Both pathways then complete the coagulation cascade in the common pathway. Factor Xa combines with activated factor V to convert prothrombin (factor II) into thrombin (factor IIa). Thrombin acts on fibrinogen (factor I) to form fibrin (factor Ia) which forms strands that together with factor XIII aggregate to form a mesh known as the fibrin plug[34]. This clot serves as a physical barrier to pathogens and prevents further blood loss.

11.1.3.2 Inflammation

The inflammatory phase of wound healing begins within the first hour of haemostasis and typically lasts for several days[31]. In this phase, the body works to protect the wound from infection and clear cellular debris. The inflammatory response is driven by the release of pro-inflammatory cytokines and chemokines from platelets, endothelial cells, and fibroblasts. These molecules include interleukins 1 and 6, and tumour necrosis factor alpha (TNF-α) which recruit neutrophils, macrophages, and other immune cells to the wound site[35].

Neutrophils arrive within hours of injury and perform phagocytosis to clear bacteria and tissue debris. They also degranulate to release toxins and proteolytic enzymes causing bacteriolysis and form neutrophil extracellular traps composed of DNA and granule proteins which bind pathogenic microbes[36-38].

Over the first 48 hours neutrophil activity reduces as bacteria are removed. They then either migrate to the wound surface, to be removed as slough, or undergo apoptosis. Debris and remnants of this process are removed by macrophages[31,33]. Macrophages are critical for resolving inflammation and transitioning to the proliferative phase and are highly versatile cells that carry out several key functions during wound healing:

- Phagocytosis: Macrophages continue the process of phagocytosis initiated by neutrophils, clearing the wound of apoptotic cells and pathogens.
- Secretion of growth factors: Macrophages release a variety of growth factors, including VEGF (for angiogenesis), TGF-β (for fibroblast activation), and fibroblast growth factor (FGF). These molecules promote tissue regeneration and stimulate the next phase of healing[33,39].
- Resolution of inflammation: Macrophages also produce anti-inflammatory cytokines, such as IL-10 and TGF-β, which help to resolve inflammation and promote tissue repair[33,39].
- Vasodilation and angiogenesis: The inflammatory response also involves vasodilation to increase blood flow to the wounded area, thereby delivering immune cells, oxygen, and nutrients. Angiogenesis, the formation of new blood vessels from existing vasculature, is stimulated by pro-angiogenic factors like VEGF.

This newly formed vascular network is essential for the supply of nutrients and oxygen during the proliferative phase[33,39].

The inflammatory phase continues as long as there is a need for bacteria and debris to be cleared from the wound. Disproportionate or prolonged inflammation can lead to tissue damage, delayed proliferation and as such may lead to a chronic wound[33,40].

11.1.3.3 Proliferation

The proliferative phase follows the inflammatory phase and typically lasts from day 3 to day 21 post-injury, depending on the size and severity of the wound. This phase is characterized by cell proliferation, tissue formation, and wound contraction, all of which are essential for tissue restoration[31,33].

11.1.3.3.1 Granulation

One of the hallmark features of the proliferative phase is the formation of granulation tissue. This tissue consists of a dense network of newly proliferated fibroblasts, endothelial cells, and ECM components[33]. Fibroblasts synthesize collagen, which provides structural support, while endothelial cells form capillaries to provide blood supply to the wound[41].

11.1.3.3.2 Fibroblast migration

Fibroblasts are activated by growth factors like TGF-β and PDGF. These cells proliferate, migrate into the wound bed, and produce ECM proteins such as collagen (mainly Type III), fibronectin, and glycosaminoglycans[31,33,41]. The deposition of these matrix proteins serves as a scaffold for tissue repair and promotes wound closure[33].

11.1.3.3.3 Angiogenesis

Angiogenesis is a key aspect of the proliferative phase. New capillaries form from pre-existing blood vessels under the influence of angiogenic factors like VEGF, FGF, and angiopoietins[33]. This process ensures that the wound area receives an adequate supply of oxygen and nutrients, which is critical for cell proliferation and tissue formation[31,33].

11.1.3.3.4 Re-epithelialisation

Re-epithelialisation occurs as keratinocytes migrate across the wound surface to restore the epidermal barrier. These keratinocytes migrate from the wound edges and proliferate

under the influence of growth factors like EGF and TGF-α[33]. In full-thickness wounds, re-epithelialisation may be delayed until granulation tissue forms and provides a suitable substrate for cell migration[41].

11.1.3.3.5 Wound retraction

In larger wounds, myofibroblasts, which are specialized fibroblasts with contractile properties, play a role in wound contraction. Myofibroblasts pull the edges of the wound together, reducing the size of the wound and facilitating tissue closure. This process is particularly important in wounds that are too large for simple epithelial closure[31,33,41].

11.1.3.4 Remodelling

The remodelling phase begins after the proliferative phase and can last from several months to years[31]. This phase is characterized by the reorganisation of collagen fibres and the maturation of the ECM, which gradually restores tissue strength and function[33].

The initial deposition of type III collagen in the proliferative phase is replaced by the stronger and more durable type I collagen during remodelling. The collagen fibres are reorganised along tension lines, improving the strength and structural integrity of the tissue. The ratio of type I to type III collagen increases, and the overall collagen content decreases as the wound matures[33,41].

Despite the remodelling process, complete restoration of the tissue architecture and function is rarely achieved. In most cases, scar tissue forms, which is structurally different from the surrounding tissue. Scar tissue is often more fibrous and less flexible than normal skin, containing a higher proportion of collagen and fewer elastic fibres[33]. This leads to reduced skin elasticity and functional limitations in some cases[31].

Over time, the scar undergoes further shrinkage, reorganisation, and softening. The wound may become less vascular, and the scar tissue will lose some of its initial redness. While scarring cannot be entirely eliminated, the process aims to restore functional integrity to the injured tissue[31]. Errors in the remodelling stage may lead to persistent granulation tissue and a chronic wound[41].

Acute wound healing is a complex, dynamic process that occurs in a tightly regulated sequence of stages. The four phases, haemostasis, inflammation, proliferation, and remodelling are interdependent with each stage building upon the previous one to restore tissue integrity and function. Understanding the cellular and molecular mechanisms involved in wound healing is critical for improving therapeutic strategies, especially in the management of chronic wounds or wounds that deviate from the normal healing trajectory. Effective management of acute wounds, from the proper control of bleeding in the haemostasis phase to strategies that promote optimal wound closure and minimize scarring in the remodelling phase, is vital for ensuring successful tissue repair and recovery.

11.1.4 Factors impacting wound healing

Wound healing is a dynamic, multifactorial process influenced by various internal and external factors. Understanding the complex interactions between these factors is crucial for optimizing treatment strategies and improving patient outcomes. The ability of a wound to heal efficiently depends on a delicate balance between cellular, molecular, and biological processes that are modulated by both systemic and local factors. The combination of these factors may make progression to a chronic wound more likely.

11.1.4.1 Local Factors

Local factors are those related to the characteristics of the wound itself and the environment surrounding the wound. These factors include wound infection, oxygenation and mechanical forces.

11.1.4.1.1 Infection

Infection is one of the most common and significant local factors impeding wound healing. Bacterial load increases, leading to the release of pro-inflammatory mediators and an extended inflammatory response[42]. Biofilm formation by bacteria can occur, especially in chronic wounds. This biofilm protects bacteria from immune surveillance and antibiotic treatment, making infection harder to clear and hindering healing[43]. Chronic infection leads to prolonged inflammation, inhibiting the progression to the proliferative and remodelling stages of healing[33,40]. The presence of infection also increases the metabolic demands of the wound, which can further impair healing, especially in individuals with compromised systemic health[43,44].

11.1.4.1.2 Oxygenation and Blood Supply

Initial phases of wounds can result in a relatively hypoxic state, with the disruption of blood supply and highly metabolic cell activity[45]. Further this state results in cytokine and growth factor production from macrophages, keratinocytes and fibroblasts[45,46]. Following this period, oxygen is required for collagen synthesis and remodelling by fibroblasts, cell proliferation and migration during the proliferative phase and neovascularisation to provide the wound with a blood supply[47]. Inadequate blood flow to the wound site can lead to delayed healing, especially in patients with vascular disease. Hypoxia, or low oxygen levels, often results in the formation of chronic wounds, where tissue oxygenation is insufficient to support normal cellular activities.

11.1.4.1.3 Mechanical Factors

The mechanical environment of a wound, including shear forces, tension, and moisture, can influence healing outcomes. For example, Langer lines correspond to bands of tension and incisions parallel to these lines experience reduced tension and heal with less scarring than perpendicular incisions[48]. Constant mechanical pressure can disrupt tissue regeneration leading to recurrent injury, preventing the wound from progressing through the normal healing stages[49]. Maintaining an appropriate moisture balance is essential for wound healing. Dry wounds may experience necrosis or eschar formation, while excessive moisture can lead to maceration, a condition where skin softens and breaks down, hindering healing[50,51].

11.1.4.2 Systemic Factors

11.1.4.2.1 Age

Advanced age is a major risk factor for delayed or impaired healing. There is reduced cellular proliferation, and the regenerative capacity of fibroblasts, keratinocytes, and other key cell types decline. This leads to slower tissue repair. Additionally, there is reduced collagen synthesis which is essential for providing strength to the healing tissue. Immunosenescence results in impaired inflammatory responses and delayed pathogen clearance, leading to an increased risk of infection and chronic wounds. Older is also associated with impaired angiogenesis, resulting in inadequate tissue oxygenation and nutrient supply[52].

11.1.4.2.2 Nutrition

Malnutrition, particularly deficiencies in essential nutrients, can impair the healing process. Protein is vital for cellular repair and collagen synthesis. Deficiencies in protein can lead to delayed wound healing, poor tissue regeneration, and increased risk of infection. Vitamin C is also essential for collagen synthesis and immune function[53]. Zinc promotes re-epithelialisation, new tissue generation and upregulates the immune response[53,54]. Vitamin A regulates epithelialization and collagen formation, while vitamin K contributes to coagulation. Adequate glucose levels are necessary for energy production and cellular metabolism during wound repair. However, in diabetic patients, high glucose levels can also lead to impaired wound healing[53].

11.1.4.2.3 Diabetes Mellitus

Diabetes is associated with impairment in several aspects of wound healing, including collagen synthesis, leukocyte function, and angiogenesis. Diabetes also promotes a state of chronic inflammation, further delaying tissue repair[55]. Additionally, extrinsic factors such as repeated trauma and mechanical stress associated with peripheral neuropathy make these patients more susceptible to poor wound healing and progression to chronic wounds[56]. Diabetes is also a major risk factor for peripheral arterial disease (poor blood supply).

11.1.4.2.4 Immunosuppression

Patients with conditions such as Human Immunodeficiency Virus (HIV) or Acquired Immunodeficiency Syndrome (AIDS), cancer, or those on immunosuppressive therapies (such as cyclosporin A, tacrolimus, azathioprine, and chronic systemic steroids) may have compromised immune responses, increasing the risk of infection and slowing the healing process[57-59].

11.1.4.3 Psychological Factors

Psychological stress and poor mental health can also significantly affect wound healing. Chronic stress may lead to the release of stress hormones such as cortisol, which can impair immune function, increase inflammation, and inhibit the normal healing process[60]. Stress can also influence wound repair through the adoption of health-damaging behaviours, such as alcohol and tobacco use, reduced physical activity, sleep disturbance and poor dietary intake[61].

11.2 Surgical site infection

11.2.1 Definition

Surgical site infection (SSI) occurs when there is infection at or below the wound created by the operative incision, or deep to this in the manifested surgical dead space, which may or may not involve viscera[62]. The Centres for Disease Control and Prevention (CDC) further categorise this by time of onset and depth. SSI may occur within 30 days or 90 days depending on the operative procedure *(table 2)* and each infection may affect the superficial incisional, deep incisional or organ/space layers[63].

Table 2: Timeframe for SSI surveillance by type of operative procedure. Adapted from CDC 2017[63]

30-day Surveillance – Operative Procedure	
Abdominal Aortic Aneurysm repair	Laminectomy
Limb amputation	Liver transplant
Appendix surgery	Neck surgery
Shunt for dialysis	Kidney surgery
Bile duct, liver or pancreatic surgery	Ovarian surgery
Carotid endarterectomy	Prostate surgery
Gallbladder surgery	Rectal surgery
Colon surgery	Small bowel surgery
Caesarean section	Spleen surgery
Gastric surgery	Thoracic surgery
Heart transplant	Thyroid and/or parathyroid surgery
Abdominal hysterectomy	Vaginal hysterectomy
Kidney transplant	Exploratory laparotomy
90-day surveillance – Operative procedure	
Breast surgery	Craniotomy
Cardiac surgery	Spinal fusion
Coronary artery bypass surgery with both chest and donor site incisions	Coronary artery bypass graft with chest incision only
Open reduction of fracture	Herniorrhaphy
Hip prosthesis	Knee prosthesis
Pacemaker surgery	Peripheral vascular bypass surgery
Ventricular shunt	

11.2.2 Epidemiology

Healthcare associated infections (HCAI) can substantially impede patient's quality and longevity of life. Now the most common nosocomial infection, SSI accounts for up to 20% of all HCAI[64]. The reported incidence varies considerably by surgical specialty and operative procedure but can be as high as 25-40% in general and vascular surgery[65,66]. The risk of developing organ/space SSI is somewhat lower, around 2.8-4.7%[67,68]. Whilst infrequent, the consequences such infections may increase mortality risk three-fold at 30 and 90 days[69,70]. Surgical procedures may also be classified into clean, clean-contaminated, contaminated and dirty, in relation to their relative risk of developing surgical site infection[71,72].

11.2.3 Presentation

Clinical description of SSI reflect a constellation of symptoms that culminate into a diagnosis. Specific features vary in agreement and can include purulent discharge[63,73,74], localised pain, tenderness and oedema[63,73], pyrexia[63,73,74], erythema[73,74] and wound dehiscence[73,74].

11.2.4 Microbiology

The microorganisms responsible for SSIs can be broadly classified into bacterial**,** fungal, and viral pathogens, with bacteria being the most common causative agents. Bacterial infections are the most frequent cause of SSIs. The primary sources of these pathogens are the patient's own microbial flora (endogenous flora), which can be introduced into the surgical site during the operation and microorganisms introduced from the external environment (exogenous flora), including the surgical team's hands, instruments, or the operating room environment.

11.2.4.1 Common Pathogens Involved in SSIs

11.2.4.1.1 Staphylococcus aureus (S. Aureus)

S. aureus is one of the most common pathogens responsible for SSIs, accounting for up to 30% of infections, particularly in orthopaedic, cardiothoracic, and general surgical procedures[75]. It is a gram-positive coccus, and a facultative anaerobe, capable of forming biofilms on surgical implants[76]. *S. aureus* produces several virulence factors to establish infection including; coagulase, protein A and exfoliative-, alpha- and entero-toxins.

Methicillin-resistant *S. aureus* (MRSA) is a particular concern due to its resistance to beta-lactam antibiotics[77].

11.2.4.1.2 Coagulase-negative staphylococci (CoNS)

These organisms are commonly involved in prosthetic joint and implant-associated infections[78]. They account for a significant portion of SSIs, particularly in immunocompromised patients. *CoNS* are gram-positive cocci, non-hemolytic, which form biofilms on foreign materials like catheters, prosthetic devices, and surgical implants[79]. They produce adhesins (e.g., biofilm production), and antibiotic resistance mechanisms as virulence factors[80].

11.2.4.1.3 Escherichia coli (E. coli)

E. Coli is one of the most common pathogens in abdominal surgeries, especially in procedures involving the gastrointestinal or urinary tract[81]. They are gram-negative, facultative anaerobes, often part of the normal gastrointestinal flora. *E. Coli* virulence factors include Fimbriae, lipopolysaccharides (LPS)**,** haemolysins, and the ability to form biofilms, leading to increased resistance to host defence mechanisms and antibiotics[82].

11.2.4.1.4 Pseudomonas aeruginosa (P. aeruginosa)

P. aeruginosa are often found in surgical wounds of immunocompromised patients, particularly after cardiac or vascular surgery[83]. These are gram-negative aerobic rods with virulence factors of exotoxin A, pyocyanin and biofilm formation[83,84].

11.2.4.1.5 Enterococci

Enterococci are frequently involved in abdominal, pelvic and urological procedures[85]. They are gram-positive, catalase-negative cocci which form part of the normal flora of gastrointestinal and genitourinary tracts. Virulence factors include vancomycin resistance (VRE), biofilm formation, and adhesion molecules[86].

11.2.4.1.6 Streptococcus pyogenes (S. pyogenes)

These bacteria are often involved in necrotising fasciitis and other soft tissue infections. They are gram-positive, catalase-negative, coagulase-negative cocci which produce exotoxins that lead to systemic toxic shock and tissue necrosis[87].

11.2.5 Risk factors for development of SSI

SSIs result from complex interactions between the surgical procedure, the patient's health status, and the hospital environment. Understanding these risk factors enables targeted strategies to reduce the likelihood of infection.

11.2.5.1 Patient-Related Risk Factors

11.2.5.1.1 Immunocompromised State

Patients with weakened immune systems are at increased risk of developing SSIs due to the body's reduced ability to mount an effective defence against infection[88]. Immunocompromise may be due to comorbidity, such as from Human Immunodeficiency Virus (HIV) and Acquired Immune Deficiency Syndrome (AIDS), due to low CD4 counts, and cancer, secondary to chemotherapy and radiotherapy[57,89]. It may also be resultant of immunosuppressive medication, such as corticosteroids, cyclosporin A, tacrolimus, and azathioprine[58,59].

11.2.5.1.2 Diabetes Mellitus

Diabetes, particularly when poorly controlled, is a significant risk factor for SSIs[90]. Hyperglycaemia can impair immune function, reduce blood flow to the wound, and delay wound healing[55]. Moreover, diabetic neuropathy and poor peripheral circulation (often seen in patients with diabetes) can result in unnoticed trauma or infection in the surgical area, leading to delayed diagnosis and treatment.

11.2.5.1.3 Obesity

Obesity is a significant risk factor for developing SSI[91]. Excess adipose tissue increases metabolic demands on the body, leading to impaired wound healing and inadequate blood supply with compromised tissue oxygenation[92]. Additionally, larger skin folds may harbour bacteria, increasing risk of contamination with surgical wounds.

11.2.5.1.4 Age

Increasing age is a significant predictor of developing surgical site infection[93]. This is likely related to the association with impaired angiogenesis, epithelialisation, and collagen synthesis required for wound healing[52].

11.2.5.1.5 Smoking

Smoking has a well-documented detrimental effect on wound healing. Postoperative surgical site infections occur significantly more in current and former smokers and

perioperative smoking cessation leads to a reduction in SSI rates[94]. Wound healing is impaired, and infection flourishes due to several factors. Nicotine results in subcutaneous vasoconstriction, diminishing tissue perfusion[95]. Smoking also impairs the function of neutrophils and macrophages, altering inflammatory response and bactericidal abilities[95,96].

11.2.5.2 Procedural Risk Factors

11.2.5.2.1 Type and length of Surgery

The nature and complexity of the surgical procedure play a major role in determining the risk of SSI. Likelihood of developing SSI increases for every 15 min, 30 min and 60 min of surgery at 13%, 17% and 37% increased likelihood respectively[97]. Procedures involving implantation of foreign material, such as prosthetic joints, vascular grafts and cardiac devices significantly increase the risk of infection, likely related to the potential for biofilm formation[98-100].

11.2.5.2.2 Inadequate Antibiotic Prophylaxis

Prophylactic antibiotics are advised to be administered within one hour before starting surgery. Failure to administer appropriate antibiotics, or the incorrect choice of antibiotic (e.g., not matching the likely pathogens), can increase the likelihood of an SSI. Additionally, antibiotics should be administered within the correct time frame—usually within one hour before surgery to ensure adequate tissue concentrations at the time of incision.

11.2.5.2.3 Re-operation

In a meta-analysis of patients undergoing lower limb revascularisation in vascular surgery, early or unplanned re-operation was associated with increased risk of SSI (pooled OR 4.50, 95% CI 2.18-9.32; low certainty)[101].

11.2.6 Recommendations for reduction in SSI

Preventing SSIs is of paramount importance in ensuring positive surgical outcomes and improving patient safety. A multifaceted approach encompassing preoperative, intraoperative, and postoperative measures is essential in reducing the incidence of SSIs.

11.2.6.1 Preoperative Measures

11.2.6.1.1 Patient Risk Assessment

Preoperative assessment of the patient related risk factors for infection should be conducted. Identifying and addressing modifiable patient related risk factors can significantly reduce the likelihood of SSIs[102,103]. Risk assessments should focus on:

- Comorbidities: Conditions such as diabetes, obesity, and immunosuppression increase the risk of SSIs, and addressing these preoperatively (e.g., optimizing blood glucose control, weight loss or improving nutrition) may help reduce infection rates[88,90,91].
- Nutritional status: Malnourished patients have delayed wound healing[53]. Providing nutritional support, including high-protein and vitamin-rich supplements, may reduce the risk of developing SSI, though clinical studies have had mixed findings[104].
- Smoking cessation: Smokers have a higher risk of SSIs due to impaired oxygenation and immune function[94]. Smoking cessation should be encouraged 4-6 weeks before surgery, when possible.

11.2.6.1.2 Preoperative Antimicrobial Prophylaxis

Antibiotic prophylaxis is recommended by the National Institute of Health and Care Excellence (NICE) SSI prevention guidelines for clean surgery with implants and clean-contaminated, contaminated and dirty surgery[105].

Frequently, antimicrobial prophylaxis is advised to be administered within 60 minutes of surgery, though evidence suggests that patients who received antibiotics greater than 120 minutes of knife to skin were at higher risk of SSI and within this time frame, no benefits can be conferred over the optimal timing of prophylaxis currently [106,107].

Antimicrobial choice should be based upon the likely causative pathogens for the specific procedure. Further, regional variation in resistance patterns to antibiotics and overall antibiogram may confer insights into individualised guidance for centres to reduce SSI[108].

11.2.6.1.3 Patient Education

Educating patients on appropriate wound care and hygiene and management of modifiable risk factors may help reduce the likelihood of infection. The added value of patient empowerment increases active participation in care and improves patient satisfaction[109]. Studies that included education within SSI prevention bundles shows a reduction in

infection rates, though further high-quality evidence of this as a targeted intervention is required[109].

11.2.6.2 Intraoperative Measures

11.2.6.2.1 Preoperative Surgical Site Preparation

International guidelines from the World Health Organisation (WHO) recommend use of alcohol-based chlorhexidine gluconate (CHG) for surgical site skin preparation for the reduction in SSI rates[107]. Recent meta-analysis of 16 RCTs supports this recommendation, but also found povidone iodine (PVI) solutions are an effective option[110]. Results of ongoing trials may yet shed further light on this[111].

Surgical site hair removal with clippers results in significantly lower risk of SSI compared to shaving using a razor (OR 0.51; 95% CI: 0.29-0.91), however there is little difference in clipping compared to no hair removal at all (RR 0.95; 95% CI 0.65 to 1.39)[107,112]. NICE and WHO guidelines both recommend therefore that hair removal should not routinely be undertaken to reduce SSI, and if hair should be removed (such as to facilitate postoperative dressings) then this should be done so with single use clippers on the day of surgery[107,113].

11.2.6.2.2 Surgical Hand Antisepsis

Surgical hand antisepsis is undoubtedly of critical importance in preparation for surgery, though in terms of SSI risk reduction, there is little evidence for one agent over another. Available studies provide low quality evidence with heterogenous comparators and often include colony forming units (CFU) rather than SSI rates as their primary outcome[114]. Significant reductions in CFU do not often equate to similar changes in SSI rates[114]. Further robustly designed studies may indicate optimal hand antisepsis.

11.2.6.2.3 Surgical Technique

Several studies have indicated that intraoperative blood loss (>100ml) is an independent predictor for developing surgical site infection, which has been evaluated in cardiothoracic, vascular and spinal surgery[115-117].

Use of sutures instead of skin staples for primary wound closure may reduce infection rates. Meta-analyses in gastrointestinal and orthopaedic surgery have both concluded higher incidences of SSI in patients who received skin staples[118,119].

11.2.7 Outcome Measures in Surgical Site Infection

11.2.7.1 Centres for Disease Control and Prevention (CDC)

The gold standard for diagnosis of surgical site infection is using CDC criteria, during an in-person review and at 30 days post-surgery, for non-implant procedures[63]. This can be up to 90 days post-surgery for those involving prosthetic implants. The CDC definition of SSI is graded into severity based upon anatomical location of the infection. Whilst widely accepted, the CDC criteria pose several challenges. The classification has subjective elements and has poor interrater agreement, resulting in variable comparisons of wounds[120].

11.2.7.1.1 Superficial Incisional SSI

A superficial incisional SSI meets the following criteria[63]:

- Infection occurs within 30 days of the operative procedure ***AND***
- Involves on the skin and subcutaneous tissue of the incision ***AND***
- The patient has at least *one* of the following:
    - Purulent discharge from the incision
    - Organism(s) identified from an aseptically obtained specimen by culture of the incision
    - The superficial incision is deliberately opened by a surgeon, physician, or physician designee ***AND*** the patient has at least one of: localised pain or tenderness; localised swelling; erythema; or heat.
    - Diagnosis of superficial incisional SSI by a physician or other designee.

11.2.7.1.2 Deep Incisional SSI

A deep incisional SSI must meet the following criteria[63]:

- Infection occurs within 30 days (or 90 days if a prosthetic implant is used) of the index procedure ***AND***
- Involves deep soft tissues of the incision, such as the fascial and muscle layers ***AND***
- The patient has at least *one* of the following:
    - Purulent discharge from the incision
    - A deep incision that is deliberately opened by a surgeon, physician or other designee, or spontaneously dehisces, ***AND*** organism(s) are identified by

culture ***AND*** the patient has at least one of: fever (>38^{o}C); or localised pain or tenderness

- An abscess of other evidence of infection involving the deep incision is detected on gross anatomical examination, histopathological examination or imaging test.

11.2.7.1.3 Organ/Space SSI

An organ/space SSI must meet the following criteria[63]:

- Infection occurs within 30 days (or 90 days if a prosthetic implant is used) of the index procedure ***AND***
- Involves the organ/space tissues (deeper than the fascia/muscle) ***AND***
- The patient has at least *one* of the following:
    - Purulent drainage from a drain placed into the organ/space (such as a closed suction drainage system, open drain, T-tube drain, CT-guided drainage)
    - Organism(s) identified from fluid or tissue in the organ/space by a culture or non-culture based microbiological testing method
    - An abscess or other evidence of infection involving the organ/space is detected on gross anatomical exam, or histopathological exam, or imaging test suggestive of infection
- ***Additionally***, the infection must also meet at least *one* criterion listed in *table 3.*

Table 3: Specific site of an organ/space SSI as per CDC criteria[63]

Category	Specific Site	Category	Specific Site
BONE	Osteomyelitis	MED	Mediastinitis
BRST	Breast abscess or mastitis	MEN	Meningitis or ventroculitis
CARD	Myocarditis or pericarditis	ORAL	Oral cavity infection (mouth, tongue, or gums)
DISC	Disc space infection	OREP	Deep pelvic tissue infection or other infection of the male or female reproductive tract
EAR	Ear, mastoid infection	PJI	Periprosthetic joint infection
EMET	Endometritis	SA	Spinal abscess/infection
ENDO	Endocarditis	SINU	Sinusitis
GIT	Gastrointestinal tract infection	UR	Upper respiratory tract, pharyngitis, laryngitis, epiglottitis
IAB	Intra-abdominal infection not otherwise specified	USI	Urinary system infection
IC	Intracranial infection	VASC	Arterial or venous infection
JNT	Joint or bursa infection	VCUF	Vaginal cuff infection
LUNG	Other infection of the lower respiratory tract		

11.2.7.2 ASEPSIS Score

The ASEPSIS score, *table 4,* is a qualitative measure of scoring a surgical wound to determine whether SSI is present[121].

Table 4: The ASEPSIS scoring system[121]

	Score
Wound Characteristic	
Serous Exudate	3
Erythema	3
Purulent Exudate	6
Separation of Wound Edges	6
Additional Treatment	
Postoperative Antibiotics	10
Abscess Drainage	5
Wound Debridement	10
Isolation of Bacteria	10
Prolonged stay/readmission to hospital	5

A score of 21 or more indicates the presence of SSI. Scores between 10 and 20 indicate impaired wound healing and a score below 10 indicates satisfactory wound healing. The score is related to the severity of infection present and uses objective criteria based upon clinical and laboratory findings, and the management provided. ASEPSIS has been reported to be repeatable and related to patient outcomes[122]. Whilst objective, in comparison to CDC criteria, ASEPSIS over classifies SSI but under reports purulent discharge[120,121,123].

11.2.7.3 Bluebelle Wound Healing Questionnaire

The Bluebelle wound healing questionnaire (WHQ) is a 19-item patient or clinician reported questionnaire which was developed and validated in general surgery[124,125]. Question development was based upon the CDC criteria as a gold standard in person assessment[63]. Given the Bluebelle WHQ was validated as a patient reported questionnaire, this could potentially be utilised as a remote outcome measure to identify SSI. Both inter- and intra-rater reliability scores were good (κ 0.6 or more for the majority of items) and discriminatory capacity for SSI was high with an area under the receiver operating characteristic (ROC) curve of 0.91. However, at the optimal self-assessment score cut-off thresholds of 6 to 8, sensitivity and specificity for SSI diagnosis ranges from 78.1%-71.9%

and 89.2%-93.8% respectively[125]. This low sensitivity diminishes the diminishes the diagnostic capacity of the Bluebelle WHQ, which maybe better suited as a screening tool to rule out those without SSI. Further validation in other cohorts, such as the older, frail and comorbid vascular population is needed to evaluate this measure.

11.3 Telemedicine

11.3.1 Definition

Telemedicine is a transformative approach to healthcare delivery which utilises digital technology to support remote medical services. It has grown significantly over the past few decades, driven by advancements in communication technology, the increasing need for accessible healthcare, and the global impact of the SARS-CoV-2 pandemic. Telemedicine allows patients to consult healthcare professionals, receive diagnoses, and access treatments without the need for in-person visits. In the current age of rapid technological advancement, there is a diverse array of both information technology ability and user capability. As such, to achieve the intended outputs of care, careful consideration of the patient's characteristics and the target condition must be given when considering any use of telemedicine.

11.3.2 The Evolution of Telemedicine

In the early 20th century, telegraphs, telephones, and radio communication were used by physicians to provide medical advice to remote areas[126]. In 1924, the concept of a "radio doctor" was even illustrated in Radio News magazine, envisioning a future where doctors could diagnose patients via video calls[127].

One of the earliest applications of telemedicine occurred in the 1950s and 1960s when the National Aeronautics and Space Administration (NASA) and the United States (U.S.) military explored ways to deliver healthcare remotely[127]. During the early space missions, NASA developed remote monitoring techniques to track astronauts' vital signs, laying the groundwork for modern telehealth technology. Around the same time, urban hospitals and medical institutions began experimenting with closed-circuit television (CCTV) systems for remote consultations between specialists and patients[126].

During the 1970s and 1980s, advancements in telecommunications enabled hospitals and clinics to adopt telemedicine for specialized care. The University of Nebraska pioneered the

use of video conferencing for medical consultations, connecting patients in rural locations with specialists at larger medical centres[126]. This period also saw the development of tele-radiology, where X-rays and other medical images were transmitted electronically for remote diagnosis[128,129]. The 1990s marked a turning point for telemedicine as the internet and personal computing became widespread. The introduction of email and online databases allowed doctors to share patient information more efficiently. Government initiatives and funding programs, such as those by the U.S. Department of Veterans Affairs, helped expand telemedicine services to serve military personnel and remote communities[126].

The 21st century has seen exponential advancements in digital technology, enabling telemedicine to become more integrated into mainstream healthcare. The proliferation of smartphones, high-speed internet, and video conferencing platforms made virtual consultations more accessible and user-friendly[130]. Telemedicine applications have expanded beyond video calls to include remote monitoring devices, AI-driven diagnostics, and electronic health records (EHRs)[127,131]. The SARS-CoV-2 pandemic in 2020 then served as a catalyst for the widespread adoption of telemedicine. With lockdowns and social distancing measures in place, healthcare providers turned to virtual consultations to continue patient care. Governments also adjusted policies to support telehealth services, further solidifying their role in modern healthcare[132,133].

11.3.3 Patient Characteristics

11.3.3.1 Age

Age plays a crucial role in determining a patient's ability to use telemedicine effectively. Younger patients, tend to be more comfortable with digital platforms, mobile apps, and video conferencing tools. They are more likely to embrace telemedicine for routine check-ups, mental health consultations, and chronic disease management[134,135]. Conversely, older adults, especially those over 65, may face challenges in using telemedicine due to lower digital literacy, difficulty navigating online platforms, and unfamiliarity with mobile applications[134]. They may struggle with tasks such as logging into patient portals, setting up video calls, or troubleshooting technical issues[136]. As such, older adults are at risk of digital exclusion and to address this, telemedicine services should include user-friendly interfaces, simple instructions, and customer support to assist older patients.

11.3.3.2 Socioeconomic Status

Socioeconomic status (SES) impacts patient's use and access to telemedicine. Disparities in income and wealth results in accessibility variation to both hardware (such as smartphone, tablet and personal computer devices used for consultations) and software (such as reliable internet connections)[137]. Internet market optionality offers prepaid plans with limited data as an affordable choice though these may affect the quality of connection required for remote healthcare. Educational attainment impacts digital health literacy, access to technology and willingness to participate in telemedicine care[138]. Patient's occupations also influence accessibility to free time and appointments in addition to other SES factors. Marital status may be associated with the uptake of telemedicine, as women have been shown to assume a healthcare liaison role for their family members, though no studies have evaluated this directly[139].

11.3.3.3 Target Condition

The target condition and intended assessment outputs necessitate telemedicine components required. For instance, individuals with chronic diseases such as diabetes, hypertension, and ischaemic heart disease benefit greatly from remote patient monitoring tools that track vital signs and alert healthcare providers to potential issues[140]. These patients may use connected devices such as glucose monitors, smart blood pressure cuffs, and wearable electrocardiogram (ECG) monitors. However, telemedicine may not be beneficial if these patients require physical examination, urgent care or altered management. Flexibility in pathways with hybrid models would enable telemedicine review to triage the need for in person assessment for such patients. Additionally, accurate and validated tools for diagnosis and monitoring remotely are required to ensure the intended evaluation is completed.

11.3.3.4 Cultural and Language Considerations

Language barriers lead to poorer healthcare outcomes and further considerations are required within telemedicine to ensure these disparities do not widen[141]. During in person consultations, often translation services may be also in person (with prior planning) or by using a remote telephone service. During synchronous remote consultations however, this becomes a three-point remote consultation or conference, and consideration for this service is needed when planning telemedicine services. Use of artificial intelligence has potential to bridge this gap may be a future solution for equitable care[142].

11.3.3.5 Patient Acceptability and Usability

Patients have shown variable acceptability towards use and integration of telemedicine in healthcare services[143,144]. In addition to optimising services around other patient demographics, ensuring remote systems and tools are usable and provide an easy-to-use experience for patients are important factors for increasing acceptability[145,146]. Some patients are hesitant to use telemedicine due to concerns about privacy, security, and data protection and fear of personal health information being compromised or misused may deter individuals from using digital health platforms[147]. Healthcare providers must build trust by implementing strong data security measures, complying with privacy regulations, and educating patients about how their information is protected.

11.3.4 Synchrony

Telemedicine services are categorised based on the temporal nature of interactions between patients and healthcare providers.

Synchronous telemedicine involves real-time communication through video conferencing, telephonic consultations, or live chat platforms. This modality is widely used for primary care consultations, emergency triage, telepsychiatry, and specialist referrals requiring immediate clinical assessment[148,149]. The primary advantage of synchronous telemedicine is its ability to facilitate direct clinician-patient interactions, allowing for real-time decision-making and immediate intervention. Consultations can be flexible, and questions tailored based upon patient responses. However, it requires both parties to be available concurrently, which may pose scheduling and connectivity challenges.

Asynchronous telemedicine (otherwise known as store-and-forward telemedicine) enables the transmission of pre-recorded health data, medical images, questionnaires and diagnostic results for later review by a healthcare provider[149]. This method is frequently employed in fields such as teleradiology, teledermatology, and pathology, where clinical evaluation does not require real-time interaction[149,150]. The asynchronous model enhances workflow efficiency by reducing response time constraints and enabling specialists to assess cases at their convenience.

11.3.5 Remote wound assessment

Wound assessment is a critical component of clinical practice, particularly in the management of chronic wounds, post-surgical care, and acute injuries. The integration of telemedicine into wound assessment has opportunity to transform traditional wound care by enabling remote monitoring, early intervention, and multidisciplinary collaboration. Remote assessment has shown to enable earlier identification of SSI and reduce additional primary and secondary care attendances[151]. There is potential for future applications in diagnosis, monitoring and integration of artificial intelligence, though further evaluation is required.

Telemedicine-based wound assessment may involve a variety of modalities, such as digital imaging, video recording, video or telephone conferencing, and remote questionnaires[125,152,153]. Wearable sensors or high-fidelity dressings have even been proposed that could detect infections remotely and alert the healthcare provider[154].

Despite its advantages, telemedicine-based wound assessment presents several challenges:

- Image quality and standardisation: variability in image resolution, lighting conditions, and angles can affect the accuracy of remote wound assessment. Best practice statements and protocols are provided by the National Wound Care Strategy Programme (NWCSP) and Wounds UK to aid standardisation of data collection[155].
- Data security and privacy concerns: transmission of wound images and patient data requires robust encryption and compliance with health information privacy regulations (e.g. General Data Protection Regulation, GDPR).
- Limited Haptic Feedback: The absence of tactile examination may hinder accurate assessment of wound depth, tissue elasticity, or signs of infection such as fluctuance.
- Technology accessibility and digital literacy: patients with limited access to smartphones, internet connectivity, or digital literacy may face barriers to using telemedicine for wound assessment.

The rapid expansion of artificial intelligence and machine learning based predictive analytics enables opportunity for the future of telemedicine in wound care. AI-driven

wound assessment tools could analyse wound progression, detect infection characteristics, and provide automated treatment recommendations. However, research is needed to develop and validate artificial intelligence (AI) algorithms, improve interoperability between telemedicine platforms and electronic health records (EHR), and develop standardised telemedicine protocols for wound assessment. Prior to this advent of remote wound assessment, improved feasibility and accuracy of remote human wound assessment is required.

11.4 Environmental Sustainability in Healthcare

11.4.1 Definition

Sustainable healthcare involves integrating and adopting environmentally conscious practices into healthcare planning, operations and delivery to ensure the current population needs are met without compromising the well-being of future generations. The aim of such practices is to maintain high quality patient care whilst optimising efficiency in utilisation of resources. Sustainable practices encompass a wide remit ranging from reducing day to day resource consumption, waste generation, greenhouse gas emissions and ensuring the responsible use of medical supplies and energy.

The global healthcare industry is responsible for approximately 4–5% of total greenhouse gas (GHG) emissions**,** with hospitals, pharmaceuticals, and medical supply chains being the primary contributors[156]. The environmental impact of healthcare stems from:

- Energy consumption: hospitals and medical facilities require substantial energy for lighting, heating, cooling, medical equipment, and laboratory operations. Fossil fuel-based energy sources contribute to carbon emissions and air pollution.
- Waste Generation**:** Healthcare produces large volumes of hazardous and non-hazardous waste, including single-use plastics, biomedical waste, and expired pharmaceuticals. Poor waste management can lead to environmental contamination.
- Water Usage: Healthcare facilities are among the largest consumers of water, required for sterilization, sanitation, and patient care. Excessive water use can contribute to resource depletion and wastewater pollution.
- Pharmaceutical Pollution: Improper disposal of medications and chemicals contaminates water sources, leading to antibiotic resistance and ecological damage.

- Travel related emissions: patient travel is responsible for 10% of all National Health Service (NHS) related GHG emissions[157].

11.4.2 Key Principles of Environmental Sustainability in Healthcare

The principles of environmental sustainability in healthcare fall within several key areas, including estates and facilities, pharmaceuticals, procurement and supply chain and clinical pathways and transformation.

11.4.2.1 Estates and facilities

Estates cover a wide range of aspects which have in many UK trusts seen large changes in recent years. Implementing energy-efficient technologies in hospitals, clinics, and healthcare facilities to reduce carbon footprints (e.g., light emitting diode (LED) lighting, smart heating, ventilation and air conditioning (HVAC) systems, and renewable energy sources like solar panels)[158].

Waste management is another impactful area of care. Reducing medical and pharmaceutical waste through recycling, safe disposal, and waste segregation practices may improve overall emissions, though careful thought needs to be considered to balance risks associated with hazardous medical waste. Current NHS England targets aim to reduce carbon emissions produced by waste management by 50% in 2026 from 2023 levels and achieve waste distribution ratios of 20:20:60 for high temperature incineration, alternative treatment and offensive waste respectively[159].

11.4.2.2 Pharmaceuticals

Sustainable production of pharmaceuticals by industry is an important consideration as healthcare partnerships progress. Similarly responsible use and disposal are key requirements of the NHS.

11.4.2.3 Procurement and Supply Chain

Sourcing of environmentally friendly and responsible medical supplies and switching to reusable alternatives where able are necessary requirements of health services. The NHS now has five requirements for suppliers providing goods:

- A carbon reduction plan (PPN 06/21)
- Social value requirements (PPN 06/20)
- An evergreen supplier assessment

- Alignment with the NHS England supplier roadmap
- Completion of the modern slavery assessment tool (PPN 02/23)[160].

11.4.2.4 Clinical Pathways and Transformation

Operations are large sources of GHG due to aspects such as anaesthetic gases, energy use for lighting, equipment and sterilisation of instruments, pharmaceuticals and devices such as prosthetics and single use items. Green surgery initiatives such as total intravenous anaesthesia (TIVA), reusable equipment, rationalised theatre trays and reusable gowns and drapes are potential alternatives[161].

One of the largest areas of healthcare is the clinical care and pathways provided. Often overlooked, improvements in care and lead to reductions in emissions. Promoting preventive medicine, telehealth, and community-based care to reduce the environmental impact associated with hospital visits and resource-intensive treatments[161].

11.4.3 Importance and Impact

Climate change results in a self-perpetuating cascade of influences on the environment and health. Rising GHG levels result in increased global average temperature levels, which in turn cause more extreme weather. In turn this brings rising sea levels and further increases in GHG[162]. The importance of ensuring sustainable healthcare solutions is twofold, with both direct and indirect consequences of climate changes on public health. The latest mortality cost of carbon emissions in 2020 estimated that every 4434 metric tonnes of CO_2e produced results in one excess death over the next 80 years[163]. In the year 2020 alone, 50.1 gigatonnes of CO_2e were produced worldwide, estimating that this will result in over 11 million excess deaths by the year 2100[164].

11.4.3.1 Direct Influences on Human Health

Extreme Heat

Extreme heat leads to heat exhaustion and heatstroke. This also results in cardiorenal disease and deterioration of chronic health conditions such as ischaemic heart disease, respiratory airway diseases and diabetes related conditions[165]. These impacts can be life threatening and heat related mortality for people over the age of 65 has risen by 85% between 2000-2004 and 2017-2021[166]. 2024 was the first year that global average temperatures reached over 1.5^{O}C greater than pre-industrial levels. At 1.5^{O}C, 14% of the

world's population are exposed to extreme heat waves at least once every five years, at 2^{O}C this would rise to 37% of the global population[167].

Severe Weather

Severe weather events include drought, cyclones and hurricanes, floods and storms, and overall climate variation. Such events are increasing in frequency and the result of climate change[168]. Health impacts include trauma from injuries and inhalational poisoning from carbon monoxide other gases, cardiopulmonary compromise, and spread of both noncommunicable and infectious diseases[168].

Air Pollution

Air pollution from GHG is a significant risk factor for all cause mortality[169]. Specifically, it is strongly linked with morbidity of cerebrovascular accidents, ischaemic heart disease, chronic obstructive pulmonary disease, lung cancer, pneumonia and cataracts[170-174].

11.4.3.2 Indirect Influences on Human Health

Changes in Vector Ecology

Climate changes affect the transmission dynamics, geographical spread and re-emergence of vector borne diseases through numerous complex pathways. Further temperature and habitat effects on ecosystems interrupt this interplay[175]. Vectors are ectotherms, and rising temperatures will likely result in increased rate of pathogen development and reduction in incubation period, as seen with the dengue virus[176]. There is potential for novel or alternative vector borne diseases to become prevalent as the climate changes.

Water Quality

Temperature extremes and alternating weather patterns may increase the risk of water borne infections such as salmonella, campylobacter and Vibrio spp[177,178]. Waterborne disease outbreaks are often preceded by extreme rainfall events, though direct causation with climate change requires further evaluation[179,180].

Water and Food Supply

Malnutrition results in depletion of fat and muscle mass, reduction in cardio-respiratory function, changes in gastrointestinal function, immunosuppression and impaired wound

healing[181]. Projections estimate climate change to the year 2100 could result in reduction of global crop yields by up to 25%, resulting in substantial food shortages worldwide[182].

11.4.4 Telemedicine

Telemedicine as a service pathway offers potential for reductions in carbon emissions. In large trauma centres which have seen increases in clinic appointments, remote virtual clinics have shown reductions in GHG emissions[183]. Additional systematic reviews have evaluated carbon footprint of remote and against in person clinic assessment further highlighting these benefits, though establish the need for context specific considerations and possible drawbacks[184,185].

The Darzi Report, 2024, was an investigation of the state of the NHS and establishes the need for care to be brought closer to home[186]. Integrating telemedicine into care pathways is an opportunity to fulfil this requirement whilst moving towards net zero targets, though the benefits and specific role in surgical care pathways is yet to be established.

12 CHAPTER 2: ESTABLISHING THE PROBLEM; STUDY ONE AND TWO - A NATIONAL AND INTERNATIONAL SURVEY OF PRACTICE IN THE PREVENTION OF SURGICAL SITE INFECTION

12.1 Study one; A survey of surgical site infection prevention practice in UK vascular surgery

12.1.1 Background

Prior research has demonstrated a significant variation in reported SSI rates and perioperative management of patients undergoing major lower limb amputations[187]. In recent years, key organisations have published updated guidelines on SSI prevention[107,113,188]. It is unclear whether the introduction of these SSI prevention recommendations has resulted in widespread implementation.

12.1.2 Objectives

Given the substantial variation in direction across national and international SSI prevention guidelines, (CDC 2017, WHO 2018 and NICE 2019)[105,189,190], there is uncertainty whether clinic practice shows similar heterogeneity. This study therefore aimed to undertake a national cross-sectional survey of current SSI prevention practice amongst UK vascular surgeons.

12.1.3 Methods

The steering group for this study consisted of a professor, a consultant vascular surgeon, an academic clinical lecturer, a specialty trainee and a research fellow. The steering group coordinated the questionnaire development, validation, distribution and analysis.

Questionnaire development; surgical site infection prevention guidelines from the National Institute for Health and Care Excellence (NICE), Centres for Disease Control and prevention (CDC) and World Health Organisation (WHO) were analysed to identify 15 preventive measures forming the basis of survey question synthesis. Each guideline was also evaluated as to the level of recommendation for all SSI prevention measures to establish a rudimentary utility of the current strategies (*table 5*). Survey questions for each of the 15 SSI prevention domains were discussed with the steering group, resulting in the addition of two further domains (type of sutures and post-discharge wound surveillance) and the

removal of a single domain (surgical gloving) as little variation was anticipated. All decisions required unanimous agreement amongst the steering group members. Additionally, questions were reviewed to ensure wording was succinct, clear and unambiguous.

Table 5: SSI prevention measure recommendations from WHO, CDC and NICE guidelines

SSI prevention measure	WHO 2018	CDC 2017	NICE 2019
Pre-operative bathing			
MRSA eradication/testing			
Surgical antibiotic prophylaxis (SAP)			
Surgical site hair removal			
Surgical site preparation			
Surgical handwashing			
Enhanced nutritional support			
Normothermia			
Blood Glucose			
Incisional wound irrigation			
Prophylactic NPWT			
Antimicrobial sutures			
Prolonged SAP			
Dressings			
GICS			

Research Needed	Recommends Use	Recommends against use / not mentioned

Questionnaire Validation; a preliminary survey of 34 questions across 16 SSI prevention domains, including a range of binary, multiple choice and free-text open ended questions, was validated through two rounds of piloting at a tertiary vascular centre with ten consultants. After round one, major (questions removed or added) and minor alterations (wording alterations) were made based on the feedback from the consultant body. Major alterations included; two questions were rationalised into one on three occasions, six questions were removed and five questions were added. Reasons for major alterations included; a lack of utility, repetition, a desire to minimised respondent fatigue, and an attempt to ensure all SSI prevention strategies were addressed. Ten minor alterations were made to wording or responses of questions. After the second pilot, no further changes were suggested.

Questionnaire distribution; the online survey was disseminated using Qualtrics XM platform™ software. Demographic data collection included background information (working grade and current hospital of practice) and the presence of a generic SSI policy within the unit (NVR submission, diagnostic criteria, infection rates, high risk procedures

and active SSI prevention policy). Participants were advised their responses would be anonymised.

The final survey was distributed 15th March to 12th April 2021, via email, inviting surgeon and trainee members of the Vascular Society of Great Britain and Ireland to participate. One month was allowed for responses with a reminder email circulated at two and three weeks.

*Questionnaire analysis; r*esponses were scrutinised by the lead researcher, and non-response questionnaires removed. Partially completed questionnaires were included. Only answers submitted within the response window were included in the analysis. Completed questionnaires were exported into Microsoft Excel Version 16.59. Binary responses were reported as percentages and multiple-choice answers were expressed as percentages of the specific question's respondents. Median reported SSI estimates are presented alongside interquartile ranges. Responses including 80% or more in one item was taken as good levels of agreement for use of that practice. Chi squared test was completed where appropriate in SPSS version 27 (IBM Corp, Armonk, NY) to determine the impact of variables on estimated SSI rates and a regression analysis performed. In the interest of the statistical analysis, infection rates were subdivided above and below the median reported infection rate. Estimated SSI rates collected from the survey were compared to the nationally reported rates from the National Vascular Registry (NVR) 2019 (with permission).

12.1.4 Results

12.1.4.1 Survey responses

A total of 109 respondents completed the survey, with the majority (n=90, 82.6%) identifying they were in a consultant role. Other positions included specialty registrar (n=14, 12.8%), core trainee (n=3, 2.8%), and not specified (n=2, 1.8%). Based on numbers of consultants registered with the Vascular Society (n=376), this is approximately a 24% response rate. Survey responses came from a total of 47 hospitals with a wide distribution

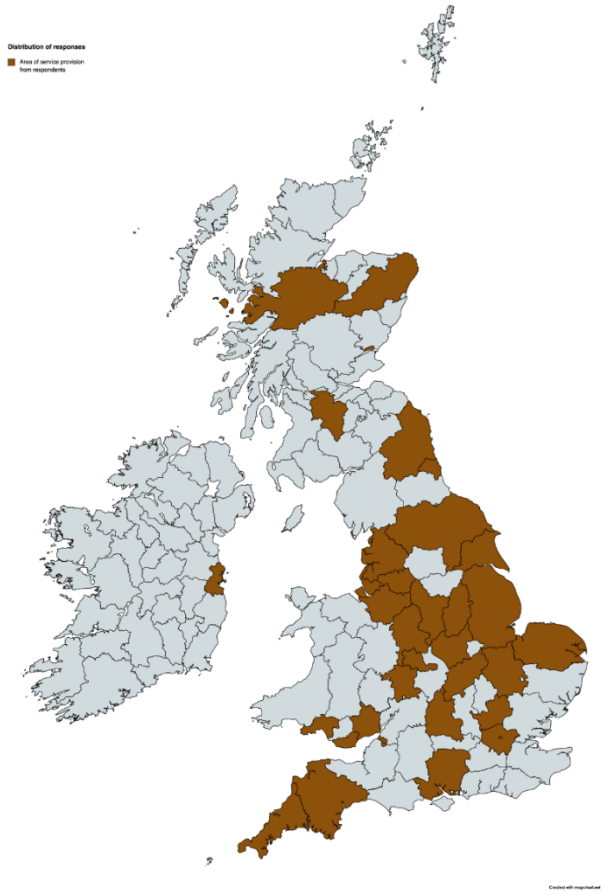


Figure 4: Distribution of survey responses

across the UK, as shown in Figure 4. Most respondents (58.7%. n=62) primarily worked in a university hospital and 41.3% (n=43) in a district general hospital.

12.1.4.2 Infection rates

The median estimated SSI rate was 7.5% (IQR 5-10%). Twenty respondents (18.3%) reported SSI rates ≥10%. Empirical criteria alone were used to diagnose SSI by 35 (52.2%) respondents (Figure 2). Lower limb arterial and major limb amputation were identified as high risk procedures for SSI (n=58, 92.1% and n= 47, 74.6% of responses respectively). All units routinely submitted data to the National Vascular Registry and 62.7% (n=47) had a dedicated SSI prevention protocol.

12.1.4.3 Pre-operative measures

12.1.4.3.1 Pre-operative bathing

Pre-operative bathing was recommended to patients by 67.1% (n=49) of clinicians, with the majority indicating standard soap as the agent of choice (54.9%, n=28). Chlorhexadine gluconate (CHG) soap, CHG cloths and other methods (betadine; n=1, hibiscrub; n=1, octenisan; n=2, stellissept; n=1) were recommended by 29.4% (n=15), 5.9% (n=3) and 9.8% (n=5) respectively. Reasons given for not advocating pre-operative bathing include; not necessary (14.7%), a lack of evidence base (50.0%), and a lack of capacity to provide (23.5%). Four surgeons indicated that they used to recommend pre-operative bathing but as they now admit elective patients on the day of surgery, this is not possible.

12.1.4.3.2 Methicillin Resistant Staphylococcus Aureus (MRSA) Screening

Pre-operative MRSA screening was practiced by 93.3% (n=56) of vascular surgeons. Reasons for not screening patients included a lack of supportive evidence base, and a lack of staff or time resource capacity. For patients colonised with MRSA, the majority of responders provide treatment with both intranasal mupirocin and CHG body wash (66.1%, n=39). Intranasal mupirocin alone is used in 16.9% (n=10) and CHG body wash alone in 5.1% (n=3) of cases.

12.1.4.3.3 Surgical antibiotic prophylaxis (SAP)

The majority of surgeons use SAP for open abdominal aortic aneurysm (AAA) repair (95.5%, n=64), lower limb arterial (94.0%, n=63), major limb amputation (92.5%, n=62), endovascular aortic aneurysm repair (EVAR; 89.6%, n=59), carotid endarterectomy (CEA; 89.6%, n=58) and minor limb amputation (77.6%, n=52) procedures. Antibiotic prophylaxis is used by less than one third of surgeons in peritoneal dialysis catheter (26.9%, n=18), open venous (20.9%, n=13), and arteriovenous fistula (13.4%, n=7) procedures. This was a multiple response question, some respondents did not indicate use of antibiotics prior to open AAA repair, lower limb arterial, or major limb amputation, which prevented these from reaching 100% use. SAP is given at incision by 21.3% (n=16) and within two hours preoperatively by 77.3% (n=58).

12.1.4.3.4 Hair removal

Only 13 responses were available for this question. Hair removal typically takes place in theatre (84.6%, n=11), with a clipper (100%, n=13). Reasons that necessitate this are to avoid hair in the closure site (84.5%), to facilitate post-operative dressings (58.6%) and for ease of skin preparation (55.2%). Only 1.72% (n=1) do not remove hair covering the incision site, though a reason was not specified.

12.1.4.3.5 Surgical site preparation

Most responders reported using alcoholic skin preparations (78.3%, n=54), whilst 11.6% (n=8) used aqueous and 10.1% (n=7) used both aqueous and alcoholic solutions. Chlorhexidine skin preparation were preferred by 56.5% (n=39) of respondents, povidone iodine based solutions by 15.9% (n=11) and 27.5% (n=19) use both preparations.

12.1.4.3.6 Hand preparation

The majority of surgeons use an aqueous based solution for surgical scrubbing (79.2%, n=61), 18.2% (n=14) use alcohol-based solutions and 2.6% (n=2) would use either.

12.1.4.4 Perioperative measures

12.1.4.4.1 Nutrition

Less than a half of respondents routinely carry out peri-operative nutritional assessments (45.6%, n=26), 33.3% (n=19) do not undertake this practice and 21.1% (n=12) would do so for targeted groups (empirical decision; n=5, elective open procedures; n=2, amputation; n=1, low albumin; n=1, frailty; n=1). Reasons for not undertaking nutritional assessments included: lack of time (33.3%) or staff (36.7%) to assess every patient. Furthermore, 30.0% indicated they had no nutritional service to refer to.

12.1.4.4.2 Temperature regulation

Methods to maintain perioperative normothermia included standard blankets (53.7%, n=36), forced air warming (86.6%, n=58), heated mattress (46.3%, n=31) and warmed fluids (50.7%, n=34).

12.1.4.4.3 Blood glucose

Just over half of surgeons monitor blood glucose perioperatively in patients without diabetes (57.4%, n=39).

12.1.4.4.4 Wound irrigation

Wound irrigation prior to closure of clean wounds was practiced by 31 (49.2%) of respondents, with saline (50.0%, n=22), povidone-iodine (31.8%, n=14), and hydrogen peroxide (16.9%, n=7) being the most commonly used wound irrigation agents.

12.1.4.4.5 Gentamicin impregnated collagen sponge (GICS)

GICS was used by 71.6% (n=48) of respondents. Indications for usage included prosthetic implants (62.5%), venous implant (10.4%), Biosynthetic implant (18.8%), re-intervention surgery (70.8%), contamination or known infection (12.5%) and groin wounds (2.1%).

12.1.4.4.6 Triclosan-coated sutures

Most respondents did not use triclosan-coated sutures (77.9%, n=53), whereas 14.7% (n=10) regularly used them and 7.4% (n=5) were unsure if antimicrobial sutures were used. Reasons for not using these sutures included a lack of evidence base (27.3%), cost (9.1%), personal choice (13.6%), being unavailable (45.5%) or an unawareness of the sutures (3.0%).

12.1.4.4.7 Dressings

Following primary skin closure, 96.4% (n=84) of respondents indicated they used a wound dressing. A basic wound dressing was the most commonly used (52.9%, n=46), while advanced dressings (14.9%, n=13) and skin glue (20.7%, n=18) were also used.

12.1.4.4.8 Negative pressure wound therapy (NPWT)

Negative pressure wound therapy was also commonly used in specific situations following primary wound closure (52.5%, n=31). Reasons provided for the use of NPWT included; re-intervention surgery (31.0%), groin surgery (51.7%), high BMI (16.7%) and long wounds (3.4%). Reasons cited for non-use of NPWT included; lack of guidelines (34.6%), a lack of evidence base (38.5%), cost (19.2%), limited resources (3.8%) and difficulty of application (3.8%).

12.1.4.5 Postoperative measures

12.1.4.5.1 Prolonged surgical antibiotic prophylaxis

Prolonged surgical antibiotic prophylaxis (>24 hours) was utilised by 22 (37.3%) respondents; most commonly after major limb amputation (73.9%) and lower limb arterial procedures (69.6%).

12.1.4.5.2 Wound Surveillance

Formal wound surveillance programmes were not undertaken by 73.7% (n=42) of respondents. Methods of monitoring wounds included; face to face (85.0%), community nurse follow-up (23.3%), wound photograph at discharge (10.0%), paper questionnaire (8.3%), automated remote follow-up (5.0%), specialist vascular nurse (3.3%) and other not specified (5.0%).

12.1.4.5.3 Impact of SSI prevention practice on estimated SSI rates

Participants were asked to estimate SSI rates for the period January-December 2019, results were investigated against SSI practices for potential influencing practices, as shown in table 6. Blood glucose monitoring in non-diabetic patients appeared to be significant in reduction of post-operative infections.

Table 6: The impact of SSI prevention on estimated infection rates

	SSI Estimate		p value	OR	95% CI
	≤7.5%	>7.5%			
SSI Policy					
Yes	34	13	0.296	1.690	0.700-2.684
No	17	11			
Non-diabetic glucose monitoring					
Yes	17	8	0.030	0.134	0.330-0.542
No	4	14			
Wound Irrigation					
Yes	9	11	0.639	0.750	0.225-2.496
No	12	11			
GICS					
Yes	16	13	0.232	0.451	0.121-1.682
No	5	9			
Dressings					
Basic	16	17	0.728	0.784	0.121-1.682
Other	6	5			
NPWT	10	12	0.650	1.320	0.398-4.378
No NPWT	11	10			
Antibiotic Prophylaxis					
≤24 hours	13	14	0.907	0.929	0.270-3.199
>24 hours	8	8			
Wound Surveillance Programme					
Yes	8	6	0.449	0.609	0.168-2.207
No	13	16			

12.1.4.6 NVR Data

Data submitted to the national vascular registry indicated a lower overall vascular SSI infection rate of 1.92% compared with the median estimated SSI rates of 7.5% (Based on submissions for all AAA surgery, carotid endarterectomy, lower limb surgical revascularisation and major limb amputation)[191].

12.1.5 Discussion

This survey corroborates guideline recommendations for further well designed RCTs to evaluate the impact on SSI rates of; pre-operative bathing, MRSA screening, surgical site preparation solutions, perioperative blood glucose management, wound irrigation solutions, antimicrobial sutures, negative pressure wound therapy, gentamicin impregnated substrates, post-operative dressings, and prolonged surgical antibiotic prophylaxis[107,113,188]. This survey also highlights the disparity in reported SSI rates between registries, clinical practice and literature. High quality RCTs are needed to provide evidence on which to base practice and inform future versions of guidelines.

Lower limb revascularisation and amputation are both reported as high risk procedures for SSI which is supported by in NVR data and this current survey[191,192]. There is however little consensus on which criteria should be used to diagnosis these infections, with most respondents here basing diagnosis on clinical experience. Given the inconsistency in use of diagnostic criteria, there is need for standardisation of a robust measure to accurately diagnose SSI. CDC criteria has widely been accepted as the gold standard but seemingly is not uniformly utilized. The recently validated Bluebelle wound healing questionnaire provides a promising prospect in this area, particularly given its patient reported element, however it is not yet widely used in clinical practice[125]. Current SSI prevention practice in vascular surgery varies considerably, with little consensus on many measures. Despite increasing awareness and uptake of strategies to prevent SSI there is a clear lack of concurrence on their implementation. There is a lack of unanimity on nutritional assessment, blood glucose monitoring in non-diabetic patients, clean incisional wound irrigation, optimal wound dressings and the use of prophylactic NPWT. This seems to be recognised in the recently published CDC, NICE and WHO guidelines, which all highlight the paucity of evidence in key areas of SSI prevention[107,113,188]. Further, not one of the 15 SSI prevention measures identified by the three regulatory bodies has an unanimously agreed

recommendation for use in practice, indicating a significant need for high quality research streams in these avenues.

There was over 80% agreement from respondents in several measures including MRSA screening, procedures requiring SAP, pre-operative hair removal and use of forced air warming. However, there are aspects within those measures with little agreement in best practice such as eradication methods for MRSA colonization and other strategies to maintain normothermia. Although surgeons seemingly agree upon which procedures to give antibiotic prophylaxis for (Open and endovascular AAA, lower limb arterial, major and minor amputation, and CEA) only 19.4% indicated using antibiotic prophylaxis in open venous surgery. The HARVEST trial demonstrated a significant reduction in SSI with antibiotic prophylaxis in open varicose vein surgery)[193]. Ascertaining the optimal SAP regimen for vascular procedures is particularly troublesome in this patient group given the confounding issue of tissue loss and ischemia alongside wound infection. The majority of surgeons (76%) indicated use of alcohol based skin preparation, compared to 48% reported in a 2014 survey[187]. This is in line with a growing body of evidence supporting the use of alcoholic chlorhexidine over aqueous povidone iodine, although evidence from the recent FALCON trial may alter this practice[194,195]. Meta-analysis of almost 12,000 participants has shown triclosan coated sutures to be clinically and cost effective in significantly reducing SSI risk[196,197]. Despite this, our survey found that most respondents did not use these sutures, for reasons of lack of evidence and expense.

Median reported surgeon SSI rate was considerably greater than the nationally reported average (7.5% vs 1.92%), however both are significantly lower than SSI rates in vascular literature, which can be up to 40%[198-200]. This presents a worrying disparity between registry data, clinical practice, and research findings. This survey suggests factors contributing to underreporting may include lack of consensus regarding SSI diagnosis and lack of formal wound surveillance. Given the substantial cost identified per SSI, under reporting misconstrues the true clinical and socioeconomic burden of this problem[201].

The impact of SSI policy, non-diabetic blood glucose monitoring, wound irrigation, GICS, dressings, antibiotic prophylaxis and presence of a wound surveillance programme on estimated infection rates were investigated. The significance of blood glucose monitoring in non-diabetic patients in this survey is likely to be a type two error given the small sample

size, although further exploration would be needed to determine the true significance of this.

Limitations

The survey achieved almost 25% response rate from consultant members registered with VS, providing a snapshot of opinions from an extensive geographical spread of UK vascular units. It was also conducted during the COVID-19 pandemic which may have influenced response rates. As with most surveys of this nature, it is open to responder and recall bias and results may have changed if there were more participants. In order to minimise bias, the focus group meticulously considered question wording (to ensure unambiguity) and survey length within development. A panel of experts reviewed the questions at each stage before piloting within the consultant body of a tertiary vascular unit.

Response fatigue is a common issue and levels of participation did drop towards the end of the survey questions. Even with attempts to address this as made during survey development, all remaining questions were felt to be relevant to comprehensively ascertaining current practice. To preserve structure and enable ease of organization for respondents to follow, questions were categorized into SSI related, pre-, peri- and postoperative themes. Additionally, not every SSI prevention measure was included in the survey, for example surgical technique and laminar flow theatres can impact infection rates. To include all aspects of SSI prevention measures would have extended the duration of the survey and risked drop out or respondent fatigue further.

12.1.6 Conclusion

There is little agreement in current guidelines on the best practice to prevent SSI. Unsurprisingly then, clinical practice follows suit and continues to show little consensus on prevention measures used. There also appears to be a disparity in registry level, clinical perception, and literature data for SSI rates. Well-designed, high-quality trials are needed to provide evidence-based recommendations in this field. Further, there is need to establish the extent of this problem across surgical specialties and international boundaries.

12.2 Study two: PRESS Survey: PREvention of Surgical Site Infection – A Global Pan-Specialty Survey of Practice

12.2.1 Background

Over 300 million surgical procedures are performed annually worldwide[202]. In recent years, guidance on the prevention of SSI has been published by key organizations; National Institute for Health Care and Excellence (NICE), Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO) [105,190,203]. However, a national survey of UK Vascular surgeons (study one), identified disparity in recommendations across these guidelines, which was noted to be due to the lack of underlying evidence [204]. This study found variability in SSI prevention practices across different institutions, as well as lack of relevant registries, clinical perception and literature data for SSI rates [204]. James Lind Alliance priority setting partnerships have found prevention, diagnosis and treatment of wound infections as fundamental priorities for further research targets[205]. This follow-on survey aimed to evaluate the barriers in establishing uniform practice in the prevention of surgical site infection across surgical subspecialties, healthcare financial system and geographical locations.

12.2.2 Objectives

With clear findings showing disparity in practice across UK vascular surgery, a further elaborative survey is designed with the following objectives;

Primary objective:

- to identify the barriers to establishing standardised SSI prevention practice

Secondary objectives:

- to identify intra- and inter-specialty variations in surgical site infection prevention practice
- to identify variations in practice amongst financial systems such as state and privately funded healthcare systems and economical classifications

12.2.3 Methods

12.2.3.1 Study Design

PRESS was an international, pan-specialty, collaborative cross-sectional survey. A global panel of experts formed the study steering committee (SSC), providing a consensus-based

approach to survey development, validation, and distribution. This study is reported in line with the checklist for reporting of survey studies (CROSS) and the checklist for reporting results of internet E-surveys (CHERRIES) [206,207]. Ethical approval is provided by the Hull York Medical School Ethics Committee (HYMS22-23/10). The protocol for this study has been published previously[208].

The survey was delivered electronically online using the QualtricsXM PlatformTM, Utah, USA. The format was designed to include a combination of binary, likert or multi-select. Free text comments were used to collect further detail within targeted sections, but kept to a minimum to reduce response degradation.

12.2.3.2 Study Steering Committee

The study steering committee (SSC) oversaw all study activities including questionnaire development, validation, distribution, data analysis and write-up. The SSC consisted of a statistician, a research manager and surgeons with expertise in Urology, General, Vascular, Orthopaedic, Plastic and Paediatric Surgery. Surgeons ranged from those in early surgical training to expert, with four professors of surgery included. Member's region of practice spanned across five time zones in three continents, including the United Kingdom, Spain, India, Greece, France, Switzerland, and Canada. The SSC held virtual meetings using the Microsoft Teams version 1415/24120100221 and over 60%-member attendance was maintained throughout.

12.2.3.3 Questionnaire Development

A pilot questionnaire was developed based on SSI prevention measures outlined in the CDC (2017), WHO (2018), NICE (2019), Wounds UK (2020) and the International Surgical Wound Complications Advisory Panel (ISWCAP) guidelines. Additionally, feedback from the survey of surgical site infection prevention practice in UK vascular surgery were used to inform survey questions and design [203 105 190 209 210]. As the survey was targeted at participants across multiple specialties, it only contained general prevention measures widely applicable.

The questionnaire was structured into five sections; demographics, SSI surveillance, preoperative, peri-operative and postoperative SSI prevention domains. Data were collected on participant surgical specialty, operative grade, country of practice and financial

healthcare system of practice. SSI data included surgeon's criteria used for diagnosis. There were 15 perioperative domains which formulated the UK questionnaire, which were scrutinized against the CDC, WHO, NICE and ISWCAP guidelines outlined above, by the SSC to form a pilot questionnaire. Questionnaire development was carried out through discussion by members of the SSC and a record of any question refinement documented. The number of questions required were not rigidly defined but the SSC did consider the impact on survey duration which can influence completion rates. Decisions on inclusion and exclusion of question items required >80% consensus from committee members. The pilot questionnaire contained 17 questions across these five domains, a copy is provided in *appendix 8.1*.

Internal and external validation were completed sequentially with review and consensus update to the questionnaire at each stage. Changes were recorded as major (whereby a question is completely added or removed), or minor (whereby there were wording or response option changes to existing questions or text. The questionnaire was developed initial through internal validation within the SSC. There were no major and 14 minor changes were considered at this stage. Minor changes included six wording changes, and eight response options changes (four other options added, three likert response changes and one free text changed to drop down options). The revised post internal validation questionnaire is provided in *appendix 8.2*. External review was provided by collaborators from the ROSSINI platform trial management group and the SSC for Surgical Infection Society of North America. There were two major and seven minor changes after external review. Major changes were the addition of two questions (on the use of surgical drapes for preparation and the intraprocedural change in gloves and instruments) and minor changes included two wording and four likert response option changes and the use of display logic for UK respondents to answer a trial equipoise question. After the final consensus changes, the final questionnaire was agreed by the SSC, containing 19 questions in total and provided in *appendix 8.3*.

12.2.3.4 Sample Characteristics

The survey was sent out electronically to surgeons of any specialty and at all levels of training worldwide. This includes consultants, and surgical trainees (specialties registrars/residents). To be included in the study, surgeons must be currently practicing and be registered with their national surgical body, college or society. The validated online

survey was distributed through QualtricsXM for single stage cluster sampling in addition to dissemination through social media, where snowballing was able occur. Offline, written questionnaires could be completed and uploaded to QualtricsXM if electronic versions were not accessible to respondents. Each network of distribution provided a cluster, a list of participating societies involved in distribution are included in *appendix 8.4.*

12.2.3.5 Survey Preparation and Administration

The survey was advertised in weekly rounds, one month prior to dissemination using affiliated society social media accounts and the Surgical Infection Research Network twitter/X account (@SIRNglobal). Standardised dissemination emails, text and tweets were prepared and personalised as required to ensure variation in information provided was minimised.

The survey was disseminated worldwide, with an international SSC to establish a network of distribution. The validated online survey was distributed using an electronic link and society participants received an email via their affiliated membership organization, inviting them to take part. Additional routes included word of mouth, direct link to the survey on twitter/X and networking. Cold emails were additionally sent to 66 surgical societies worldwide, six (9.1%) agreed to disseminate, two (3.0%) declined and 58 (87.9%) did not respond.

The survey was open for responses from 26th June 2023 for a three-month period, closing on 26th September 2023. Afterwards, the survey was locked and unable to receive further responses. During the dissemination period, reminders were sent out via networks and social media platforms every two weeks. The 'prevent multiple submissions' option in Qualtrics was enabled to prevent multiple participation of respondents. A secondary IP address check followed to ensure there are no remaining duplicate entries. No two entries from the same IP address were allowed within 24 hours. Participants were offered an opportunity to win a £50 Amazon voucher as an incentive to participate in the survey. Survey items were not randomized to improve participation, as the logical order of each survey section was unanimously agreed by the SSC to improve the response flow. The survey was presented across seven pages on both mobile and computer formats, corresponding to the five question domains with a title page and closing items. Participants were able to view a progress bar during completion.

12.2.3.6 Statistical Analysis

Given the global nature of the survey, and planned snowballing, no sample size was calculated. Raking was used to assign weight values to each survey respondent in such a manner, that the weighted distribution of the sample is in very close agreement with two or more marginal control variables. Socio-economic (developing vs developed countries) variable and surgical specialties were used to weigh the sample of responses.

For sub-group analyses likert responses were coded from one to five with answers of one indicating a 'never' response and five reflecting 'always'. As such higher scores indicated a practice occurred more often. The mean and standard deviation of each score was presented. A statistician (KMK) supported study design and conducted data analysis for this study.

12.2.4 **Results**

12.2.4.1 Respondent characteristics

In total there were 1236 responses within the study period. Mean survey progress was 64.9±42.1% and median time to completion was 6.2 minutes (IQR, 2.0-10.3). The breakdown of responses by completion rates and time to complete the survey of each is shown in table 7. Most respondents (768, 62.1%) were 'expert surgeons' (classified as chief of surgery, consultant, attending or staff), with the majority practicing in Europe (n=500, 40.5%) and General Surgery (n=369, 29.9%). The most common financial system surgeons working in was a public system (n=675, 54.6%) defined as one which was government funded. Descriptive characteristics are shown in *table 8*.

Table 7: PRESS survey completion rates and time to complete.

Survey Completion	*n*	Percentage of responses	Mean Survey Completion (%)	±SD	Median Time to Completion (Minutes)	IQR
>0%	1235	100.0	64.9	42.1	6.2	2.0-10.3
>25%	889	72.0	86.8	27.1	8.0	5.5-12.2
>50%	736	59.6	98.8	5.8	8.5	6.1-13.1
>75%	714	57.8	99.8	2.0	8.5	6.1-13.2
100%	700	56.7	100.0	0.0	8.5	6.1-13.2

Table 8: Characteristics of respondents

	Number of responses	Percentage of responses (%)
Level of training		
Expert surgeon (chief of surgery / consultant / attending / staff)	768	62.1
Surgeon in training (surgical resident / surgical registrar / core surgical trainee)	253	20.5
Missing	214	17.4
Region of practice		
Africa	79	6.4
Americas	138	11.2
Asia	276	22.3
Europe	500	40.5
Oceania	28	2.3
Missing	214	17.4
Surgical specialty		
Cardiac surgery	47	3.8
Endocrine surgery	9	0.7
General surgery (Upper gastrointestinal, hepatobiliary, colorectal, breast, community)	369	29.9
Neurosurgery	66	5.3
Obstetrics and gynaecology	39	3.2
Ophthalmic surgery	11	0.9
Oral and maxillofacial surgery	8	0.6
Orthopaedic surgery	118	9.5
Otolaryngology (ENT)	16	1.3
Paediatric surgery	24	1.9
Plastic and reconstructive surgery	28	2.3
Surgical oncology	28	2.3
Thoracic surgery	21	1.7
Transplant surgery	7	0.6
Trauma	22	1.8
Urology	110	8.9
Vascular surgery	94	7.6
Missing	218	17.7
Financial health system		
Public (government funded)	675	54.6
Private (insurance based)	163	13.2
Both / mixture	174	14.1
Missing	223	18.1

12.2.4.2 Descriptive results

12.2.4.2.1 Surgical site infection diagnosis

When asked how they diagnosed SSI in their day-to-day practice. clinical examination was used always by most respondents (n=652, 52.8%) as the primary method of diagnosis. CDC criteria was used variably with 144 (11.7%) always using this for diagnosis and 305 (24.7%) never using. ASEPSIS and Southampton scores were rarely used for diagnosis, with only 412 (33.4%) and 345 (27.9%) respectively ever using these scores at all. Respondents also reported using supportive investigations such as c-reactive protein, wound microbiology, culture and sensitivity and commuted tomography scans to aid diagnoses.

12.2.4.2.2 Preoperative SSI prevention

Antibiotic prophylaxis was often or always given within one hour of surgery by 474 (60.8% of responses). It was rarely or never given beyond two hours of incision by 563 (72.2% of responses). Respondents did not show any preference for any type of solution agent for surgical handwashing, with no partiality towards aqueous or alcoholic, or povidone iodine (PVP-I) or chlorhexidine gluconate (CHG) based washes. Additional agents suggested for hand washing included sterilium, soap and hydroalcoholic gel. When choosing solution agents for surgical site preparation, respondents often or always chose alcoholic PVP-I or alcoholic CHG in 340 (43.6% of responses) and 372 (47.7% of responses) respectively, compared with 217 (27.8% of responses) and 136 (17.4% of responses) for aqueous PVP-I and aqueous CHG solutions. Additionally, some respondents reported using octenisept, double preparation with both chlorhexadine and iodine and cetrimide for surgical site preparation. The distribution of responses to pre-operative questions is shown in figure 5.

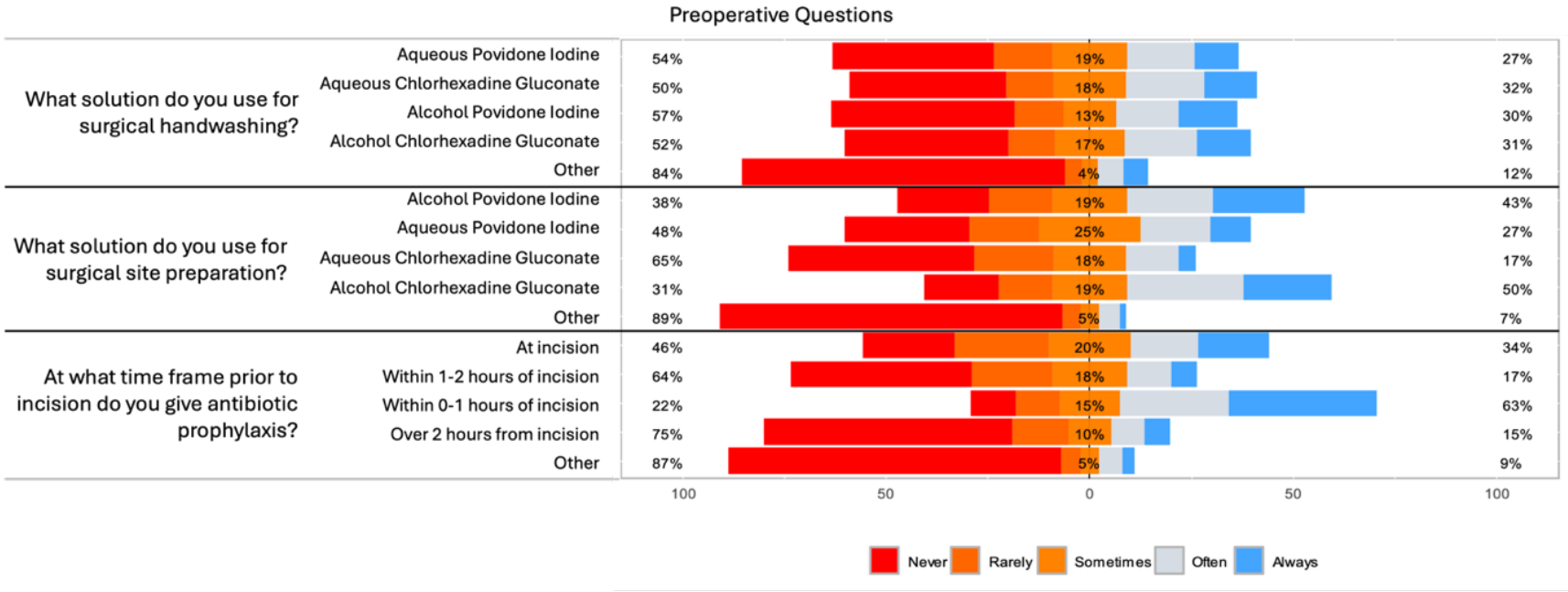


Figure 5: Breakdown of respondent answers by preoperative surgical site infection prevention practice questions

12.2.4.2.3 Perioperative SSI prevention

Nutritional assessments are carried out perioperatively (never, n=50, 6.8% of responses), though these are performed variably, as 118 (16.0% of responses) always and 243 (33.0% of responses) sometimes do so. For methods of maintaining normothermia, standard blankets and forced air warming are used often and always by 391 (53.1% of responses) and 436 (59.2% of responses) respondents respectively. Warmed fluids were used variably (256, 34.8% of respondents, would use these sometimes) and heated mattresses were rarely or never used by 384 (52.2% of responses) respondents. Some respondents indicated using silver foil blankets to maintain normothermia. Non-iodinated surgical drapes were used by 617 (86.8% or respondents) compared to 474 (64.4%) would use iodinated. If deep or subcutaneous tissue irrigation was performed, saline was often or always used by 481 (65.4% of respondents) respondents, compared to 94 (12.8% or responses) and 79 (10.7% of responses) for PVP-I and hydrogen peroxide respectively. Other agents used included prontosan, chlorhexadine, octenisept, lavasept, hartmans solution, bactisure, and antibiotic solutions in saline which included; rifampicin, gentamicin and vancomycin. Both gloves and surgical instruments were variably changed prior to closure. Triclosan-coated antimicrobial sutures were never used by 367 (49.9% of responses) respondents. The most common wound dressing to be used was a basic wound contact layer, used often and always by 529 (71.9% of responses) respondents. Other dressings reported by surgeons included leukomed sorbact and dermabond prineo. The distribution of responses to peri-operative questions is shown in figure 6.

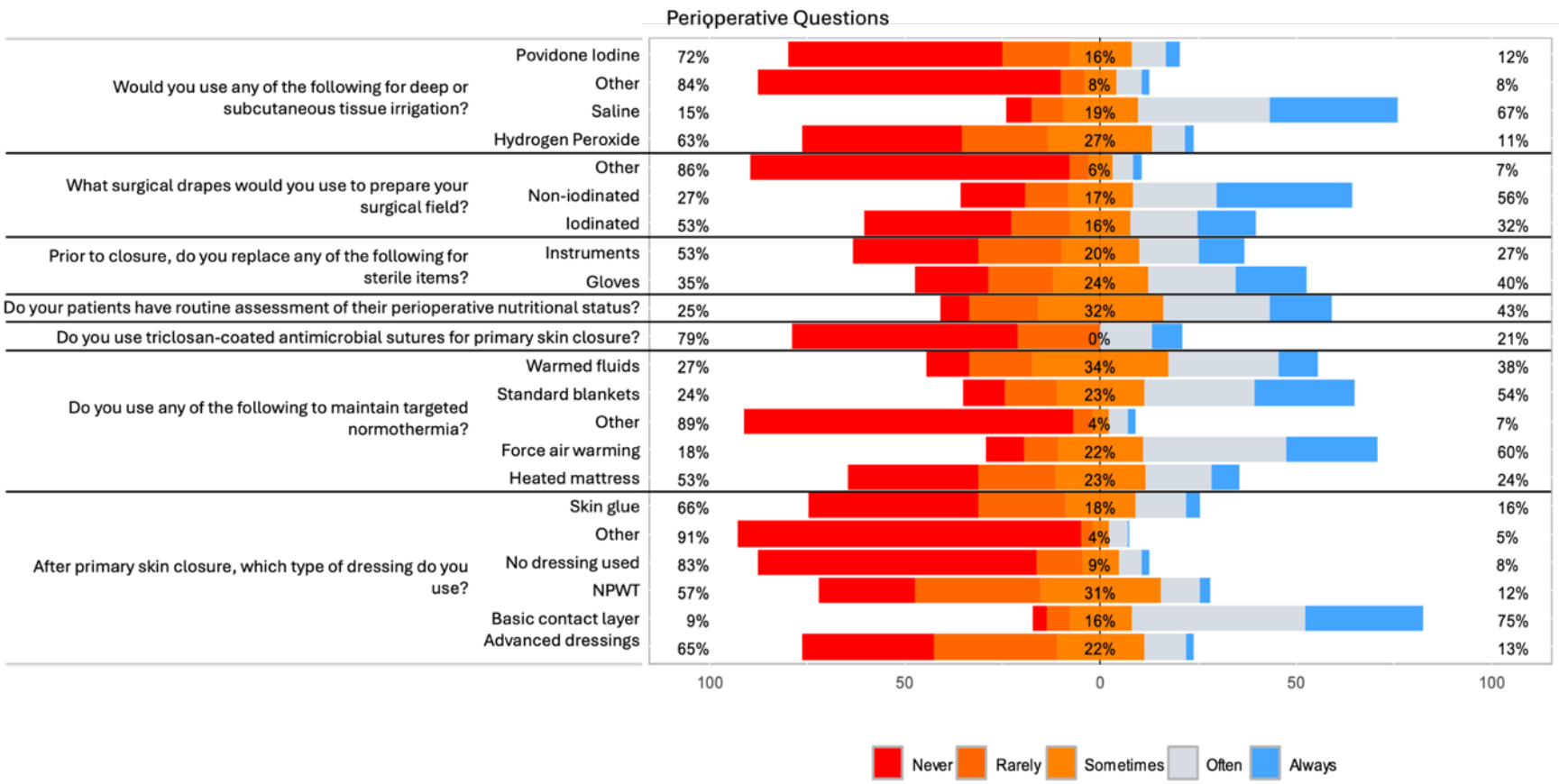


Figure 6: Breakdown of respondent answers by perioperative surgical site infection prevention practice questions. NPWT; negative pressure wound therapy

12.2.4.2.4 Postoperative SSI prevention

Postoperative antibiotic prophylaxis was given variably and 113 (15.4% of responses) would never prescribe this. Reasons for providing postoperative doses of antibiotics included patient factors (age, obesity, poor nutrition, uncontrolled diabetes, immunosuppression, reintervention, smoking status), operative factors (use of prosthetic material, type of procedure, length of procedure, inadequate theatre asepsis or contamination, active infection at time of surgery), guidance based (local antibiogram, international guidelines, evidence from RCTs), and subjective (personal experience, routine practice or fear of infection including hospital flora. Almost half of respondents always follow-up their patients in person after surgery (n=307, 42.9% of responses). Over half would always follow-up their patients by any method (n=384, 52.4% of responses). Other responses included dedicated SSI nurse, app based, GP, and patient-initiated follow-up. The distribution of responses by postoperative questions is shown in figure 7.

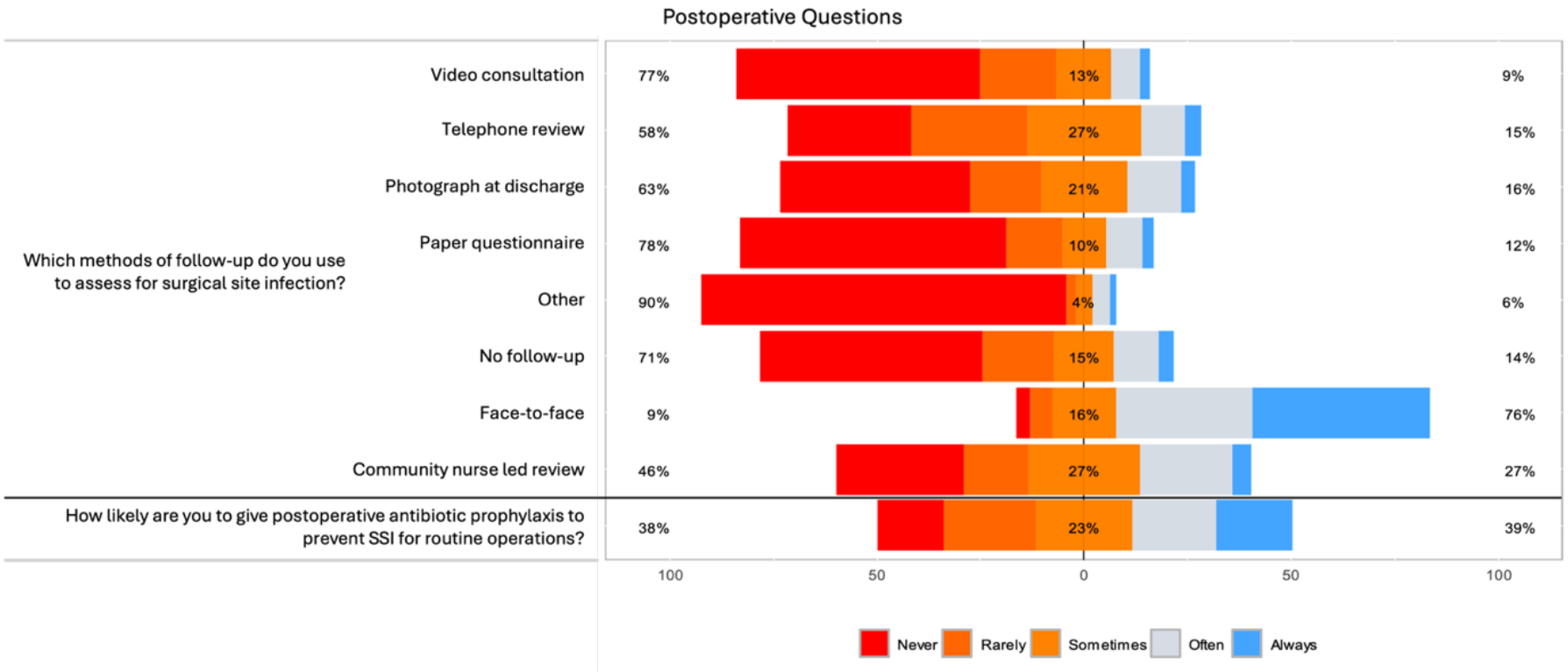


Figure 7: Breakdown of respondent answers by postoperative surgical site infection prevention practice questions

12.2.4.3 Subgroup Analyses

12.2.4.3.1 Surgical training grade

Expert surgeons use CDC criteria to guide diagnosis of SSI compared to surgeons in training (2.81±1.52 vs 2.40±1.41, p<0.001). With regards to surgical hand washing, surgeons in training use alcoholic povidone iodine (2.67±1.51 vs 2.39±1.50, p=0.027) and aqueous povidone iodine (2.67±1.36 vs 2.40±1.43, p=0.018) more frequently than expert surgeons. They were also more likely to use triclosan coated sutures in their practice (2.11±1.42 vs 1.86±1.32, p=0.045). Expert surgeons frequently used a basic wound contact layer after wound closure (3.90±1.03 vs 3.72±0.98, p=0.012) whereas surgeons in training were significantly more likely to use advanced dressings (2.48±1.03 vs 2.12±1.07, p<0.001), skin glue (2.45±1.13 vs 2.08±1.21, p<0.001), and negative pressure wound therapy (2.62±0.98 vs 2.29±1.03, p<0.001). When follow-up patients up after surgery, expert surgeons frequently see patients face-to-face (4.12±1.05 vs 3.89±0.99, p<0.001), whereas surgeons in training were more likely to have no follow-up for patients (2.19±1.25 vs 1.86±1.18, p<0.001). Response distribution for expert surgeons and surgeons in training are shown in *appendix 8.5.*

12.2.4.3.2 Financial system

Responses from surgeons operating in public, private and a mixture of both financial healthcare systems were compared. Surgeons in public systems less likely to diagnose SSI using CDC criteria than both private (2.59±1.50 vs 2.93±1.44, *p=0.031*) and mixed practices (2.59±1.50 vs 2.96±1.49, *p=0.021*). Surgeons operating only in private practice more frequently use ASEPSIS or Southampton score than those in public (2.40±1.34 vs 1.86±1.19, *p<0.001* and 2.22±1.32 vs 1.66±1.06, *p<0.001*, and respectively) or mixed systems (2.40±1.34 vs 1.99±1.23, *p*=0.017, and 2.22±1.32 vs 1.78±1.21, *p=0.004)*. Those in private practice less frequently use clinical examination to diagnose SSI than those in public (4.28±0.97 vs 4.61±0.85, *p<0.001*) or mixed systems (4.28±0.97 vs 4.60±0.79, *p=0.004*). Those in private practice gave antibiotic prophylaxis over two hours before skin incision more frequently than those in public and mixed systems (2.39±1.34 vs public; 1.83±1.22, *p<0.001,* vs mixed;

1.84±1.29, *p<0.001*). Private practicing surgeons were also more likely to give antibiotic prophylaxis one to two hours before incision than public systems (2.57±1.24 vs 2.09±1.23, *p<0.001*).

For surgical site preparation surgeons in public systems use alcoholic chlorhexidine more often than private practice (3.29±1.41 vs 2.88±1.30, *p=0.004)* and less frequently use aqueous povidone iodine than private practice (2.50±1.32 vs 3.02±1.30, *p<0.001*). Conversely, for surgical hand washing, those in private practice more frequently use alcoholic chlorhexidine than public systems (2.87±1.37 vs 2.56±1.51, *p=0.010*). Active warming was used more often by surgeons in public rather than private practice (3.68±1.16 vs 3.12±1.27, *p<0.001*). Surgeons in private practice used both povidone iodine (2.42±1.31 vs 1.87±1.12, *p<0.*001) and hydrogen peroxide (2.66±1.15 vs 2.00±1.06, *p<0.001*) more frequently than those in public systems for deep or subcutaneous tissue irrigation when required. Those in private practice also change instruments for sterile wound closure more frequently than public and mixed systems (2.91±1.27 vs public; 2.55±1.41, *p=0.017*, vs mixed; 2.36±1.27, *p=0.003*).

For wound dressings, those in public systems used a basic wound contact layer more often than private (3.92±0.99 vs 3.67±1.05, *p=0.027*) and those in private practice use skin glue (2.50±1.24 vs public; 2.15±1.19, *p=0.*017, vs mixed; 1.94±1.18, *p<0.*001) or no dressing (2.17±1.28 vs public; 1.49±0.95, *p<0.*001, vs mixed; 1.56±1.01. *p<0.*001) more frequently than both public or mixed systems. Postoperative antibiotic prophylaxis is prescribed more often in private practice than public (3.35±1.28 vs 2.97±1.34, *p=0.019*). Surgeons in private practice reported they used video consultations (2.55±1.36 vs public; 1.60±0.96, *p<0.001*, vs mixed; 1.72±0.99, *p<0.001*), photograph at discharge (2.52±1.25 vs public; 2.04±1.22, *p<0.001*, vs mixed; 2.05±1.11, *p=0.010*), paper questionnaires (2.27±1.40 vs public; 1.60±1.03, *p<0.001*, vs mixed; 1.74±1.13, *p=0.010*) and no follow-up (2.39±1.43 vs public; 1.90±1.16, *p=0.*002, vs mixed; 1.69±1.04, *p<0.001)* than both those in public and

mixed systems. Surgeons in public systems used community nurse led follow-up more frequently than those in mixed systems (2.63±1.27 vs 2.44±1.24, *p=0.022*).

12.2.4.3.3 Geographical region of practice

Respondents from Africa, America, Asia, Europe and Oceania were compared for significant differences in practice. Surgeons from Europe reported using CDC (2.45±1.55 vs Asia; 2.89±1.42, *p=0.001*, vs America; 3.19±1.25, *p<0.001*, vs Africa; 3.05±1.45, *p=0.013*), ASEPSIS (1.59±1.06 vs Asia; 2.31±1.24, *p<0.001*, vs Americas; 2.43±1.28, *p<0.001*, vs Africa; 2.61±1.41, *p<0.001*) and Southampton scores (1.41±0.86 vs Asia; 2.17±1.28, *p<0.001,* vs Americas; 2.19±1.32, *p<0.001,* vs Africa; 2.11±1.29, *p<0.001*) less frequently than those from Asia, America or Africa. When using clinical examination for diagnosis, those in Europe do so more often than Asia (4.69±0.78 vs 4.54±0.86, *p=0.027*) and both Europe (4.69±0.78 vs 4.13±1.09, *p<0.001*) and Asia (4.54±0.86 vs 4.13±1.09, *p=0.001*) do so more frequently than Americas.

Surgeons from Europe were more likely to give antibiotic prophylaxis within one hour of surgery compared with Asia and Americas (3.74±1.36 vs Asia; 3.42±1.39, *p=0.035*, vs Americas; 3.40±1.22, *p=0.014*). Those in Europe were less likely to give antibiotics both 1-2 hours before incision compared to Asia and Americas (1.85±1.13 vs Asia; 2.52±1.31, *p<0.001,* vs Americas; 2.75±1.27, *p<0.001*) and over two hours before surgery compared to Africa, Americas, Asia and Oceania (1.51±0.98 vs Africa; 2.30±1.49, *p<0.001*, vs Americas; 2.44±1.27, *p<0.001,* vs Asia; 2.33±1.48, *p<0.001,* vs Oceania; 2.16±1.25, *p=0.012*).

For surgical site preparation, surgeons from Asia reported using alcohol povidone iodine more frequently than Americas, Oceania and Europe (3.84±1.41 vs Americas; 2.71±1.23, *p<0.001,* vs Oceania; 3.12±1.36, *p=0.046*, vs Europe; 2.75±1.39, *p<0.001*). Those in Africa also reported using this more often than those in Europe (3.61±1.53 vs 2.75±1.39, *p=0.001*). Surgeons from Asia (2.55±1.42 vs Americas; 3.26±1.18, *p<0.*001, vs Europe; 3.52±1.33, *p<0.*001, vs Oceania; 3.60±1.12, *p=0.*004) and Africa

(2.13±1.31 vs Americas; 3.26±1.18, *p<0.*001, vs Europe; 3.52±1.33, *p<0.001,* vs Oceania; 3.12±1.36, *p<0.*001) were less likely to use alcoholic chlorhexidine compared to Americas, Europe and Oceania. Aqueous povidone iodine was more likely to be used in Europe than Americas or Asia (2.34±1.23 vs Americas; 3.02±1.20, *p<0.001,* vs Asia; 2.99±1.47, *p<0.001*). Surgeons in America were most likely to use aqueous chlorhexadine (2.79±1.15 vs Africa; 1.83±1.04, *p<0.001*, vs Asia; 2.03±1.31, *p>0.001*, vs Europe; 2.05±1.18, *p<0.001*).

For surgical hand preparation, surgeons from Asia reported using alcohol povidone iodine more frequently than Americas, Europe (3.08±1.55 vs Americas; 2.52±1.32, *p=0.012,* vs Europe; 2.10±1.44, *p<0.001*). Those in Africa also reported using this more often than those in Europe (2.89±1.43 vs 2.10±1.44, *p=0.001*). Surgeons in Americas use alcohol chlorhexadine more frequently than those in Africa (2.58±1.32 vs 1.96±1.19, *p=0.003*). Aqueous povidone iodine is used less frequently by those in Africa (2.15±1.35 vs Americas; 2.71±1.18, *p=0.035,* vs Asia; 2.86±1.52, *p=0.043*) and Europe (2.25±1.41 vs Americas; 2.71±1.18, *p=0.001,* vs Asia; 2.86±1.52, *p<0.001*). Aqueous chlorhexadine is used more frequently in America (3.06±1.31 vs Africa; 2.02±1.32, *p<0.001*, vs Asia; 1.52±1.12, *p<0.001*).

For techniques used to maintain normothermia, standard blankets were reportedly used more often in Asia than Americas (3.69±1.20 vs 3.35±1.03, *p=0.020*). Forced air warming is used less frequently in Africa (2.07±1.08 vs Americas; 3.17±1.12, *p<0.001*, vs Asia; 2.07±1.08, *p<0.001*, vs Europe 4.03±0.96, *p<0.001*, vs Oceania; 3.87±0.63, *p<0.001*) and by both Americas (3.17±1.12 vs Europe; 4.03±0.96, *p<0.001,* vs Oceania; 3.87±0.63, *p=0.029*) and Asia (3.02±1.23 vs Europe; 4.03±0.96, *p<0.001,* vs Oceania; 3.87±0.63, *p=0.008*). Heated mattresses were more likely to be used in Oceania (3.09±1.08 vs Africa; 2.05±1.13, *p=0.010*, vs Asia; 2.35±1.26, *p=0.044*).

Iodinated drapes are used to prepare surgical field less often in Africa (1.81±1.24 vs Americas; 2.67±1.28, *p<0.001,* vs Europe; 2.73±1.53, *p=0.002*, vs Oceania; 3.04±1.19, *p=0.003*). For deep and subcutaneous tissue irrigation, saline was used more often in

Asia than Americas (3.90±1.10 vs 3.54±1.08, *p=0.030*). Povidone iodine was used more frequently in Americas (2.58±1.28 vs Africa; 1.93±1.10, *p=0.029,* vs Asia; 2.04±1.30, *p=0.002*, vs Europe; 1.74±1.02, *p>0.001*). Hydrogen peroxide was use less often in Europe (1.83±0.99 vs Africa; 2.42±1.18, *p=0.010*, vs Americas; 2.57±1.09, *p<0.001*, vs Asia; 2.41±1.13, *p<0.001*).

Prior to skin closure, instruments are changed more frequently in Americas (2.96±1.26 vs Europe; 2.41±1.38, *p<0.001*, vs Oceania; 2.17±1.15, *p=0.049*). Triclosan coated sutures were also used more often in Americas (2.29±1.43 vs 1.51±1.12, *p=0.032*).

After primary skin closure, basic wound contact layers are used less frequently by Americas (3.65±0.96 vs Asia; 3.95±1.17, *p=0.*009, Europe; 3.92±0.94, *p=0.*034) and Oceania (3.35±0.89 vs Asia; 3.95±1.17, *p=0.*012, Europe; 3.92±0.94, *p=0.016*). Advanced dressings were more likely to be used in Americas (2.50±1.17 vs Africa; 1.81±1.01, *p=0.006*, vs Asia; 2.10±1.09, *p=0.025*). Skin glue is used less frequently in Africa (1.70±1.10 vs Americas; 2.38±1.18. *p=0.004*, vs Europe; 2.32±1.24, *p=0.007*, vs Oceania; 2.52±1.24, *p=0.050*) and Asia (1.75±1.02 vs Americas; 2.38±1.18. *p<0.001*, vs Europe; 2.32±1.24, *p<0.001*, vs Oceania; 2.52±1.24, *p=0.020*). Negative pressure wound therapy (NPWT) is used less frequently in Africa (1.79±1.06 vs Americas; 2.61±1.11, *p<0.001*, vs Europe; 2.38±0.91, *p<0.001*, vs Oceania; 3.04±0.93, *p<0.001*). NPWT is used more often by America (2.62±1.11 vs Asia; 2.24±1.15) and Oceania (3.04±0.93 vs Europe; 2.38±0.91, *p=0.005*, vs Asia; 2.24±1.15, *p=0.006*). Surgeons in Europe are less likely to use no dressing (1.35±0.81 vs Africa; 1.77±1.04, *p=0.004*, vs Americas; 2.13±1.20, *p<0.001*, vs Asia; 1.75±1.19, *p=0.001*) and use this more often in Americas (2.13±1.20 vs Asia; 1.75±1.19, *p=0.013*).

Surgeons in Africa use postoperative antibiotics less often than Asia (3.23±1.13 vs 4.08±1.16, *p<0.001*) and more often than Europe (3.23±1.13 vs 2.55±1.22, *p=0.003*). Those in Asia use antibiotics more often (4.08±1.16 vs Africa; 3.23±1.13, *p<0.001*, vs Americas; 3.09±1.14, *p<0.001*, vs Europe; 2.55±1.22, *p<0.001,* vs Oceania; 3.22±1.17,

p=0.003). Those in America use antibiotics more frequently than in Europe (3.09±1.14 vs 2.55±1.22, *p<0.001*).

For postoperative follow-up, surgeons in Asia see patients face-to-face more often than in Americas (4.24±1.06 vs 3.83±1.06, *p=0.001*). Telephone follow up is used more often in Americas (2.68±1.14 vs Asia; 2.27±1.13, *p=0.026*, vs Europe; 2.24±1.11, *p=0.002*). Video follow-up is used more often in Americas (2.61±1.21 vs Africa; 1.79±1.23, *p<0.*001, vs Asia; 1.81±1.06, *p<0.*001, vs Europe; 1.49±0.91, *p=0.*001, vs Oceania; 1.68±0.78, *p=0.*007) and Asia (1.81±1.06 vs Europe; 1.49±0.91, *p=0.001*). Wound photograph at discharge is used more often in America (2.82±1.24 vs Africa; 2.12±1.14, *p=0.018*, vs Asia; 2.34±1.24, *p=0.020*, vs Europe; 1.83±1.11, *p<0.001*, vs Oceania; 1.73±1.03, *p=0.002*) and Asia (2.34±1.24 vs Europe; 1.83±1.11, *p<0.001*). Paper questionnaires are used more often by Africa (2.05±1.34 vs Europe; 1.54±1.02, *p=0.030*) and America (2.28±1.29 vs Asia; 1.69±1.08, *p=0.001*, vs Europe; 1.54±1.02, *p<0.001*). Community nurse led follow-up is used less frequently in Africa (2.02±1.17 vs America; 2.73±1.18, *p=0.009*, vs Europe; 2.76±1.23, *p=0.002*, vs Oceania; 2.91±0.97, *p=0.024*) and Asia (1.98±1.21 vs America; 2.73±1.18, *p<0.001*, vs Europe; 2.76±1.23, *p<0.001*, vs Oceania; 2.91±0.97, *p=0.003*). Surgeons in America are more likely to have no follow-up (2.30±1.27 vs Asia; 1.83±1.26, *p=0.007*, vs Europe; 1.87±1.14, *p=0.007*).

12.2.5 **Discussion**

This international, pan-specialty survey finds significant disparities in many areas of surgeon's SSI prevention practice. The survey was developed from recommendations within international guidelines and feedback from an earlier UK vascular surgery centred study, with a pre-published protocol and both internal and external validation of the questionnaire[105,190,203,211]. The SSC aimed to ensure the items were clear and relatable to surgeons from all internationalities and generalisable to the practice of all specialties. Whilst aiming to encompass all areas of practice, the survey was designed to be as succinct as possible, resulting in a median completion time of 6.2 minutes from respondents.

For surgical hand washing there was no preference for solution agent or preparation but with regards to surgical site preparation, alcohol-based preparations were preferred. Whilst there is a paucity of RCT data on this, one would expect similar efficacy in preparation agent for SSI prevention for both hand washing and site preparation. A network meta-analysis published in 2022 concluded that chlorhexadine in alcohol is most effective in prevention of SSIs for procedures of any wound classification[212]. Several respondents reported using double preparation with chlorhexadine followed by povidone iodine, which similarly lacks any robust data. In orthopaedic surgery, an observational cohort of 40 patients found double preparation significantly reduced bacterial load in patients undergoing reduction and fixation of proximal humeral fractures, but no surgical site infections were recorded[213]. Further RCTs should consider the evaluation of single versus double surgical site preparation for prevention of SSI.

For iodine impregnated drapes, practice seemingly varied with the majority not using regularly (86.8%) but two-thirds (64.4%) indicating they would use them at some point. This divide is in keeping with literature with previous systematic review only showing a benefit of iodine impregnated drapes in cardiac surgery though overall there seems to be need for high quality evidence in this area, and notably one multi-arm, multi-stage, multicentre RCT in UK general surgery has dropped this intervention due to a robust lack of effect seen[214,215]. Despite the publication of the ChEETAh trial results regarding significant reductions in SSI when changing gloves and surgical instruments prior to closure of abdominal surgery, globally surgeons practice was varied regarding using these measures[216]. Those working in Americas and in private practice work more likely to engage in changing instruments prior to closure. This may highlight a perception that these practices are costly in other regions, though the cost-effectiveness modelling in this trial also showed that costs were similar to current practice[217]. Further implementation work may be needed to translate this evidence into practice.

In the UK, NICE published medical technologies guidance 59 in 2021 recommending the use of triclosan coated or impregnated sutures for the prevention of SSI and reduction in cost, based upon 31 randomised controlled trials of over 14,000 patients[218]. Similarly, CDC guidelines recommend consideration of the use of triclosan-coated sutures (weak recommendation based on moderate quality evidence) and WHO suggest their use, though based on low to moderate quality evidence[190,203]. In this study, 68.3% of surgeons indicated never or rarely using triclosan sutures despite these recommendations, highlighting a possible translational issue. It is worth noting that the sutures do not appear visibly different, and some surgeons may be using triclosan sutures unknowingly, which was highlighted by some respondents.

Use of postoperative antibiotics varied considerably by geographical location, with higher frequency in private practice. Reasons for providing this also varied, many citing patient and operative risk factors guiding decisions and others using published guidelines and evidence. There were several subjective reasons, including fear of infection, which may reflect experience in surgery and risk stratification, but where possible decisions should formulate based upon evidence-based practice. Meta-analysis has previously concluded no benefit for continuation of antibiotic prophylaxis, though most studies included general surgery patients with varying quality of evidence[219]. More recent RCT data has shown benefit in high-risk vascular surgery, highlighting potential benefits in using such measures when appropriately using risk stratification[200].

12.2.5.1 Limitations

This study is not without limitations. Whilst providing a reference of current practice in preventing SSI globally, this does reflect the time point of this study, which may change with evolving evidence in these areas surveyed. The questionnaire was written in English, and though synonyms of terms used more frequently in other regions were included, this was not translated into other languages due to a lack of capacity and services to do so. This may have precluded some non-English reading and writing surgeons from participating. Whilst a global SSC was formulated, this was

a predominantly European based network, which may have reflected in responses from this region being the highest (40.5%). Data on worldwide proportions of surgeons practicing in each specialty were not available at the time of this study's development, and so raking was chosen as a statistical measure of balancing this in analysis. The highest proportion of responses were from general surgery, and it is likely that this is reflective of worldwide practice, though some specialties with smaller number of responses may be under-represented. Some aspects of this study, such as maintaining perioperative normothermia, may not be accurately representing by surgeon's practice, and rather decisions made by anaesthetic colleagues during procedures. Future work may require inclusion of these stakeholders to accurately reflect such practices.

12.2.6 Conclusion

This study highlights substantial disparity in practice across geographical, financial and training level barriers. There is a paucity of robust evidence to guide SSI prevention for many of the included measures, but in those that do have multicentre RCT or meta-analysis data, this study also highlights potential evidence of implementation lag. Future work should focus on ensuring high quality RCT data for SSI prevention, have systematic dissemination plans and continue to support centres to engage with implementation of best practice. Contemporary updates to international guidelines will assist in these aims.

13 CHAPTER 3: STUDY THREE – TELEMEDICINE FOR THE DIAGNOSIS OF SURGICAL SITE INFECTION, A SYSTEMATIC REVIEW AND META-ANALYSIS

13.1 Background

Surgical site infections (SSI) complicate up to 40% of surgical procedures depending on operative type and procedure[198]. By definition, an SSI occurs within 30 days of surgery (or within 90 days if an implant is left in place)[63]. Given the current health landscape, the mean postoperative inpatient stay is four days, therefore the majority of SSI become apparent after discharge[220,221]. Early recognition of SSI is essential to minimise associated morbidity and mortality, and patients frequently seek care from primary or community care providers, who may not be familiar with managing surgical complications. Strategies are required to enable secondary care providers to conduct robust surveillance and follow up of surgical wounds[222,223].

Telemedicine is an innovative solution for monitoring patients and their wounds postoperatively. Remote consultations ameliorate the need to leave home and associated carer requirement, reduce travel times and costs, and reduce waiting room times and risk of nosocomial infection[224-226]. Patients frequently find the experience reassuring and many would prefer future consultations by this method[227-229]. A reduction in patient travel seems to have wider implications still; a recent review concluded that the use of telemedicine consistently reduces carbon footprint compared with face-to-face reviews, even when factoring the impact of equipment and resource use[184]. With national targets such as net zero emissions by 2045, implementation of remote measures may become a mainstay of practice in years to come[230]. The SARS-CoV-2 pandemic catalysed integration of digital health models worldwide and telemedicine was applied at the forefront of many patient facing services. Surgical follow-up has followed with rapid adoption of remote post-operative follow-up, but cautious examination is warranted before being welcomed as standard practice[231]. Telephone consultations, whilst providing invaluable information at a fraction of clinic resource use, do not provide direct visualisation of a patient's post-operative wound. However, even with the addition of a visual aspect in photo- or video-based approaches, there are barriers to this service. For example,

erythema, a hallmark characteristic of accepted SSI definitions, has poor levels of interobserver agreement on photograph assessment[121,152,232]. Before telemedicine can be unanimously recognised as established practice substantial evidence of diagnostic accuracy is required.

13.2 Objectives

The aim of this study was to;

1. Establish the overall accuracy of telemedicine for diagnosis of SSI;
2. Identify factors associated with heterogeneity of findings between studies; and
3. Assess the effect of individual telemedicine methods and impact of varying reference standards on diagnostic accuracy.

13.3 Methods

This study was conducted in accordance with the Cochrane handbook for systematic reviews of diagnostic test accuracy, and has been reported in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA-DTA) statement, a copy of which is attached to this article in the *appendix 8.6*[233-235]. The protocol for this review was prospectively registered with PROSPERO (ID CRD42021290610) and has been submitted for peer reviewed publication, with a pre-print available online[236].

13.3.1 Search strategy and selection criteria

Studies meeting the following criteria were considered for inclusion:

i) Participants: All post-operative patients over 18, of any operation type. No restrictions were placed on the study setting or length of follow-up.

ii) Index tests: Telemedicine by any method (telephone, video call, photograph or questionnaire), including the use of questionnaires as these can be delivered remotely.

iii) Reference Standards: Face to face review, as per the United States (US) Centres for Disease Control and Prevention (CDC) criteria for SSI is

deemed the gold standard, but no restrictions were placed if other methods were use. This was to ensure all available evidence would be synthesised.

iv) Target condition: SSI as defined by the CDC criteria; infection within 30 days of surgery or within 90 days if an implant is left in place[237].

v) Study design: Abstracts, reviews and conference proceedings were excluded. All other research designs were included in the systematic review, but only comparative, paired methodologies were taken forward to meta-analysis as all patients would experience index tests and reference standards.

Studies were excluded if they did not meet the inclusion criteria or were not presented in English (for lack of resources to translate other languages). The following databases were searched from inception to January 2022: Medline, Embase, CENTRAL and CINAHL. A combination of synonyms related to the keywords; "telemedicine" AND "surgical wound infection" formulated the terms used. The strategy used for Medline, Embase and CINAHL can be found in *appendix 8.7.*

The search strategy was developed with and conducted by an information specialist who uploaded results onto the Rayyan, a bespoke tool for conducting systematic reviews[238]. These were deduplicated before screening of titles and abstracts by two independent reviewers against the inclusion criteria. Relevant manuscripts were retrieved for full text review and assessed for eligibility by two independent reviewers. Reference lists of these articles were searched manually for any additional studies not identified in preliminary search. Any disagreement at each stage was resolved by a third reviewer for consensus.

There were no limitations placed on study design for qualitative synthesis to comprehensively synthesise the literature. Reports with paired designs were taken forward for quantitative analysis to enable random-effects bivariate meta-analysis, and summary receiver operator characteristic (SROC) curves to be plotted.

13.3.2 Data extraction

A bespoke data spreadsheet (Microsoft Excel Version 16.59) was designed and utilised for data extraction by two independent authors. Data on study and diagnostic characteristics (author, year, country, study design, sample size, gender, age, telemedicine method, reference standard, type of surgery, follow-up schedule) among potential confounding factors (diabetes, BMI, and smoking status) were collected in addition to SSI rates, sensitivity, and specificity of diagnosis.

Surgical site infections were defined as per CDC criteria[63]. Only superficial SSI were included due to inherent barriers of diagnosing deep SSI remotely. No restrictions were placed on classification of telemedicine, reference standard type, or other characteristics.

13.3.3 Assessment of methodological quality

Risk of bias and the applicability of studies were assessed again by two independent reviewers with the QUADAS-2 tool[239]. The tool was first piloted by the reviewers with agreement of 80% across all categories on two of the included studies considered sufficient before further assessment of remaining studies, as recommended by the Cochrane handbook for systematic reviews of diagnostic test accuracy[234]. QUADAS-2 contains four domains, each assessed for risk of bias; patient selection, index tests, reference standard and flow and timing. The first three domains are also investigated for applicability concerns. For each domain category, signalling questions are asked to assist judgments with answers 'yes', 'no' or 'unclear', such that 'yes' indicates low risk of bias. If any question is answered 'no,' this domain category is judged as high risk of bias or has applicability concerns. Answers of 'unclear' are used only if there was insufficient data reported. Risk of bias and applicability scores were taken into consideration for subgroup meta-analysis, ascertaining a strength of recommendation from data retrieved.

13.3.4 Statistical analysis

Continuous descriptive characteristics were expressed as weighted mean averages with standard error. A bivariate model for meta-analysis was used to produce summary measures of sensitivity and specificity with confidence regions. All studies with paired designs had pooled forest plots and summary receiver operator characteristic curves synthesised in the initial exploratory analysis. Analysis was conducted with MetaDTA and plots constructed with Review Manager 5.4[240,241]. Additional sources of heterogeneity were investigated through covariates (study country, type of surgery, telemedicine method, reference standard used). Overall index test effectiveness is expressed through diagnostic odds ratios.

For cases of multi-threshold test positivity, the cut-off achieving the maximum possible sensitivity – specificity trade off were taken forward. Indeterminate index test results were classified as 'no SSI' as this more closely reflects what would happen in practice. Tests were grouped as a unified 'telemedicine' and through the sub-groups; 'photograph,' 'telephone,' and 'questionnaire.' No studies reported video-based methods.

13.3.5 Subgroup analysis

All studies which compared photograph to face to face review will be referred to as photograph-based telemedicine methods. Photograph-based methods utilise visual input whereas questionnaire and telephone do not incorporate trained physicians viewing a patient's wound. As such, pre-specified analysis is conducted for studies including these methods for their sensitivity and specificity. Further analyses are performed as per the reference standard used and whether a pre-specified threshold was stated.

13.4 Results

13.4.1 Study selection

The study selection process flow diagram is shown in figure 8. A total of 1400 records were screened after 488 duplicates removed. After title and abstract screening, 61

full text reports were assessed for eligibility. The final review included 19 studies, and 17 had paired designs taken into a meta-analysis[151-153,242-257]. 11,437 observations were made in 19,090 patients as ten studies only included telemedicine investigation in a subset of patients[151,242-246,249,251,253,255].Three reports were unable to be retrieved. For each, contact was attempted through the publishing journal and first author on two separate occasions, after which studies were excluded from review.

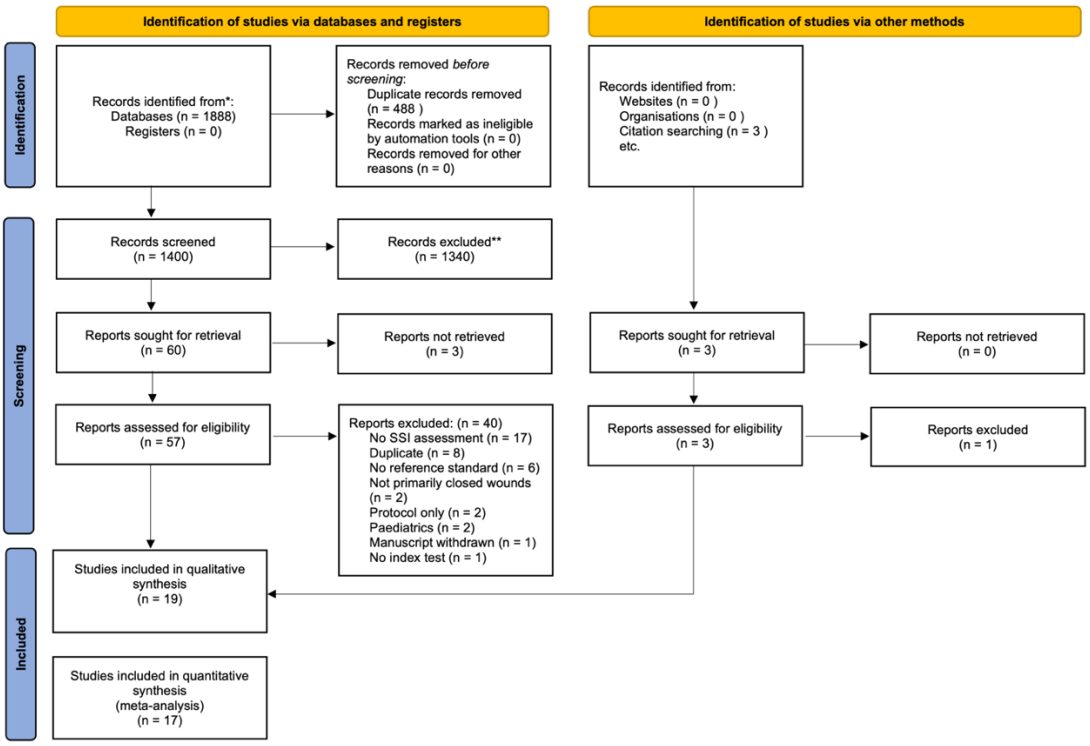


Figure 8: PRISMA study flow diagram

13.4.2 Characteristics of included studies

Studies were conducted in nine countries across five continents globally. Five were in low or lower-middle income economies, as per the World Bank classification[242,243,246,250,251]. The remaining reports were from high income economies. Weighted mean age of participants across the included reports was 47.1 ±13.3 years. Female patients made up 57.4% participants. Pooled SSI rate was 5.6% (95% CI, 5.49-5.74). Individual study characteristics can be found in *table 9*.

13.4.3 Methodological quality of included studies

A summary of QUADAS-2 assessments is presented in figure 4. Risk of bias was present in all studies, and two studies were scored as high risk of bias in all domains[246,253]. This was largely owing to inconsecutive sampling, clarity over interpretation of index tests without knowledge of the reference standard (and vice versa), the interval time between interpretation of index test and reference standard, and only subgroups of patients being included in study analysis. Nine reports had high applicability concerns, principally from the index test, patients or reference standard differing from the review question[246-249,251,252,255,256]. Risk proportions are displayed in figure 9.

Figure 9: Risk of bias and applicability concerns for each study

Table 9: Individual study characteristics

Author	Year	Country	Mean Age (+/-SD)	Total events	Total Patients	Female Gender (%)	Telemedicine method	Reference standard	Type of surgery	SSI review provider	Diabetes (%)	Smoking (%)	BMI (+/-SD)
Abu-sheasha	2020	Egypt	-	309	351	-	Telephone	CDC	Multispecialty	Healthcare worker	-	-	
Aiken	2013	Kenya	30.0 (9.0)	89	1172	1060	Telephone	CDC	Multispecialty	Healthcare worker	-	-	-
Bluebelle	2019	UK	53.2 (17.5)	208	732	428	Questionnaire	CDC	Multispecialty	Research Team	60 (7.7)	350 (45.1)	28.0 (6.1)
Bruce	2021	UK	44.1 (14.1)	1036	1550	302	Photograph	CDC	Trauma	Surgeon	63 (8.1)	218 (28.6)	26.4 (5.9)
Cherian	2020	Rwanda	26.5	219	596	456	Telephone	Empirical	O&G	Community healthcare worker	-	-	-
Gunter	2018	USA	63.0	40	40	10	Photograph	Site protocol	Vascular	Clinical or research team	-	-	-
Halwani	2016	USA	28.5 (6.8)	177	193	193	Telephone	CDC	O&G	-	-	-	33.3 (9.2)
Hedrick	2015	USA	59.5 (6.7)	171	171	89	Photograph	CDC	General	Surgeon	21 (12.3)	28 (16.4)	29.0 (7.5)
McLean	2021	UK	44.3 (17.3)	335	489	266	Photograph	CDC	General	Surgeon	23 (4.7)	-	24.2
Mitchell	1999	Australia	63.3	649	1360	636	Questionnaire	CDC	Multispecialty	Research nurse	-	-	-
Mousa	2019	USA	64.0 (7.2)	30	30	14	Photograph		Vascular	-	12 (40.0)	15 (50.0)	28.4 (5.6)
Nguhuni	2017	Tanzania	26.3 (6.5)	484	324	324	Telephone	CDC	Obstetrics	Surgeon / Research nurse	-	-	26.1 (5.0)
Pathak	2015	India	-	156			Telephone	CDC	-	'Study assistant'	-	-	-
Pham	2016	USA	54.1(19.0)	2853	2853	1844	Telephone	CDC	Multispecialty	Surgeon	367 (12.9)	359 (12.6)	29.5 (7.4)
Reilly	2005	UK	67.0 (10.4)	105	422	201	Telephone	CDC	Orthopaedics	GP / district nurse	-	-	-
Richter	2017	Israel	50.5 (17.7)	263	266	125	Telephone	CDC	General	Surgeon (face-to-face) / Surveyor (telephone)	-	-	-
Sands	1996	USA	42.0	1799	5572	3343	Questionnaire	CDC	Multispecialty	Record reviewer	-	-	-
Taylor	2003	UK	-	2665	-		Telephone	CDC	General	Healthcare worker	-	-	-
Totty	2018	UK	61.1	56	37	14	Photograph	ASEPSIS/CDC	Vascular	Surgeon	10 (27.0)	28 (75.7)	-

SD: Standard Deviation. BMI: Body mass index

13.4.4 Synthesis of results

Individual study estimates of test accuracy are presented in figure 10 as a coupled forest plot of sensitivity and specificity. Index tests were categorised into photograph, telephone and questionnaire based methods, with five[151,152,245,247,248], nine[153,242,243,246,250-254] and three studies[244,249,255] available for each respectively. 15 manuscripts[151-153,242-245,248-255] utilised a CDC based reference standard, with the remaining two[246,247] having empirical or site-specific protocol for these. Two studies[246,247] conducted follow up within 14 days, and a further four studies[248,249,253,255] were unclear as to the timeframe for reference standard review. There were no studies available that compared multiple index tests or reference standards.

The mean sensitivity of all telemedical methods for SSI diagnosis is 87.9% (95% CI, 68.4-96.1) and mean specificity is 96.8% (95% CI, 93.5-98.4). Mean values broken down by index test is shown in table 10. Youden's index is acceptable at 0.847. The mean positive and negative predictive values for diagnosis of SSI are 54.8% (95% CI, 52.1-57.4) and 98.5% (95% CI, 98.2-98.6) respectively. Random effects SROC curve for all methods of telemedicine in diagnosis of SSI shows a symmetric design approaching the top left corner and is plotted in figure 11. Heterogeneity seen in the 95% prediction region is explored further in subgroup analysis. Overall diagnostic odds ratio indicates high effectiveness for SSI diagnosis at 217.6 (95% CI, 47.0-1006.8).

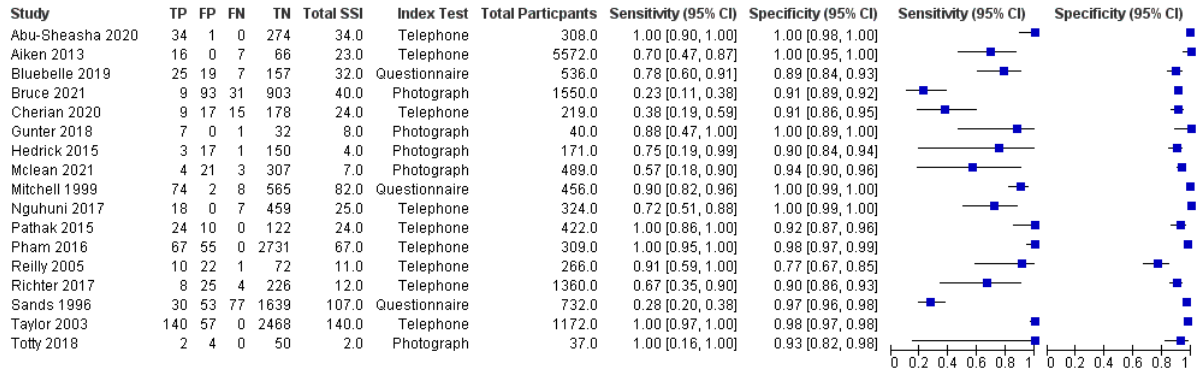


Figure 10: Coupled forest plot of sensitivity and specificity of test accuracy studies included.

Table 10: Summary test accuracy of surgical site infection diagnosis by index test method

Index Test	Reference Standard	Number of Studies (Participants)	Number with SSI (%)	Summary sensitivity % (95% CI)	Summary Specificity % (95% CI)	Diagnostic Odds Ratio (95% CI)
All	All	17 (11437)	642 (5.6)	87.9 (68.4-96.1)	96.8 (93.5-98.4)	217.6 (47.0-1006.8)
Photograph	All	5 (1638)	61 (3.7)	63.9 (30.4-87.8)	92.6 (89.9-94.5)	22.0 (4.7-102.5)
Telephone	All	9 (7143)	360 (5.0)	97.0 (70.8-99.8)	97.7 (92.0-99.4)	1351.5 (73.1-24994.7)
Questionnaire	CDC	3 (2656)	221 (8.3)	69.8 (32.6-91.7)	97.6 (88.7-99.5)	93.8 (6.4-1366.8)

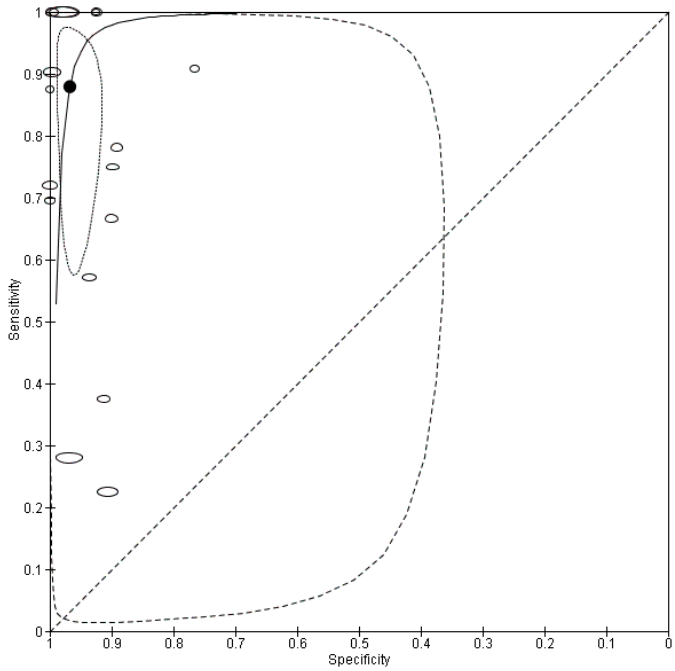


Figure 11: Random effects summary receiver operator characteristic curve for all methods of telemedicine in diagnosis of SSI.

13.4.5 Subgroup analysis

Five studies utilised photograph-based telemedicine[151,152,245,247,248]. Two studies[152,245] retrieved images with a digital camera, another two[151,247] used smartphone and a final study[248] did not specify the platform used. No studies used machine learning or 'artificial intelligence' methods to assist in diagnosis of SSI. A total of 1638 observations were available in 2287 patients, again due to subsets being included in diagnostic test accuracy analysis. The weighted average age was 46.8 ± 11.7 years and 35.8% of patients were female. All studies were conducted in high income countries (HIC). SSI rate across the available studies was 3.72% (95% CI, 3.16-4.29). The mean sensitivity for photograph-based methods is 63.9% (95% CI, 30.4-87.8) and mean specificity 92.6% (95% CI, 89.9-94.5). The mean positive and negative predictive values for SSI diagnosis are 15.6% (95% CI, 11.6-20.7) and 97.6% (95% CI, 97.0-98.0). The random effects SROC curve for photograph-based methods shows a symmetric distribution and is displayed in figure 12. Overall diagnostic odds ratio indicates good test effectiveness at 22.0 (95% CI, 4.7-102.5). Heterogeneity is largely reduced, although the region of confidence is conversely enlarged.

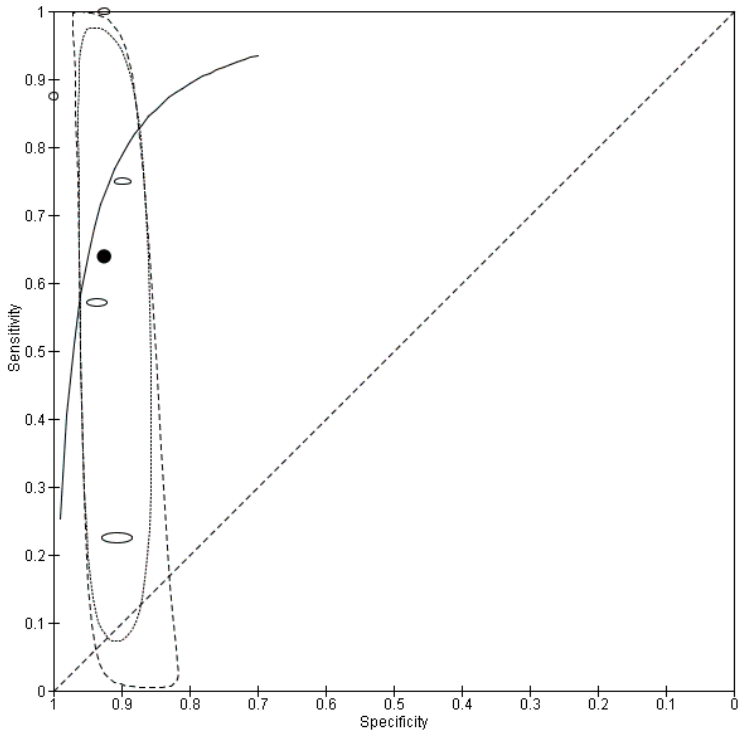


Figure 12: Random effects summary receiver operator characteristic curve for photo-based methods of SSI diagnosis.

Comparative index test SROC curve analysis reveals three distinct distributions of symmetric plots with telephone methods showing superior test accuracy, approaching the upper left corner, *figure 13*. CDC criteria were used as the reference standard in all but two studies[246,247]. Analysis of tests standardised by CDC reference standard marginally increases overall sensitivity to 90.3% (95% CI, 0.695-0.974) but has no significant impact on specificity (96.8%, 95% CI, 0.932-0.985). SROC curve for telemedicine using CDC criteria reflects this marginal increase in sensitivity but 95% prediction region is also increased in size, *figure 14.* Summary test accuracy by CDC reference standard is represented in *table 11*. All methods of telemedical follow-up are informative with diagnostic odds ratios >10. Five studies diagnosed SSI through review by surgeons. Observations from 4451 participants were available resulting in lower overall sensitivity at 84.5% (95% CI, 22.3-99.0) and specificity at 94.5% (95% CI, 90.9-96.8). Heterogeneity in diagnosis was reduced with this limitation but at the cost of a greater 95% confidence region.

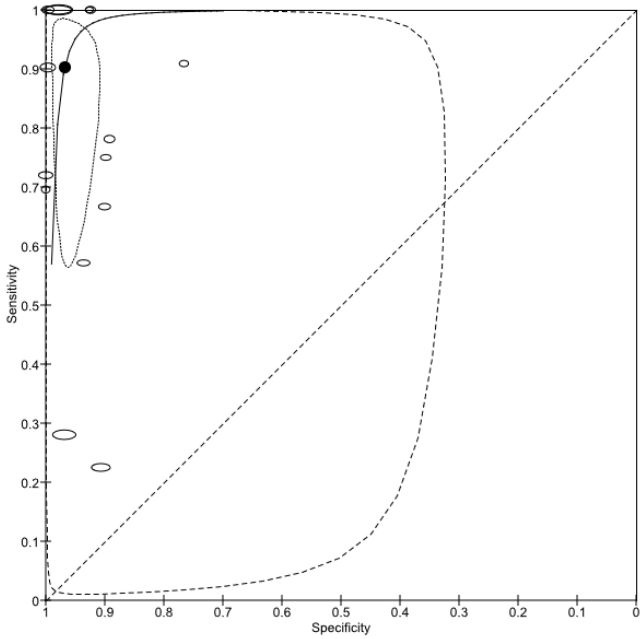


Figure 13: Random effects bivariate SROC curve of telemedical SSI diagnosis using CDC criteria as reference standard.

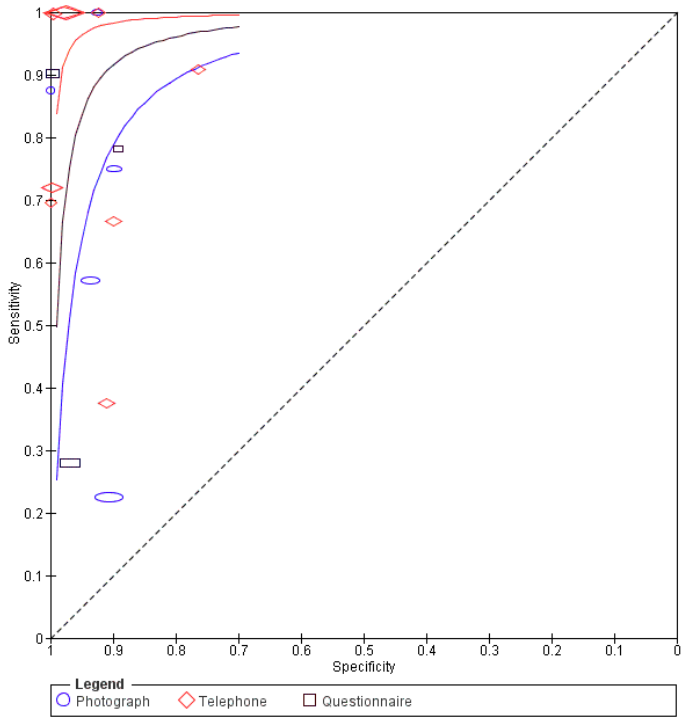


Figure 14: Random effects summary receiver operator characteristic curve for all telemedicine modalities

Table 11: Summary test accuracy of SSI diagnosis by telemedicine methods and CDC reference standard

Index Test	Reference Standard	Number of Studies (Participants)	Number with SSI (%)	Summary sensitivity % (95% CI)	Summary Specificity % (95% CI)	Diagnostic Odds Ratio (95% CI)
All	CDC	15 (11178)	610 (5.5)	90.3 (69.5-97.4)	96.8 (93.2-98.5)	277.5 (50.6-1521.2)
Photograph	CDC	4 (1598)	53 (3.3)	52.4 (20.7-82.2)	91.8 (89.6-93.6)	12.4 (2.7-57.1)
Telephone	CDC	8 (6924)	336 (4.8)	98.3 (77.2-99.9)	98.3 (92.1-99.6)	3230.3 (153.1-68137.0)
Questionnaire	CDC	3 (2656)	221 (8.3)	69.8 (32.6-91.7)	97.6 (88.7-99.5)	93.8 (6.4-1366.8)

13.5 Discussion

Telemedicine achieves good sensitivity (88%) and high specificity (97%) irrespective of geographical location and socioeconomic status. As such, remote methods could be considered globally as a screening tool for SSI post discharge, on the basis that correctly identifying patients without an infection can prevent them from needing to travel long distances to see a clinician, and conversely those diagnosed as having had infection can be signposted to appropriate post-operative care at an earlier stage. Telephone-based appears to be the most accurate telemedicine method in SSI diagnosis and has been the most extensively studied index test in the last two decades. Arguably this is the most readily deployable and economically viable option. Telephone discussions enable real-time data collection from the patient with follow-up questions adaptable to the scenario, and conversely, can be used to deliver validated questionnaires by untrained individuals, should the need arise (as part of widespread screening, for example). Clinicians can obtain further information from patients in response to signalling, such as exploring systemic symptoms of infection, that may not be derived through images alone.

In contrast, photograph-based methods are contemporary, with all studies conducted within the last seven years. This index test offers additional visual stimuli which other methods do not, debatably of paramount importance in the diagnosis of SSI. Unlike telephone methods, photograph reviews are asynchronous, with data collected at a time prior to their review, preventing flexible further questioning. There may be a lack of standardisation across photograph based studies as image quality and provision of wound photography guidance (or training) are important factors in determining test accuracy, however these elements were not extractable from the available literature and may have contributed to the lower accuracy compared with telephone based methods[258]. In addition, diagnosis of SSI based on appearance alone is subjective, whether in person or using digital images, and this subjectivity may reduce the overall accuracy of digital assessment. Standardisation of wound photograph technique, and patient acceptability in digitally naïve populations (due to both age and socioeconomic status) are important research

factors to be established in this area. Further, no single study investigated more than one diagnostic method or the impact on test accuracy with a combination of techniques i.e. photograph review with simultaneous questionnaire submission or with telephone review for concurrent data extraction, or the impact of video based assessments, where dialog and a contemporaneous wound assessment can take place. Future studies should assess the diagnostic accuracy of combined or novel telemedicine methods in order to determine the optimal approach.

Postoperative wound surveillance is notoriously challenging, resulting in underreporting of SSI rates[259,260]. Overstretched primary care services are often burdened with facilitating management of such complications after discharge. Digital telemedicine requires limited resources and has potential utility in alleviating primary care exigency by offering a direct connection with secondary or tertiary care providers. Healthy wounds can be easily identified without the inconvenience of travelling great distances to clinic. Equally, obvious and indeterminate infection can be swiftly identified and either appropriately managed remotely or returned to secondary care for definitive treatment.

The National Health Service (NHS) in the UK is committed to delivering a net zero service by 2045[261]. In the NHS in England, up to 10% of total carbon dioxide emissions are attributable to personal travel, and specifically, emissions from patient travel have almost doubled since 1990 (0.63 to 1.23 Mt CO_2e)[157]. Each hospital outpatient appointment is estimated to produce 76 kg CO_2e, and a visit to general practice produces an estimated 66 kg CO_2e [157]. Digital, remote follow-up offers some mitigation in the personal travel targets for a greener NHS. Further, artificial intelligence, or machine learning has been identified as a route to buttress the emission reduction effort[262]. If established into practice, machine learning could reasonably be applied to digital wound surveillance models to alleviate clinician time, minimise carbon footprint and unburden clinical resource use.

The telemedicine population studied is relatively young (weighted mean average age 47.1 years) which may reflect usability and is unlikely to represent the entire surgical

population. Vascular patients for instance, are frequently much older (average age 64.1 years) and comorbid, as such may not be able to comply with smartphone-based telemedicine methods[263]. Investigation of telemedicine in elderly patients has identified a lack of access and experience with technology, and hearing, visual and communication challenges as barriers to utilisation[264,265]. Widespread adoption of such strategies without efforts to improve inclusion may be disproportionately disadvantageous to the elderly or infirm population groups.

This study has some limitations. High levels of heterogeneity were apparent in the initial meta-analysis (figure 11), as expected from diagnostic test accuracy studies. Photograph based subgroup analysis provided moderation (figure 12), but substantially fewer observations (1638 compared with 11437 for all telemedicine) should warrant cautious interpretation, and were all from high income economies. All included studies contained high risk of bias and so no exclusions were made on this basis alone. Most studies did not report test accuracy as their primary outcome and as such only subgroups of participants were included in analysis. No studies used a case-control design and one had a retrospective nature[255]. Three reports either had all or subsets of patients recruited in non-consecutive samples[244,249,255]. An unclear or inadequate (more than one week) time interval between index test reference standard was apparent in five studies[247-249,253,255]. Two studies investigated index tests or reference standards within two weeks of surgery[246,247]. The same reference standard was not used throughout, giving rise to potential for verification bias. Accuracy of diagnosis and heterogeneity did not however alter significantly in subgroup analysis using CDC criteria. Whilst recognised as the gold standard, CDC criteria is not without challenges. The classification is subjective and has poor interrater agreement, resulting in variable comparisons of wounds[120]. When compared with the ASEPSIS criteria, which are objective, ASEPSIS over classify SSI but under report SSI if pus is present[120,121,123]. The Southampton score is another alternative[123]. CDC is the most widely used, and as often regarded as the reference standard despite the inherent flaws. The need for a robust gold standard has been identified, but does not seem to have been accomplished yet.

The evidence suggests that using telemedicine, in the form of telephone consultation, with or without photographic adjuncts, to diagnose SSI is highly specific and as such could be utilised as an effective screening tool in patients post discharge. Implementation of this method has great potential in the reduction of resource use, associated healthcare cost, and patient and clinician time expenditure. It has widespread applications spanning geographical and socioeconomic barriers and would improve the carbon footprint of health services globally. However, the average age of participants in all studies is relatively young and as such may under-represent the surgical population. Widespread adoption of telemedicine without strategies to improve inclusion may therefore disproportionately discriminate against the elderly or infirm. Included studies were also at risk of bias which may impact upon the validity of results. Further work is required to maximise engagement with telemedicine in digitally naïve or incapable populations, and to determine the specific utility of telemedicine within clinical practice in order to maximise its benefits.

14 CHAPTER 4: STUDIES FOUR AND FIVE – DEVELOPMENT AND VALIDATION OF A NOVEL MULTI-MODAL MEASURE FOR REMOTE DIAGNOSIS OF SURGICAL SITE INFECTION

14.1 Study four: ASSIST – Development of a simplified clinician-patient hybrid reporting outcome measure for remote diagnosis of surgical site infection

14.1.1 Background

Over three million procedures were performed in the reduced capacity NHS during 2020, with a median of 4,685,106 procedures per year prior to this[266]. To review each patient face-to-face post-operatively would require every surgical consultant in the NHS to see 15 patients per every week, in addition to new referrals and routine follow-ups. Given that most patients have an uncomplicated postoperative trajectory, and this limited capacity for review, remote assessment offers the prospect of effective triage and streaming of patients through postoperative pathways, either face-to-face or an alternative.

Using telemedicine by either synchronous or asynchronous methods improves patient experience and reduces impact on the environment, in line with national net zero targets[230,267,268]. Current evidence suggests remote assessment has been deployed using telephone, photograph or questionnaire-based methods, in isolation. This implementation allows for screening patients but lacks sensitivity to diagnose SSI remotely[269]. A combination of modalities, such as wound photographs with patient questionnaire responses have not been developed and evaluated together to assess diagnostic accuracy, though have been evaluated as a triage tool[151]. Further, remote assessment has not been evidenced in elderly populations, who may derive more benefit from its use, but are more likely to be digitally naïve and struggle with utilisation.

The Bluebelle wound healing questionnaire (WHQ) is a 19-item patient or clinician reported questionnaire which was developed and validated in general (abdominal)

surgery[124,125]. This was based upon the existing gold standard for diagnosis which is face-to-face assessment using the Centres for Disease Control and Prevention (CDC) criteria[270]. Alternative measures include the ASEPSIS criteria and the Southampton score[121,123]. The WHQ has visual elements relating to a patient's wound and items on other signs, symptoms and interventions for infections, and therefore could potentially form the basis of a mixed modality remote diagnostic measure.

The necessity for improved service configuration and consistent assessment and diagnosis of patients with wounds has been recognised by both patients and clinicians in James Lind Alliance Priority Setting Partnerships[205]. This study aimed to develop a novel remote SSI assessment measure combining photograph and questionnaire modalities.

14.1.2 Methods

14.1.2.1 Study Design

This mixed methods study consists of outcome measure development in three phases:

- Phase I - clinician review of the existing WHQ measure[125], and creation of an outcome measure hypothesis
- Phase II - a prospective observational cohort to explore which items should be included in the final measure, testing the initial hypotheses.
- Phase III will then be validation of the ASSIST measure, and will be described elsewhere.

Both development and validation of ASSIST were undertaken in the same cohort of patients. The COSMIN study design checklist for patient reported outcome measures was used to guide study design, sample size calculation and hypothesis formulation and testing[271]. All participants provided written consent as part of an ongoing randomised controlled trial (NCT02992951). Ethical approval for this trial was obtained (16/LO/2135) from London – Harrow Research Ethics Committee, and study conduct was in accordance with the Declaration of Helsinki (2013)[272]. Eligibility

criteria followed the parent trial including all capacitous adult patients undergoing clean or clean-contaminated lower limb vascular surgery. Patients on concurrent antibiotics at the time of screening for conditions not related to the index procedure were not eligible for enrolment. Participants were recruited between 8th June 2022 and 9th January 2024, in a tertiary vascular centre in the United Kingdom (UK).

14.1.2.2 Phase I: hypothesis generation

The Bluebelle WHQ is a validated 19-item patient or clinician observed questionnaire for identification of SSI in primarily closed wounds in general surgery. It includes eleven WHQ items related to signs and symptoms of possible SSI (six visual; erythema, serous exudate, haemoserous exudate, purulent exudate, superficial dehiscence and deep dehiscence and five non-visual; wound warmth, swelling, smell and pain, and systemic temperature), with response categories for: 'not at all' (score 0), 'a little' (1), 'quite a bit' (2) and 'a lot' (3). A further eight items relate to wound care interventions (sought wound care advice, application of a dressing, return to hospital, use of antibiotics for the wound, deliberate wound separation by healthcare professional, wound debridement, wound drainage, operation under general anaesthetic, GA). Response categories for interventions are 'yes' (score 1) and no (score 0).

Five authors (RL, LH, BR, JW, MS), four vascular and one general surgeon individually reviewed all 19-items of the WHQ, scoring each on a five-point Likert scale (1-strongly disagree, 2 - disagree, 3 - neither agree or disagree, 4 - agree, and 5 - strongly agree) of agreement for necessity to diagnose SSI when considering the possibility of ambiguous interpretation of the item. Views were explored around the necessity of items to identify SSI and where these could be misinterpreted by patients, and hence scored in the absence of SSI. The mean Likert ratings for each item were taken, with 1.0-2.4 indicating disagreement, 2.5-3.4 uncertainty and 3.5-5.0 agreement that items should be included. These scores were combined with the qualitative discussion to formulate a priori hypotheses around which items should be retained within the ASSIST measure.

14.1.2.3 Phase II: cohort study

Participants enrolled into the cohort study were followed up at 30 days postoperatively, or before if they presented prior to this with a wound problem, their review was conducted at that time. All participants received both a remote and face-to-face assessment. Each were asked to complete all 19 items of the WHQ remotely, and additionally submit a wound photograph to their clinical team. Where this was not possible, relatives, carers and community nurses provided these images, or as a last resort, this was taken in person. Each patient was provided with wound photography guidance in attempt to standardise images and ensure sufficient quality for review. All participants had lower limb vascular surgery, and so wounds varied dependent on procedure located between groin and ankle. At face-to-face review, which occurred on the same day as remote submission, a clinician blinded to the remote assessment made a reference diagnosis as per the Centres for Disease Control and Prevention (CDC) criteria for SSI.

14.1.2.4 Sample Size

The COSMIN Study Design checklist guided appropriate sample size estimations for structural validity factor analysis (five to seven times the number of construct items and $\geq$100 participants) and internal consistency ($\geq$100 participants). Accounting for a 20% attrition rate, a sample size of 140 participants would provide 115 responses ensuring appropriate outcomes. Additionally, combining the reviews of five reviewers would therefore provide an inflated sample of 575 participants.

14.1.2.5 Data analyses

Exploratory factor analyses examined the structure and constructs of the measure. Analyses were conducted from combined clinician photograph review (of the six visual items) and patient responses to the remaining 13 items using a combined dataset from all five reviewers.

For each analysis, all iterations of item pairs were explored using Pearson's correlation coefficients. Correlation matrices determinants <0.00001 were explored

for cases of multicollinearity. Pairs with high correlations (r>0.8) were appraised for similarity and redundancy considered with exclusion before conducting factor analyses[273].

Four factor analyses models were run, principal components analysis (PCA) with scree plot examination for determination of factor extraction based upon eigenvalues greater than one, and maximum likelihood of estimation specifying one, two, and three factors. Kaiser-Meyer-Olkin (KMO) measure of sample adequacy was accepted with values >0.5, with values approaching 1.0 considered excellent. Significant values (<0.05) for Bartlett's test of Sphericity ensured correlation matrices were not identity matrices. Oblique (promax with kaiser normalisation, κ=4) rotations were explored for model fit. Small coefficients loading below 0.5 were suppressed, and items with no or cross loading considered for exclusion. Residuals were evaluated to ensure the adequacy of each factor analysis. Where less than 50% of nonredundant residuals had absolute values greater than 0.05 indicated good model fit[274].

Internal consistency of the scales identified from factor analyses were evaluated with Cronbach's α coefficient. Values >0.7 were considered to have good internal consistency[275].

All data were collected and analysed using IBM SPSS (IBM SPSS Corporation, version 28; Rochester, New York).

14.1.3 Results

14.1.3.1 Phase I: hypothesis generation

All five reviewers evaluated each WHQ item in the context of clinician and patient responses. For clinician responses, there was no mean disagreement for any item (all items had means $\geq$3.4), and two items indicated strong agreement for inclusion, erythema (mean 4.6) and purulent exudate (mean 4.8). Comments indicated reasons for ambivalence over other items; serous exudate could be 'part of the healing

process', haemoserous exudate may indicate a 'herald bleed' and dehiscence may be caused by SSI but also other patient factors such as 'nutrition, diabetes and operative technique.' It was also felt that it can be 'challenging to evaluate the depth' of exudate and deep dehiscence over photos. After discussion, the reviewers felt on balance, the measure should include all these items when wounds are reviewed by a clinician.

For patient reported items, most found that wound swelling (mean 2.2) and use of a wound dressing (mean 1.4) would not be a necessity in this context *(Table 12)*. This was corroborated with discussion; "swelling could be from other causes e.g. oedema" and "dressings often used post-operatively" indicating reviewers felt these items would be potential sources for ambiguity or redundancy in the measure. There was some agreement for inclusion of wound pain (mean 3.6), systemic fever (mean 3.6), wound deliberately opened (mean 3.6) and sought advice for wound problem (mean 3.4). Opinions for these items included; pain being 'subjective' and some patients may perceive 'expected postoperative pain as abnormal,' systemic fever could be due to 'other sources, e.g. respiratory,' wound deliberately opened may be mistaken during 'normal practices such as removal of staples or non-absorbable suture,' and sought wound advice, the patient may have had 'non-infection related issues' with the wound. Additional opinions felt that operation under GA could have been for problems other than infection. In discussion, there seemed to be four items with similar operative management themes; wound deliberately opened, wound debridement, wound drainage, and operation under general anaesthetic (items 16-19), which may skew results and whilst are indicators of SSI, may not be relevant to a remote diagnostic measure. It was concluded that potentially only one of the operative items should be included, which would likely be items 17 or 18 (wound debridement, wound drainage). Additionally, reviewers determined that wound swelling, pain, systemic fever, use of dressing and potentially sought wound advice would be sources of ambiguity and therefore should be removed.

Table 12: Likert responses of agreement for necessity to diagnose SSI in a combined clinician-patient remote outcome measure.

		Reviewer					Mean
		1	2	3	4	5	
	Questions to be answered by clinicians						
1.	Was there redness spreading away from the wound? (erythema/cellulitis)	5	5	4	5	4	**4.6**
2.	Has any part of the wound leaked clear fluid? (serous exudate)	5	4	2	4	2	**3.4**
3.	Has any part of the wound leaked blood-stained fluid? (haemoserous exudate)	5	2	4	4	2	**3.4**
4.	Has any part of the wound leaked thick and yellow/green fluid? (pus/purulent exudate)	5	5	5	5	4	**4.8**
5.	Have the edges of any part of the wound separated/gaped open on their own accord? (spontaneous dehiscence)	5	4	2	2	4	**3.4**
6.	Did the deeper tissue also separate?	5	4	4	2	4	**3.8**
	Questions to be answered by patients						
7.	Was the area around the wound warmer than the surrounding skin?	5	5	5	4	4	**4.6**
8.	Has the area around the wound become swollen?	1	2	4	2	2	**2.2**
9.	Has the wound been smelly?	5	5	5	4	2	**4.2**
10.	Has the wound been painful to touch?	2	4	4	4	4	**3.6**
11.	Have you had, or felt like you have had, a raised temperature or fever? (fever >38^{o}C)	1	5	4	4	4	**3.6**
12.	Have you sought advice because of a problem with your wound, other than at a planned follow-up appointment?	4	5	2	4	2	**3.4**
13.	Has anything been put on the skin to cover the wound? (dressing)	1	2	2	1	1	**1.4**
14.	Have you been back into hospital for treatment of a problem with your wound?	4	5	4	4	2	**3.8**
15.	Have you been given antibiotics for a problem with your wound?	5	5	4	5	4	**4.6**
16.	Have the edges of your wound been deliberately separated by a doctor or nurse?	2	5	4	3	4	**3.6**
17.	Has your wound been scraped or cut to remove any unwanted tissue? (debridement of wound)	2	5	5	5	4	**4.2**
18.	Has your wound been drained? (drainage of pus / abscess)	2	5	5	5	4	**4.2**
19.	Have you had an operation under general anaesthetic for treatment of a problem with your wound?	2	5	5	4	4	**4.0**

Score legend; strongly disagree (1), disagree (2), neither agree nor disagree (3), agree (4), strongly agree (5). Mean reviewer score *presented on far right column.*

The final hypothesis was that the final measure would include between 10-12 items, which would comprise of all six visual elements (items 1 to 6), wound warmth (item 7), wound smell (item 9), return to hospital (item 14), use of antibiotics (item 15) and with or without; seeking wound advice (item 12) and either of wound debridement (item 17) or wound drainage (item 18).

14.1.3.2 Phase II: cohort study

In total 140 participants were included over the study period (*Figure 15)*. There were six (4.3%) participants followed up who completed the questionnaire, but did not provide a wound image, and therefore were excluded from the final analysis. These six participants were of similar age (65.3±14.3 years), had lower body mass index (BMI, 22.5±2.3) and fewer comorbidities (2.8±1.9) than the whole cohort *(Table 13)*. None were complicated with SSI. Reasons for no image provided included having no email address and unable to use a smartphone. This left 114 (81.4% of all participants, and 87.7% of participants able to provide review) participants who provided both wound images and WHQ at follow-up. Of the responses returned, there were no missing items. Raw responses from reviewers and participants are shown in *appendix 8.8* and *8.9.* Generally, responses showed little variation, though patients tended to report greater levels of serous and haemoserous exudate. A final combined sample comprising all five reviewers therefore contained 570 responses. SSI was present in 29 of the 114 participants (SSI rate; 25.4%).

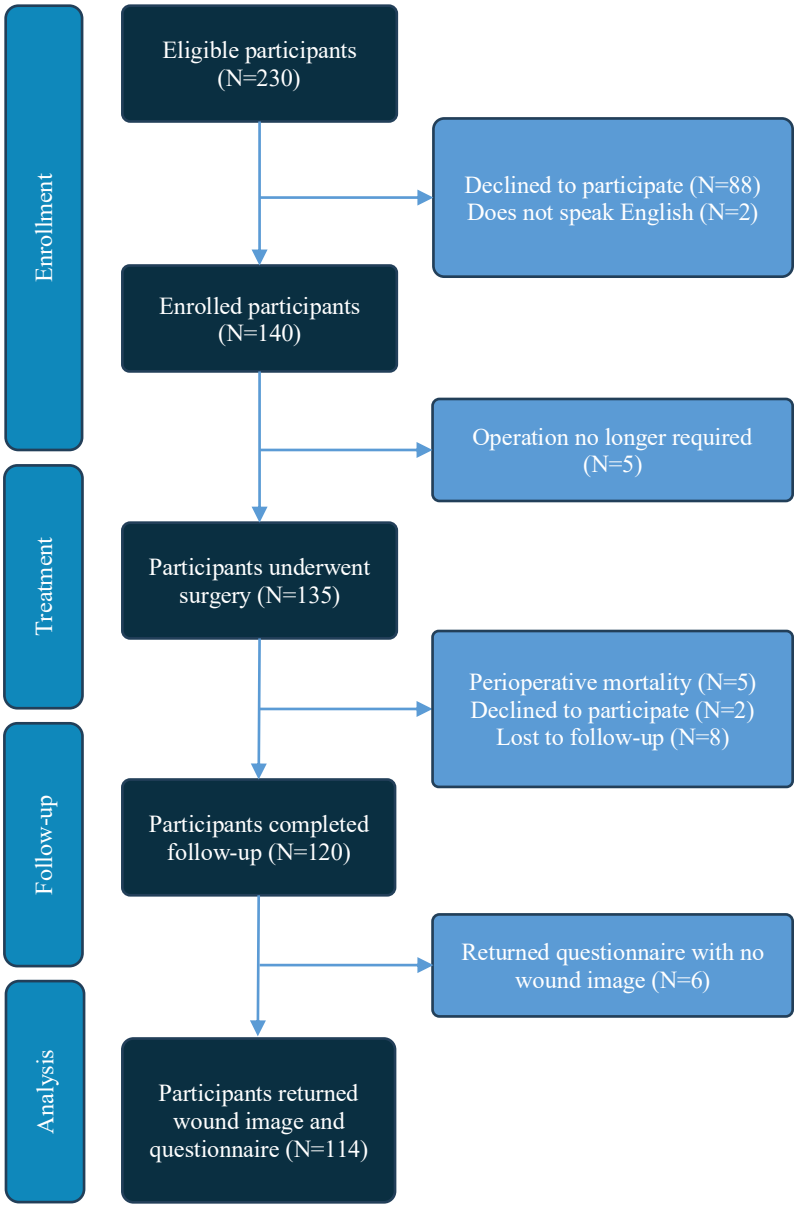


Figure 15: Study participant flow chart

Table 13: Baseline characteristics of participants.

Characteristic	N (140)	(%)
Sex		
Female	39	27.9
Male	101	72.1
Age†	65.5	12.7
BMI†	26.2	6.4
Ethnicity		
Caucasian	140	100
Smoking history		
Current	50	35.7
Ex-smoker	71	50.7
Never Smoked	19	13.6
Comorbidities		
Diabetes	58	41.4
Previous cerebrovascular accident	13	9.3
Hypertension	77	55.0
Cardiovascular disease	55	39.3
Peripheral vascular disease	124	88.6
Chronic Obstructive Pulmonary disease	41	29.3
Chronic kidney disease	25	17.9
Dermatological disease	14	10.0
Gastrointestinal disease	43	30.7
Musculoskeletal disease	38	27.1
Previous operation	88	62.9
Mean number of comorbidities per patient†	4.1	2.0

14.1.3.2.1 Principal Component Analysis

A high correlation was not observed between any of the 19 Bluebelle WHQ item pairs and the matrix determinant was 0.001 indicating absence of any multicollinearity *(Table 14)*. The sample was middling (KMO = 0.793) and there was no indication of an identity matrix (X^2 = 4,146.5, p<0.001). In initial extraction, PCA found five factors with eigenvalues greater than one, and a combined variance of 61.4%. There was however no loading above threshold on two of these factors, and scree plot analysis suggested three factors would provide a better model fit *(Figure 16).* Low communalities (<0.300) were found for items 8 (wound swelling, 0.298), 11 (systemic fever, 0.204) and 13 (wound dressing, 0.028) and therefore were dropped *(Table 15).* Further, significant cross-loading was identified for the operative items 16 (wound opened), 18 (wound drained), and 19 (operation under GA) *(Table 16).* In the context of a remote diagnostic measure, the hypothesis generation and significant negative cross-loadings, these items were decidedly removed. Subsequently, item 17 (wound debridement) no longer had a good fit with the model (communality of 0.285) and was also removed. Finally, 12 items were extracted across three factors with a meritorious KMO of 0.824 and no indication of an identity matrix (X^2 = 2,436.1, p<0.001). The scree plot is shown in figure three. There were 31 (46.0%) nonredundant residuals greater than 0.05 between observed and reproduced correlations. Combined variance of the factors accounted for 60.2% of the variance.

Table 14: Correlation matrix for matching Bluebelle wound healing questionnaire response items

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
	Correlation Matrix	Erythema	Serous exudate	Haemoserous exudate	Purulent exudate	Superficial dehiscence	Deep dehiscence	Wound warmth	Wound swelling	Wound smell	Wound pain	Systemic fever	Sought wound	Wound dressing	Return to hospital	Antibiotics	Wound opened	Wound debridemen	Wound drained	Operation under GA
1.	Erythema	**1.00**	0.43	0.30	0.44	0.59	0.42	0.18	0.11	0.25	0.25	0.12	0.38	0.10	0.33	0.40	0.18	0.24	0.19	0.25
2.	Serous exudate	0.43	**1.00**	0.45	0.38	0.56	0.40	0.11	0.04	0.34	0.19	0.04	0.32	0.07	0.39	0.23	0.36	0.11	0.24	0.14
3.	Haemoserous exudate	0.30	0.45	**1.00**	0.28	0.42	0.41	0.08	-0.03	0.11	0.11	0.08	0.21	-0.01	0.21	0.10	0.25	0.13	0.33	0.22
4.	Purulent exudate	0.44	0.38	0.28	**1.00**	0.59	0.63	0.07	0.02	0.24	0.25	0.12	0.23	0.06	0.30	0.21	0.25	0.28	0.26	0.22
5.	Superficial dehiscence	0.59	0.56	0.42	0.59	**1.00**	0.59	0.13	0.05	0.34	0.30	0.12	0.39	0.10	0.36	0.28	0.26	0.30	0.24	0.21
6.	Deep dehiscence	0.42	0.40	0.41	0.63	0.59	**1.00**	0.04	-0.01	0.26	0.17	0.07	0.23	0.06	0.31	0.20	0.34	0.32	0.40	0.27
7.	Wound warmth	0.18	0.11	0.08	0.07	0.13	0.04	**1.00**	0.23	0.40	0.38	0.26	0.44	0.02	0.19	0.39	-0.08	0.32	-0.06	-0.08
8.	Wound swelling	0.11	0.04	-0.03	0.02	0.05	-0.01	0.23	**1.00**	0.10	0.31	0.21	0.24	0.05	-0.03	0.14	-0.02	0.19	-0.07	-0.02
9.	Wound smell	0.25	0.34	0.11	0.24	0.34	0.26	0.40	0.10	**1.00**	0.44	0.17	0.33	0.11	0.23	0.04	0.07	0.23	-0.03	-0.04
10.	Wound pain	0.25	0.19	0.11	0.25	0.30	0.17	0.38	0.31	0.44	**1.00**	0.13	0.33	0.05	0.16	0.14	-0.03	0.25	-0.08	0.05
11.	Systemic fever	0.12	0.04	0.08	0.12	0.12	0.07	0.26	0.21	0.17	0.13	**1.00**	0.09	-0.08	0.04	0.23	-0.05	0.22	-0.03	-0.05
12.	Sought wound advice	0.38	0.32	0.21	0.23	0.39	0.23	0.44	0.24	0.33	0.33	0.09	**1.00**	0.22	0.48	0.54	0.21	0.24	0.14	0.21
13.	Wound dressing	0.10	0.07	-0.01	0.06	0.10	0.06	0.02	0.05	0.11	0.05	-0.08	0.22	**1.00**	0.11	0.05	0.05	0.07	0.03	0.05
14.	Return to hospital	0.33	0.39	0.21	0.30	0.36	0.31	0.19	-0.03	0.23	0.16	0.04	0.48	0.11	**1.00**	0.34	0.43	0.24	0.30	0.20
15.	Antibiotics	0.40	0.23	0.10	0.21	0.28	0.20	0.39	0.14	0.04	0.14	0.23	0.54	0.05	0.34	**1.00**	0.24	0.28	0.17	0.24
16.	Wound opened	0.18	0.36	0.25	0.25	0.26	0.34	-0.08	-0.02	0.07	-0.03	-0.05	0.21	0.05	0.43	0.24	**1.00**	0.30	0.70	0.49
17.	Wound debridement	0.24	0.11	0.13	0.28	0.30	0.32	0.32	0.19	0.23	0.25	0.22	0.24	0.07	0.24	0.28	0.30	**1.00**	0.44	0.30
18.	Wound drained	0.19	0.24	0.33	0.26	0.24	0.40	-0.06	-0.07	-0.03	-0.08	-0.03	0.14	0.03	0.30	0.17	0.70	0.44	**1.00**	0.70
19.	Operation under GA	0.25	0.14	0.22	0.22	0.21	0.27	-0.08	-0.02	-0.04	0.05	-0.05	0.21	0.05	0.20	0.24	0.49	0.30	0.70	**1.00**

a. Determinant = 0.001

The matrix determinant, 0.001 does not indicate any multicollinearity

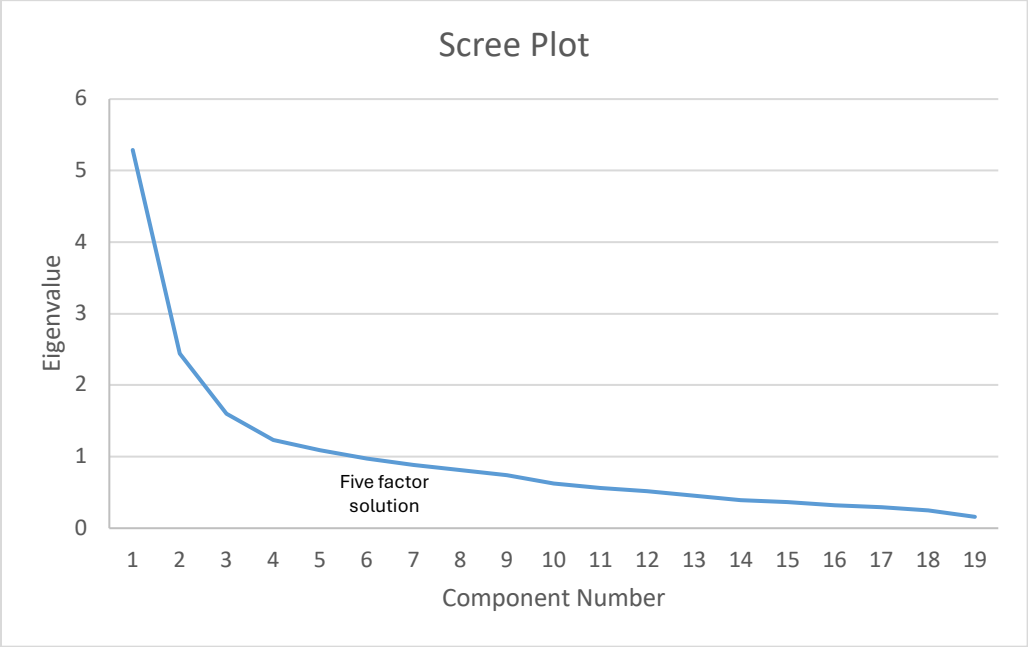


Figure 16: Scree plot for all 19 items extracted by principal components analysis

Table 15: Table of communalities

Communalities

No.	Item	Initial	Extraction
1.	Erythema	1.000	.492
2.	Serous exudate	1.000	.549
3.	Haemoserous exudate	1.000	.383
4.	Purulent exudate	1.000	.540
5.	Superficial dehiscence	1.000	.722
6.	Deep dehiscence	1.000	.610
7.	Wound warmth	1.000	.611
8.	**Wound swelling**	**1.000**	**.298**
9.	Wound smell	1.000	.447
10.	Wound pain	1.000	.448
11.	**Systemic fever**	**1.000**	**.204**
12.	Sought wound advice	1.000	.555
13.	**Wound dressing**	**1.000**	**.028**
14.	Return to hospital	1.000	.378
15.	Antibiotics	1.000	.486
16.	Wound opened	1.000	.659
17.	Wound debridement	1.000	.451
18.	Wound drained	1.000	.827
19.	Operation under GA	1.000	.634

Extraction Method: Principal Component Analysis.

Table 16: Component matrix extracted by principal component analysis.

Component Matrix[a]

	Component		
	1	2	3
Superficial dehiscence	.763		
Deep dehiscence	.697		
Erythema	.667		
Purulent exudate	.653		
Serous exudate	.650		
Return to hospital	.613		
Sought wound advice	.610		
Wound opened	.563	-.554	
Wound debridement	.527		
Haemoserous exudate	.521		
Antibiotics	.516		.486
Wound drained	.556	-.681	
Wound warmth		.619	.433
Operation under GA	.480	-.558	
Wound pain		.543	
Wound smell	.432	.517	

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

Items one to six (erythema, serous exudate, haemoserous exudate, purulent exudate, superficial dehiscence and deep dehiscence) all loaded onto factor one *(Table 17)*. Items 12 (sought wound advice), 14 (return to hospital), and 15 (antibiotics) loaded onto factor two and items seven (wound warmth), nine (wound smell) and 10 (wound pain) loaded onto factor three. After discussion, the study team felt the factors appropriately described 'the appearance of the wound' (factor one), 'the treatment(s) given to the patient' (factor two) and 'the feel and smell of the wound' (factor three). There was debate over factor three describing non-visual signs and symptoms, but the team concluded 'feel and smell' better reflected and distinguished the factors and was. More appropriate language for a tool designed to be used by patients. Total percentage of variance for factors one, two and three was 37.3%, 13.9% and 9.0% respectively (cumulative total; 60.2%). Cronbach's α was high with a coefficient of 0.841.

Table 17: Pattern matrix of a 12 item model extracted by principal component analysis

Pattern Matrix[a]

	Component		
	1	2	3
Superficial dehiscence	0.827		
Deep dehiscence	0.781		
Purulent exudate	0.76		
Serous exudate	0.662		
Haemoserous exudate	0.651		
Erythema	0.547		
Antibiotics		0.945	
Sought wound advice		0.735	
Return to hospital		0.549	
Wound smell			0.853
Wound pain			0.809
Wound warmth			0.590

Extraction Method: Principal Component Analysis.

Rotation Method: Promax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

14.1.3.2.2 Maximum likelihood of estimation

Maximum likelihood of estimation models for one, two and three extracted factors specified measures with eight *(Table 18),* ten *(Table 19),* and eleven *(Table 20)* items respectively, though a three-factor model most closely resembled PCA extraction methods. One and two factor solutions were meritorious (KMO = 0.814 and 0.807 respectively) and a three-factor model was middling (KMO = 0.793). No identity matrices were found (X^2 = 3,523.8, 3,872.6 and 4,146.5, p<0.001 for factors one, two and three respectively). Model fit for one, two and three factor models were good with 6 (40.0%), 4 (14.0%) and 51 (29.0%) nonredundant residuals greater than 0.05 respectively. The total variance explained for one, two and three factors' models were 29.7%, 39.8% and 41.4% respectively. No cross-loadings were present across two and three factor models. Cronbach's α was good with coefficients of 0.838, 0.827 and 0.823 respectively.

Table 18: Factor matrix extracted by maximum likelihood of estimation with one factor.

Factor Matrix[a]

	Factor 1
Superficial dehiscence	0.786
Deep dehiscence	0.704
Purulent exudate	0.663
Erythema	0.651
Serous exudate	0.636
Return to hospital	0.541
Sought wound advice	0.514
Haemoserous exudate	0.500

Extraction Method: Maximum Likelihood.

a. 1 factors extracted. 5 iterations required.

Table 19: Factor matrix extracted by maximum likelihood of estimation with two factor.

Factor Matrix[a]

	Factor	
	1	2
Wound drained	0.999	
Wound opened	0.705	
Operation under GA	0.704	
Superficial dehiscence		0.772
Erythema		0.653
Purulent exudate		0.6
Serous exudate		0.594
Deep dehiscence		0.558
Sought wound advice		0.541
Wound smell		0.501

Extraction Method: Maximum Likelihood.

a. 2 factors extracted. 7 iterations required.

Table 20: Factor matrix extracted by maximum likelihood of estimation with three factors.

Rotated Factor Matrix[a]

	Factor		
	1	2	3
Superficial dehiscence	0.817		
Deep dehiscence	0.682		
Purulent exudate	0.676		
Serous exudate	0.612		
Erythema	0.594		
Wound drained		0.979	
Operation under GA		0.69	
Wound opened		0.67	
Wound warmth			0.739
Sought wound advice			0.634
Antibiotics			0.523

Extraction Method: Maximum Likelihood.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

14.1.4 Discussion

Principal components analysis and maximum likelihood of estimation identified two potential three-factor models for a remote measure to diagnose surgical site infection with eleven and twelve items in each. Hypothesis generation suggested a measure with between ten and twelve items would comprise all the relevant clinical questions. Overall, the twelve-item model appears to have the best fit with the greatest overall variance explained through contained items, though one item, wound pain was identified as a potential source of ambiguity during hypothesis generation. A third model therefore should be explored with wound pain removed. One and two factor solutions explained low levels of variance and did not coincide with scree plot analysis, and so will not be explored further. The next phase in the development of the ASSIST measure will be to validate a remote diagnostic model to identify surgical site infection based upon wound images and questionnaire responses provided by patients. All three of the potential models identified here will be evaluated for diagnostic accuracy, in addition to all 19 items of the Bluebelle WHQ with the best taken into the ASSIST measure.

Current evidence suggests remote assessments have been used by either telephone, photograph or questionnaire-based methods in isolation and are able to screen for but not diagnose SSI[269]. The ASSIST measure combines both photograph and questionnaire assessment in a single measure. Further validation will show whether this improves diagnostic accuracy to identify postoperative infections. Accurate remote assessment will ensure efficient triage of complications, enabling 'remote first' approaches to postoperative care, and safeguarding patients from unnecessary return visits to hospital. This transition to 'remote first' postoperative care is also a key factor in reducing rising carbon emissions from patient travel, which have almost doubled in the last three decades[157,268]. Post discharge surveillance with serial assessments have been utilised with high response rates and may also be integral to ensuring optimal efficiency in a remote first care pathway[267].

Mixed methods were used to generate and test the hypothesis as per the COSMIN study design checklist[271]. As the ASSIST measure is based upon an existing tool, and

the specific wording and questions from this have been developed and validated involving patient and clinician representatives previously, clinicians provided responses to the hypothesis generation questions[276]. This provided the perspective of aiming to summarise the prior items into a remote diagnostic measure which would minimise ambiguity or redundancy in potential questions. As such, some of the cardinal signs and symptoms of infection were removed, such as swelling and systemic pyrexia. Whilst integral to a holistic definition of SSI, these features would not occur in isolation, or may be indicative of a non-SSI complication leaving the possibility of diagnosis in their absence. Those identified with infection remotely could have the additional features confirmed at in person assessment where required.

Both principal components and maximum likelihood of estimation were used as methods of factor analysis. Whilst a three-factor model appears to have the best fit, these resulted in marginally differing solutions varying between 11 and 12 items. Given the subjectivity involved factor analysis, each of the three-factor solutions will be evaluated for diagnostic accuracy and reliability in the identification of SSI. An oblique rotation was used (promax with kaiser normalisation) given the large, combined dataset and likelihood of having some correlation between items.

Analysis of wound images is from a single snapshot in time, whereas patient responses likely incorporate their experience of a duration of time. The combination of these different time centred items may have implications during factor analysis and scale structure. The differences in variation seemed to coincide with qualitative interpretation of ambiguous and redundant question items in this study, though should be considered in the final measure. Further, the use of the combined measure as either a single diagnostic measure or serial assessment tool may be impacted by such differences.

This study does have some limitations. Data were collected in a tertiary vascular centre in a patient group at high risk for SSI; exploration of the final model in other contexts would be required for generalisability of findings. A hypothesis was

generated a priori from five independent clinicians who then discussed and came to a consensus in line with COSMIN guidelines[271]. Given the prior development work on item wordings and the unique context of the ASSIST measure, a wider group were not sought, and additional input from patients, community nurses and general practitioners may have provided alternative perspectives. During future iterations, feedback from these stakeholders will be incorporated into the measure design. Whilst the initial sample (n=114) was adequate to evaluate structural validity through factor analysis (at least five times the number of items, of which there were 19, and ≥100 participants), a combined sample (n=570) ensured 'very good' outcomes as per the COSMIN guidelines, there is potential for bias in the outcomes when completed this way[271]. A combination of responses rather than review based upon the number of wounds risks interference of the inter-rater reliability on the interpretation on the variation in factor analysis. Results of the factor analyses did not differ when the initial sample (n=114) from a single rater was evaluated. Further validation across diverse populations, specifically covering a broad range of ethnicities, and low infection risk groups will be sought to ensure applicability in as generalisable contexts as possible. During such projects, evaluation of the optimal delivery modality or system will be undertaken for their impact on response rates. Comparison should also be considered with alternative SSI definitions and surveillance guidelines such as the United Kingdom Health Security Agency (UKHSA)[277].

14.1.5 Conclusion

This study identified three potential models for a remote diagnostic measure to identify surgical site infection which combines clinician review of patient provided wound images and patient reported questionnaire items. Each model is substantially shorter than alternative available measures which have not been designed for combined use, ensuring this is simple and easy to use. Further evaluation of each model for reliability and diagnostic accuracy to validate a final measure is required before this approach that can be implemented in routine clinical practice.

This study will follow recombinant innovative processes to develop and validate a novel combined measure to detect SSI remotely. The aim is to establish whether a

combined test approach will improve overall test accuracy for the detection of surgical site infection. The study will follow STARD reporting guidelines for diagnostic test accuracy studies[278]. The COSMIN study design checklist for outcome measurement instruments will be followed to guide sample size requirements[271]. 100 participants will be needed for 'very good' outcomes as per this standard. This will utilise wound photograph images and the bluebelle wound healing questionnaire[244]. Comparisons will be made between the combined questionnaire and photographs, the entire patient reported bluebelle questionnaire, alternative scoring system such as ASEPSIS[121] and the gold standard of face-to-face review. This will establish a new, accurate and reliable measure which can be utilised in trials and practice to determine SSI remotely without requiring patients to return to hospital.

14.2 Study five: Validation of a clinician-patient reported diagnostic measure for identifying surgical site infection

14.2.1 Background

Over four and a half million procedures are performed each year in the NHS[266]. This equates to reviewing 15 patients every week per surgical consultant requiring a clinical wound review appointment. As most patients have an uncomplicated postoperative period, and there is limited capacity for face-to-face review, and remote assessment offers the prospect of effective triage in the postoperative pathway. Remote assessments improve patient experience and reduce the overall healthcare impact on the environment[230,267,268]. Current methods are able to screen patients for SSI but lack sensitivity in diagnosis, and no studies have evaluated combined modalities such as wound image assessment with patient reported questionnaires for improvement in diagnostic accuracy[269].

The Bluebelle wound healing questionnaire (WHQ) is a patient or clinician reported questionnaire developed and validated in general surgery[125,276]. Given the WHQ contains both wound appearance items and non-visual or management elements, and it has been designed in line with the gold standard Centres for Disease Control and Prevention (CDC) criteria, this provides a framework for which to develop a combined wound image and questionnaire diagnostic measure[63].

The necessity for improved service configuration and consistent assessment and diagnosis of patients with wounds has been recognised by both patients and clinicians in James Lind Alliance Priority Setting Partnerships[205]. Following on from initial development phases, this study aims to validate a remote SSI assessment measure combining photograph and questionnaire modalities.

14.2.2 Methods

14.2.2.1 Study Design

This prospective observational cohort study recruited participants between 8th June 2022 and 9th January 2024, in a tertiary vascular centre in the United Kingdom (UK). All participants provided written consent as part of an ongoing randomised controlled trial (NCT02992951). Ethical approval for this trial was obtained (16/LO/2135) from London – Harrow Research Ethics Committee, and study conduct was in accordance with the Declaration of Helsinki (2013)[272]. The study was conducted and reported in line with the Standards for Reporting Diagnostic Accuracy (STARD) and the Transparent reporting of a multivariable prediction model for individual prognosis or diagnosis (TRIPOD) statements[278,279]. The COSMIN study design checklist for patient-reported outcome measurement instruments was also followed[271].

14.2.2.2 Participants

Eligibility criteria included all adult patients undergoing clean or clean-contaminated lower limb vascular surgery with capacity. Patients on concurrent antibiotics at the time of screening for conditions not related to the index procedure were not eligible for enrolment. Consecutive participants enrolled into the cohort study were followed up at 30 days postoperatively, or if they presented prior with a wound related problem, their review was conducted at that time. All participants received both in person review (as a reference standard) and prior assessment of their wounds using the remote assessments being tested on the same day using a combination of modified Bluebelle wound healing questionnaire (WHQ) and patient submitted wound images. Participants were included in final analysis if both questionnaire and wound image were provided.

14.2.2.3 Test methods

Index test

Five remote index tests were evaluated in this study. The WHQ consists of 19 items, 6 of which relate to visual wound signs. Patient responses to the WHQ in combination

with the clinician review of the patient's wound photograph formulated the basis of the index test. The development phase of the ASSIST measure identified three distinct test combinations consisting of 11-12 items (11 and 12 item measures from principal components analysis, ASSIST1 and ASSIST2, and 12 item from maximum likelihood of estimation, ASSIST3). The other two tests were formulated from the original 19 item WHQ responded by patients alone (WHQ) and as a combination of patient's responses with clinician review of wound photographs (WHQI). For each test which included clinician review of wound photographs (ASSIST1, ASSIST2, ASSIST3 and WHQI), five clinicians independently reviewed all the included wound appearance items (items 1-6). Details of each test, the items included and who responded to each item are shown in *table 21*.

Table 21: Index tests evaluated for diagnostic accuracy as possible inclusion in the ASSIST measure.

		ASSIST index test				
		ASSIST1	ASSIST2	ASSIST3	WHQ	WHQI
		1	2	3	4	5
1.	Erythema	X	X	X	X	X
2.	Serous exudate	X	X	X	X	X
3.	Haemoserous exudate	X	X		X	X
4.	Purulent exudate	X	X	X	X	X
5.	Superficial dehiscence	X	X	X	X	X
6.	Deep dehiscence	X	X	X	X	X
7.	Wound warmth	X	X	X	X	X
8.	Wound swelling				X	X
9.	Wound smell	X	X		X	X
10.	Wound pain		X		X	X
11.	Systemic fever				X	X
12.	Sought wound advice	X	X	X	X	X
13.	Wound dressing				X	X
14.	Return to hospital	X	X		X	X
15.	Antibiotics	X	X	X	X	X
16.	Wound opened			X	X	X
17.	Wound debridement				X	X
18.	Wound drained			X	X	X
19.	Operation under GA			X	X	X

ASSIST1, ASSIST2, ASSIST3 and WHQI contain clinician review of the wound visual elements (items 1-6 where included) and patient responses from the remainder. X denotes where items are included with that measure.

ASSIST1: 11-item measure developed with principal components analysis and qualitative clinician discussion

ASSIST2: 12-item measure developed with principal components analysis

ASSIST3: 11-item measure developed with maximum likelihood of estimation

WHQ: 19-item Bluebelle WHQ responded by patients

WHQI: 19-item Bluebelle WHQ with six wound visual items responded by clinicians and 13-items responded by patients.

Reference standard / control assessment

Face-to-face assessment of each participant using the Centres for Disease Control and Prevention (CDC) definition was taken as the gold standard diagnosis for comparison[63]. This reference standard review was conducted on the same day as index test assessment for all patients. Reference standard assessors were blinded to those conducting index tests, and vice versa.

14.2.2.4 Data analysis

All items planned for each index test were included in the initial analysis. Missing responses to items were imputed with values of zero if no response was expected (for example, the sign or symptom had not occurred). Items 1-11 (numbering indicated in table 21) have response categories for: 'not at all' (score 0), 'a little' (1), 'quite a bit' (2) and 'a lot' (3) and items 12-19 have response categories for 'yes' (score 1) and no (score 0). Total scores from responses are summed with higher scores reflecting more wound infection features. Reference SSI diagnoses were dichotomised into a binary variable with 0 = no SSI and 1 = SSI present. Analyses were performed using IBM SPSS (IBM SPSS Corporation, version 28; Rochester, New York).

Acceptability

Acceptability of the measure was investigated through response rates to the index measures (the proportion of completed items in each index test) and missing items within the responses.

Reliability

Test-retest reliability was assessed by comparing responses completed twice over a period of no health change, one week after the initial review, in a subset of participants. If participants had not returned to hospital for treatment of a wound related problem between assessments, this period of no change was assumed. Intraclass correlation coefficient (ICC) for consistency assessed the overall intra-observer agreement for each rater and weighted kappa (κ) statistics were calculated for agreement across individual scale items comparison. Equal weights were applied

to response variables 1-11 with values of 0, 0.333, 0.667 and 1 between categories. ICC for absolute agreement between raters for the overall measure was used to evaluate interobserver variation with weighted κ for individual scale items as described above.

Validity

Criterion validity was evaluated for each index test against the reference SSI diagnosis to determine ability to discriminate between individuals with and without SSI. The binary reference CDC diagnosis was cross tabulated against each index test at potential cut-off scores for the diagnosis of SSI (for example, SSI was present with an index test score greater than or equal to x). The sensitivity, specificity, and positive and negative predictive values, in addition to the diagnostic odds ratio (DOR) and Youden's Index (the sum of the sensitivity and specificity subtracted by one) at cut-off scores for each index test, and across all five clinician raters for tests involved wound image review were compared and optimal cut-off scores identified. DOR values above 10.00 were taken to be a very good diagnostic test, with higher values indicating superior accuracy and sensitivity and specificity[280]. A Youden's Index of 1.0 indicated a perfect test whereas a value of 0.0 signified poor diagnostic accuracy[281]. Sensitivity and 1 – specificity values of each index test were then plotted onto receiver operating characteristic (ROC) curves to evaluate the trade-off between sensitivity and specificity, and the difference in performance between tests. The overall ability of the index tests to discriminate between individuals with and without SSI was measured by the area under the ROC (AUROC) with 95% confidence intervals estimated. An AUROC value approaching 1.0 indicated good discrimination for SSI with >0.9 considered outstanding, whereas 0.5 suggested no discrimination[282]. The maximal Kolmogorov-Smirnov (K-S) statistic was used to evaluate each measure's deviation from reference standard observations, as a representation of the measure with the best model fit. A value of 1.0 indicates perfect fit. Optimal cut-off values were estimated based upon the score which achieved maximal sensitivity, specificity, PPV, NPV, DOR and Youden's index. For comparison, the largest cut-off score that represented the K-S value was also presented.

Precision

Precision for each index text was evaluated by dividing the true positives by the sum of the true positives and false positives as each cut off score (equivalent to positive predictive value, PPV). Similarly, recall was evaluated by dividing the true positives by the sum of the true positives and false negatives at each cut off score (equivalent to Sensitivity). For each test, precision was plotted against recall in a precision-recall curve (PRC) and the Gini index indicated overall performance of each measure. A value approaching 1.0 indicates high performance.

Sample size

Sample size calculations were based upon previous telemedicine specificity rates of 98% and improvement of sensitivity to 98% for SSI diagnosis[269]. Prevalence was taken from SSI rates recorded in the same patient group and hospital evaluated in a previous randomised controlled trial at 25.8%[283]. Assuming the above sensitivity, specificity and prevalence, with precision of 0.05, 95% confidence level, 117 participants would be required to power sample size for the sensitivity change, rising to 138 to account for an attrition rate of 15%. Recruitment continued until the completed follow-up for the sample size was met.

14.2.3 Results

In total, 140 participants were enrolled in the study and there were 114 included in the final analysis, *figure 17*. There were six (4.3%) participants followed up who completed the questionnaire, but did not provide a wound image, and therefore were excluded from the final analysis. These six participants were of similar age (65.3±14.3 years), had lower body mass index (BMI, 22.5±2.3) and fewer comorbidities (2.8±1.9) than the whole cohort, *table 22*. None were complicated with SSI. Reasons for no image provided included having no email address and unable to use a smartphone. A final combined sample comprising all five reviewers therefore contained 570 responses. SSI was present in 29 of the 114 participants (SSI rate; 25.4%).

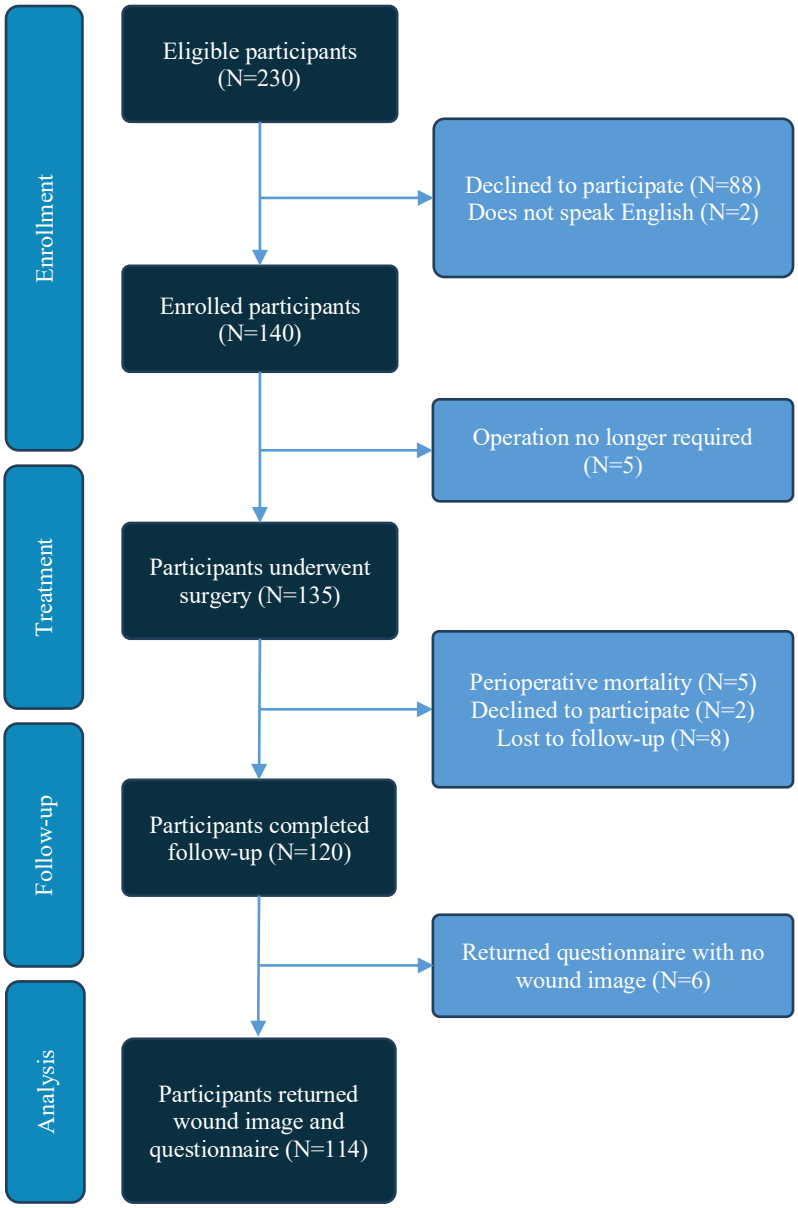


Figure 17: Study participant chart

Table 22: Baseline characteristics of participants

Characteristic	N (140)	(%)
Sex		
Female	39	27.9
Male	101	72.1
Age†	65.5	12.7
BMI†	26.2	6.4
Ethnicity		
Caucasian	140	100
Smoking history		
Current	50	35.7
Ex-smoker	71	50.7
Never Smoked	19	13.6
Comorbidities		
Diabetes	58	41.4
Previous cerebrovascular accident	13	9.3
Hypertension	77	55.0
Cardiovascular disease	55	39.3
Peripheral vascular disease	124	88.6
Chronic Obstructive Pulmonary disease	41	29.3
Chronic kidney disease	25	17.9
Dermatological disease	14	10.0
Gastrointestinal disease	43	30.7
Musculoskeletal disease	38	27.1
Previous operation	88	62.9
Mean number of comorbidities per patient†	4.1	2.0

Acceptability

At follow-up there were 128 participants eligible to provide remote assessment responses. There were 14 (10.9%) non- or incomplete responses (lost to follow-up, *n*=8, and questionnaire returned without wound image, *n*=6). Acceptability of a sole patient reported measure was therefore greater than a combined measure including both questionnaire and wound image (patient only; 93.8% versus combined; 89.1% response rates). Across the six items responded by the five clinicians, there were no missing items where an image was available to be reviewed (3,420/3,420 item responses). Across all 19 WHQ items responded by participants there was also no missing items (2,280/2,280 item responses).

Reliability

Inter-rater reliability: Patient (self), in-person clinician and remote clinician (all five observers) assessments at day 30 review were available for all participants. For items one to six, there was generally high levels of agreement across all respondents except for the presence of serous (item 2) and haemoserous (item 3) exudate which were over-reported by patients, *appendix 8.10.* Between in-person clinician and patient assessments for items 7 to 19, agreement again was generally high, though patients tended to report higher levels of wound warmth, swelling, pain and smell and some participants reported never having had a wound dressing, despite every patient receiving this as part of standard care *appendix 8.11*. Compared to face-to-face assessment most responders indicated moderate to excellent agreement (ICC; 0.4-1.0, κ; 0.4-1.0). For haemoserous and purulent exudate, patients indicated poor to fair agreement (ICC; 0.342, 0.230, and κ 0.255, 0.453, respectively), *appendix 8.12*. Between items 7-19, patients indicated moderate to excellent agreement with in-person review (ICC; 0.6-1.0, and κ; 0.4-1.0), *appendix 8.13*. Agreement for use of wound dressings was however poor (ICC; 0.0, κ; 0.0).

Intra-rater reliability: For items 1-6, clinicians indicated moderate to excellent reliability for all items (ICC 0.4-1.0, κ; 0.2-1.0) except haemoserous exudate which was variable (ICC 0.0-1.0, κ; 0.0-1.0), *appendix 8.14*. Patients also had moderate to excellent agreement (ICC; 0.6-0.8, κ; 0.3-0.7) except haemoserous exudate and deep dehiscence (ICC; 0.2 and 0.0, κ; 0.2 and 0.6 respectively). For items 7-19 there was moderate to excellent reliability for all items (ICC; 0.4-0.9, κ; 0.3-0.8) other than use of a wound dressing, drainage of pus and operation under general anaesthetic (ICC; 0.1, 0.0 and 0.0, κ; 0.1, 0.0 and 0.0 respectively), *appendix 8.15*.

Validity

Accuracy statistics for each remote measure at potential cut off scores are shown in *table 23.* Measures with more items (WHQ and WHQI) tended to have higher estimated optimal cut-off scores. Kolgomorov-Smirnov metrics suggested similar optimal cut-off scores to previous interpretation, except for ASSIST1 (cut off score;

4) and WHQ/WHQI (cut off score 7), *table 24*. Generally, all measures showed good to excellent accuracy. The patient only response measure (WHQ) had the lowest ability to identify SSI (Cut-off score; 6, sensitivity; 89.7%, specificity; 87.1%, PPV; 70.9%, NPV; 96.1%, DOR; 58.3, Youden's Index; 0.767). Comparatively, the same measure but where clinicians review visual wound characteristics (items 1-6) instead of patients (WHQI) improved diagnostic accuracy (cut-off score; 6, sensitivity; 93.1%, specificity; 92.7%, PPV; 81.3%, NPV; 97.5%, DOR; 171.6, Youden's Index; 0.858). PCA-11 at a cut-off score of three displayed optimal accuracy for identifying SSI (sensitivity 97.9%, specificity 92.5%, PPV; 81.6%, NPV; 99.2%, DOR; 581.3, Youden's Index; 0.904) with few miscalculations (false positive rate; 7.5% and false negative rate; 2.1%). ROC curves approach the top left corner for all index tests, with lower discriminatory ability of a patient only measure (WHQ), *figure 18.* AUROC was greatest for the ASSIST1 measure indicating excellent diagnostic ability for discriminating SSI; 0.997 (95% confidence interval; 0.991-1.000, $p<0.001$), *table 23*.

Table 23a-e: Cut off scores for each diagnostic measure

23a. ASSIST1 (11 items)

Cut-off	TN	FN	TP	FP	Sensitivity	Specificity	PPV	NPV	DOR	Youden's Index
0	205	0	145	220	1.000	0.482	0.397	1.000	#DIV/0!	0.482
1	300	0	145	125	1.000	0.706	0.537	1.000	#DIV/0!	0.706
2	363	0	145	62	1.000	0.854	0.700	1.000	#DIV/0!	0.854
3	**393**	**3**	**142**	**32**	**0.979**	**0.925**	**0.816**	**0.992**	**581.313**	**0.904**
4	409	13	132	16	0.910	0.962	0.892	0.969	259.558	0.873
5	421	46	99	4	0.683	0.991	0.961	0.901	226.516	0.673
6	422	60	85	3	0.586	0.993	0.966	0.876	199.278	0.579
7	424	76	69	1	0.476	0.998	0.986	0.848	384.947	0.474
8	424	97	48	1	0.331	0.998	0.980	0.814	209.814	0.329

23b. ASSIST2 (12 items)

Cut-off	TN	FN	TP	FP	Sensitivity	Specificity	PPV	NPV	DOR	Youden's Index
0	136	0	145	289	1.000	0.320	0.334	1.000	#DIV/0!	0.320
1	251	0	145	174	1.000	0.591	0.455	1.000	#DIV/0!	0.591
2	317	0	145	108	1.000	0.746	0.573	1.000	#DIV/0!	0.746
3	362	2	143	63	0.986	0.852	0.694	0.995	410.841	0.838
4	**394**	**8**	**137**	**31**	**0.945**	**0.927**	**0.815**	**0.980**	**217.653**	**0.872**
5	411	15	130	14	0.897	0.967	0.903	0.965	254.429	0.864
6	420	40	105	5	0.724	0.988	0.955	0.913	220.500	0.712
7	421	60	85	4	0.586	0.991	0.955	0.875	149.104	0.577
8	423	77	68	2	0.469	0.995	0.971	0.846	186.779	0.464

23c. ASSIST3 (11 items)

Cut-off	TN	FN	TP	FP	Sensitivity	Specificity	PPV	NPV	DOR	Youden's Index
0	210	0	145	215	1.000	0.494	0.403	1.000	#DIV/0!	0.494
1	312	0	145	113	1.000	0.734	0.562	1.000	#DIV/0!	0.734
2	370	0	145	55	1.000	0.871	0.725	1.000	#DIV/0!	0.871
3	**400**	**7**	**138**	**25**	**0.952**	**0.941**	**0.847**	**0.983**	**315.429**	**0.893**
4	411	24	121	14	0.834	0.967	0.896	0.945	148.009	0.802
5	422	45	100	3	0.690	0.993	0.971	0.904	312.593	0.683
6	424	77	68	1	0.469	0.998	0.986	0.846	374.442	0.467
7	424	92	53	1	0.366	0.998	0.981	0.822	244.261	0.363
8	424	106	39	1	0.269	0.998	0.975	0.800	156.000	0.267

23d. WHQ (19 items)

Cut-off	TN	FN	TP	FP	Sensitivity	Specificity	PPV	NPV	DOR	Youden's Index
1	19	0	29	66	1.000	0.224	0.305	1.000	#DIV/0!	0.224
2	34	0	29	51	1.000	0.400	0.363	1.000	#DIV/0!	0.400
3	44	0	29	41	1.000	0.518	0.414	1.000	#DIV/0!	0.518
4	58	0	29	27	1.000	0.682	0.518	1.000	#DIV/0!	0.682
5	66	1	28	19	0.966	0.776	0.596	0.985	97.263	0.742
6	**74**	**3**	**26**	**11**	**0.897**	**0.871**	**0.703**	**0.961**	**58.303**	**0.767**
7	79	5	24	6	0.828	0.929	0.800	0.940	63.200	0.757
8	81	6	23	4	0.793	0.953	0.852	0.931	77.625	0.746

23e. WHQI (19 items)

Cut-off	TN	FN	TP	FP	Sensitivity	Specificity	PPV	NPV	DOR	Youden's Index
1	112	0	145	313	1.000	0.264	0.317	1.000	#DIV/0!	0.264
2	208	0	145	217	1.000	0.489	0.401	1.000	#DIV/0!	0.489
3	275	0	145	150	1.000	0.647	0.492	1.000	#DIV/0!	0.647
4	311	2	143	114	0.986	0.732	0.556	0.994	195.057	0.718
5	364	5	140	61	0.966	0.856	0.697	0.986	167.082	0.822
6	**394**	**10**	**135**	**31**	**0.931**	**0.927**	**0.813**	**0.975**	**171.581**	**0.858**
7	405	20	125	20	0.862	0.953	0.862	0.953	126.563	0.815
8	410	33	112	15	0.772	0.965	0.882	0.926	92.768	0.737

For all measures other than patient only reported, the combined sample is used. Optimal suggested cut off score for each measure highlighted in bold. TN: True Negative, FN: False negative, TP: True positive, FP: false positive, PPV: Positive predictive value, NPV: Negative predictive value, DOR: Diagnostic odds ratio.

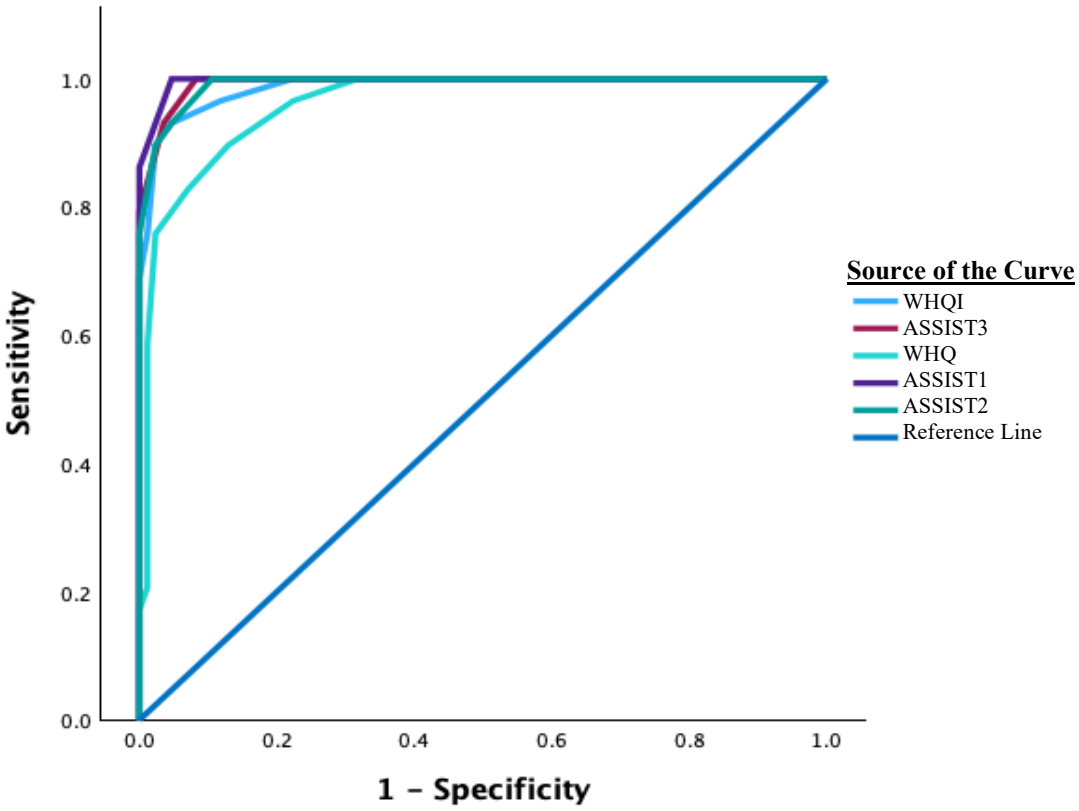


Figure 18: Receiver operator characteristic curve for all index tests to identify

Precision

At a cut-off score of three, the ASSIST1 measure indicates good precision for SSI diagnosis (0.816). The trade-offs between precision and recall (sensitivity) for all index tests were plotted in a comparative precision-recall curve, *figure 19.* All measures approach the top right-hand corner, except for a patient only reported measure (WHQ). Gini index indicated excellent model performance across all tests (all values >0.92), *table 24*. Breakdown for ROC and PR curves for all index tests by individual rater are shown in *appendix 8.16.*

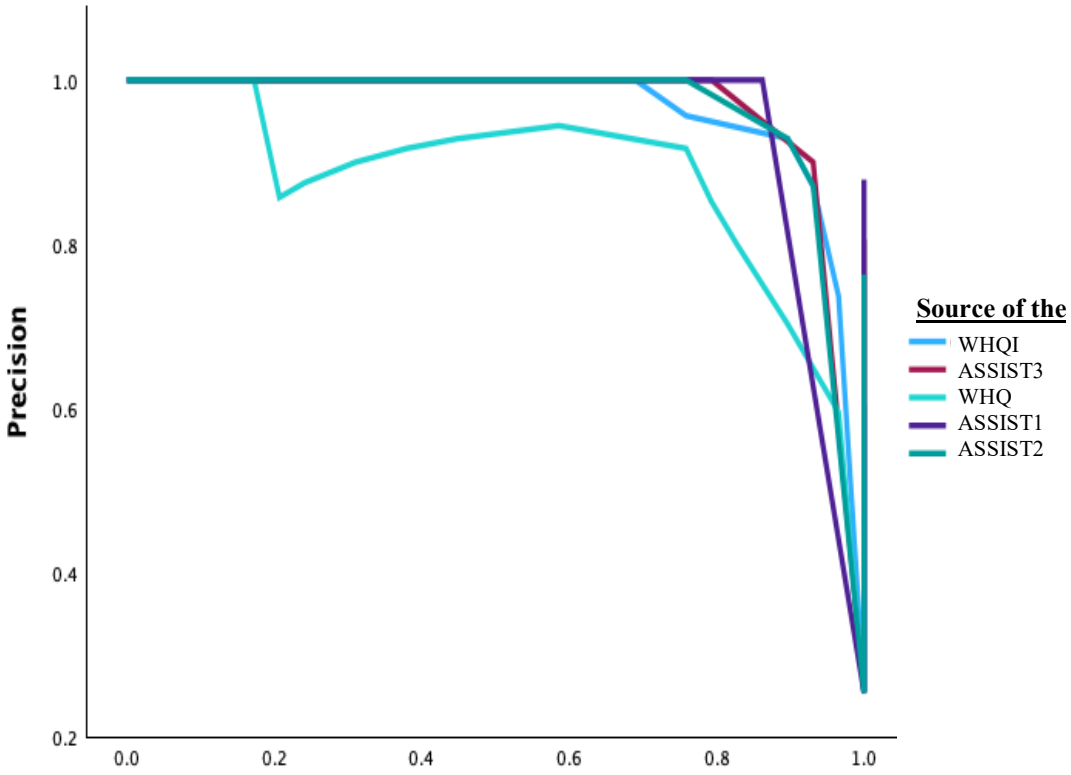


Figure 19: Precision-recall curve for all index tests to identify surgical site infection.

Table 24: Index test discriminatory capacity to identify surgical site infection represented by maximal Kolmogorov-Smirnov statistics and area under the receiver operator characteristic curve.

Index test	Max K-S[a]	Cut off Score[b]	AUROC	95% Confidence Interval		P-value	Gini Index
				Lower Bound	Upper Bound		
ASSIST1	0.953	3.5	0.997	0.991	1.000	<0.001	0.994
ASSIST2	0.894	3.5	0.992	0.981	1.000	<0.001	0.984
ASSIST3	0.918	2.5	0.994	0.985	1.000	<0.001	0.987
WHQI	0.884	6.5	0.987	0.972	1.000	<0.001	0.974
WHQ	0.767	6.5	0.961	0.928	0.994	<0.001	0.921

Precision-recall Gini index is also shown.

a. *Max K-S; maximal Kolmogorov-Smirnov statistic, AUROC; Area under the receiver operator characteristic curve.*

b. The maximum Kolmogorov-Smirnov (K-S) metric. Also the maximum value of Youden's index.

c. In case of multiple cutoff values associated with Max K-S, the largest one is reported

14.2.4 Discussion

In this study, five potential index tests were evaluated for optimal diagnostic accuracy in the remote identification of surgical site infection. Scale structure for each test has been examined previously[284]. Four were combined measures (ASSIST1, ASSIST2, ASSIST3 and WHQI), with a clinician reviewing wound images to assess items 1-6 and self-assessment from a patient for the remaining items. ASSIST1, an 11-item measure, showed excellent discriminatory capacity between those with and without SSI (AUROC; 0.997 95% CI; 0.991-1.000, p<0.001). This measure demonstrates high diagnostic accuracy at a cut-off score of 3-4. Both inter- and intra-rater agreement of this measure was good, and there was high acceptability. The ASSIST measure using the ASSIST1 items is then suggested to be acceptable, reliable and valid as a remote diagnostic measure to identify SSI in primarily closed surgical wounds.

Specific remote wound monitoring questionnaires, such as the Bluebelle wound healing questionnaire (WHQ) have been developed and validated in general surgery showing promising SSI screening capabilities[124,285]. A cut-off score of 6-8 was suggested for the Bluebelle WHQ, which provided sensitivity and specificity ranges of 78.1-71.9% and 89.2-93.8% respectively[285]. In comparison, whilst this study evaluated patients undergoing lower limb vascular surgery, patient only responses to the 19-item Bluebelle WHQ showed slightly improved sensitivity and relatively similar specificity (cut off 6-8, sensitivity; 89.7-79.3% and specificity; 87.1-95.3%). Performance of the 19-item WHQ may be somewhat transferrable across these specialties, though parallel evaluation should be considered. Current data suggest that the use of telemedicine by any method, telephone, photograph or questionnaire (use of video consultations were not evidenced in any studies), is able to screen patients with SSI, but lacks sensitivity to diagnose infections remotely[269]. There have been no studies previously which have evaluated the combination of clinician reviewed wound images with patient reported questionnaires to see if this improves diagnostic accuracy. In this study, when comparing patient only responses to the 19-item WHQ (WHQ) to combined patient questionnaire and clinician wound image review (WHQ-CP), both sensitivity and specificity at the optimal cut off score

improved using a combined approach to review (WHQ versus WHQI; sensitivity; 89.7% vs 93.1% and specificity; 87.1% vs 92.7%).

In this patient group, scale structure evaluation identified redundancy in several of the 19-item WHQ items. All three of the modified WHQ measures, ASSIST1, ASSIST2 and ASSIST3, outperformed the 19-item WHQ at their optimal cut off scores (sensitivity; 94.5%, 97.9% and 95.2%, and specificity; 92.7%, 92.5% and 94.1% respectively). Using a streamlined WHQ therefore appears to improve diagnostic accuracy in addition to reducing the time to complete and questionnaire burden on patients (given fewer items to complete). Such benefits may be critical for further evaluation in serial remote surveillance regimes, which show excellent patient engagement rates and could improve accuracy of diagnosis even further when combined with the ASSIST measure[267,286]. Another novel avenue which could be explored either in conjunction or isolation, would be the development and validation of machine learning algorithms for image and questionnaire response analysis. Such developments may be able to aid in triage of serial assessments prior to clinician based assessment, and precision-recall data presented here may be used as a comparator for model performance.

This study does have limitations. The sensitivity and specificity of the highest performing measure did not meet the initial sample size calculation, though did surpass the requirements in a combined sample. Data here will be used to inform sample size calculations for evaluation in a larger study without combined samples. Data were collected in a single tertiary vascular centre which limits generalisation to wider contexts. Results for a 19-item patient reported WHQ were however similar to those reported previously in general surgery, further evaluation across specialties is needed to corroborate this generalisation. CDC criteria used in face-to-face assessment are the accepted gold standard for SSI identification, and were used as a reference diagnosis, though are at risk of subjectivity[123].

14.2.5 Conclusion

Clinician reviewed wound images in combination with patient reported questionnaire responses improved diagnostic accuracy of surgical site infection in this study. Additionally, removal of redundant questionnaire items reduced patient burden and further improved accuracy of diagnosis. The proposed optimal ASSIST measure, therefore, comprises the best performing 11-items including six wound image characteristics and five patient reported elements. Further corroboration in a larger study will follow, with exploratory studies on the impact of serial surgical site surveillance programmes with ASSIST and the impact of machine learning algorithms on patient triage.

15 CHAPTER 5: SUSTAINABILITY IN POSTOPERATIVE CARE; STUDIES SIX AND SEVEN – FINANCIAL AND ENVIRONMENTAL COSTS OF SURGICAL SITE INFECTION AND POSTOPERATIVE REMOTE FIRST CARE

15.1 Study six; environmental and financial cost of surgical site infection by severity following lower limb vascular surgery

15.1.1 Background

SSI is often evaluated as a binary present / absent outcome measure, though it is likely that there is an unequal distribution in infection severity when SSI do occur. Patients treated with a course of oral antibiotics in the community are likely to have a very different experience, and require less resource use, compared to those who are hospitalised or require further surgical intervention to manage their infection.

Aside from this clinical burden, there are other substantial costs associated with SSI. The financial costs (fC) of SSI have been estimated in the region of £4531-£7324 per infection[201,287] when considering the National Health Service (NHS) cost perspective, though some estimates extend far above these[288]. The variation in cost estimates is likely due to the large variation in SSI incidence with procedure, specialty and geography, but may also be related to the significant heterogeneity in infection severity.

The National Health Service (NHS) in England is committed to reducing its carbon footprint and delivering a 'net zero' service by 2045. Identification of problematic areas with high environmental cost maybe key to targeting strategies and clinical interventions toward achieving this goal[230]. The environmental cost (eC) of SSI has been estimated in cardiac surgery to be between 5-2615 $kgCO_2e$ per episode[267]. However, this was a secondary outcome and the exact methods were not clear. In addition severity was not assessed and patients without SSI were not evaluated for comparison.

15.1.2 Objectives

The aim of this study was to evaluate the environmental ($kgCO_2e$) and financial (£) costs associated with SSI in patients undergoing lower limb vascular procedures and explore the relationships between these costs and SSI severity.

15.1.3 Methods

15.1.3.1 Study Design

This prospective observational cohort study mapped financial (fC, in £) and environmental costs (eC, in $kgCO_2e$) of patients with and without surgical site infection (SSI) after lower limb vascular surgery. All participants provided written consent as part of an ongoing randomised controlled trial (NCT02992951). Ethical approval for this trial was obtained (16/LO/2135) from London – Harrow Research Ethics Committee, and study conduct was in accordance with the Declaration of Helsinki (2013)[272]. Eligibility criteria followed the parent trial including all adult patients undergoing clean or clean-contaminated lower limb vascular surgery with capacity. Patients on concurrent antibiotics at the time of screening for conditions not related to the index procedure were not eligible for enrolment. Participants were recruited between 13th May 2022 and 9th October 2023, in a tertiary vascular centre in the United Kingdom (UK).

A process analysis rich approach to carbon accounting modelling for a hybrid life cycle analysis (LCA) was performed. International Standards ISO 14060:2006 for quantification and reporting of greenhouse gases were followed[289]. Costs were evaluated using National Health Service (NHS) and Personal and Social Services (PSS) perspectives. Healthcare resource use was evaluated to base eC and fC.

The eC and fC from each index procedure and routine post-procedure stay (defined by operative clinician) were not included as costs should be equivocal until this point. After the planned discharge date all emissions and financial costs were mapped, i.e if discharge was delayed or from the point of discharge. SSI developed during the initial inpatient stay were evaluated. The eC and fC were evaluated until 3 months post procedure. Follow-up was conducted using a 'remote first' model, whereby all

patients had a planned remote appointment 30 days post-surgery consisting of wound assessment via submitted wound images combined with a modified bluebelle wound healing questionnaire[244]. If a wound related problem was identified remotely, patients were then seen face-to-face. Reviews were conducted earlier if patients reported concerns to the clinical team. SSI was diagnosed using the centres for disease control and prevention (CDC) criteria[63]. Two comparative SSI severity classifications were used; the CDC criteria[63] (superficial incisional, deep incisional and organ/space SSI) and a management-based scale;

- Mild: managed with oral antibiotics
- Moderate: managed with intravenous antibiotics
- Severe: required surgical intervention in addition to antibiotics.

15.1.3.2 Outcomes

15.1.3.2.1 Primary outcome

Environmental cost ($kgCO_2e$) of mild, moderate and severe SSI compared to no SSI.

15.1.3.2.2 Secondary outcomes

- Financial cost (£) of mild, moderate and severe SSI
- Emissions ($kgCO_2e$) distribution across healthcare resource use activity areas
- Financial cost (£) distribution across healthcare resource use activity areas
- Financial-environment cost (£/$kgCO_2e$) for mild, moderate and severe SSI
-

15.1.3.3 Data Collection

All consumable and reusable items and packaging were weighed using Model Scout Pro (SPU123) Electronic Balance for items $\leq$120g and Marsden medical weighing scales (DS-673SS) for items >120g for evaluation of production and waste emissions values. All items included are shown in the *appendix 8.17* and *8.18.*

15.1.3.3.1 Follow-up Review

The same process for mapping remote and face-to-face reviews was used. Resources evaluated during follow-up reviews included time taken (minutes), staff involved (profession and grade), consumables used during review (such as dressings, sodium chloride for sterilisation, gauze, gloves, paper bed roll, disposable aprons), estimated water use for handwashing (at 0.0051m^3), room size (286x460x220cm) and lighting (bulb type and quantity). Data on time, room size and lighting were combined with energy tariffs and emissions factors[290] for heating and electricity use. These energy data were also used to evaluate eC and fC from computer use. Consumables and their packaging were evaluated for eC for their production, use and disposal. Each item was weighed, and emissions factors for production were used based upon item material and number used. Disposal was evaluated based upon whether items underwent high or low energy incineration and associated emissions factors. NHS supply chain data was used for consumable item costs[291]. Costs associated with patient travel were included, using distance travelled from home to clinic post code, parking costs, and mode of travel.

15.1.3.3.2 Other Reviews

Reviews were evaluated based upon 10 minutes for general practitioner review and 30-minute appointments for all other reviews. National tariff data from Personal Social Services Research Unit (PSSRU)[292] and emissions factors using staff in person and remote consultation factors from the Sustainable Development Unit (SDU)[293].

15.1.3.3.3 Imaging

The NIHR interactive costing tool for investigation and intervention tariffs provided radiological investigation financial costs[294] and emissions factors per scan were taken from previously published models[295].

15.1.3.3.4 Admission

Additional low-dependency and high-dependency ward days were recorded for each patient. Financial costs were sourced using models from 2016/2017 NHS costs

inflated to 2022/2023 prices[296]. Emissions factors for each were taken from SDU data[293].

15.1.3.3.5 Pharmaceuticals

All medications were evaluated for production using cost and pharmaceutical emissions factors. Packaging was appraised for production and disposal using DEFRA emissions factors, material and weight[290]. British National Formulary (BNF) formulated the basis for pharmaceutical cost calculations[297].

15.1.3.3.6 Consumable Items

All consumable items were evaluated for composition material, including packaging with each part weighed. DEFRA emissions factors were then applied to estimate emissions production and disposal[290]. NHS supply chain data provided individual item financial costs[291]. In addition to disposable gloves, aprons, towels, dressings and wound cleaning equipment, data were collected on blood and microbiological samples and cannulation items (Appendix 8.17 and 8.18).

15.1.3.3.7 Procedures

For all surgical procedures, data on consumable items, pharmaceuticals and staff time were evaluated for eC and fC as described. Additionally, reusable items which underwent sterilisation processes in line with local practices. Post-procedure items underwent 90^{o}C thermal disinfection on 45-minute cycles with autoclave at 144^{o}C for 3.5 minutes. Instrument sets were weighed and calculated for production using DEFRA emissions factors over the estimated lifetime usage (2040 uses)[290]. Energy tariff data were then used to estimate emissions for reusable sterilisation processes. Data on anaesthetic gases were derived from operative time and emissions factors provided by the Association of Anaesthetists Anaesthetic Gases Calculator[298].

15.1.3.4 Data Analysis

Data were collected and entered into IBM SPSS (IBM SPSS Corporation, version 28; Rochester, New York), and a two-sided P-value of <0.05 was considered significant.

Descriptive statistics are presented as proportions, mean ± standard deviation or median with interquartile range (IQR) as appropriate. Data are reported as mean ± standard deviation or median with IQR as appropriate. Groups were compared using Mann-Whitney U test for binary SSI outcomes and One-way ANOVA test with Tukey post-hoc analysis for SSI severity. SSI severity, financial and environmental costs were plotted on scatter graphs with lines of best fit plotted to establish whether relationships were linear or monotonic. Correlation was then assessed between SSI severity and financial or environmental costs using spearman rank. Pearson correlation was used to assess the relationship between financial and environmental costs. Calculations for carbon offsetting value in trees planted are based upon the $kgCO_2e$ sequestered over one year by a 10-year-old, 5m tall, 25cm diameter tree with dry weight of 155.6kg[299].

Sensitivity analyses were conducted for financial and environmental costs by varying the mean and median antibiotic days by the 95% confidence interval and interquartile range.

15.1.4 Results

A total of 105 participants were enrolled into the study with a high proportion being elderly, male with a smoking history (*table 25*). There were two cancelled procedures, three perioperative deaths (two cardiac events and one pulmonary embolus) and one participant lost to follow-up, leaving 99 participants for analysis. SSI were diagnosed in 22 participants (SSI rate 22.2%). Using the management-based SSI severity grading, distribution was 14 (63.3%) mild SSI, four (18.2%) moderate SSI and four (18.2%) severe SSI. Using a CDC based severity score identified 11 (50.0%) mild SSI, eight (36.4%) moderate SSI and three (13.6%) severe SSI.

Table 25: Baseline patient characteristics

		No SSI		SSI		
		n=77	%	n=22	%	P value
Age (SD)		67.66	11.56	65.18	11.75	0.797
Gender	Male	60	77.9	13	59.1	
	Female	17	22.1	9	40.9	0.077
BMI (SD)		25.17	4.13	28.53	6.41	0.424
Smoking History	Non-Smoker	10	13.0	2	9.1	
	Ex-Smoker	42	54.5	10	45.5	
	Current Smoker	25	32.5	10	45.5	0.522
Diabetes	None	42	54.5	13	59.1	
	Diet controlled	9	11.7	1	4.5	
	Non-insulin	17	22.1	2	9.1	
	Insulin dependent	9	11.7	6	27.3	0.159
Previous CVA/TIA	No	65	84.4	21	95.5	0.209
	Yes	12	15.6	1	4.5	
Hypertension	No	30	39.0	8	36.4	
	Yes	47	61.0	14	63.6	0.741
IHD	No	41	53.2	14	63.6	
	Yes	36	46.8	8	36.4	0.387
COPD	No	59	76.6	11	50.0	
	Yes	18	23.4	11	50.0	0.016
CKD	No	59	76.6	17	77.3	
	Yes	18	23.4	5	22.7	0.949
Procedure	CFEA	13	16.9	6	27.3	
	Femoro-popliteal bypass	37	48.1	6	27.3	
	Femoro-distal	11	14.3	6	27.3	
	Femoro-femoral crossover	1	1.3	2	9.1	
	Aorto-bifemoral bypass	10	13.0	1	4.5	
	Major lower limb amputation	4	5.2	0	0.0	
	Femoral or popliteal Embolectomy	0	0.0	1	4.5	
	Saphenofemoral junction ligation	1	1.3	0	0.0	0.055
Redo procedure	No	73	94.8	21	95.5	
	Yes	4	5.2	1	4.5	0.902
Emergency procedure	No	76	98.7	21	95.5	
	Yes	1	1.3	1	4.5	0.34
Prosthetic	No	51	66.2	19	86.4	
	Yes	26	33.8	3	13.6	0.067

SSI; Surgical Site Infection, SD; Standard deviation, BMI; Body Mass Index, CVA; Cerebrovascular Accident, TIA; Transient Ischaemic Attack, IHD; Ischaemic Heart Disease, COPD; Chronic Obstructive Pulmonary Disease, CKD; Chronic Kidney Disease, CFEA; Common Femoral Endarterectomy.

15.1.4.1 SSI-associated Emissions

Overall, the mean emissions produced without SSI was 10.3±24.3 $kgCO_2e$ (95% CI, 4.8 to 15.9, 0.4±0.9 trees). For participants that developed SSI, carbon emissions were over 60-fold higher at 643.8±1,276.4 $kgCO_2e$ (95% CI, 110.4 to 1,177.2, 22.6±44.8 trees) per participant, mean difference, 633.5 $kgCO_2e$, 95% CI 348.3 to 918.6, $t(97)=-4.409$, $p<0.001$.

Emissions increased in line with SSI severity, mild producing 94.6±53.9 $kgCO_2e$ (95% CI, 63.5 to 125.8, 3.3±1.9 trees), moderate responsible for 648±407.6 $kgCO_2e$ (95% CI, -0.1 to 1296.6, 22.7±14.3 trees) and 2651.4±2217.1 $kgCO_2e$ (95% CI, -966.5 to 6347.2, 93.0±77.8 trees) per patient for severe SSI. The difference between groups was significant ($F(3,95) = 53.298$, *p<0.001*). Tukey post hoc test revealed a significant difference in environmental cost between patients with moderate SSI and no infection (*p=0.013)* and between severe SSI and all other groups (no infection; *p<0.001*, mild; *p<0.001,* and moderate; *p<0.001*), as shown in *table 26*. There was a moderately positive association between SSI severity and rising carbon emissions (rs=0.698, *p<0.001*). Scatter plot of environmental cost by SSI severity category suggested a strong exponential relationship (adjusted $R^2 = 0.677$, R^2 linear = 0.462) and marginally favoured a linear relationship with extreme outliers removed (adjusted $R^2 = 0.645$, R^2 linear = 0.663), figure 20A.

Table 26: Tukey post hoc analysis of intergroup significance in emission produced by no infection, and both SSI severity scores (CDC and management-based).

			Management based SSI Severity				CDC Severity			
	Comparison		Mean difference	95% Confidence interval			Mean difference	95% Confidence interval		
Criteria (CDC)	SSI Severity		($kgCO_2e$)	Lower bound	Upper bound	P value	($kgCO_2e$)	Lower bound	Upper bound	P value
No infection	0	1	-84.3	-389.5	220.9	0.888	-78.3	-394.8	238.1	0.916
		2	-637.8	-1176.5	-99.2	0.013	-495.4	-860.1	-130.8	0.003
		3	-2551.1	-3089.8	-2012.4	<0.001	-3037.0	-3614.7	-2459.3	<0.001
Mild (Superficial)	1	0	84.3	-220.9	389.5	0.888	78.3	-238.1	394.8	0.916
		2	-553.5	-1149.1	42.0	0.078	-417.1	-873.2	39.0	0.086
		3	-2466.8	-3062.3	-1871.3	<0.001	-2958.6	-3598.0	-2319.2	<0.001
Moderate (Deep)	2	0	637.8	99.2	1176.5	0.013	495.4	130.8	860.1	0.003
		1	553.5	-42.0	1149.1	0.078	417.1	-39.0	873.2	0.086
		3	-1913.3	-2656.0	-1170.5	<0.001	-2541.5	-3206.1	-1877.0	<0.001
Severe (Organ/Space)	3	0	2551.1	2012.4	3089.8	<0.001	3037.0	2459.3	3614.7	<0.001
		1	2466.8	1871.3	3062.3	<0.001	2958.6	2319.2	3598.0	<0.001
		2	1913.3	1170.5	2656.0	<0.001	2541.5	1877.0	3206.1	<0.001

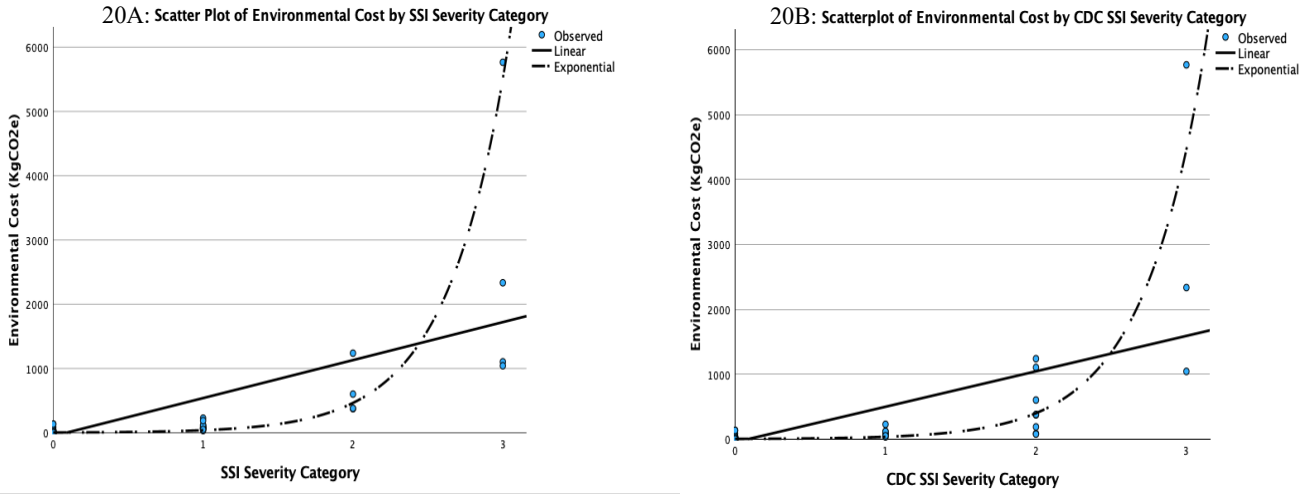


Figure 20: Scatterplots of environmental cost by SSI severity classifications

Comparatively, emissions also raised with CDC severity score, whereby management of superficial SSI resulted in 88.7±53.2 $kgCO_2e$ (95% CI, 53.0 to 124.4, 3.1±1.9 trees), deep SSI in 505.8±447.1 $kgCO_2e$ (95% CI, 132.0 to 879.5, 17.7±15.7 trees) and organ/space SSI in 3,047.3±2,440.7 $kgCO_2e$ (95% CI, -3,015.8 to 9110.4, 106±85.3 trees). The difference between groups was significant ($F(3,95) = 65.618$, *p<0.001*), and Tukey post hoc test identified significant differences between deep SSI and no infection (*p=0.003*) and between organ/space SSI and all other groups (no infection; *p<0.001*, superficial SSI; *p<0.001,* moderate SSI; *p<0.001*), table 26. CDC severity was moderately correlated with raised emissions cost (rs=0.697, *p<0.001*). Scatterplots also display a strong exponential relationship (adjusted $R^2 = 0.675$, R^2 linear = 0.412), which is maintained with the extreme outlier removed (adjusted $R^2 = 0.643$, R^2 linear = 0.560), figure 20B. There was a very strong positive association between SSI scoring using CDC and management-based methods (rs=0.965, *p<0.001*).

15.1.4.2 Emissions Distribution

Overall, 796.3 $kgCO_2e$ (range; 1.2-134.8, n=77, 5.3%) were produced managing patients without infection, compared to 14,163.6 $kgCO_2e$ (range; 33.1-5765.2, n=22, 94.7%) for those with SSI. With management-based severity, there were 1,325.1

$kgCO_2e$ (range; 33.1-227.1, n=14, 8.9%) related to mild SSI, 2,592.7 $kgCO_2e$ (range; 373.4-1,238.2, n=4, 17.3%) for moderate SSI and 10,245.8 $kgCO_2e$ (range; 1,042.7-5,765.2, n=4, 68.5%) for severe SSI. For CDC SSI severity, treatment of superficial SSI resulted in 975.5 $kgCO_2e$ (range; 60.5-227.1, n=11, 6.5%), 4,046.2 $kgCO_2e$ (range; 161.9-1,238.2, n=8, 27.0%) for deep SSI, and 9,141.9 $kgCO_2e$ (range; 1,688.4-5,765.2, n=3, 61.1%).

Most emissions were due to readmission (7,648.5 $kgCO_2e$, 51.1% of all emissions), procedures (2,687.6 $kgCO_2e$, 18.0% of all emissions), clinical review (2,559.8 $kgCO_2e$, 17.1% of all emissions) and medications (1,705.1 $kgCO_2e$, 11.4% of all emissions), *table 27***.** Ten procedures were performed on the four patients with SSI who required reintervention: one angioplasty (external iliac and femoro-tibio-peroneal trunk), five wound debridements, one graft thrombectomy, one excision of infected graft with further bypass, one below knee amputation (due to both infection and irretrievable ischaemia), and one combined procedure (wound exploration, graft salvage, angiogram and drainage of collections). One patient without SSI had a seroma drained in clinic. Across the eight patients who were readmitted, a total of 195 additional bed days were accrued, including 190 (97.4%) days being on a low intensity ward and five (2.6%) days on a high-intensity ward.

Table 27: Resource breakdown for all patients and by infection status

	All patients		SSI	No SSI
	$kgCO_2e$	%	$kgCO_2e$/patient	$kgCO_2e$/patient
Procedures	2687.6	(18.0)	122.1	0.0
Review	2559.8	(17.1)	89.5	7.7
Transfer	18.2	(0.1)	0.8	0.0
Admission	7648.5	(51.1)	347.7	0.0
Imaging	64.6	(0.4)	2.6	0.1
Other consumables	72.7	(0.5)	3.3	0.0
Pharmaceuticals	1705.1	(11.4)	77.5	0.0
Dressings	203.3	(1.4)	6.4	0.8
	14959.9	(100.0)	649.8	8.6

15.1.4.3 Financial Cost

The mean overall financial cost of SSI was £8,355.08±18,144.84 (95% CI, 772.97 to 15,937.19) compared to £61.10±133.67 (95% CI, 30.76 to 91.43) per patient without SSI, mean difference £8,293.99, 95% CI 4,242.81 to 12,345.15, $t[97]=-4.063$, $p<0.001$.

Mean financial cost increased with SSI severity with mild SSI resulting in £327.15±188.23 (95% CI, 218.47 to 435.83), moderate SSI with £8,135.56±4,220.03 (95% CI, 1,420.54 to 14,850.57) and severe SSI with £30,863±27,448.8 (95% CI, -12,813.39 to 74,539.60) per episode. Financial cost difference between severity groups was significant ($F(3,95) = 51.979$, *p<0.001*). Specifically, only mean differences between mild SSI episode and no SSI were not significant (*p=0.998*) and all other comparisons were significant (*p<0.05*), *table 28*. SSI severity was moderately correlated with financial cost (rs=0.669, *p<0.001*). Scatter plot of financial cost by SSI severity category suggested a strong exponential relationship (adjusted $R^2 = 0.761$, R^2 linear = 0.441) and continued to favour an exponential relationship with extreme outliers removed (adjusted $R^2 = 0.730$, R^2 linear = 0.664), figure 21A.

Table 28: Tukey post hoc analysis of intergroup mean difference in financial cost per episode of no infection, mild, moderate and severe SSI.

			Management based SSI Severity				CDC SSI Severity			
	Comparison		Mean difference	95% Confidence interval			Mean difference	95% Confidence interval		
Criteria (CDC)	SSI Severity		(£)	Lower bound	Upper bound	P value	(£)	Lower bound	Upper bound	P value
No infection	0	1	-266.1	-4017.1	3485.0	0.998	-253.55	-4813.34	4306.24	0.999
		2	-8074.5	-14695.3	-1453.6	0.010	-6717.20	-11972.10	-1462.31	0.006
		3	-30802.0	-37422.9	-24181.2	<0.001	-41980.32	-50305.32	-33655.33	<.001
Mild (Superficial)	1	0	266.1	-3485.0	4017.1	0.998	253.55	-4306.24	4813.34	0.999
		2	-7808.4	-15128.0	-488.8	0.032	-6463.65	-13036.91	109.60	0.056
		3	-30536.0	-37855.6	-23216.3	<0.001	-41726.77	-50940.85	-32512.69	<.001
Moderate (Deep)	2	0	8074.5	1453.6	14695.3	0.010	6717.20	1462.31	11972.10	0.006
		1	7808.4	488.8	15128.0	0.032	6463.65	-109.60	13036.91	0.056
		3	-22727.5	-31856.7	-13598.4	<0.001	-35263.12	-44840.25	-25685.98	<.001
Severe (Organ/Space)	3	0	30802.0	24181.2	37422.9	<0.001	41980.32	33655.33	50305.32	<.001
		1	30536.0	23216.3	37855.6	<0.001	41726.77	32512.69	50940.85	<.001
		2	22727.5	13598.4	31856.7	<0.001	35263.12	25685.98	44840.25	<.001

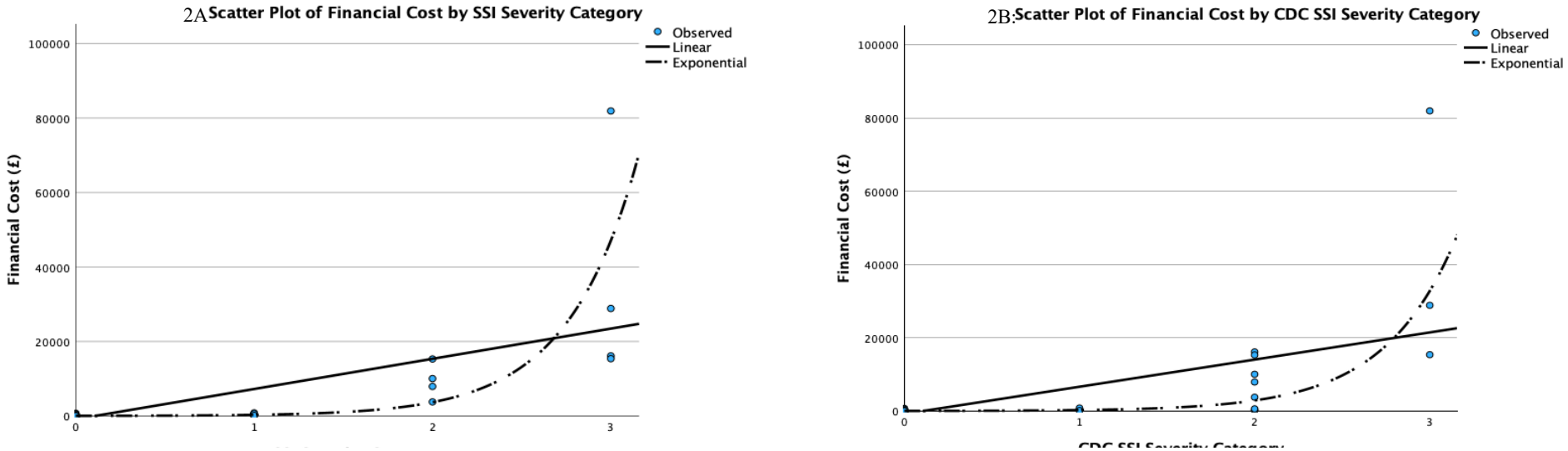


Figure 21: Scatterplots of financial cost by SSI severity

Comparatively, financial costs increased with CDC severity score, whereby management of superficial SSI resulted in £314.65±195.62 (95% CI, 183.23 to 446.06), deep SSI in £6,778.30±6,588.94 (95% CI, 1,269.81 to 12,286.79) and organ/space SSI in £42,041.42±35,173.33 (95% CI, -45,333.97 to 129,416.80). The difference between groups was significant ($F(3,95) = 60.514$, $p<0.001$), though Tukey post hoc test identified significant differences between deep SSI and no infection ($p=0.006$) and between organ/space SSI and all other groups (no infection; $p<0.001$, superficial; $p<0.001$, deep; $p<0.001$), table 28. CDC severity was moderately correlated with financial cost (rs=0.668, $p<0.001$). Scatter plot of financial cost by SSI severity category suggested a strong exponential relationship (adjusted $R^2 = 0.724$, R^2 linear = 0.386) and continued to favour an exponential relationship with extreme outliers removed (adjusted $R^2 = 0.690$, R^2 linear = 0.536), figure 21B.

Financial costs per patient were largely attributable to re-admission (£119,614.90, 72.4% of all SSI related costs), followed by procedures (£12,436.63, 7.5% of all SSI related costs), clinical review (£12,048.79, 7.3% of all SSI related costs), medications (£10,571.92, 6.4% of all SSI related costs) and imaging (£9,438.00, 5.7% of all SSI related costs). In patients with SSI, financial costs display a linear relationship with environmental costs, figure 22.

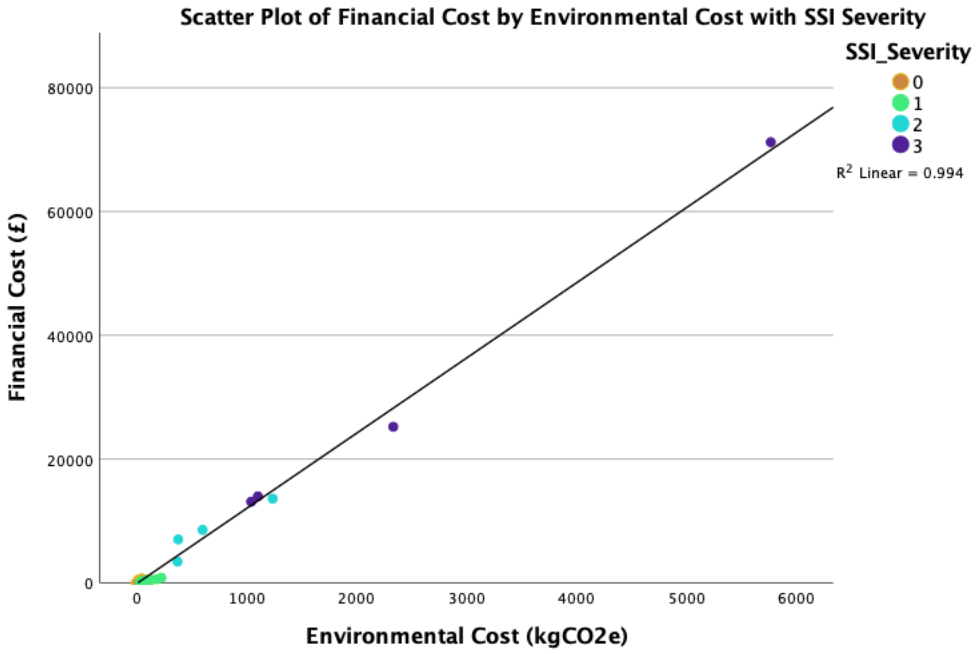


Figure 22: Scatterplot of financial cost by environmental cost for SSI

15.1.4.4 Sensitivity Analyses

The mean and median antibiotic days for all SSI (mean, 24.75; median 18.75) and each SSI severity category; mild (mean, 13.50; median 7.00), moderate (mean, 41.00; median 31.50), and severe (mean, 47.92; median 50.58) were varied within their respective 95% confidence intervals for sensitivity analyses for both environmental and financial cost. For all SSI emissions, data were skewed ranging from 91.86 $kgCO_2e$ to 1,163.02 $kgCO_2e$ per episode. Emissions cost estimates rose exponentially in line with increasing severity, from mild resulting in 59.84 $kgCO_2e$ to 115.68 $kgCO_2e$, moderate in 350.28 $kgCO_2e$ to 946.08 $kgCO_2e$ and severe in 1,054.41 $kgCO_2e$ to 4,068.50 $kgCO_2e$. All SSI episode financial cost estimates were skewed ranging from £378.02 to £15,849.63. Episode estimates all raised exponentially with severity from mild SSI resulting in £145.58 to £385.85, moderate in £4,519.76 to £13,972.66 and severe in £4,930.72 to £66,192.67. All sensitivity analyses are shown in table 29. Financial cost per emissions produced in each category appears to be highest in for moderate SSI.

Table 29: Sensitivity analysis for emissions and financial cost of all SSI and by SSI severity category. Mean and median additional antibiotic days were used throughout

			Estimated Emissions Cost ($kgCO_2e$)			**Estimated Financial Cost (£)**			**Financial - Emissions Cost Ratio**
SSI Category	Method	Antibiotic days	Mean	Lower 95% CI[a]	Upper 95% CI	Mean	Lower 95% CI[a]	Upper 95% CI	Financial cost (£) / Emissions Cost ($kgCO_2e$)
All SSI	Mean	24.75	**643.78**	124.54	1163.02	**8355.08**	860.53	15849.63	12.98
	Median	18.75	**111.67**	91.86	550.03	**437.83**	378.02	9296.80	3.92
Mild SSI	Mean	13.50	**94.65**	73.61	115.68	**327.15**	268.45	385.85	3.46
	Median	7.00	**65.14**	59.84	81.30	**220.74**	145.58	260.64	3.39
Moderate SSI	Mean	41.00	**648.18**	350.28	946.08	**9246.21**	4519.76	13972.66	14.26
	Median	31.50	**518.22**	354.67	788.37	**8687.60**	6287.83	11506.31	16.76
Severe SSI	Mean	47.92	**2561.45**	1054.41	4068.50	**35561.69**	4930.72	66192.67	13.88
	Median	50.58	**1706.50**	1092.46	3158.48	**22486.14**	16032.33	42054.71	13.18

Abbreviations: CI confidence interval

[a]Lower and upper interquartile range used for the median estimate

15.1.5 Discussion

In patients with SSI, environmental and financial costs are correlated strongly in a linear relationship (R^2 = 0.994). There appears to be an exponential increase in financial and environmental cost as SSI severity increases, though this may be influenced by outlying values and warrants further evaluation. Every, one $kgCO_2e$ produced with SSI incurs a financial cost of £12.98. Across severity, mild SSI are relatively inexpensive, costing £3.92 per $kgCO_2e$, however this rises for moderate and severe SSI to £14.26 and £13.88 per $kgCO_2e$ respectively (table 29). Moderate and severe SSI accounted for a small proportion (8/22, 36.4%) of infections in this study, but are responsible for most of both the environmental (88.2%) and financial costs (95.1%). Strategies to prevent SSI may offer substantial environmental and financial benefits, but targeted interventions which might reduce the severity of SSIs are likely to have even more significant benefit to environmental and financial costs. Randomised controlled trials of interventions to prevent or reduce SSI would ideally report SSI severity to allow for patient impact, environmental and financial costs to be explored in evaluations. Further to this, sustainable strategies should focus on prevention of disease to provide considerable environmental benefit in addition to considering utilisation of green equipment alternatives.

SSI severity classification has often been under-reported in RCTs which may reflect its complex definition that requires interpretation for each surgical specialty. Both the accepted CDC definition and management-based SSI severity were strong predictors of eC (CDC; adjusted R^2 = 0.675, Management; adjusted R^2 = 0.677) and fC (CDC; adjusted R^2 = 0.724, Management; adjusted R^2 = 0.761) in this study. Further, both the CDC and management-based method were very strongly correlated (rs=0.965). The breakdown of SSI did change however, with more participants graded anatomically as in the 'deep SSI' category with CDC criteria rather than moderate SSI based on management criteria. Whilst strong associations were shown, these differences in severity distributions may alter findings and warrant investigation in larger studies.

Readmission was responsible for the largest proportion of carbon emissions (51.1%) and financial (75.8%) costs. Prevention of moderate and severe SSI is likely to have the largest impact on healthcare resource use and carbon emissions. Policies to reduce traditionally inpatient hospital treatments, such as outpatient antibiotic therapy services may offer both financial and environmental cost-efficient approaches. Further development and evaluation of these optimised regional service delivery schemes in specialty areas should be explored. Surgical procedures accounted for 18.0% of emissions and 6.6% of financial costs in this study and sustainable strategies such as total intravenous anaesthesia, reusable textiles (hats, gowns, drapes and trolley covers) and condensed instrument trays (though the size of tray needs to be reduced to make an impact) have been suggested to improve environmental cost, though cost evaluation and clinician acceptability would also need to be considered[300-302].

Carbon emissions related to SSI have not previously been explored. Boundary setting in studies aiming to capture SSI related emissions risk substantial heterogeneity due to the variable timeframe of diagnosis. During previous reviews SSI follow-up varies from 10-90 days post-surgery[269]. This study aimed to encompass emissions related to the sequelae of SSI in addition to the initial infection diagnosis, therefore providing a comprehensive understanding of the emissions cost. Financial costs estimations here (mean £8355.08 per episode) are representative of prior modelling of SSI costs (£3776-£6103), accounting for inflation and the broad perspectives considered in this study[287,303].

Environmental cost of SSI will vary year on year as national emissions factors change with rising or falling progress towards net zero targets. Common practice in economic analyses is to apply inflation on historical prices to account for rising financial costs. Similarly, sustainable discounting must be applied to environmental analyses of healthcare activity to account for the changing environmental cost landscape over time. Currently, no such accepted application exists and further workstreams should endeavour to ascertain such values for robust carbon accounting methodologies. Further, ‘dual discounting’ may lead to an alternate financial discounting rate for

economic analyses, when factoring the net long term positive benefits of sustainable outcomes[304]. Exploration of the linear relationship between environmental and financial cost (and non-linear with SSI severity) in wider contexts over time may yield such answers. Without accounting for environmental discounting, incorporating sustainable outcomes into health technology assessment will risk erroneous appraisal of novel interventions.

This study has several limitations. Firstly, study design was conducted in a single UK tertiary vascular centre within the National Health Service (NHS), limiting generalisability of findings. Further evidence in wider UK contexts would substantiate the current environmental and financial valuation of SSI, and from non-UK settings for holistic comparison. Follow-up was evaluated using a novel and hybrid method of 'remote first' approach comprising single planned remote assessment with in-person review where required. Current follow-up practices within UK vascular surgery vary with from face-to-face reviews, remote, and combinations based upon clinical experience and risk stratification, which will vary the cost calculations at each site[211]. Alternatively, serial remote assessments have been proposed, which are a promising concept with additional patient benefits, though also provide an added variable to these calculations[267,286]. The remote first follow-up system presented is the result of environmental and financial cost modelling within several follow-up strategies and therefore presents the most accurate and representative values available in literature for post-surgical follow-up. These models will be published separately. Additionally, geographical location of surgical centre and the associated variable distance of patients from clinic will all factor into the diverse costs. Data were collected from general practitioner records where possible on healthcare resource use in community, however it is likely that data captured are not comprehensive of all resources used and are under-representative of the true values of for both patient with and without SSI. Sensitivity analyses were conducted using the mean and median additional length of stay which present a likely range of values for environmental and financial cost considering the variables unable to be accounted for in this analysis.

15.1.6 Conclusion

SSI complicates the patient journey and experience but also results in substantial environmental and financial costs. Readmission and surgical procedures comprise most of the resource use for SSI, and the subsequent costs. These factors all vary significantly as the severity of SSI increases, suggesting that future reporting should ideally include an indication of severity rather than simply the presence of SSI. One severe infection has equivalent environmental and financial cost of 28 and 95 mild infections respectively. Further research is needed to substantiate these data on a wider scale and establish ongoing environmental cost discounting rates as the NHS progresses into a greener future.

15.2 Study seven; Postoperative remote first care for financially and environmentally sustainable healthcare

15.2.1 Background

Worldwide, healthcare accounts for up to five percent of global greenhouse gas (GHG) emissions.[305] Since 1990, the National Health Service (NHS) in England reduced its carbon footprint by 26%, but further diminutions are necessitated to achieve a 'net zero' service by 2045.[157,230] Wholescale changes such as switching from single to reusable products, non-desflurane anaesthesia and checklists to ensure powering-off of electrical items have been proposed to help bridge the current emissions gap.[302,306,307]

Whilst there is an ongoing need to reduce carbon emissions, novel greener practices are currently being introduced into the clinical setting without the assessment of their effectiveness or sustainability. Currently, carbon accounting is not formally included within cost effectiveness analysis in healthcare, despite 'carbon pricing,' the cost applied to carbon emissions activities, being utilised in other sectors.[308] Health technology assessment (HTA) focuses on changes in health utility and associated financial cost. This fails to consider the NHS's commitment and responsibility towards reducing its environmental impact. Accurate identification of carbon emissions associated with new interventions will ensure HTA decisions are driven by clinical, cost and carbon improvements, and that they support sustainable changes beyond the 2045 targets.

Although national emissions have been on a downward trend, emissions related to patient travel have almost doubled in the last three decades.[157] In part, centralisation of surgical services into 'hub and spoke' models of care has contributed to this. Use of telemedicine has risen dramatically since the SARS-CoV-2 pandemic and may play a key role in the future health system organisation.[133] Remote appointments reduce carbon emissions compared with established in-person alternatives, but there are limitations to what can be achieved digitally.[184] Specific postoperative patient

pathways, utilising remote assessment and even treatment and limiting or even minimising face-to-face review have not been evaluated for their environmental and financial cost.

In surgery, current evidence suggests remote assessment can safely screen, but not accurately diagnose surgical site infection (SSI), though there is emerging work which may alter this.[269]

15.2.2 Objectives

The aim of this study was to assess the financial costs and emissions associated with remote follow-up models of care post open lower limb revascularisation surgery.

15.2.3 Methods

15.2.3.1 Study Design

This prospective paired observational study mapped healthcare resource use to enable quantification of carbon emissions and associated costs for patients followed-up both remotely and face-to-face at 30 days after lower limb vascular surgery. Each patient was first reviewed remotely and then subsequently face-to-face. Scenario analysis was used to evaluate the three possible models of remote wound infection follow-up;

- Model 1 (Standard of care): Routine face-to-face clinical assessment for all patients as a base case comparator.
- Model 2: 'Remote first screening' (RFS), whereby every patient is reviewed remotely and those with potential complications, such as SSI are invited for face-to-face clinical review.
- Model 3: 'Remote first treatment' (RFT), again patients are seen remotely first but this time low risk complications (such as mild SSI, or mild post procedural oedema for example) are managed remotely, and high-risk or indeterminate complications are brought in for face-to-face clinical assessment and treatment.

Remote wound assessment was undertaken using a validated measure comprising a patient reported questionnaire combined with submission of wound images reviewed by their surgeon. Surgical site infection (SSI) was diagnosed as per the measure, which is aligned with the centres for disease control and prevention (CDC) criteria.[63] SSI severity was evaluated on a bespoke management-based scale; mild = participants requiring oral antibiotics in community, moderate = readmission for intravenous antibiotics and severe = requiring surgical reintervention and antibiotics for a wound complication. Cost analyses were performed from an NHS and personal social services (PSS) perspective.

A process analysis rich approach to carbon accounting modelling for a hybrid life cycle analysis (LCA) was performed. International Standards ISO 14060:2006 for quantification and reporting of greenhouse gases were followed.[289] Emissions were evaluated from the point of discharge, or delayed discharge, up until day 30. Prior to this, emissions were assumed to be equal.

All participants provided written consent as part of an ongoing randomised controlled trial (NCT02992951). Ethical approval for this trial was obtained from London–Harrow Research Ethics Committee (16/LO/2135). Participants were recruited between 13th May 2022 and 9th October 2023, in a tertiary vascular centre in the United Kingdom (UK). Eligibility criteria followed those set in the ongoing trial (NCT02992951), all participants in the parent trial were eligible for inclusion. Patients were eligible for inclusion even if they did not own a smartphone to transfer wound images. In this instance, relatives, carers or community nursing teams provided wound photographs with patient consent. No additional equipment or software was used other than that already routinely available to participants and clinicians.

15.2.3.2 Outcomes

15.2.3.2.1 Primary outcome

- Difference in kilograms of carbon dioxide equivalent ($kgCO_2e$) for each model of care compared with face-to-face review.

15.2.3.2.2 Secondary outcomes

- Carbon offsetting value ($\Delta kgCO_2e/kgCO_2e$ sequestered by UK variety tree) of implementing each model over 1 year.
- Cost (£) per review and change in cost (Δ£) per review for each remote model compared with face-to-face review.
- Difference in clinician time (minutes) using remote assessment compared with face-to-face review.
- Difference in total travel distance (miles) using each remote assessment model.
- Environmental (eC) and financial cost (fC) of each remote model of care compared to face-to-face review (change in fC plotted against change in eC)

15.2.3.3 Data Collection

15.2.3.3.1 Process analysis and life cycle inventory analysis (LCIA)

All patients completed both remote and face-to-face reviews on the same day. Face-to-face assessors were blind to the outcomes of remote reviews and vice versa. Carbon emissions ($kgCO_2e$) for the remote review were mapped based on healthcare resource use of the participants. Patients who developed wound complications sought medical advice and treatment through the standard care pathway. Additional healthcare resource use data were collected on general practitioner, face-to-face and remote reviews, community and general practice nurse reviews, dressings and antibiotic prescriptions. As the purpose of this study was to model environmental emissions inclusive of postoperative follow-up, $kgCO_2e$ for the initial admission and initial index procedure were not included within this analysis. All consumable items for disposal were weighed using Model Scout Pro (SPU123) Electronic Balance for items $\leq$120g and Marsden medical weighing scales (DS-673SS) for items >120g.

The footprint analysis covers greenhouse gas (GHG) emissions under Scopes 1, 2 and 3 of the Greenhouse Gas Protocol,[309] in addition to personal travel emissions not usually covered within these analyses, providing a comprehensive NHS Carbon Footprint Plus model, *appendix 8.19*.[230]

National tariff data from Personal Social Services Research Unit (PSSRU) provided hourly cost data for hospital clinician, general practitioner and community nurse time.[310] For remote review, time to complete assessment was applied to clinician cost and staff services emissions factor. For clinic review, recorded appointment review time were multiplied by cost and the staff services emissions factor.

15.2.3.3.2 Emissions Outside GHG Protocol Scope

Patient travel emissions were evaluated by collecting mode of transport, return mileage from home postcode to clinic postcode, and application of the emissions factor for method of transport (DEFRA/BEIS conversion factors).[311] Economical cost used the same metrics applied to national mileage allowances and parking costs as described in *appendix 8.20*.

15.2.3.4 Cost-Emissions Analyses

Carbon emissions for healthcare activity and items were evaluated based upon production, use and disposal. Where possible weight-based metrics were applied to emissions factors for to calculate emissions for production and disposal. Pharmaceuticals production values were calculated based upon unit cost. Total emissions were calculated as the sum of emissions values from the production, use and/or waste of each item or activity per patient. Review time was used as the base multiplication factor for staff and electricity related emissions, and patient return travel distance for travel related emissions. Carbon emissions related to each remote model were subtracted from clinic emissions to derive emissions benefit. Remote and face-to-face follow-up costs were estimated by the sum total of the staffing cost associated (clinician cost[310] x review time) and the follow-up resource cost.[310] Resource cost was estimated using the concomitant costs of individual items used in each respective review. Environmental and financial cost for each model were bootstrapped to a sample of 1000 participants. Cost-emissions planes were plotted using the bootstrapped comparative financial cost against environmental cost for RFS and RFT against face-to-face standard of care. The incremental cost-emissions ratio

was defined as the mean change in cost (£) / the mean emissions benefit (tCO_2e). All formulas used are provided in *appendix 8.21*.

Separate sensitivity analyses were conducted using the mean and median clinic review times and patient travel distances varied within their respective 95% confidence intervals and applied to each model. Further extrapolation and sensitivity analyses were performed by modelling the spectrum of follow-up methods from entirely remote to entirely face-to-face. Emissions cost of RFS and RFT models were subtracted from the variation model for emissions net benefit. Additional variation models ranging from 100% face-to-face to 100% RFS and RFT were evaluated and compared against RFS and RFT pathways. RFS and RFT models were extrapolated for wider potential environmental and financial cost benefits based the number upon open vascular recorded by the National Vascular Registry[312] and total surgical procedures reported in literature[266].

15.2.3.5 Statistics

Data were collected and entered into IBM SPSS (IBM SPSS Corporation, version 28; Rochester, New York), and a two-sided P-value of <0.050 was considered significant. Descriptive statistics are presented as proportions or mean ± standard deviation as appropriate. Emissions outcomes are reported as mean ± standard deviation or median with interquartile range as appropriate. Total values are presented with range and groups were compared using Wilcoxon Sign Rank Test. Calculations for carbon offsetting value in trees planted are based upon the $kgCO_2e$ sequestered by a 10-year-old, 5m tall, 25cm diameter tree with dry weight of 155.6kg.

15.2.4 Results

There were 171 patients screened and five (2.9%) were ineligible (lacked capacity, n=2; unable to speak English, n=2; on concurrent antibiotics, n=1). Of the remaining 166 patients, 61 declined to participate (unable to return for face-to-face review, n=37; too many questionnaires, n=5, unwilling to participate, n=19). In total 105 (62.5%) participants were enrolled into the study, baseline characteristics are shown in *table 30*. There were two procedures cancelled and no longer required, three

perioperative deaths (two cardiac events and one pulmonary embolus) and one participant lost to follow-up, leaving 99 participants for analysis. SSI was diagnosed during face-to-face review in 22 participants (SSI rate 22.2%). Remote assessment correctly identified SSI in 20 participants (sensitivity; 90.9%), and those without SSI in 70 participants (specificity; 90.9%). The positive and negative predictive values for remote assessment were 74.1% and 97.2% respectively. The distribution of SSI severity was 14 (63.6%) mild, 4 moderate (18.2%) and 4 (18.2%) severe. Summary carbon emissions for face-to-face and remote assessment models are shown in *table 31.*

Table 30: Baseline characteristics of participants

Characteristic	*N*	(%)
Sex		
Male	78	74.3
Female	27	25.7
Age	67	11†
BMI	25.7	4.9†
Smoking Status		
Current Smoker	38	36.2
Ex-Smoker	55	54.4
Non-Smoker	12	11.4
Comorbidities		
Diabetes	44	41.9
Hypertension	65	61.9
COPD	32	30.8
Previous TIA/CVA	13	12.4
IHD	46	43.8
CKD	23	21.9

. †Values expressed as standard deviation. BMI = body mass index, COPD = Chronic Obstructive Pulmonary Disease. TIA = Transient Ischaemic Attack, CVA = Cerebrovascular accident, IHD = Ischaemic Heart Disease, CKD = Chronic Kidney Disease

Table 31: Summary emissions table for in person and remote models of postoperative assessment.

Model	Unit of analysis	Emissions ($kgCO_2e$)		Change compared to in person (-$kgCO_2e$)		Absolute reduction (-%)	P value
Face-to-face	Median	40.89	(33.45-49.00)Δ	-	-	-	-
	Mean	43.37	(10.94)†	-	-	-	-
	Total	4293.70	(31.11-75.79)*	-	-	-	-
Remote first Screening	Median	1.34	(1.29-1.51)Δ	39.55	(29.92-46.88)Δ	96.7	<0.001
	Mean	12.58	(21.99)†	30.79	(26.23)†	71.0	<0.001
	Total	1245.50	(1.24-77.23)*	3048.21	(0.39-74.46)*	71.0	<0.001
Remote first Treatment	Median	1.33	(1.29-1.43)Δ	39.55	(31.58-47.56)Δ	96.7	<0.001
	Mean	4.87	(12.39)†	38.50	(17.39)†	88.8	<0.001
	Total	482.52	(1.24-66.58)*	3811.17	(0.10-74.46)*	88.8	<0.001

ΔValues expressed as IQR, †Values expressed as SD, *Values expressed as range

15.2.4.1 Model one (standard of care): Face-to-face review

The eC related to face-to-face assessment across all participants totalled 4293.7 $kgCO_2e$ (range 31.1-75.8). Mean emissions per patient were 43.4±10.94 $kgCO_2e$. The median return distance to clinic was 26.4 miles (IQR 9.4-57.4), and total distance travelled by all patients for face-to-face review 3312.2 miles (range 1.6-134.2 miles). Median time to review patients was 12.3 minutes (IQR 10.6-14.9). The breakdown of emissions per resource type is presented in *table 32*.

Table 32: Carbon emissions related breakdown by resource use categories.

	Clinic		Model 2		Model 3	
	$kgCO_2e$	(%)	$kgCO_2e$	(%)	$kgCO_2e$	(%)
Staff	3286.8	(76.5)	978.4	(81.4)	299.0	(84.5)
Consumables	45.3	(1.1)	16.8	(1.4)	2.9	(<0.1)
Waste	51.9	(1.2)	0.1	(<0.1)	3.3	(<0.1)
Electricity	-	-	0.7	(<0.1)	0.1	(<0.1)
Patient Travel	909.7	(21.2)	206.3	(17.2)	48.5	(13.7)

15.2.4.2 Model two: RFS

Assuming each patient with SSI required face-to-face review after their initial remote review, a RFS approach resulted in a total eC of 1,245.5 $kgCO_2e$ (range 1.2-77.2). Compared to a face-to-face model, RFS would result in a mean reduction of 30.8±26.2 $kgCO_2e$ per patient (face-to-face vs RFS; 43.4 vs 12.6 $kgCO_2e$, relative reduction 71.0%, *p<0.001*). For each patient reviewed in a RFS clinic, carbon offsetting would be equivalent to CO_2 sequestered by 1.24 trees/year. The median return distance to clinic using a remote first screening model was 26.7 miles per patient (IQR 13.7-56.4 miles), and the total distance travelled by all patients for face-to-face review reduced by 2461.2 miles (range 4.6-102 miles, face-to-face vs RFS 3312.2 vs 751.0 miles, relative reduction 77.3%). Using a RFS approach reduces median review time by 7.2 minutes (IQR 6.1-9.4, face-to-face vs remote 12.3 vs 3.6 minutes, relative reduction 58.5%, *p<0.001*).

15.2.4.3 Model three: RFT

Assuming each patient diagnosed with a mild SSI (requiring oral antibiotics) in a remote first treatment approach was managed in community, and those with moderate (requiring intravenous antibiotics) and severe (requiring surgical intervention and antibiotics) required face-to-face review, there would be a mean reduction of 38.5±17.4 $kgCO_2e$ per patient (face-to-face vs RFT 43.4 vs 4.9 $kgCO_2e$, relative reduction 88.8%, *p<0.001*). Each patient managed in this model would have a carbon offsetting value of 1.42 trees/year. The median return distance to clinic using a RFT model would be 19.3 miles per patient (IQR 9.8-27.6 miles), and total distance travelled by all patients reduced by 3135.6 miles (range 8.0-53.8 miles, face-to-face vs RFT 3312.2 vs 176.6 miles, relative reduction 94.7%). RFT reduces median review time by 8.1 minutes (IQR 6.8-9.8, face-to-face vs remote 12.3 vs 3.5 minutes, relative reduction 65.9%, *p<0.001*).

15.2.4.4 Cost Analysis

Model one (standard of care) resulted in a total fC of £9,541.75 for the whole patient group, and median fC of £89.20 (IQR 79.50-113.73, 95% CI; 81.02-97.36) per patient. Using a RFS approach results in a median fC per review of £11.62 (IQR 11.44-12.11, 95% CI 11.62-11.72), a reduction of £77.58 (95% CI; 62.92-79.24, relative reduction 87.0%, *p<0.001)* per patient. Total fC would be £4,468.22 (relative reduction compared to face-to-face £5,073.53, 53.2%). Median fC per review using RFT is £11.60 (IQR 11.43-11.87, 95% CI 11.50-11.70), a reduction of £77.60 (95% CI; 61.68-77.99, relative reduction 87.0%, *p<0.001*) per patient. The total fC of applying RFT would be £2,180.22 (relative reduction compared to face-to-face £7,361.53, 77.2%).

15.2.4.5 Sensitivity Analysis

As a sensitivity analysis, the mean (13.7 min) and median clinic review time (12.3 min) were varied within their respective 95% confidence intervals and applied to each model. The cost estimates ranged from £11.43-£11.87 for face-to-face, £11.44-£51.63 for RFS, and £11.43-£28.63 for RFT (S5). Mean (33.46 miles) and median

(26.40 miles) patient travel distances were varied within their 95% confidence intervals and applied to each model for both cost and emissions estimates (*table 33*).

Table 33: Sensitivity analysis using the mean and median patient distance travelled varied around 95% confidence intervals and interquartile range respectively.

	Model Variation	Sensitivity Estimation	Face-to-face		Remote First Screening		Remote First Treatment	
Emissions		Miles	$kgCO_2e$	95% CI[a]	$kgCO_2e$	95% CI[a]	$kgCO_2e$	95% CI[a]
	Mean	33.46	43.12	41.64-44.67	12.41	12.07-12.74	5.08	4.96-5.21
	Median	26.40	41.22	36.58-49.71	11.97	10.94-13.86	4.93	4.55-5.61
Cost		Miles	Cost (£)	95% CI[a]	Cost (£)	95% CI[a]	Cost (£)	95% CI[a]
	Mean	33.46	£96.38	94.18-98.58	£45.83	45.34-46.32	£24.33	24.15-24.50
	Median	26.40	£93.56	86.8-105.92	£45.21	43.70-47.95	£24.10	23.56-25.10

[a] Upper and lower interquartile ranges used for median estimates.

15.2.4.6 Cost-Emissions Analysis

All remote first methods demonstrate reduction in both eC and fC compared with face-to-face standard of care irrespective of chosen model. Cost-emissions planes for each remote model are distributed to the bottom left axis indicating environmental and financial domination over a face-to-face model (Figure 23A-C). As there is no accepted ceiling ratio threshold, a range are presented in Figure 23C, indicating acceptance of all remote methods. Mean incremental cost-emissions ratios are not calculated due to the cost-emissions domination.

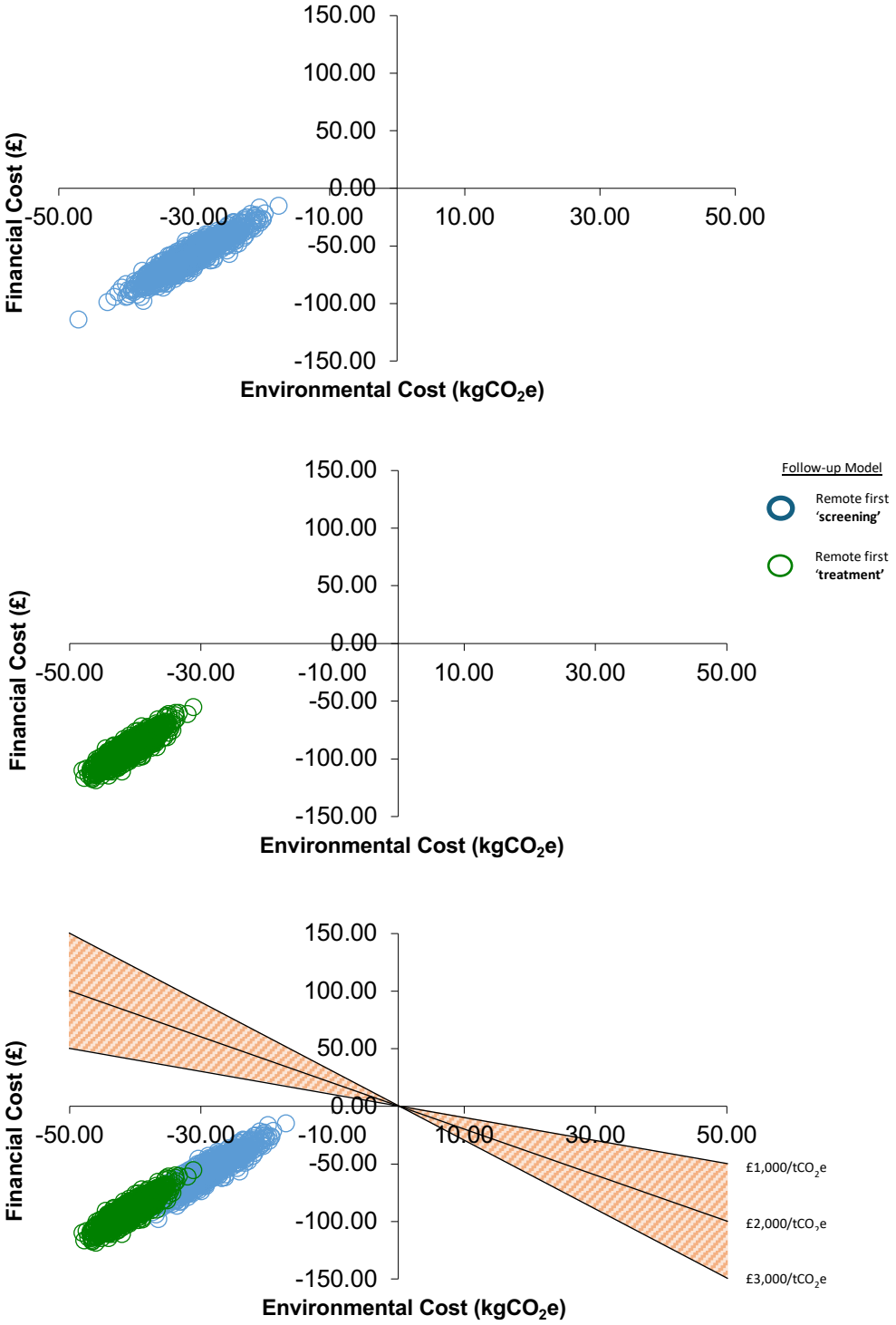


Figure 23: Financial-environmental cost planes for remote assessment compared to in-person assessment.

15.2.4.7 Model Extrapolation

Scenarios were modelled to evaluate the impact of a change in practice varying postoperative review from 100% face-to-face to 100% remote assessment. There is a net benefit eC if 30% or more patients are offered RFS. This falls to just 10% of patients with RFT (*table 34*). In 2022 there were 14,700 open vascular procedures in the NHS, UK.[312] No data are available to base the actual current proportions of in person or remote postoperative appointments, however general practice clinic-remote follow-up ratio is 7:3.[313] Under this assumption, further implementation of remote models of postoperative care would produce estimated cost savings ranging £389,059,56-£728,792.89 and a reduction in carbon emissions of 267.4-380.7 tCO_2e (938.2-1,335.8 trees. Looking across the entire NHS, 3,102,674 surgical procedures were performed in 2020.[266] Extrapolating using the same clinic-remote follow-up assumption of 7:3 could enable cost savings ranging £82,117,344.50-£153,823,588.00 and a reduction in carbon emissions of 56,435.7-80,347.3 tCO_2e (198,020.0-281,920.4 trees, *table 35*).

Table 34: Emissions (kgCO2e) produced per patient from potential follow-up scenarios by varying proportion of patients from entirely face-to-face to entirely remotely.

Face-to-face follow-up proportion		Possible current $kgCO_2e$ produced	Net benefit ($kgCO_2e$) using only RFS	Net benefit $kgCO_2e$ using only RFT	Possible $kgCO_2e$ if varied with RFS	Net benefit $kgCO_2e$ using only RFS	Net benefit $kgCO_2e$ using only RFT	Possible $kgCO_2e$ if varied with RFT	Net benefit $kgCO_2e$ using only RFS	Net benefit $kgCO_2e$ using only RFT	$kgCO_2e$ using RFS	$kgCO_2e$ using RFT
100% remote	0.0	1.4	11.2	3.5	12.6	0.0	-7.7	4.9	7.7	0.0	12.6	4.9
	0.1	5.6	7.0	-0.7	15.7	-3.1	-10.8	8.8	3.9	-3.9	12.6	4.9
	0.2	9.8	2.8	-4.9	18.8	-6.2	-13.9	12.6	0.0	-7.7	12.6	4.9
	0.3	14.0	-1.4	-9.1	21.8	-9.2	-16.9	16.5	-3.9	-11.6	12.6	4.9
	0.4	18.2	-5.6	-13.3	24.9	-12.3	-20.0	20.3	-7.7	-15.4	12.6	4.9
	0.5	22.4	-9.8	-17.5	28.0	-15.4	-23.1	24.2	-11.6	-19.3	12.6	4.9
	0.6	26.6	-14.0	-21.7	31.1	-18.5	-26.2	28.0	-15.4	-23.1	12.6	4.9
	0.7	30.8	-18.2	-25.9	34.2	-21.6	-29.3	31.9	-19.3	-27.0	12.6	4.9
	0.8	35.0	-22.4	-30.1	37.2	-24.6	-32.3	35.7	-23.1	-30.8	12.6	4.9
100% face-to-face	0.9	39.2	-26.6	-34.3	40.3	-27.7	-35.4	39.6	-27.0	-34.7	12.6	4.9
	1.0	43.4	-30.8	-38.5	43.4	-30.8	-38.5	43.4	-30.8	-38.5	12.6	4.9
Mean (Net benefit)		22.4	(-9.8)	(-17.5)	28.0	(-15.4)	(-23.1)	24.2	(-11.6)	(-19.3)	12.6	4.9

Additional comparison made with variation using RFS and RFT models. Change in variation at each proportion using entirely RFS and RFT model presented.

Table 35: Model extrapolation of potential annual cost and carbon footprint savings with UK national vascular and all surgical procedure data.

	Annual Procedures	Potential cost savings	Potential tCO_2e savings	Carbon offsetting (trees/10 years)	Clinician Time Saved (hours)
Vascular Surgery					
Model 2: Screening	14,700	£389,059,56	267.4	938.2	1,764.0
Model 3: Diagnosis	14,700	£728,792.89	380.7	1,335.8	1,984.5
All NHS Surgery					
Model 2: Screening	3,102,674	£82,117,344.50	56,435.7	198,020.0	372,320.9
Model 3: Diagnosis	3,102,674	£153,823,588.00	80,347.3	281,920.4	418,861.0

Assumption based upon current system of 70% in person and 30% remote surgical follow-up appointments

15.2.5 Discussion

This study demonstrates the potential benefit in aligning carbon accounting with cost analysis and highlights the positive implications within health technology assessment. There is superior environmental and fiscal benefit implementing 'remote first' models of post-operative monitoring for SSI in patients undergoing vascular surgery compared to face-to-face assessments. Moreover, substantial savings in review time for both clinicians and patients as well as travel distance are evident. Considering the benefits and feasibility demonstrated, a RFT model of postoperative care appears to provide the optimal economic and sustainable benefits to patient care. Further prospective evaluation of this model may be beneficial to corroborate the findings shown here. Utilisation of a 'remote first' approach to post-surgical follow-up is substantiated by a growing evidence base, indicating remote assessments facilitate earlier identification of SSI, improved follow-up adherence and reliable wound complication screening.[267,269,314].

Carbon footprint related to specific models of surgical follow-up have not been described previously, though the relationship between face-to-face and telemedicine emissions has been reported. Purohit and colleagues identify emissions savings ranging between 0.70-372 $kgCO_2e$ per consultation. The large range in carbon emissions per consultation was in part related to considerable variation in mean travel distances (range; 15-1,387km).[315] Travel distances likely vary by region in the UK with densely populated urban regions covering smaller geographical areas than others. Specific postoperative models for such centres may require evaluation for potential influence on care pathway decisions. A US-based study identified lower reductions in $kgCO_2e$ than shown here, though this was in a contrasting financial system, evaluated a range of specialties, and did not consider environmental impact of staff, which was found to be a significant contributor in this study.[316]

Carbon offsetting is a strategy of compensating for the emissions produced by supporting activities which generate equivalent carbon dioxide savings elsewhere, often involving the planting of new trees to theoretically sequester carbon dioxide

from the atmosphere. The feasibility of relying on tree planting as a solution to rising emissions is hindered by geopolitical and social constraints, limited available land mass, and the delayed benefits which will not manifest for centuries.[317] Consequently, tree planting is impractical for physical offsetting, but standardisation of reporting could provide an equitable offsetting quantification. Further research is needed to formally standardise carbon offsetting and carbon accounting methodology as well as reporting, and has been highlighted as research priority previously.[318]

Costs of remote follow-up vary considerably depending on healthcare system, mode of delivery, application or device and type of telemedicine used.[319,320] There is limited evaluation within UK NHS contexts, particularly in surgical follow-up.[321,322] Within this study, no specific digital application was utilised, which may impact on patient adherence rates. Though this likely aided in the low economic costs associated with remote follow-up modelled here, given the inherent cost of utilising digital applications. This does however highlight feasibility in delivering remote care pathways without use of costly software and digital applications.

Cost-emissions analyses describe the financial cost associated with achieving environmental benefits. Incorporating such evaluations within health technology assessment is crucial to ensure improvements in clinical care are aligned with environmental benefits and consequently, national and international targets.[230,323] Unsurprisingly, remote assessments offer both sustainable and cost benefits, although many other interventions may have associated financial costs for similar advantages. Presently, there is no pre-existing data to estimate a threshold or 'ceiling effect' for environmental analyses. Future randomised controlled trials should encompass carbon accounting and evaluate associations with cost and health utility, the latter unable to be assessed within this study design. These evaluations are unlikely to impede policy-level decisions for clinically effective interventions costing below threshold values, but with an established sustainable ceiling, mitigation or offsetting can be considered when implementing such technologies.

This study does have limitations. The paired design limits analysis within the same cohort. Further research through RCT or observational cohorts should aim to evaluate the methodologies presented. Base case analysis of an entire cohort of face-to-face reviews is used for comparison to the proposed remote models. The true nature of current practice may be a mixed modality system whereby some patients are reviewed face-to-face and others remotely, depending on surgeon discretion and system constraints. Therefore, the differential benefits estimated are liable to be slightly exaggerated from the true difference. Further evaluation of current proportions of face-to-face and remote assessment are required to inform future care pathway decision making. Some mitigation for this mixed modality was attempted, in model extrapolation (table 5) whereby comparison was made to a hypothetical system of 70% face-to-face and 30% remote follow-up, based upon current GP appointments in the absence of surgical follow-up data[313]. Further extrapolation into variation of face-to-face and remote follow-up proportions was assessed to identify possible net benefit in emissions with each approach. Additional models of care may be plausible which were not considered here. For instance patient initiated follow-up may have environmental and financial benefits as only those requiring review would have this, though evaluation for safety and efficacy would be required. Both the environmental and cost analyses are performed within and in reference to the NHS, England, limiting the generalisability of findings somewhat from wider geographical locations and financial systems. These factors are unlikely to substantially alter the sustainable and financial benefits found in this study, however. Modelling was based upon a centralised face-to-face review clinic, though some centres may operate 'spoke' clinics in community or at secondary centres. Further evaluation should consider how the remote models suggested here may interplay with such care pathways.

Integration of emissions analyses into health technology assessment is key to maintaining sustainable healthcare systems beyond initial wholescale reductions, and a framework for doing so has been presented here. A 'remote first' approach to postoperative follow-up, screening patients without complications, reduces carbon emissions whilst being both cost and clinically effective.[269,314] Employment of this

care pathway additionally saves considerable unnecessary travel distance for patients and clinic appointments for healthcare services. Further, this pathway would likely have additional benefits not quantified here, such as redirection of patients from overburdened primary care services with surgical complications.

16 CHAPTER 6: CONCLUSIONS

Surgical site infection is now the most common healthcare associated infection, and is a significant cause of morbidity, disruption to quality of life and mortality. Multiple international guidelines have been published within the last decade though there have been substantial shifts in healthcare systems in that period, in the wake of the SARs-CoV-2 virus, notably widespread adoption of remote healthcare pathways and a drive as a community of practice to reduce the environmental footprint of care provided.

Traditional health economic evaluations are designed to inform efficient allocation of finite financial resources by comparing costs and health outcomes, most commonly expressed as cost per quality-adjusted life year. While this framework has underpinned health-care decision-making for decades, it does not account for environmental externalities associated with health-care delivery. As health systems now operate under explicit net-zero commitments, carbon emissions represent an additional constrained resource with real opportunity cost. Incorporating carbon accounting alongside conventional economic evaluation therefore constitutes a methodologically coherent extension rather than a departure from established practice. By quantifying both financial cost and carbon impact at the level of clinical pathways, decision-makers can identify interventions that are simultaneously clinically safe, cost-effective, and environmentally sustainable, as well as transparently evaluate trade-offs where these objectives diverge. The findings of this thesis demonstrate the feasibility and policy relevance of such integrated analyses and support the future development of health-economic models that routinely include environmental metrics, either as parallel outcomes or as explicit constraints, to better align clinical decision-making with long-term health system sustainability.

The workstreams within this thesis have led to the following additional conclusions:

1. Despite publication of international guidelines there remains disparity and lack of consensus amongst the surgical community on best practice to

prevent surgical site infection. This may be due to low levels of robust evidence best to base recommendations.

2. Telemedicine, by any modality, may have use as a screening tool for patients with possible surgical site infection.
3. Combining wound images with the Bluebelle Wound Healing Questionnaire improved accuracy of diagnosis irrespective of the number of measure items used.
4. The ASSIST measure with 11 items had optimal reliability, acceptability, validity and precision for surgical site infection remote diagnosis in these studies.
5. Surgical site infections are a considerable source of resource burden, costing the NHS financially and the planet environmentally in drastic amounts.
6. The resource burden from infections is comparatively small for 'mild' infections but rises astronomically in an exponential manner with severity. Severity needs to be evaluated to truly capture the impact of interventions to prevent or reduce surgical site infection.
7. Modelling suggests utilising the ASSIST measure in practice would save substantial financial and environmental costs to the NHS.
8. It would be justified to evaluate the ASSIST measure in wider surgical specialties and regions to evaluate generalisability of these findings before implementing into practice.

Future work should focus on the external validation and implementation of the ASSIST remote assessment pathway to support safe and scalable adoption. First, the diagnostic performance of ASSIST should be validated in independent and more diverse populations, including non-vascular surgical cohorts and centres with differing baseline SSI prevalence, to assess generalisability and recalibrate thresholds where necessary. Multicentre prospective studies would allow assessment of performance stability across variation in case-mix, clinician experience, and organisational context.

Second, patient experience and acceptability should be explored in greater depth. While feasibility has been demonstrated, further mixed-methods evaluation incorporating structured patient-reported experience measures and qualitative feedback would provide insight into usability, reassurance, perceived safety, and equity of access. Comparisons between remote-first**,** hybrid, and traditional face-to-face follow-up models would help determine which pathway best balances patient preference with clinical safety.

Third, parallel evaluation of clinician experience and workflow impact is required. Understanding how remote assessment influences decision confidence, workload, escalation behaviour, and integration with electronic health records will be essential for sustainable implementation. Comparative assessment of clinician feedback across remote and in-person models would inform training requirements and service design.

Finally, future studies should adopt an implementation science framework to guide scale-up, addressing factors such as digital literacy, infrastructure, governance, and safety-netting processes. Taken together, these steps would enable ASSIST to progress from a validated diagnostic tool to a routinely embedded component of postoperative care pathways.

17 CHAPTER 7: REFERENCES

1 Sreejith, N. *Coagulation*, <https://teachmephysiology.com/immune-system/haematology/coagulation/> (2023).

2 Mayhew, J. & Pandya, B. *Ultrastructure of Skin*, <https://teachmeanatomy.info/the-basics/ultrastructure/skin/> (2024).

3 Learning, L. *Structure and Function of Skin*, <https://courses.lumenlearning.com/suny-wmopen-biology2/chapter/structure-and-function-of-skin/> (2025).

4 Yousef, H., Alhajj, M., Fakoya, A. O. & Sharma, S. in *StatPearls* (2025).

5 Richardson, M. Understanding the structure and function of the skin. *Nurs Times* **99**, 46-48 (2003).

6 Lopez-Ojeda, W., Pandey, A., Alhajj, M. & Oakley, A. M. in *StatPearls* (2025).

7 Burns, T. & Rook, A. *Rook's textbook of dermatology*. Vol. 4 (Oxford: Blackwell Science, 2004).

8 Thingnes, J., Lavelle, T. J., Hovig, E. & Omholt, S. W. Understanding the melanocyte distribution in human epidermis: an agent-based computational model approach. *PLoS One* **7**, e40377 (2012). https://doi.org:10.1371/journal.pone.0040377

9 Katz, S. I., Tamaki, K. & Sachs, D. H. Epidermal Langerhans cells are derived from cells originating in bone marrow. *Nature* **282**, 324-326 (1979). https://doi.org:10.1038/282324a0

10 Boulais, N. & Misery, L. Merkel cells. *J Am Acad Dermatol* **57**, 147-165 (2007). https://doi.org:10.1016/j.jaad.2007.02.009

11 Modules., S. T. *Layers of the Skin*, <https://training.seer.cancer.gov/melanoma/anatomy/layers.html> (2025).

12 Eichner, R., Sun, T. T. & Aebi, U. The role of keratin subfamilies and keratin pairs in the formation of human epidermal intermediate filaments. *J Cell Biol* **102**, 1767-1777 (1986). https://doi.org:10.1083/jcb.102.5.1767

13 Steven, A. C., Bisher, M. E., Roop, D. R. & Steinert, P. M. Biosynthetic pathways of filaggrin and loricrin--two major proteins expressed by terminally differentiated epidermal keratinocytes. *J Struct Biol* **104**, 150-162 (1990). https://doi.org:10.1016/1047-8477(90)90071-j

14 Armengot-Carbo, M., Hernandez-Martin, A. & Torrelo, A. The role of filaggrin in the skin barrier and disease development. *Actas Dermosifiliogr* **106**, 86-95 (2015). https://doi.org:10.1016/j.ad.2013.10.019

15 Murphrey, M. B., Miao, J. H. & Zito, P. M. in *StatPearls* (2025).

16 Menon, G. K., Cleary, G. W. & Lane, M. E. The structure and function of the stratum corneum. *Int J Pharm* **435**, 3-9 (2012). https://doi.org:10.1016/j.ijpharm.2012.06.005

17 Brown, T. M. & Krishnamurthy, K. in *StatPearls* (2025).

18 Prost-Squarcioni, C., Fraitag, S., Heller, M. & Boehm, N. [Functional histology of dermis]. *Ann Dermatol Venereol* **135**, 1S5-20 (2008). https://doi.org:10.1016/S0151-9638(08)70206-0

19 Ochoa, M. T., Loncaric, A., Krutzik, S. R., Becker, T. C. & Modlin, R. L. "Dermal dendritic cells" comprise two distinct populations: CD1+ dendritic cells and

CD209+ macrophages. *J Invest Dermatol* **128**, 2225-2231 (2008). https://doi.org:10.1038/jid.2008.56

20 Huang, J. *et al.* Dermal extracellular matrix molecules in skin development, homeostasis, wound regeneration and diseases. *Semin Cell Dev Biol* **128**, 137-144 (2022). https://doi.org:10.1016/j.semcdb.2022.02.027

21 Singh, D., Rai, V. & Agrawal, D. K. Regulation of Collagen I and Collagen III in Tissue Injury and Regeneration. *Cardiol Cardiovasc Med* **7**, 5-16 (2023). https://doi.org:10.26502/fccm.92920302

22 Kim, J. Y. & Dao, H. in *StatPearls* (2025).

23 Kujath, P. & Michelsen, A. Wounds - from physiology to wound dressing. *Dtsch Arztebl Int* **105**, 239-248 (2008). https://doi.org:10.3238/arztebl.2008.0239

24 Leaper, D. J. Traumatic and surgical wounds. *BMJ* **332**, 532-535 (2006). https://doi.org:10.1136/bmj.332.7540.532

25 Azmat, C. E. & Council, M. in *StatPearls* (2025).

26 Jais, S. Various Types of Wounds That Diabetic Patients Can Develop: A Narrative Review. *Clin Pathol* **16**, 2632010X231205366 (2023). https://doi.org:10.1177/2632010X231205366

27 NICE CKS. *Burns and Scalds*, <https://cks.nice.org.uk/topics/burns-scalds/> (2023).

28 Demidova-Rice, T. N., Hamblin, M. R. & Herman, I. M. Acute and impaired wound healing: pathophysiology and current methods for drug delivery, part 1: normal and chronic wounds: biology, causes, and approaches to care. *Adv Skin Wound Care* **25**, 304-314 (2012). https://doi.org:10.1097/01.ASW.0000416006.55218.d0

29 Ding, X. *et al.* Challenges and innovations in treating chronic and acute wound infections: from basic science to clinical practice. *Burns Trauma* **10**, tkac014 (2022). https://doi.org:10.1093/burnst/tkac014

30 Onyekwelu, I., Yakkanti, R., Protzer, L., Pinkston, C. M., Tucker, C. & Seligson, D. Surgical Wound Classification and Surgical Site Infections in the Orthopaedic Patient. *J Am Acad Orthop Surg Glob Res Rev* **1**, e022 (2017). https://doi.org:10.5435/JAAOSGlobal-D-17-00022

31 Wallace, H. A., Basehore, B. M. & Zito, P. M. in *StatPearls* (2025).

32 Pakala, R. Serotonin and thromboxane A2 stimulate platelet-derived microparticle-induced smooth muscle cell proliferation. *Cardiovasc Radiat Med* **5**, 20-26 (2004). https://doi.org:10.1016/j.carrad.2003.12.002

33 Schultz, G., Chin, G., Moldawer, L. & Diegelmann, R. *Mechanisms of Vascular Disease: A Reference Book for Vascular Specialists*. (2011).

34 Chaudhry, R., Usama, S. M. & Babiker, H. M. in *StatPearls* (2025).

35 Mahmoud, N. N. *et al.* Investigating Inflammatory Markers in Wound Healing: Understanding Implications and Identifying Artifacts. *ACS Pharmacol Transl Sci* **7**, 18-27 (2024). https://doi.org:10.1021/acsptsci.3c00336

36 Rada, B. Neutrophil Extracellular Traps. *Methods Mol Biol* **1982**, 517-528 (2019). https://doi.org:10.1007/978-1-4939-9424-3_31

37 Wang, J. Neutrophils in tissue injury and repair. *Cell Tissue Res* **371**, 531-539 (2018). https://doi.org:10.1007/s00441-017-2785-7

38 Wilgus, T. A., Roy, S. & McDaniel, J. C. Neutrophils and Wound Repair: Positive Actions and Negative Reactions. *Adv Wound Care (New Rochelle)* **2**, 379-388 (2013). https://doi.org:10.1089/wound.2012.0383

39 Corliss, B. A., Azimi, M. S., Munson, J. M., Peirce, S. M. & Murfee, W. L. Macrophages: An Inflammatory Link Between Angiogenesis and Lymphangiogenesis. *Microcirculation* **23**, 95-121 (2016). https://doi.org:10.1111/micc.12259

40 Holzer-Geissler, J. C. J. *et al.* The Impact of Prolonged Inflammation on Wound Healing. *Biomedicines* **10** (2022). https://doi.org:10.3390/biomedicines10040856

41 Alhajj, M. & Goyal, A. *Physiology, Granulation Tissue*. (StatPearls, 2025).

42 Khair, O. A., Davies, R. J. & Devalia, J. L. Bacterial-induced release of inflammatory mediators by bronchial epithelial cells. *Eur Respir J* **9**, 1913-1922 (1996). https://doi.org:10.1183/09031936.96.09091913

43 Zhao, A., Sun, J. & Liu, Y. Understanding bacterial biofilms: From definition to treatment strategies. *Front Cell Infect Microbiol* **13**, 1137947 (2023). https://doi.org:10.3389/fcimb.2023.1137947

44 Demling, R. H. Nutrition, anabolism, and the wound healing process: an overview. *Eplasty* **9**, e9 (2009).

45 Hong, W. X. *et al.* The Role of Hypoxia-Inducible Factor in Wound Healing. *Adv Wound Care (New Rochelle)* **3**, 390-399 (2014). https://doi.org:10.1089/wound.2013.0520

46 Ghahremani-Nasab, M., Del Bakhshayesh, A. R., Akbari-Gharalari, N. & Mehdipour, A. Biomolecular and cellular effects in skin wound healing: the association between ascorbic acid and hypoxia-induced factor. *J Biol Eng* **17**, 62 (2023). https://doi.org:10.1186/s13036-023-00380-6

47 Yip, W. L. Influence of oxygen on wound healing. *Int Wound J* **12**, 620-624 (2015). https://doi.org:10.1111/iwj.12324

48 Silver, F. H., Siperko, L. M. & Seehra, G. P. Mechanobiology of force transduction in dermal tissue. *Skin Res Technol* **9**, 3-23 (2003). https://doi.org:10.1034/j.1600-0846.2003.00358.x

49 Barnes, L. A. *et al.* Mechanical Forces in Cutaneous Wound Healing: Emerging Therapies to Minimize Scar Formation. *Adv Wound Care (New Rochelle)* **7**, 47-56 (2018). https://doi.org:10.1089/wound.2016.0709

50 Junker, J. P., Kamel, R. A., Caterson, E. J. & Eriksson, E. Clinical Impact Upon Wound Healing and Inflammation in Moist, Wet, and Dry Environments. *Adv Wound Care (New Rochelle)* **2**, 348-356 (2013). https://doi.org:10.1089/wound.2012.0412

51 Okan, D., Woo, K., Ayello, E. A. & Sibbald, G. The role of moisture balance in wound healing. *Adv Skin Wound Care* **20**, 39-53; quiz 53-35 (2007). https://doi.org:10.1097/00129334-200701000-00013

52 Khalid, K. A., Nawi, A. F. M., Zulkifli, N., Barkat, M. A. & Hadi, H. Aging and Wound Healing of the Skin: A Review of Clinical and Pathophysiological Hallmarks. *Life (Basel)* **12** (2022). https://doi.org:10.3390/life12122142

53 Seth, I. *et al.* Impact of nutrition on skin wound healing and aesthetic outcomes: A comprehensive narrative review. *JPRAS Open* **39**, 291-302 (2024). https://doi.org:10.1016/j.jpra.2024.01.006

54 Agren, M. S., Chvapil, M. & Franzen, L. Enhancement of re-epithelialization with topical zinc oxide in porcine partial-thickness wounds. *J Surg Res* **50**, 101-105 (1991). https://doi.org:10.1016/0022-4804(91)90230-j

55 Dasari, N. *et al.* Updates in Diabetic Wound Healing, Inflammation, and Scarring. *Semin Plast Surg* **35**, 153-158 (2021). https://doi.org:10.1055/s-0041-1731460

56 Tsourdi, E., Barthel, A., Rietzsch, H., Reichel, A. & Bornstein, S. R. Current aspects in the pathophysiology and treatment of chronic wounds in diabetes mellitus. *Biomed Res Int* **2013**, 385641 (2013). https://doi.org:10.1155/2013/385641

57 Albaran, R. G., Webber, J. & Steffes, C. P. CD4 cell counts as a prognostic factor of major abdominal surgery in patients infected with the human immunodeficiency virus. *Arch Surg* **133**, 626-631 (1998). https://doi.org:10.1001/archsurg.133.6.626

58 Wang, A. S., Armstrong, E. J. & Armstrong, A. W. Corticosteroids and wound healing: clinical considerations in the perioperative period. *Am J Surg* **206**, 410-417 (2013). https://doi.org:10.1016/j.amjsurg.2012.11.018

59 Bootun, R. Effects of immunosuppressive therapy on wound healing. *Int Wound J* **10**, 98-104 (2013). https://doi.org:10.1111/j.1742-481X.2012.00950.x

60 Ebrecht, M., Hextall, J., Kirtley, L. G., Taylor, A., Dyson, M. & Weinman, J. Perceived stress and cortisol levels predict speed of wound healing in healthy male adults. *Psychoneuroendocrinology* **29**, 798-809 (2004). https://doi.org:10.1016/S0306-4530(03)00144-6

61 Steptoe, A., Wardle, J., Pollard, T. M., Canaan, L. & Davies, G. J. Stress, social support and health-related behavior: a study of smoking, alcohol consumption and physical exercise. *J Psychosom Res* **41**, 171-180 (1996). https://doi.org:10.1016/0022-3999(96)00095-5

62 National Healthcare Safety Network & Centres for Disease Control and Prevention. *Surgical Site Infection Event (SSI)*, <https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf> (2023).

63 *Centres for Disease Control and Prevention (CDC). Surgical Site Infection (SSI) Event*, <https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf> (2017).

64 Ban, K. A. *et al.* American College of Surgeons and Surgical Infection Society: Surgical Site Infection Guidelines, 2016 Update. *J Am Coll Surg* **224**, 59-74 (2017). https://doi.org:10.1016/j.jamcollsurg.2016.10.029

65 Pinkney, T. D. *et al.* Impact of wound edge protection devices on surgical site infection after laparotomy: multicentre randomised controlled trial (ROSSINI Trial). *BMJ : British Medical Journal* **347**, f4305 (2013). https://doi.org:10.1136/bmj.f4305

66 Matatov, T., Reddy, K. N., Doucet, L. D., Zhao, C. X. & Zhang, W. W. Experience with a new negative pressure incision management system in prevention of groin wound infection in vascular surgery patients. *Journal of Vascular Surgery* **57**, 791-795 (2013). https://doi.org:10.1016/j.jvs.2012.09.037

67 Sun, C., Gao, H., Zhang, Y., Pei, L. & Huang, Y. Risk Stratification for Organ/Space Surgical Site Infection in Advanced Digestive System Cancer. *Front Oncol* **11**, 705335 (2021). https://doi.org:10.3389/fonc.2021.705335

68 Lawson, E. H., Hall, B. L. & Ko, C. Y. Risk factors for superficial vs deep/organ-space surgical site infections: implications for quality improvement initiatives. *JAMA Surg* **148**, 849-858 (2013). https://doi.org:10.1001/jamasurg.2013.2925

69 Papadopoulos, A. *et al.* Risk Factors for Surgical Site Infections in Patients Undergoing Emergency Surgery: A Single-centre Experience. *In Vivo* **35**, 3569-3574 (2021). https://doi.org:10.21873/invivo.12660

70 Pollmann, C. T., Dahl, F. A., Røtterud, J. H. M., Gjertsen, J. E. & Årøen, A. Surgical site infection after hip fracture - mortality and risk factors: an observational cohort study of 1,709 patients. *Acta Orthop* **91**, 347-352 (2020). https://doi.org:10.1080/17453674.2020.1717841

71 Culver, D. H. *et al.* Surgical wound infection rates by wound class, operative procedure, and patient risk index. National Nosocomial Infections Surveillance System. *Am J Med* **91**, 152S-157S (1991). https://doi.org:10.1016/0002-9343(91)90361-z

72 Ortega, G. *et al.* An evaluation of surgical site infections by wound classification system using the ACS-NSQIP. *J Surg Res* **174**, 33-38 (2012). https://doi.org:10.1016/j.jss.2011.05.056

73 Zabaglo M & T., S. *Postoperative Wound Infection (Updated 2022 Sep 19)*, <https://www.ncbi.nlm.nih.gov/books/NBK560533/> (2023).

74 Seidelman, J. L., Mantyh, C. R. & Anderson, D. J. Surgical Site Infection Prevention: A Review. *JAMA* **329**, 244-252 (2023). https://doi.org:10.1001/jama.2022.24075

75 Saadatian-Elahi, M., Teyssou, R. & Vanhems, P. Staphylococcus aureus, the major pathogen in orthopaedic and cardiac surgical site infections: a literature review. *Int J Surg* **6**, 238-245 (2008). https://doi.org:10.1016/j.ijsu.2007.05.001

76 Missiakas, D. M. & Schneewind, O. Growth and laboratory maintenance of Staphylococcus aureus. *Curr Protoc Microbiol* **Chapter 9**, Unit 9C 1 (2013). https://doi.org:10.1002/9780471729259.mc09c01s28

77 Guignard, B., Entenza, J. M. & Moreillon, P. Beta-lactams against methicillin-resistant Staphylococcus aureus. *Curr Opin Pharmacol* **5**, 479-489 (2005). https://doi.org:10.1016/j.coph.2005.06.002

78 Charalambous, L. T. *et al.* Prosthetic Knee Infection With Coagulase-Negative Staphylococcus: A Harbinger of Poor Outcomes. *J Arthroplasty* **37**, S313-S320 (2022). https://doi.org:10.1016/j.arth.2022.02.050

79 Winston, D. J., Dudnick, D. V., Chapin, M., Ho, W. G., Gale, R. P. & Martin, W. J. Coagulase-negative staphylococcal bacteremia in patients receiving immunosuppressive therapy. *Arch Intern Med* **143**, 32-36 (1983).

80 Franca, A., Gaio, V., Lopes, N. & Melo, L. D. R. Virulence Factors in Coagulase-Negative Staphylococci. *Pathogens* **10** (2021). https://doi.org:10.3390/pathogens10020170

81 Bargavi, K., Secunda, R., Saravana, J. & Satyanesan, J. Surgical Site Infections in Gastrointestinal Surgeries: Estimation of Prevalence, Risk Factors and

Bacteriological Profile. *Cureus* **16**, e62589 (2024). https://doi.org:10.7759/cureus.62589

82 Pakbin, B., Bruck, W. M. & Rossen, J. W. A. Virulence Factors of Enteric Pathogenic Escherichia coli: A Review. *Int J Mol Sci* **22** (2021). https://doi.org:10.3390/ijms22189922

83 Reynolds, D. & Kollef, M. The Epidemiology and Pathogenesis and Treatment of Pseudomonas aeruginosa Infections: An Update. *Drugs* **81**, 2117-2131 (2021). https://doi.org:10.1007/s40265-021-01635-6

84 Qin, S. *et al.* Pseudomonas aeruginosa: pathogenesis, virulence factors, antibiotic resistance, interaction with host, technology advances and emerging therapeutics. *Signal Transduct Target Ther* **7**, 199 (2022). https://doi.org:10.1038/s41392-022-01056-1

85 Barie, P. S., Christou, N. V., Dellinger, E. P., Rout, W. R., Stone, H. H. & Waymack, J. P. Pathogenicity of the enterococcus in surgical infections. *Ann Surg* **212**, 155-159 (1990). https://doi.org:10.1097/00000658-199008000-00007

86 Fisher, K. & Phillips, C. The ecology, epidemiology and virulence of Enterococcus. *Microbiology (Reading)* **155**, 1749-1757 (2009). https://doi.org:10.1099/mic.0.026385-0

87 Kanwal, S. & Vaitla, P. *Streptococcus Pyogenes*. (StatPearls, 2025).

88 Liu, J., Xu, X., Lv, X. & Shen, G. Correlation between surgical site infection and time-dependent blood platelet count in immunocompromised patients after femoral neck fracture. *J Int Med Res* **50**, 3000605211068689 (2022). https://doi.org:10.1177/03000605211068689

89 Adwall, L., Pantiora, E., Hultin, H. & Norlen, O. Association of postoperative infection and oncological outcome after breast cancer surgery. *BJS Open* **5** (2021). https://doi.org:10.1093/bjsopen/zrab052

90 Martin, E. T. *et al.* Diabetes and Risk of Surgical Site Infection: A Systematic Review and Meta-analysis. *Infect Control Hosp Epidemiol* **37**, 88-99 (2016). https://doi.org:10.1017/ice.2015.249

91 Thelwall, S., Harrington, P., Sheridan, E. & Lamagni, T. Impact of obesity on the risk of wound infection following surgery: results from a nationwide prospective multicentre cohort study in England. *Clin Microbiol Infect* **21**, 1008 e1001-1008 (2015). https://doi.org:10.1016/j.cmi.2015.07.003

92 Gurunathan, U., Ramsay, S., Mitric, G., Way, M., Wockner, L. & Myles, P. Association Between Obesity and Wound Infection Following Colorectal Surgery: Systematic Review and Meta-Analysis. *J Gastrointest Surg* **21**, 1700-1712 (2017). https://doi.org:10.1007/s11605-017-3494-y

93 Kaye, K. S. *et al.* The effect of increasing age on the risk of surgical site infection. *J Infect Dis* **191**, 1056-1062 (2005). https://doi.org:10.1086/428626

94 Sorensen, L. T. Wound healing and infection in surgery. The clinical impact of smoking and smoking cessation: a systematic review and meta-analysis. *Arch Surg* **147**, 373-383 (2012). https://doi.org:10.1001/archsurg.2012.5

95 McDaniel, J. C. & Browning, K. K. Smoking, chronic wound healing, and implications for evidence-based practice. *J Wound Ostomy Continence Nurs* **41**, 415-423; quiz E411-412 (2014). https://doi.org:10.1097/WON.0000000000000057

96 Lee, J., Taneja, V. & Vassallo, R. Cigarette smoking and inflammation: cellular and molecular mechanisms. *J Dent Res* **91**, 142-149 (2012). https://doi.org:10.1177/0022034511421200

97 Cheng, H., Chen, B. P., Soleas, I. M., Ferko, N. C., Cameron, C. G. & Hinoul, P. Prolonged Operative Duration Increases Risk of Surgical Site Infections: A Systematic Review. *Surg Infect (Larchmt)* **18**, 722-735 (2017). https://doi.org:10.1089/sur.2017.089

98 Li, T., Zhang, H., Chan, P. K., Fung, W. C., Fu, H. & Chiu, K. Y. Risk factors associated with surgical site infections following joint replacement surgery: a narrative review. *Arthroplasty* **4**, 11 (2022). https://doi.org:10.1186/s42836-022-00113-y

99 Stockschlader, L., Margaryan, D., Omran, S., Schomaker, M., Greiner, A. & Trampuz, A. Characteristics and Outcome of Vascular Graft Infections: A Risk Factor and Survival Analysis. *Open Forum Infect Dis* **11**, ofae271 (2024). https://doi.org:10.1093/ofid/ofae271

100 Christie, S., McGregor, M. & Krahn, A. D. Cardiac implantable electronic device infection. *Trends Cardiovasc Med* (2025). https://doi.org:10.1016/j.tcm.2025.02.001

101 Kirkham, A. M. *et al.* Risk Factors for Surgical Site Infection after Lower Limb Revascularisation Surgery: a Systematic Review and Meta-Analysis of Prognostic Studies. *Eur J Vasc Endovasc Surg* **67**, 455-467 (2024). https://doi.org:10.1016/j.ejvs.2023.10.038

102 Silvestri, M. *et al.* Modifiable and non-modifiable risk factors for surgical site infection after colorectal surgery: a single-center experience. *Surg Today* **48**, 338-345 (2018). https://doi.org:10.1007/s00595-017-1590-y

103 Florschutz, A. V., Fagan, R. P., Matar, W. Y., Sawyer, R. G. & Berrios-Torres, S. I. Surgical site infection risk factors and risk stratification. *J Am Acad Orthop Surg* **23 Suppl**, S8-S11 (2015). https://doi.org:10.5435/JAAOS-D-14-00447

104 Ralph, N. *et al.* Oral nutritional supplements for preventing surgical site infections: protocol for a systematic review and meta-analysis. *Syst Rev* **9**, 37 (2020). https://doi.org:10.1186/s13643-020-01293-x

105 Excellence, N. I. f. H. a. C. N. (NICE, 2019).

106 de Jonge, S. W., Gans, S. L., Atema, J. J., Solomkin, J. S., Dellinger, P. E. & Boermeester, M. A. Timing of preoperative antibiotic prophylaxis in 54,552 patients and the risk of surgical site infection: A systematic review and meta-analysis. *Medicine (Baltimore)* **96**, e6903 (2017). https://doi.org:10.1097/MD.0000000000006903

107 World Health Organization. *Global guidelines for the prevention of surgical site infection*. 2nd ed. edn, 184 p. (World Health Organization, 2018).

108 Vierra, M., Rouhani Ravari, M., Soleymani Sardoo, F. & Shogan, B. D. Tailored Pre-Operative Antibiotic Prophylaxis to Prevent Post-Operative Surgical Site Infections in General Surgery. *Antibiotics (Basel)* **13** (2024). https://doi.org:10.3390/antibiotics13010099

109 Michail, K., Tsitsi, T. & M., C. Effect of patient education on surgical site infection rates: a systematic review of the literature. *International Journal of Healthcare Management*, 1-10 (2024). https://doi.org:https://doi.org/10.1080/20479700.2024.2403893

110 Santos, A. *et al.* Povidone Iodine vs Chlorhexidine Gluconate for Preoperative Skin Antisepsis: A Systematic Review and Meta-analysis of Randomised Controlled Trials. *J Hosp Infect* (2024). https://doi.org:10.1016/j.jhin.2024.09.005

111 Pinkney, T. *ROSSINI II Trial - Reduction of Surgical Site Infection using several Novel Interventions. A multi-arm, multi-stage surgical RCT utilising an adaptive design*, 2016).

112 Tanner, J. & Melen, K. Preoperative hair removal to reduce surgical site infection. *Cochrane Database Syst Rev* **8**, CD004122 (2021). https://doi.org:10.1002/14651858.CD004122.pub5

113 NICE. *Surgical site infections: prevention and treatment*, <https://www.nice.org.uk/guidance/ng125/resources/surgical-site-infections-prevention-and-treatment-pdf-66141660564421> (2019).

114 Tanner, J., Dumville, J. C., Norman, G. & Fortnam, M. Surgical hand antisepsis to reduce surgical site infection. *Cochrane Database Syst Rev* **2016**, CD004288 (2016). https://doi.org:10.1002/14651858.CD004288.pub3

115 Aeschbacher, P., Nguyen, T. L., Dorn, P., Kocher, G. J. & Lutz, J. A. Surgical Site Infections Are Associated With Higher Blood Loss and Open Access in General Thoracic Practice. *Front Surg* **8**, 656249 (2021). https://doi.org:10.3389/fsurg.2021.656249

116 Kalish, J. A. *et al.* Factors associated with surgical site infection after lower extremity bypass in the Society for Vascular Surgery (SVS) Vascular Quality Initiative (VQI). *J Vasc Surg* **60**, 1238-1246 (2014). https://doi.org:10.1016/j.jvs.2014.05.012

117 Wang, X., Lin, Y., Yao, W., Zhang, A., Gao, L. & Feng, F. Surgical site infection in spinal surgery: a bibliometric analysis. *J Orthop Surg Res* **18**, 337 (2023). https://doi.org:10.1186/s13018-023-03813-6

118 Kouzu, K. *et al.* Association between skin suture devices and incidence of incisional surgical site infection after gastrointestinal surgery: systematic review and network meta-analysis. *J Hosp Infect* **150**, 134-144 (2024). https://doi.org:10.1016/j.jhin.2024.04.029

119 van de Kuit, A. *et al.* Surgical site infection after wound closure with staples versus sutures in elective knee and hip arthroplasty: a systematic review and meta-analysis. *Arthroplasty* **4**, 12 (2022). https://doi.org:10.1186/s42836-021-00110-7

120 Wilson, A. P. *et al.* Surgical wound infection as a performance indicator: agreement of common definitions of wound infection in 4773 patients. *Bmj* **329**, 720 (2004). https://doi.org:10.1136/bmj.38232.646227.DE

121 Wilson, A. P., Treasure, T., Sturridge, M. F. & Grüneberg, R. N. A scoring method (ASEPSIS) for postoperative wound infections for use in clinical trials of antibiotic prophylaxis. *Lancet* **1**, 311-313 (1986). https://doi.org:10.1016/s0140-6736(86)90838-x

122 Byrne, D. J., Malek, M. M., Davey, P. G. & Cuschieri, A. Postoperative wound scoring. *Biomedicine & pharmacotherapy = Biomédecine & pharmacothérapie* **43**, 669-673 (1989).

123 Campwala, I., Unsell, K. & Gupta, S. A Comparative Analysis of Surgical Wound Infection Methods: Predictive Values of the CDC, ASEPSIS, and Southampton

Scoring Systems in Evaluating Breast Reconstruction Surgical Site Infections. *Plast Surg (Oakv)* **27**, 93-99 (2019). https://doi.org:10.1177/2292550319826095

124 Macefield, R. C. *et al.* Development of a single, practical measure of surgical site infection (SSI) for patient report or observer completion. *J Infect Prev* **18**, 170-179 (2017). https://doi.org:10.1177/1757177416689724

125 M*acefie*ld R *et al.* Validation of the Bluebelle Wound Healing Questionnaire for assessment of surgical-site infection in closed primary wounds after hospital discharge. *Br J Surg* **106**, 226-235 (2019). https://doi.org:10.1002/bjs.11008

126 Field MJ. *Telemedicine: A Guide to Assessing Telecommunications for Health Care*. (National Academic Press, 1996).

127 Nesbitt, T. (2012).

128 Bashshur, R. L., Krupinski, E. A., Thrall, J. H. & Bashshur, N. The Empirical Foundations of Teleradiology and Related Applications: A Review of the Evidence. *Telemed J E Health* **22**, 868-898 (2016). https://doi.org:10.1089/tmj.2016.0149

129 Kruger, R. A. *et al.* Digital K-edge subtraction radiography. *Radiology* **125**, 243-245 (1977). https://doi.org:10.1148/125.1.243

130 Malasanos, T. H., Burlingame, J. A. & Muir, A. Advances in telemedicine in the 21st century. *Adv Pediatr* **51**, 131-169 (2004).

131 Bajwa, J., Munir, U., Nori, A. & Williams, B. Artificial intelligence in healthcare: transforming the practice of medicine. *Future Healthc J* **8**, e188-e194 (2021). https://doi.org:10.7861/fhj.2021-0095

132 Monaghesh, E. & Hajizadeh, A. The role of telehealth during COVID-19 outbreak: a systematic review based on current evidence. *BMC Public Health* **20**, 1193 (2020). https://doi.org:10.1186/s12889-020-09301-4

133 Shaver, J. The State of Telehealth Before and After the COVID-19 Pandemic. *Prim Care* **49**, 517-530 (2022). https://doi.org:10.1016/j.pop.2022.04.002

134 Mao, A. *et al.* Barriers to Telemedicine Video Visits for Older Adults in Independent Living Facilities: Mixed Methods Cross-sectional Needs Assessment. *JMIR Aging* **5**, e34326 (2022). https://doi.org:10.2196/34326

135 Wardlow, L., Roberts, C. & Archbald-Pannone, L. Perceptions and Uses of Telehealth in the Care of Older Adults. *Telemed J E Health* **29**, 1143-1151 (2023). https://doi.org:10.1089/tmj.2022.0378

136 Heponiemi, T., Kaihlanen, A. M., Kouvonen, A., Leemann, L., Taipale, S. & Gluschkoff, K. The role of age and digital competence on the use of online health and social care services: A cross-sectional population-based survey. *Digit Health* **8**, 20552076221074485 (2022). https://doi.org:10.1177/20552076221074485

137 Tong, L. *et al.* Telemedicine and health disparities: Association between patient characteristics and telemedicine, in-person, telephone and message-based care during the COVID-19 pandemic. *IPEM Transl* **3**, 100010 (2022). https://doi.org:10.1016/j.ipemt.2022.100010

138 Lee, C. *et al.* Educational attainment and willingness to use technology for health and to share health information - The reimagining healthcare survey. *International Journal of Medical Informatics* **164** (2022).

139 Darrat, I., Tam, S., Boulis, M. & Williams, A. M. Socioeconomic Disparities in Patient Use of Telehealth During the Coronavirus Disease 2019 Surge. *JAMA Otolaryngol Head Neck Surg* **147**, 287-295 (2021). https://doi.org:10.1001/jamaoto.2020.5161

140 Salisbury, C. *et al.* TElehealth in CHronic disease: mixed-methods study to develop the TECH conceptual model for intervention design and evaluation. *BMJ Open* **5**, e006448 (2015). https://doi.org:10.1136/bmjopen-2014-006448

141 Al Shamsi, H., Almutairi, A. G., Al Mashrafi, S. & Al Kalbani, T. Implications of Language Barriers for Healthcare: A Systematic Review. *Oman Med J* **35**, e122 (2020). https://doi.org:10.5001/omj.2020.40

142 Barwise, A. K., Curtis, S., Diedrich, D. A. & Pickering, B. W. Using artificial intelligence to promote equitable care for inpatients with language barriers and complex medical needs: clinical stakeholder perspectives. *J Am Med Inform Assoc* **31**, 611-621 (2024). https://doi.org:10.1093/jamia/ocad224

143 Moulaei, K., Sheikhtaheri, A., Fatehi, F., Shanbehzadeh, M. & Bahaadinbeigy, K. Patients' perspectives and preferences toward telemedicine versus in-person visits: a mixed-methods study on 1226 patients. *BMC Med Inform Decis Mak* **23**, 261 (2023). https://doi.org:10.1186/s12911-023-02348-4

144 Walley, D. *et al.* Use of telemedicine in general practice in Europe since the COVID-19 pandemic: A scoping review of patient and practitioner perspectives. *PLOS Digit Health* **3**, e0000427 (2024). https://doi.org:10.1371/journal.pdig.0000427

145 Khairat, S., Chourasia, P., Muellers, K. A., Andreadis, K., Lin, J. J. & Ancker, J. S. Patient and Provider Recommendations for Improved Telemedicine User Experience in Primary Care: A Multi-Center Qualitative Study. *Telemed Rep* **4**, 21-29 (2023). https://doi.org:10.1089/tmr.2023.0002

146 Sauers-Ford, H. S. *et al.* Acceptability, Usability, and Effectiveness: A Qualitative Study Evaluating a Pediatric Telemedicine Program. *Acad Emerg Med* **26**, 1022-1033 (2019). https://doi.org:10.1111/acem.13763

147 Garg, V. & Brewer, J. Telemedicine security: a systematic review. *J Diabetes Sci Technol* **5**, 768-777 (2011). https://doi.org:10.1177/193229681100500331

148 Lindenfeld, Z. *et al.* Synchronous Home-Based Telemedicine for Primary Care: A Review. *Med Care Res Rev* **80**, 3-15 (2023). https://doi.org:10.1177/10775587221093043

149 Mechanic, O. J., Persaud, Y. & Kimball, A. B. in *StatPearls* (2025).

150 Deshpande, A. *et al.* Asynchronous telehealth: a scoping review of analytic studies. *Open Med* **3**, e69-91 (2009).

151 McLean, K. A. *et al.* Remote diagnosis of surgical-site infection using a mobile digital intervention: a randomised controlled trial in emergency surgery patients. *npj Digital Medicine* **4**, 160 (2021). https://doi.org:10.1038/s41746-021-00526-0

152 Totty, J. P., Harwood, A. E., Wallace, T., Smith, G. E. & Chetter, I. C. Use of photograph-based telemedicine in postoperative wound assessment to diagnose or exclude surgical site infection. *J Wound Care* **27**, 128-135 (2018). https://doi.org:10.12968/jowc.2018.27.3.128

153 Taylor, E. W. *et al.* Telephone call contact for post-discharge surveillance of surgical site infections. A pilot, methodological study. *J Hosp Infect* **55**, 8-13 (2003). https://doi.org:10.1016/s0195-6701(03)00217-2

154 Hughes, C. M. L., Jeffers, A., Sethuraman, A., Klum, M., Tan, M. & Tan, V. The detection and prediction of surgical site infections using multi-modal sensors and machine learning: Results in an animal model. *Front Med Technol* **5**, 1111859 (2023). https://doi.org:10.3389/fmedt.2023.1111859

155 National Wound Care Strategy Programme. Recommenations for the Use of Digital Images in Wound Care. (2021).

156 Rodriguez-Jimenez, L., Romero-Martin, M., Spruell, T., Steley, Z. & Gomez-Salgado, J. The carbon footprint of healthcare settings: A systematic review. *J Adv Nurs* **79**, 2830-2844 (2023). https://doi.org:10.1111/jan.15671

157 Tennison, I. *et al.* Health care's response to climate change: a carbon footprint assessment of the NHS in England. *Lancet Planet Health* **5**, e84-e92 (2021). https://doi.org:10.1016/s2542-5196(20)30271-0

158 NHS England. *Greening the business case*, <https://www.england.nhs.uk/long-read/greening-the-business-case/> (2023).

159 NHS England. *NHS clinical waste strategy*, <https://www.england.nhs.uk/long-read/nhs-clinical-waste-strategy/> (2023).

160 NHS Supply Chain. *A Net Zero Supply Chain and Suppliers*, <https://www.supplychain.nhs.uk/programmes/sustainability/net-zero-supply-chain-and-suppliers/> (2023).

161 Brighton & Sussex Medical School. Green surger: Reducing the environmental impact of surgical care., (UK Health Alliance on Climate Change, Centre for Sustainable Healthcare, 2023).

162 Metzke R. *Here's how healthcare can reduce it's carbon footprint*, <https://www.weforum.org/stories/2022/10/cop27-how-healthcare-can-reduce-carbon-footprint/> (2022).

163 Bressler, R. D. The mortality cost of carbon. *Nat Commun* **12**, 4467 (2021). https://doi.org:10.1038/s41467-021-24487-w

164 Rivera A, Movalia S, Pitt H & Larsen K. *Preliminary 2020 Global Greenhouse Gas Emissions Estimates*, <https://rhg.com/research/preliminary-2020-global-greenhouse-gas-emissions-estimates/> (2021).

165 World Health Organisation. *Heat and Health*, <https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health> (2024).

166 Romanello, M. *et al.* The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms. *Lancet* **402**, 2346-2394 (2023). https://doi.org:10.1016/S0140-6736(23)01859-7

167 International Panel on Climate Change. Global Warming of 1.5 degrees. (IPCC, 2018).

168 Ebi, K. L. *et al.* Extreme Weather and Climate Change: Population Health and Health System Implications. *Annu Rev Public Health* **42**, 293-315 (2021). https://doi.org:10.1146/annurev-publhealth-012420-105026

169 Pinho-Gomes, A. C. *et al.* Air pollution and climate change. *Lancet Planet Health* **7**, e727-e728 (2023). https://doi.org:10.1016/S2542-5196(23)00189-4

170 World Health Organisation. *Air quality, energy and health*, <https://www.who.int/teams/environment-climate-change-and-health/air-quality-energy-and-health/health-impacts#:~:text=Air%20pollution%20is%20a%20risk,(household%20air%20pollution%20only).> (2025).

171 Lee, K. K., Miller, M. R. & Shah, A. S. V. Air Pollution and Stroke. *J Stroke* **20**, 2-11 (2018). https://doi.org:10.5853/jos.2017.02894

172 Montone, R. A. *et al.* Impact of air pollution on ischemic heart disease: Evidence, mechanisms, clinical perspectives. *Atherosclerosis* **366**, 22-31 (2023). https://doi.org:10.1016/j.atherosclerosis.2023.01.013

173 Wang, L., Xie, J., Hu, Y. & Tian, Y. Air pollution and risk of chronic obstructed pulmonary disease: The modifying effect of genetic susceptibility and lifestyle. *EBioMedicine* **79**, 103994 (2022). https://doi.org:10.1016/j.ebiom.2022.103994

174 Hill, W. *et al.* Lung adenocarcinoma promotion by air pollutants. *Nature* **616**, 159-167 (2023). https://doi.org:10.1038/s41586-023-05874-3

175 Rocklov, J. & Dubrow, R. Climate change: an enduring challenge for vector-borne disease prevention and control. *Nat Immunol* **21**, 479-483 (2020). https://doi.org:10.1038/s41590-020-0648-y

176 Liu-Helmersson, J., Stenlund, H., Wilder-Smith, A. & Rocklov, J. Vectorial capacity of Aedes aegypti: effects of temperature and implications for global dengue epidemic potential. *PLoS One* **9**, e89783 (2014). https://doi.org:10.1371/journal.pone.0089783

177 UK Health Security Agency. *How does climate change threaten our health? From flooding to wildfires*, <https://ukhsa.blog.gov.uk/2023/12/11/11-things-to-know-about-the-health-effects-of-climate-change-report/#:~:text=Rising%20temperatures%20and%20changing%20weather,%2C%20campylobacter%2C%20and%20Vibrio%20spp.> (2023).

178 Levy, K., Smith, S. M. & Carlton, E. J. Climate Change Impacts on Waterborne Diseases: Moving Toward Designing Interventions. *Curr Environ Health Rep* **5**, 272-282 (2018). https://doi.org:10.1007/s40572-018-0199-7

179 Curriero, F. C., Patz, J. A., Rose, J. B. & Lele, S. The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948-1994. *Am J Public Health* **91**, 1194-1199 (2001). https://doi.org:10.2105/ajph.91.8.1194

180 Thomas, K. M., Charron, D. F., Waltner-Toews, D., Schuster, C., Maarouf, A. R. & Holt, J. D. A role of high impact weather events in waterborne disease outbreaks in Canada, 1975 - 2001. *Int J Environ Health Res* **16**, 167-180 (2006). https://doi.org:10.1080/09603120600641326

181 Saunders, J. & Smith, T. Malnutrition: causes and consequences. *Clin Med (Lond)* **10**, 624-627 (2010). https://doi.org:10.7861/clinmedicine.10-6-624

182 Wing IS, De Cian E & Mistry MN. Global vulnerability of crop yields to climate change. *Journal of Environmental Economics and Management* **109** (2021). https://doi.org:https://doi.org/10.1016/j.jeem.2021.102462

183 Thiel, C. L. *et al.* Telemedicine and the environment: life cycle environmental emissions from in-person and virtual clinic visits. *NPJ Digit Med* **6**, 87 (2023). https://doi.org:10.1038/s41746-023-00818-7
184 Purohit, A., Smith, J. & Hibble, A. Does telemedicine reduce the carbon footprint of healthcare? A systematic review. *Future Healthc J* **8**, e85-e91 (2021). https://doi.org:10.7861/fhj.2020-0080
185 Ravindrane, R. & Patel, J. The environmental impacts of telemedicine in place of face-to-face patient care: a systematic review. *Future Healthc J* **9**, 28-33 (2022). https://doi.org:10.7861/fhj.2021-0148
186 Denham, L. D. o. Independent investigation of the Nationa Health Service in England. (GOV.UK, 2024).
187 Barnes, R., Souroullas, P. & Chetter, I. C. A survey of perioperative management of major lower limb amputations: current UK practice. *Ann Vasc Surg* **28**, 1737-1743 (2014). https://doi.org:10.1016/j.avsg.2014.06.055
188 Berríos-Torres, S. I. *et al.* Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017. *JAMA Surgery* **152**, 784-791 (2017). https://doi.org:10.1001/jamasurg.2017.0904
189 Berríos-Torres SI, Umscheid CA & DW, B. Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017. *JAMA Surgery* **152**, 784-791 (2017). https://doi.org:10.1001/jamasurg.2017.0904
190 Organization, W. H. (2018).
191 VSQIP. Surgical Site Infection Rates Reported on the NVR. (2020).
192 Inui, T. & Bandyk, D. F. Vascular surgical site infection: risk factors and preventive measures. *Semin Vasc Surg* **28**, 201-207 (2015). https://doi.org:10.1053/j.semvascsurg.2016.02.002
193 Mekako, A. I., Chetter, I. C., Coughlin, P. A., Hatfield, J. & McCollum, P. T. Randomized clinical trial of co-amoxiclav versus no antibiotic prophylaxis in varicose vein surgery. *Br J Surg* **97**, 29-36 (2010). https://doi.org:10.1002/bjs.6849
194 Maiwald, M. & Chan, E. S. The forgotten role of alcohol: a systematic review and meta-analysis of the clinical efficacy and perceived role of chlorhexidine in skin antisepsis. *PLoS One* **7**, e44277 (2012). https://doi.org:10.1371/journal.pone.0044277
195 Ademuyiwa AO, Hardy P & A, B. Reducing surgical site infections in low and middle income countries: a pragmatic, multicentre, stratified, randomised controlled trial (FALCON). *Lancet* **398**, 1687-1699 (2021).
196 Ahmed, I. *et al.* The use of triclosan-coated sutures to prevent surgical site infections: a systematic review and meta-analysis of the literature. *BMJ Open* **9**, e029727 (2019). https://doi.org:10.1136/bmjopen-2019-029727
197 Singh, A., Bartsch, S. M., Muder, R. R. & Lee, B. Y. An economic model: value of antimicrobial-coated sutures to society, hospitals, and third-party payers in preventing abdominal surgical site infections. *Infect Control Hosp Epidemiol* **35**, 1013-1020 (2014). https://doi.org:10.1086/677163
198 Matatov, T., Reddy, K. N., Doucet, L. D., Zhao, C. X. & Zhang, W. W. Experience with a new negative pressure incision management system in prevention of groin wound infection in vascular surgery patients. *J Vasc Surg* **57**, 791-795 (2013). https://doi.org:10.1016/j.jvs.2012.09.037

199 Bradbury, A. W. *et al.* Bypass versus Angioplasty in Severe Ischaemia of the Leg (BASIL) trial: An intention-to-treat analysis of amputation-free and overall survival in patients randomized to a bypass surgery-first or a balloon angioplasty-first revascularization strategy. *J Vasc Surg* **51**, 5s-17s (2010). https://doi.org:10.1016/j.jvs.2010.01.073

200 Souroullas, P., Barnes, R., Carradice, D., Smith, G., Huang, C. & Chetter, I. Extended-course antibiotic prophylaxis in lower limb amputation: randomized clinical trial. *Br J Surg* **109**, 426-432 (2022). https://doi.org:10.1093/bjs/znac053

201 Totty JP *et al.* The impact of surgical site infection on hospitalisation, treatment costs, and health-related quality of life after vascular surgery. *International Wound Journal* **18**, 261-268 (2020). https://doi.org:10.1111/iwj.13526

202 Meara, J. G. *et al.* Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Int J Obstet Anesth* **25**, 75-78 (2016). https://doi.org:10.1016/j.ijoa.2015.09.006

203 Berríos-Torres SI, U. C., Bratzler DW, Leas B, Stone EC, Kelz RR, et al. Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017. **152** (2017).

204 Lathan R, Y. M., Long J, Mohamed A, Hitchman L, Ravindhran B, et al. A survey of surgical site infection prevention practice in UK vascular surgery. **1** (2022).

205 Long J, Lathan R, Sidapra M, Gronlund T, Chetter IC & Group, O. b. o. t. V. S. o. G. B. a. I. W. S. I. Research priorities for vascular wounds: results of the Vascular Society GBI/James Lind Alliance Priority Setting Process. *Journal of Vascular Societies Great Britain and Ireland* **1**, 110-116 (2022). https://doi.org:http://doi.org/10.54522/jvsgbi.2022.027

206 Sharma A, M. D. N., Luu Lam Thang T, et al. A Consensus-Based Checklist for Reporting of Survey Studies (CROSS). **36**

207 Eysenbach, G. Improving the quality of Web surveys: the Checklist for Reporting Results of Internet E-Surveys (CHERRIES). *J Med Internet Res* **6**, e34 (2004). https://doi.org:10.2196/jmir.6.3.e34

208 Heinz, J. *et al.* PRESS survey: PREvention of surgical site infection-a global pan-specialty survey of practice protocol. *Front Surg* **10**, 1251444 (2023). https://doi.org:10.3389/fsurg.2023.1251444

209 Holmer, H. *et al.* Global distribution of surgeons, anaesthesiologists, and obstetricians. *Lancet Glob Health* **3 Suppl 2**, S9-11 (2015). https://doi.org:10.1016/S2214-109X(14)70349-3

210 Younis I, D. F., Edwards J, et al. Post-operative wound care: reducing the risk of surgical site infection. (2020).

211 Lathan R *et al.* A survey of surigical site infection prevention practice in UK vascular surgery. *Journal of vascular societies Great Britain and Ireland* **Online ahead of publication** (2022). https://doi.org:http://doi.org/10.54522/jvsgbi.2022.030

212 Jalalzadeh, H. *et al.* Efficacy of different preoperative skin antiseptics on the incidence of surgical site infections: a systematic review, GRADE assessment, and network meta-analysis. *Lancet Microbe* **3**, e762-e771 (2022). https://doi.org:10.1016/S2666-5247(22)00187-2

213 Blonna, D. *et al.* Single versus Double Skin Preparation for Infection Prevention in Proximal Humeral Fracture Surgery. *Biomed Res Int* **2018**, 8509527 (2018). https://doi.org:10.1155/2018/8509527

214 Sworn, K. *et al.* Effectiveness of iodine-impregnated incise drapes for preventing surgical site infection in patients with clean or clean contaminated wounds: A systematic literature review and cost-consequence analysis. *J Perioper Pract* **33**, 368-379 (2023). https://doi.org:10.1177/17504589221139603

215 ClinicalTrials.gov. *ROSSINI 2 - Reduction of Surgical Site Infection Using Several Novel Interventions*, <https://clinicaltrials.gov/study/NCT03838575> (2023).

216 Surgery, N. G. R. H. U. o. G. Routine sterile glove and instrument change at the time of abdominal wound closure to prevent surgical site infection (ChEETAh): a pragmatic, cluster-randomised trial in seven low-income and middle-income countries. *Lancet* **400**, 1767-1776 (2022). https://doi.org:10.1016/S0140-6736(22)01884-0

217 Surgery, N. G. H. R. U. o. G. Routine sterile glove and instrument change at the time of abdominal wound closure to prevent surgical site infection (ChEETAh): a model-based cost-effectiveness analysis of a pragmatic, cluster-randomised trial in seven low-income and middle-income countries. *Lancet Glob Health* **12**, e235-e242 (2024). https://doi.org:10.1016/S2214-109X(23)00538-7

218 NICE. Plus sutures for prevention surgical site infection: medical technologies guidance 59. (National Institute for Health and Care Excellence, 2021).

219 de Jonge, S. W. *et al.* Effect of postoperative continuation of antibiotic prophylaxis on the incidence of surgical site infection: a systematic review and meta-analysis. *Lancet Infect Dis* **20**, 1182-1192 (2020). https://doi.org:10.1016/S1473-3099(20)30084-0

220 Crothers, H. *et al.* Outcomes for surgical procedures funded by the English health service but carried out in public versus independent hospitals: a database study. *BMJ Quality & Safety*, bmjqs-2021-013522 (2021). https://doi.org:10.1136/bmjqs-2021-013522

221 Woelber E, Schrick EJ, Gessner BD & Evans HL. Proportion of Surgical Site Infections Occuring after Hospital Discharge: A Systematic Review. *Surgical Infections* **17** (2016). https://doi.org:10.1089/sur.2015.241

222 Lodise, T. P., McKinnon, P. S., Swiderski, L. & Rybak, M. J. Outcomes analysis of delayed antibiotic treatment for hospital-acquired Staphylococcus aureus bacteremia. *Clin Infect Dis* **36**, 1418-1423 (2003). https://doi.org:10.1086/375057

223 Owens, P. L., Barrett, M. L., Raetzman, S., Maggard-Gibbons, M. & Steiner, C. A. Surgical site infections following ambulatory surgery procedures. *Jama* **311**, 709-716 (2014). https://doi.org:10.1001/jama.2014.4

224 Finkelstein, S. M. *et al.* Development of a remote monitoring satisfaction survey and its use in a clinical trial with lung transplant recipients. *J Telemed Telecare* **18**, 42-46 (2012). https://doi.org:10.1258/jtt.2011.110413

225 Gunter, R. L. *et al.* Current Use of Telemedicine for Post-Discharge Surgical Care: A Systematic Review. *J Am Coll Surg* **222**, 915-927 (2016). https://doi.org:10.1016/j.jamcollsurg.2016.01.062

226 Urquhart, A. C., Antoniotti, N. M. & Berg, R. L. Telemedicine--an efficient and cost-effective approach in parathyroid surgery. *Laryngoscope* **121**, 1422-1425 (2011). https://doi.org:10.1002/lary.21812

227 McGillicuddy, J. W. *et al.* Mobile Health Medication Adherence and Blood Pressure Control in Renal Transplant Recipients: A Proof-of-Concept Randomized Controlled Trial. *JMIR Res Protoc* **2**, e32 (2013). https://doi.org:10.2196/resprot.2633

228 Wiseman, J. T., Fernandes-Taylor, S., Barnes, M. L., Tomsejova, A., Saunders, R. S. & Kent, K. C. Conceptualizing smartphone use in outpatient wound assessment: patients' and caregivers' willingness to use technology. *J Surg Res* **198**, 245-251 (2015). https://doi.org:10.1016/j.jss.2015.05.011

229 Sanger, P. C. *et al.* Patient perspectives on post-discharge surgical site infections: towards a patient-centered mobile health solution. *PLoS One* **9**, e114016 (2014). https://doi.org:10.1371/journal.pone.0114016

230 NHS. *Delivering a 'Net Zero' National Health Service*, <https://www.england.nhs.uk/greenernhs/wp-content/uploads/sites/51/2020/10/delivering-a-net-zero-national-health-service.pdf> (2020).

231 Irarrázaval, M. J. *et al.* Telemedicine for postoperative follow-up, virtual surgical clinics during COVID-19 pandemic. *Surg Endosc* **35**, 6300-6306 (2021). https://doi.org:10.1007/s00464-020-08130-1

232 *Centres for Disease Control and Prevention (CDC). Surgical Site Infection (SSI) Event*, <https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf> (2017).

233 Moher, D. *et al.* Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews* **4**, 1 (2015). https://doi.org:10.1186/2046-4053-4-1

234 Deeks J, B. P., Leeflang M, Takwoingi Y, Flemyng E, Mellor L. *Cochrane Handbook for Systematic Reviews of Diagnostic Test Accuracy*, <https://training.cochrane.org/handbook-diagnostic-test-accuracy/PDF/v2> (2021).

235 McInnes, M. D. F. *et al.* Preferred Reporting Items for a Systematic Review and Meta-analysis of Diagnostic Test Accuracy Studies: The PRISMA-DTA Statement. *Jama* **319**, 388-396 (2018). https://doi.org:10.1001/jama.2017.19163

236 Lathan R, Sidapra M, Yiasemidou M, Totty J, Smith G & I, C. *Telemedicine for surgical site infection: a systematic review.* , <https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42021290610> (2021).

237 Horan, T. C., Gaynes, R. P., Martone, W. J., Jarvis, W. R. & Emori, T. G. CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. *Infect Control Hosp Epidemiol* **13**, 606-608 (1992).

238 Ouzzani, M., Hammady, H., Fedorowicz, Z. & Elmagarmid, A. Rayyan—a web and mobile app for systematic reviews. *Systematic Reviews* **5**, 210 (2016). https://doi.org:10.1186/s13643-016-0384-4

239 Whiting, P. F. *et al.* QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. *Ann Intern Med* **155**, 529-536 (2011). https://doi.org:10.7326/0003-4819-155-8-201110180-00009

240 Freeman, S. C., Kerby, C. R., Patel, A., Cooper, N. J., Quinn, T. & Sutton, A. J. Development of an interactive web-based tool to conduct and interrogate meta-analysis of diagnostic test accuracy studies: MetaDTA. *BMC Medical Research Methodology* **19**, 81 (2019). https://doi.org:10.1186/s12874-019-0724-x

241 Review Manager (RevMan). Version 5.4 (The Cochrane Collaboration, 2020).

242 Abu-Sheasha, G. A., Bedwani, R. N., Anwar, M. M. & Yassine, O. G. Cost-effectiveness analysis of three methods of surgical-site infection surveillance: Less is more. *Am J Infect Control* **48**, 1220-1224 (2020). https://doi.org:10.1016/j.ajic.2019.12.022

243 Aiken, A. M. *et al.* Evaluation of surveillance for surgical site infections in Thika Hospital, Kenya. *J Hosp Infect* **83**, 140-145 (2013). https://doi.org:10.1016/j.jhin.2012.11.003

244 Validation of the Bluebelle Wound Healing Questionnaire for assessment of surgical-site infection in closed primary wounds after hospital discharge. *Br J Surg* **106**, 226-235 (2019). https://doi.org:10.1002/bjs.11008

245 Costa, M. L. *et al.* Effect of Incisional Negative Pressure Wound Therapy vs Standard Wound Dressing on Deep Surgical Site Infection After Surgery for Lower Limb Fractures Associated With Major Trauma: The WHIST Randomized Clinical Trial. *Jama* **323**, 519-526 (2020). https://doi.org:10.1001/jama.2020.0059

246 Cherian, T. *et al.* Diagnosing Post-Cesarean Surgical Site Infections in Rural Rwanda: Development, Validation, and Field Testing of a Screening Algorithm for Use by Community Health Workers. *Surg Infect (Larchmt)* **21**, 613-620 (2020). https://doi.org:10.1089/sur.2020.062

247 Gunter, R. L. *et al.* Feasibility of an Image-Based Mobile Health Protocol for Postoperative Wound Monitoring. *J Am Coll Surg* **226**, 277-286 (2018). https://doi.org:10.1016/j.jamcollsurg.2017.12.013

248 Hedrick, T. L. *et al.* Defining Surgical Site Infection in Colorectal Surgery: An Objective Analysis Using Serial Photographic Documentation. *Dis Colon Rectum* **58**, 1070-1077 (2015). https://doi.org:10.1097/dcr.0000000000000466

249 Mitchell, D. H., Swift, G. & Gilbert, G. L. Surgical wound infection surveillance: the importance of infections that develop after hospital discharge. *Aust N Z J Surg* **69**, 117-120 (1999). https://doi.org:10.1046/j.1440-1622.1999.01500.x

250 Nguhuni, B. *et al.* Reliability and validity of using telephone calls for post-discharge surveillance of surgical site infection following caesarean section at a tertiary hospital in Tanzania. *Antimicrob Resist Infect Control* **6**, 43 (2017). https://doi.org:10.1186/s13756-017-0205-0

251 Pathak, A., Sharma, S., Sharma, M., Mahadik, V. K. & Lundborg, C. S. Feasibility of a Mobile Phone-Based Surveillance for Surgical Site Infections in Rural India. *Telemed J E Health* **21**, 946-949 (2015). https://doi.org:10.1089/tmj.2014.0199

252 Pham, J. C., Ashton, M. J., Kimata, C., Lin, D. M. & Nakamoto, B. K. Surgical site infection: comparing surgeon versus patient self-report. *J Surg Res* **202**, 95-102 (2016). https://doi.org:10.1016/j.jss.2015.12.039

253 Reilly, J. *et al.* A study of telephone screening and direct observation of surgical wound infections after discharge from hospital. *The Journal of Bone and Joint Surgery. British volume* **87-B**, 997-999 (2005). https://doi.org:10.1302/0301-620X.87B7.16061

254 Richter, V., Cohen, M. J., Benenson, S., Almogy, G. & Brezis, M. Patient Self-Assessment of Surgical Site Infection is Inaccurate. *World J Surg* **41**, 1935-1942 (2017). https://doi.org:10.1007/s00268-017-3974-y

255 Sands, K., Vineyard, G. & Platt, R. Surgical site infections occurring after hospital discharge. *J Infect Dis* **173**, 963-970 (1996). https://doi.org:10.1093/infdis/173.4.963

256 Halwani, M. A., Turnbull, A. E., Harris, M., Witter, F. & Perl, T. M. Postdischarge surveillance for infection following cesarean section: A prospective cohort study comparing methodologies. *Am J Infect Control* **44**, 455-457 (2016). https://doi.org:10.1016/j.ajic.2015.10.023

257 Mousa, A. Y., Broce, M., Monnett, S., Davis, E., McKee, B. & Lucas, B. D. Results of Telehealth Electronic Monitoring for Post Discharge Complications and Surgical Site Infections following Arterial Revascularization with Groin Incision. *Ann Vasc Surg* **57**, 160-169 (2019). https://doi.org:10.1016/j.avsg.2018.09.023

258 Zhang, J., Mihai, C., Tüshaus, L., Scebba, G., Distler, O. & Karlen, W. Wound Image Quality From a Mobile Health Tool for Home-Based Chronic Wound Management With Real-Time Quality Feedback: Randomized Feasibility Study. *JMIR Mhealth Uhealth* **9**, e26149 (2021). https://doi.org:10.2196/26149

259 Wilson, J. Preventing surgical site infection: The challenge of 'getting it right first time'. *J Infect Prev* **18**, 164-166 (2017). https://doi.org:10.1177/1757177417714044

260 Singh, S., Davies, J., Sabou, S., Shrivastava, R. & Reddy, S. Challenges in reporting surgical site infections to the national surgical site infection surveillance and suggestions for improvement. *Ann R Coll Surg Engl* **97**, 460-465 (2015). https://doi.org:10.1308/rcsann.2015.0027

261 NHS. (2020).

262 Bloomfield, P. S., Clutton-Brock, P., Pencheon, E., Magnusson, J. & Karpathakis, K. Artificial Intelligence in the NHS: Climate and Emissions☆,☆☆. *The Journal of Climate Change and Health* **4**, 100056 (2021). https://doi.org:https://doi.org/10.1016/j.joclim.2021.100056

263 Savji, N. *et al.* Association between advanced age and vascular disease in different arterial territories: a population database of over 3.6 million subjects. *J Am Coll Cardiol* **61**, 1736-1743 (2013). https://doi.org:10.1016/j.jacc.2013.01.054

264 Lam, K., Lu, A. D., Shi, Y. & Covinsky, K. E. Assessing Telemedicine Unreadiness Among Older Adults in the United States During the COVID-19 Pandemic. *JAMA Internal Medicine* **180**, 1389-1391 (2020). https://doi.org:10.1001/jamainternmed.2020.2671

265 Elbaz, S. *et al.* A Systematic Review of Telemedicine for Older Adults With Dementia During COVID-19: An Alternative to In-person Health Services? *Frontiers in Neurology* **12** (2021). https://doi.org:10.3389/fneur.2021.761965
266 Dobbs, T. D. *et al.* Surgical activity in England and Wales during the COVID-19 pandemic: a nationwide observational cohort study. *Br J Anaesth* **127**, 196-204 (2021). https://doi.org:10.1016/j.bja.2021.05.001
267 Rochon, M., Jawarchan, A., Fagan, F., Otter, J. A. & Tanner, J. Image-based digital post-discharge surveillance in England: measuring patient enrolment, engagement, clinician response times, surgical site infection, and carbon footprint. *J Hosp Infect* **133**, 15-22 (2023). https://doi.org:10.1016/j.jhin.2023.01.001
268 Lathan, R. *et al.* Telemedicine for sustainable postoperative follow-up: a prospective pilot study evaluating the hybrid life-cycle assessment approach to carbon footprint analysis. *Frontiers in Surgery* **11** (2024). https://doi.org:10.3389/fsurg.2024.1300625
269 Lathan R *et al.* Diagnostic accuracy of telemedicine for detection of surgical site infection: a systematic review and meta-analysis. *NPJ Digit Med* **5**, 108 (2022). https://doi.org:10.1038/s41746-022-00655-0
270 Centres for Disease Control and Prevention (CDC). *Surgical Site Infection (SSI) Event*, <https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf> (2017).
271 Mokkink LB *et al.* COSMIN Study Design checklist for Patient-reported outcome measurement instruments. *COSMIN* (2019). <https://www.cosmin.nl/>.
272 Association, W. M. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA* **310**, 2191-2194 (2013). https://doi.org:10.1001/jama.2013.281053
273 de Vet HCW, Terwee CB, Mokkink LB & DL., K. *Measurement in Medicine: a Practical Guide*. (Cambridge University Press: New York, 2011).
274 Hu, L. & Bentler, P. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Structural Equation Modelling* **6**, 1-55 (1999).
275 Taber, K. The use of cronbach's alpha when developing and reporting research instruments in science education. *Res Sci Educ* **48**, 1273-1296 (2018).
276 Macefield RC *et al.* Development of a single, practical measure of surgical site infection (SSI) for patient report or observer completion. *J Infect Prev* **18**, 170-179 (2017).
277 UK Health Security Agency. Protocol for the Surveillance of Surgical Site Infection. (2013).
278 Bossuyt, P. M. *et al.* STARD 2015: an updated list of essential items for reporting diagnostic accuracy studies. *BMJ* **351**, h5527 (2015). https://doi.org:10.1136/bmj.h5527
279 Collins, G. S., Reitsma, J. B., Altman, D. G. & Moons, K. G. Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD): the TRIPOD Statement. *Br J Surg* **102**, 148-158 (2015). https://doi.org:10.1002/bjs.9736

280 Blackman, N. J. Systematic reviews of evaluations of diagnostic and screening tests. Odds ratio is not independent of prevalence. *BMJ* **323**, 1188 (2001).
281 Simundic, A. M. Measures of Diagnostic Accuracy: Basic Definitions. *EJIFCC* **19**, 203-211 (2009).
282 Mandrekar, J. N. Receiver operating characteristic curve in diagnostic test assessment. *J Thorac Oncol* **5**, 1315-1316 (2010). https://doi.org:10.1097/JTO.0b013e3181ec173d
283 Totty JP *et al.* A pilot feasibility randomised clinical trial comparing dialkylcarbamoylchloride-coated dressings versus standard care for the primary prevention of surgical site infection. *International Wound Journal* **16**, 883-890 (2019). https://doi.org:10.1111/iwj.13113
284 Lathan R *et al.* ASSIST: Development of a Simplified Clinician-Patient Hybrid Reporting Outcome Measure for Remote Diagnosis of Surgical Site Infection. *International Wound Journal* ***in press*** (2025). https://doi.org:10.1111/iwj.70234
285 Macefield, R. *et al.* Validation of the Bluebelle Wound Healing Questionnaire for assessment of surgical-site infection in closed primary wounds after hospital discharge. *British Journal of Surgery* **106**, 226-235 (2019).
286 Rochon M *et al.* Post-discharge surgical site infection surveillance using patient smartphones: a single-centre experience in cardiac surgery. *British Journal of Cardiac Nursing* **19** (2024). https://doi.org:https://doi.org/10.12968/bjca.2023.0099
287 Purba, A. K. R. *et al.* The Impacts of Deep Surgical Site Infections on Readmissions, Length of Stay, and Costs: A Matched Case-Control Study Conducted in an Academic Hospital in the Netherlands. *Infect Drug Resist* **13**, 3365-3374 (2020). https://doi.org:10.2147/IDR.S264068
288 Tanner, J., Khan, D., Aplin, C., Ball, J., Thomas, M. & Bankart, J. Post-discharge surveillance to identify colorectal surgical site infection rates and related costs. *J Hosp Infect* **72**, 243-250 (2009). https://doi.org:10.1016/j.jhin.2009.03.021
289 International Organisation for Standardisation. ISO 14064: Specification with guidance at the organisation level for quantification and reporting of greenhouse gas emissions and removals., 47 (ISO, 2018).
290 Department for Environment Food and Rural Affairs. *Emission Factors Toolkit v11.0*, <https://laqm.defra.gov.uk/air-quality/air-quality-assessment/emissions-factors-toolkit/> (2021).
291 National Health Service. *NHS Supply Chain Online Catalogue*, <https://www.supplychain.nhs.uk/> (2023).
292 Jones K *et al.* Unit Costs of Health and Social Care 2022. *Personal Social Services Research Unit* (2022).
293 Sustainable Development Unit. *Sustainability Reporting Template*, <http://www.sduhealth.org.uk/delivery/measure/reporting.aspx> (2019).
294 National Institute for Health and Care Research. *Interactive Costing Tool 2022/2023*, <https://www.nihr.ac.uk/documents/interactive-costing-tool-ict-getting-started/12170> (2023).

295 McAlister, S. *et al.* The carbon footprint of hospital diagnostic imaging in Australia. *Lancet Reg Health West Pac* **24**, 100459 (2022). https://doi.org:10.1016/j.lanwpc.2022.100459

296 Guest JF, Keating T, Gould D & Wigglesworth N. Modelling the annual NHS costs and outcomes attributable to healthcare-associated infections in England. *BMJ Open.* **10** (2020). https://doi.org:10.1136/bmjopen-2019-033367

297 National Institute for Health and Care Excellence. *British National Formulary (BNF)*, <https://bnf.nice.org.uk/> (2023).

298 Pierce T. *Anaesthetic Gases Calculator*, <https://anaesthetists.org/Home/Resources-publications/Environment/Guide-to-green-anaesthesia/Anaesthetic-gases-calculator> (2023).

299 University of New Mexico. *Calculating the amount of CO2 sequestered in a tree per year*, <https://www.unm.edu/~jbrink/365/Documents/Calculating_tree_carbon.pdf> (2023).

300 Bernat, M. *et al.* Reducing the carbon footprint of general anaesthesia: a comparison of total intravenous anaesthesia vs. a mixed anaesthetic strategy in 47,157 adult patients. *Anaesthesia* **79**, 309-317 (2024). https://doi.org:10.1111/anae.16221

301 Rizan, C., Lillywhite, R., Reed, M. & Bhutta, M. F. The carbon footprint of products used in five common surgical operations: identifying contributing products and processes. *J R Soc Med* **116**, 199-213 (2023). https://doi.org:10.1177/01410768231166135

302 Royal College of Surgeons of Edinburgh, Royal College of Surgeons of England, Royal College of Surgeons in Ireland & Royal College of Physicians and Surgeons of Glasgow. *Intercollegiate green theatre checklist*, <https://www.rcsed.ac.uk/professional-support-development-resources/environmental-sustainability-and-surgery/green-theatre-checklist/> (2022).

303 Totty, J. P. *et al.* The impact of surgical site infection on hospitalisation, treatment costs, and health-related quality of life after vascular surgery. *Int Wound J* **18**, 261-268 (2021). https://doi.org:10.1111/iwj.13526

304 Kula, E. & Evans, D. Dual discounting in cost-benefit analysis for environmental impacts. *Environmental Impact Assessment Review* **31**, 180-186 (2011). https://doi.org:https://doi.org/10.1016/j.eiar.2010.06.001

305 Watts, N. *et al.* The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. *Lancet* **394**, 1836-1878 (2019). https://doi.org:10.1016/S0140-6736(19)32596-6

306 Keil, M., Viere, T., Helms, K. & Rogowski, W. The impact of switching from single-use to reusable healthcare products: a transparency checklist and systematic review of life-cycle assessments. *Eur J Public Health* **33**, 56-63 (2023). https://doi.org:10.1093/eurpub/ckac174

307 Wyssusek, K., Chan, K. L., Eames, G. & Whately, Y. Greenhouse gas reduction in anaesthesia practice: a departmental environmental strategy. *BMJ Open Qual* **11** (2022). https://doi.org:10.1136/bmjoq-2022-001867

308 UNFCCC. *About Carbon Pricing*, <https://unfccc.int/about-us/regional-collaboration-centres/the-ciaca/about-carbon-pricing#What-is-Carbon-Pricing?-> (2024).

309 World Resource Institute. Greenhouse Gas Protocol: a corporate accounting and reporting standard. Revised edition., (Geneva, 2004).

310 Jones, K. *et al.* Unit Costs of Health and Social Care 2023 Manual., (Personal Social Services Research Unit (University of Kent) & Centre for Health Economics (University of York), Kent, UK, 2024).

311 Department for Environment Food and Rural Affairs / Business Energy and Industrial Strategy. *Greenhouse Gas Reporting: Conversion Factors 2023*, <https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023> (2023).

312 Waton, S. *et al. National Vascular Registry: 2023 State of the Nation Report.*, (2023).

313 Digital, N. *Apointments in General Practice*, <https://digital.nhs.uk/data-and-information/publications/statistical/appointments-in-general-practice> (2023).

314 McLean, K. A. *et al.* Tracking wound infection with smartphone technology (TWIST): A randomised controlled trial in emergency surgery patients. *British Journal of Surgery* **108** (2021).

315 Purohit, A., Smith, J. & Hibble, A. Does telemedicine reduce the carbon footprint of healthcare? A systematic review. *Future Healthc J* **8**, e85-e91 (2021). https://doi.org:10.7861/fhj.2020-0080

316 Thiel C.L., Mehta N., Sejo C.S. & *al., e.* Telemedicine and the environment: life cycle environmental emissions from in-person and virtual clinic visits. *npj Digit. Med.* **6** (2023). https://doi.org:https://doi.org/10.1038/s41746-023-00818-7

317 Fleischman F *et al.* Pitfalls of Tree Planting SHow Why We Need People - Centred Natural Climate Solutions. *BioScience* **70**, 947-950 (2020). https://doi.org:https://doi.org/10.1093/biosci/biaa094

318 Singh, H., Eckelman, M., Berwick, D. M. & Sherman, J. D. Mandatory Reporting of Emissions to Achieve Net-Zero Health Care. *N Engl J Med* **387**, 2469-2476 (2022). https://doi.org:10.1056/NEJMsb2210022

319 Lee, J. S., Lowe Beasley, K., Schooley, M. W. & Luo, F. Trends and Costs of US Telehealth Use Among Patients With Cardiovascular Disease Before and During the COVID-19 Pandemic. *J Am Heart Assoc* **12**, e028713 (2023). https://doi.org:10.1161/JAHA.122.028713

320 Morrow, C., Woodbury, M., Simpson, A. N., Almallouhi, E. & Simpson, K. N. Determining the Marginal Cost Differences of a Telehealth Versus an In-person Occupational Therapy Evaluation Session for Stroke Survivors Using Time-driven Activity-based Costing. *Arch Phys Med Rehabil* **104**, 547-553 (2023). https://doi.org:10.1016/j.apmr.2022.11.006

321 Afolabi, O., Parsekar, K., Sibson, L., Patel, A. & Fordham, R. Cost effectiveness analysis of the East of England stroke telemedicine service. *J Stroke*

Cerebrovasc Dis **32**, 106939 (2023). https://doi.org:10.1016/j.jstrokecerebrovasdis.2022.106939

322 Steventon, A. *et al.* Effect of telehealth on use of secondary care and mortality: findings from the Whole System Demonstrator cluster randomised trial. *BMJ* **344**, e3874 (2012). https://doi.org:10.1136/bmj.e3874

323 UNFCCC. (United Nations, Paris Climate Change Conference 2015, 2016).

18 CHAPTER 8: APPENDICES

18.1 PRESS pilot questionnaire

Start of Block: Introduction

Prevention of Surgical Site Infection: A Global Pan-Surgical Survey of Practice
Dear colleagues,

Thank you for taking the time to participate in this important global survey looking into the current practices in the prevention of surgical site infection (SSI).

The questions have been developed based on current international guidelines published by Centres for Disease Control and Prevention (CDC 2017), World Health Organisation (WHO 2018), National Institute for Health and Care Excellence (NICE 2019).

By completing this survey, you are giving consent for the analysis and dissemination (including academic and other publications) of anonymised, grouped results.

At the end of the survey you will have the opportunity to participate in a prize draw for an ???apple watch

End of Block: Introduction

Start of Block: Demographics

Q1 What describes your current professional status?

- ○ Expert surgeon (Chief of Surgery / Consultant / Attending / Staff) (1)
- ○ Surgeon in training (Surgical Resident / Surgical Registrar / Core Surgical Trainee) (2)

Q2 What country is your surgical practice in?

▼ Afghanistan (4) ... Zimbabwe (198)

Q3 What surgical specialty best describes your current practice?

▼ Cardiac surgery (13) ... Other (45)

Display this question:
If What surgical specialty best describes your current practice? = Other

Q3b If other, please specify your current surgical specialty

_____

Q4 What financial healthcare system do you operate in?

- Public (Government Funded) (1)
- Private (Insurance Based) (2)
- Both / Mixture (3)

End of Block: Demographics

Start of Block: SSI Surveillance

Surgical Site Infection Surveillance

Q5 What criteria do you most often use to diagnose SSI (select all that apply)

- ☐ Centers for Disease Control and Prevention (CDC) (1)
- ☐ ASEPSIS score (2)
- ☐ Southampton score (5)
- ☐ Clinical examination (3)
- ☐ Other criteria, please specify (4)

_____

End of Block: SSI Surveillance

Start of Block: Preoperative Methods

Preoperative Methods

The following questions consider clean or clean-contaminated procedures.

CDC surgical wound definitions

- **Clean** - Non-traumatic elective procedure where surgical site is not inflamed or contaminated, no break in aseptic technique
- **Clean-contaminated** - Elective opening of respiratory, gastrointestinal, biliary, or genitourinary tract with minimal spillage, minor break in aseptic technique
- **Contaminated** - Gross contamination present at surgical site, spillage of gastrointestinal, biliary, or genitourinary tract, no active infection, major break in aseptic technique
- **Dirty** - Active infection at surgical site (purulent exudate encountered), old traumatic wounds

Q6 At what time frame prior to incision do you give antibiotic prophylaxis?

- >2 hours (1)
- 1-2 hours (2)
- 0-1 hours (17)
- At time of incision (18)
- Other (please specify) (19)

_____

Q7 What solution agent do you use for surgical site preparation?

- Alcohol Povidone-iodine (1)
- Alcohol Chlorhexadine gluconate (2)
- Aqueous Povidone-iodine (3)
- Aqueous Chlorhexadine gluconate (4)
- Other (please specify) (5)

_____

Q8 What solution do you use for surgical hand washing?

- Alcohol Povidone-iodine (1)
- Alcohol Chlorhexadine gluconate (2)
- Aqueous Povidone-iodine (5)
- Aqueous Chlorhexadine gluconate (6)
- Other (please specify) (7)

_____

End of Block: Preoperative Methods

Start of Block: Peri-operative Methods

Peri-operative Methods

Q9 Do your patients have routine assessment of their perioperative nutritional status?

- Never (8)
- Rarely (9)
- Sometimes (13)
- Often (15)
- Always (16)

Q10 Do you to use the following to maintain targeted normothermia?

	Never (1)	Rarely (7)	Sometimes (8)	Often (9)	Always (10)
Standard blankets (1)	○	○	○	○	○
Active warming (Forced air warming) (2)	○	○	○	○	○
Warmed fluids (6)	○	○	○	○	○
Heated mattress (4)	○	○	○	○	○
Other (please specify) (3)	○	○	○	○	○

Q11 Would you use any of the following for deep or subcutaneous tissue irrigation?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Saline (1)	○	○	○	○	○
PVP-I (2)	○	○	○	○	○
Hydrogren peroxide (3)	○	○	○	○	○
Other, please specify: (4)	○	○	○	○	○

Q12 Do you to use triclosan-coated antimicrobial sutures for primary skin closure?

- ○ Never (1)
- ○ Rarely (2)
- ○ Sometime (4)
- ○ Often (5)
- ○ Always (6)

Q13 After primary skin closure, which type of wound dressing do you use?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Basic wound contact layer (absorbent / low-adherence dressings)	○	○	○	○	○
Advanced dressings (hydrogel / hydrocolloid / alginate / foam dressings)	○	○	○	○	○
Skin glue	○	○	○	○	○
Negative pressure wound therapy	○	○	○	○	○
No dressing used	○	○	○	○	○
Other dressing used, please specify:	○	○	○	○	○

End of Block: Peri-operative Methods

Start of Block: Postoperative methods

Postoperative Methods

Q14 How likely are you to give **postoperative** antibiotic prophylaxis to prevent SSI for routine operations in your specialty?

- ○ Never (17)
- ○ Rarely (19)
- ○ Sometimes (20)
- ○ Often (22)
- ○ Always (23)

Display this question:
If How likely are you to give postoperative antibiotic prophylaxis to prevent SSI for routine operat... != Never

Q14b What reasons guide your decision to provide **postoperative** antibiotic prophylaxis?

_____

Q15 Which methods of follow-up do you use to assess for SSI?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Face to face review (1)	○	○	○	○	○
Telephone review (7)	○	○	○	○	○
Video consultation (8)	○	○	○	○	○
Photograph at discharge (2)	○	○	○	○	○
Paper questionnaire (4)	○	○	○	○	○
Community nurse led wound monitoring (5)	○	○	○	○	○
No follow-up (9)	○	○	○	○	○
Other (please specify) (6)	○	○	○	○	○

Display this question:
If Which methods of follow-up do you use to assess for SSI? = Paper questionnaire [Rarely]
Or Which methods of follow-up do you use to assess for SSI? = Paper questionnaire [Sometimes]
Or Which methods of follow-up do you use to assess for SSI? = Paper questionnaire [Often]
Or Which methods of follow-up do you use to assess for SSI? = Paper questionnaire [Always]

Q15b What questionnaire do you use to assess patients' postoperative wounds? (select all that apply)

- ○ Bluebelle Wound Healing Questionnaire (WHQ) (1)
- ○ ASEPSIS (2)
- ○ Other (please specify) (3)

_____

End of Block: Postoperative methods

Start of Block: Closing

Q16 Are there any other comments you would like to make?

_____
_____
_____
_____

Page Break

End of Block: Closing

18.2 PRESS revised pilot questionnaire

Start of Block: Introduction

Prevention of Surgical Site Infection: A Global Pan-Surgical Survey of Practice
Dear colleagues,

Thank you for taking the time to participate in this important global survey looking into the current practices in the prevention of surgical site infection (SSI).

The questions have been developed based on current international guidelines published by Centres for Disease Control and Prevention (CDC 2017), World Health Organisation (WHO 2018), National Institute for Health and Care Excellence (NICE 2019).

By completing this survey, you are giving consent for the analysis and dissemination (including academic and other publications) of anonymised, grouped results.

At the end of the survey you will have the opportunity to participate in a prize draw for a £50 amazon voucher.

Thank you,
On behalf of the Surgical Infection Research Network (@SIRNglobal)

End of Block: Introduction

Start of Block: Demographics
What describes your current professional status?

- ○ Expert surgeon (Chief of Surgery / Consultant / Attending / Staff) (1)
- ○ Surgeon in training (Surgical Resident / Surgical Registrar / Core Surgical Trainee) (2)

Q2 What country is your surgical practice in?

▼ Afghanistan (4) ... Zimbabwe (198)

Q3 What surgical specialty best describes your current practice?

▼ Cardiac surgery (13) ... Other (45)

Display this question:
If What surgical specialty best describes your current practice? = Other

Q3b If other, please specify your current surgical specialty

_____

Q4 What financial healthcare system do you operate in?

- ○ Public (Government Funded) (1)
- ○ Private (Insurance Based) (2)
- ○ Both / Mixture (3)

End of Block: Demographics

Start of Block: SSI Surveillance

Surgical Site Infection Surveillance

Q5 What criteria do you most often use to diagnose SSI (select all that apply)

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Centers for Disease Control and Prevention (CDC) (1)	○	○	○	○	○
ASEPSIS score (2)	○	○	○	○	○
Southampton score (5)	○	○	○	○	○
Clinical examination (3)	○	○	○	○	○
Other criteria (please specify or select never) (4)	○	○	○	○	○

End of Block: SSI Surveillance

Start of Block: Preoperative Methods

Preoperative Methods

The following questions consider clean or clean-contaminated procedures.

CDC surgical wound definitions

- **Clean** - Non-traumatic elective procedure where surgical site is not inflamed or contaminated, no break in aseptic technique
- **Clean-contaminated** - Elective opening of respiratory, gastrointestinal, biliary, or genitourinary tract with minimal spillage, minor break in aseptic technique
- **Contaminated** - Gross contamination present at surgical site, spillage of gastrointestinal, biliary, or genitourinary tract, no active infection, major break in aseptic technique

- **Dirty** - Active infection at surgical site (purulent exudate encountered), old traumatic wounds

Q6 At what time frame prior to incision do you give antibiotic prophylaxis?

	Never (6)	Rarely (7)	Sometimes (8)	Often (9)	Always (10)
>2 hours (1)	○	○	○	○	○
1-2 hours (2)	○	○	○	○	○
0-1 hours (17)	○	○	○	○	○
At time of incision (18)	○	○	○	○	○
Other (please specify or select never) (19)	○	○	○	○	○

Q7 What solution agent do you use for surgical site preparation?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Alcohol Povidone-iodine (1)	○	○	○	○	○
Alcohol Chlorhexadine gluconate (2)	○	○	○	○	○
Aqueous Povidone-iodine (3)	○	○	○	○	○
Aqueous Chlorhexadine gluconate (4)	○	○	○	○	○
Other (please specify or select never) (5)	○	○	○	○	○

Q8 What solution do you use for surgical hand washing?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Alcohol Povidone-iodine (1)	○	○	○	○	○
Alcohol Chlorhexadine gluconate (2)	○	○	○	○	○
Aqueous Povidone-iodine (5)	○	○	○	○	○
Aqueous Chlorhexadine gluconate (6)	○	○	○	○	○
Other (please specify or select never) (7)	○	○	○	○	○

End of Block: Preoperative Methods

Start of Block: Peri-operative Methods

Peri-operative Methods

Q9 Do your patients have routine assessment of their perioperative nutritional status?

- ○ Never (8)
- ○ Rarely (9)
- ○ Sometimes (13)
- ○ Often (15)
- ○ Always (16)

Q10 Do you to use the following to maintain targeted normothermia?

	Never (1)	Rarely (7)	Sometimes (8)	Often (9)	Always (10)
Standard blankets (1)	○	○	○	○	○
Active warming (Forced air warming) (2)	○	○	○	○	○
Warmed fluids (6)	○	○	○	○	○
Heated mattress (4)	○	○	○	○	○
Other (please specify or select never) (3)	○	○	○	○	○

Q165 What surgical drapes would you use to prepare your surgical field?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Iodinated (2)	○	○	○	○	○
Non-iodinated (3)	○	○	○	○	○
Other (please specify or select never) (4)	○	○	○	○	○

Q11 Would you use any of the following for deep or subcutaneous tissue irrigation?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Saline (1)	○	○	○	○	○
PVP-I (2)	○	○	○	○	○
Hydrogren peroxide (3)	○	○	○	○	○
Other (please specify or select never) (4)	○	○	○	○	○

Q162 Prior to closure do you replace any of the following for sterile items?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Instruments (1)	○	○	○	○	○
Gloves (2)	○	○	○	○	○

Q12 Do you to use triclosan-coated antimicrobial sutures for primary skin closure?

- ○ Never (1)
- ○ Rarely (2)
- ○ Sometime (4)
- ○ Often (5)
- ○ Always (6)

Q13 After primary skin closure, which type of wound dressing do you use?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Basic wound contact layer (absorbent / low-adherence dressings)	○	○	○	○	○
Advanced dressings (hydrogel / hydrocolloid / alginate / foam dressings)	○	○	○	○	○
Skin glue	○	○	○	○	○
Negative pressure wound therapy	○	○	○	○	○
No dressing used	○	○	○	○	○
Other dressing used (please specify or select never)	○	○	○	○	○

End of Block: Peri-operative Methods

Start of Block: Postoperative methods

Postoperative Methods

Q14 How likely are you to give **postoperative** antibiotic prophylaxis to prevent SSI for routine operations in your specialty?

- ○ Never (17)
- ○ Rarely (19)
- ○ Sometimes (20)
- ○ Often (22)
- ○ Always (23)

Display this question:
If How likely are you to give postoperative antibiotic prophylaxis to prevent SSI for routine operat... != Never

Q14b What reasons guide your decision to provide **postoperative** antibiotic prophylaxis?

_____

Q15 Which methods of follow-up do you use to assess for SSI?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Face to face review (1)	○	○	○	○	○
Telephone review (7)	○	○	○	○	○
Video consultation (8)	○	○	○	○	○
Photograph at discharge (2)	○	○	○	○	○
Paper questionnaire (4)	○	○	○	○	○
Community nurse led wound monitoring (5)	○	○	○	○	○
No follow-up (9)	○	○	○	○	○
Other (please specify or select never) (6)	○	○	○	○	○

Display this question:
If Which methods of follow-up do you use to assess for SSI? = Paper questionnaire [Rarely]
Or Which methods of follow-up do you use to assess for SSI? = Paper questionnaire [Sometimes]
Or Which methods of follow-up do you use to assess for SSI? = Paper questionnaire [Often]
Or Which methods of follow-up do you use to assess for SSI? = Paper questionnaire [Always]

Q15b What questionnaire do you use to assess patients' postoperative wounds? (select all that apply)

- ○ Bluebelle Wound Healing Questionnaire (WHQ) (1)
- ○ ASEPSIS (2)
- ○ Other (please specify or select never) (3)

_____

Display this question:
If What country is your surgical practice in? = United Kingdom

Q163 In a platform trial investigating SSI prevention, would you have equipoise in randomising patients to any of the interventions in this survey?

- ○ Yes, for any intervention (1)
- ○ Yes, but only certain interventions (please specify which) (2)

_____

- ○ Not at all (please specify what would prevent equipoise) (4)

_____

End of Block: Postoperative methods

Start of Block: Closing

Page Break

Q166
Thank you, click to submit your responses

End of Block: Closing

18.3 PRESS survey final version

Start of Block: Introduction

Prevention of Surgical Site Infection: A Global Pan-Surgical Survey of Practice
Dear colleagues,

Thank you for taking the time to participate in this **5 minute** important global survey looking into the current practices in the prevention of surgical site infection (SSI).

The questions have been developed based on current international guidelines published by Centres for Disease Control and Prevention (CDC 2017), World Health Organisation (WHO 2018), National Institute for Health and Care Excellence (NICE 2019).

By completing this survey, you are giving consent for the analysis and dissemination (including academic and other publications) of anonymised, grouped results.

At the end of the survey you will have the opportunity to participate in a prize draw for a £50 amazon voucher.

Thank you,
On behalf of the Surgical Infection Research Network (@SIRNglobal)

End of Block: Introduction

Start of Block: Demographics

Q1 What describes your current professional status?

- Expert surgeon (Chief of Surgery / Consultant / Attending / Staff) (1)
- Surgeon in training (Surgical Resident / Surgical Registrar / Core Surgical Trainee) (2)

Q2 What country is your surgical practice in?

▼ Afghanistan (4) ... Cayman Islands (200)

Q3 What surgical specialty best describes your current practice?

▼ Cardiac surgery (13) ... Other (45)

Display this question:
If What surgical specialty best describes your current practice? = Other

Q3b If other, please specify your current surgical specialty

_____

Q4 What financial healthcare system do you operate in?

- ○ Public (Government Funded) (1)
- ○ Private (Insurance Based) (2)
- ○ Both / Mixture (3)

End of Block: Demographics

Start of Block: SSI Surveillance

Surgical Site Infection Surveillance

Q5 What criteria do you most often use to diagnose SSI (select all that apply)

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Centers for Disease Control and Prevention (CDC) (1)	○	○	○	○	○
ASEPSIS score (2)	○	○	○	○	○
Southampton score (5)	○	○	○	○	○
Clinical examination (3)	○	○	○	○	○
Other criteria (please specify or select never) (4)	○	○	○	○	○

End of Block: SSI Surveillance

Start of Block: Preoperative Methods

Preoperative Methods
The following questions consider clean or clean-contaminated procedures.

CDC surgical wound definitions
- **Clean** - Non-traumatic elective procedure where surgical site is not inflamed or contaminated, no break in aseptic technique
- **Clean-contaminated** - Elective opening of respiratory, gastrointestinal, biliary, or genitourinary tract with minimal spillage, minor break in aseptic technique
- **Contaminated** - Gross contamination present at surgical site, spillage of gastrointestinal, biliary, or genitourinary tract, no active infection, major break in aseptic technique
- **Dirty** - Active infection at surgical site (purulent exudate encountered), old traumatic wounds

Q6 At what time frame prior to incision do you give antibiotic prophylaxis?

	Never (6)	Rarely (7)	Sometimes (8)	Often (9)	Always (10)
>2 hours (1)	○	○	○	○	○
1-2 hours (2)	○	○	○	○	○
0-1 hours (17)	○	○	○	○	○
At time of incision (18)	○	○	○	○	○
Other (please specify or select never) (19)	○	○	○	○	○

Q7 What solution agent do you use for surgical site preparation?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Alcohol Povidone-iodine (1)	○	○	○	○	○
Alcohol Chlorhexadine gluconate (2)	○	○	○	○	○
Aqueous Povidone-iodine (3)	○	○	○	○	○
Aqueous Chlorhexadine gluconate (4)	○	○	○	○	○
Other (please specify or select never) (5)	○	○	○	○	○

Q8 What solution do you use for surgical hand washing?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Alcohol Povidone-iodine	○	○	○	○	○
Alcohol Chlorhexadine gluconate	○	○	○	○	○
Aqueous Povidone-iodine	○	○	○	○	○
Aqueous Chlorhexadine gluconate	○	○	○	○	○
Other (please specify or select never)	○	○	○	○	○

End of Block: Preoperative Methods

Start of Block: Peri-operative Methods

Peri-operative Methods

Q9 Do your patients have routine assessment of their perioperative nutritional status?

- Never (8)
- Rarely (9)
- Sometimes (13)
- Often (15)
- Always (16)

Q10 Do you to use the following to maintain targeted normothermia?

	Never (1)	Rarely (7)	Sometimes (8)	Often (9)	Always (10)
Standard blankets (1)	○	○	○	○	○
Active warming (Forced air warming) (2)	○	○	○	○	○
Warmed fluids (6)	○	○	○	○	○
Heated mattress (4)	○	○	○	○	○
Other (please specify or select never) (3)	○	○	○	○	○

Q165 What surgical drapes would you use to prepare your surgical field?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Iodinated (2)	○	○	○	○	○
Non-iodinated (3)	○	○	○	○	○
Other (please specify or select never) (4)	○	○	○	○	○

Q11 Would you use any of the following for deep or subcutaneous tissue irrigation?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Saline (1)	○	○	○	○	○
PVP-I (2)	○	○	○	○	○
Hydrogren peroxide (3)	○	○	○	○	○
Other (please specify or select never) (4)	○	○	○	○	○

Q162 Prior to closure do you replace any of the following for sterile items?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Instruments (1)	○	○	○	○	○
Gloves (2)	○	○	○	○	○

Q12 Do you to use triclosan-coated antimicrobial sutures for primary skin closure?

- ○ Never (1)
- ○ Rarely (2)
- ○ Sometime (4)
- ○ Often (5)
- ○ Always (6)

Q13 After primary skin closure, which type of wound dressing do you use?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Basic wound contact layer (absorbent / low-adherence dressings)	○	○	○	○	○
Advanced dressings (hydrogel / hydrocolloid / alginate / foam dressings)	○	○	○	○	○
Skin glue	○	○	○	○	○
Negative pressure wound therapy	○	○	○	○	○
No dressing used	○	○	○	○	○
Other dressing used (please specify or select never)	○	○	○	○	○

End of Block: Peri-operative Methods

Start of Block: Postoperative methods

Postoperative Methods

Q14 How likely are you to give **postoperative** antibiotic prophylaxis to prevent SSI for routine operations in your specialty?

- ○ Never (17)
- ○ Rarely (19)
- ○ Sometimes (20)
- ○ Often (22)
- ○ Always (23)

Display this question:
If How likely are you to give postoperative antibiotic prophylaxis to prevent SSI for routine operat... != Never

Q14b What reasons guide your decision to provide **postoperative** antibiotic prophylaxis?

_____

Q15 Which methods of follow-up do you use to assess for SSI?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Face to face review (1)	○	○	○	○	○
Telephone review (7)	○	○	○	○	○
Video consultation (8)	○	○	○	○	○
Photograph at discharge (2)	○	○	○	○	○
Paper questionnaire (4)	○	○	○	○	○
Community nurse led wound monitoring (5)	○	○	○	○	○
No follow-up (9)	○	○	○	○	○
Other (please specify or select never) (6)	○	○	○	○	○

Display this question:
If Which methods of follow-up do you use to assess for SSI? = Paper questionnaire [Rarely]
Or Which methods of follow-up do you use to assess for SSI? = Paper questionnaire [Sometimes]
Or Which methods of follow-up do you use to assess for SSI? = Paper questionnaire [Often]
Or Which methods of follow-up do you use to assess for SSI? = Paper questionnaire [Always]

Q15b What questionnaire do you use to assess patients' postoperative wounds? (select all that apply)

- ○ Bluebelle Wound Healing Questionnaire (WHQ) (1)
- ○ ASEPSIS (2)
- ○ Other (please specify or select never) (3)

_____

End of Block: Postoperative methods

Start of Block: Closing

Q166 Thank you, click to submit your responses

End of Block: Closing

18.4 Distribution societies

Society	Region	Surgical Specialty
World Society of Emergency Surgery	Global	General Surgery
Vascular Society of Great Britain & Ireland	UK	Vascular
Australian and New Zealand Society for Vascular Surgery	Australia and NZ	Vascular
British Association of Surgical Oncology	UK	Orthopaedics
Society of British Neurological Surgeons	UK	Neurosurgery
Association of Breast Surgery	UK	Breast Surgery
Thoracic Surgery Residents Association	USA	Cardiothoracics
European Society of Vascular Surgery	Europe	Vascular
Surgical Infection Society Europe	Europe	All
Surgical Infection Society North America	North America	All
Vascular and Endovascular Research Network	Worldwide	Vascular
Swiss Surgical Society	Switzerland	All
British Orthopaedic Association	UK	Orthopaedics
Moroccan Society of Surgery	Morocco	All
Iranian Society of Metabolic Surgery	Iran	General Surgery
Belgian Section of Obesity and Metabolic Surgery	Belgium	General Surgery
Hellenic Society of Laparoscopic Surgery	Greece	General Surgery
Sociedad Argentina de Coloproctologia	Argentina	General Surgery

18.5 Response comparisons for expert surgeons versus surgeons in training

Group Descriptives							
Response category	Group	N	Mean	Median	SD	SE	P-value
What criteria do you most often use to diagnose SSI?							
CDC	**Expert surgeon**	**665**	**2.81**	**3.00**	**1.52**	**0.06**	**<0.001**
	Surgeon in training	**226**	**2.40**	**2.00**	**1.41**	**0.09**	
ASEPSIS	Expert surgeon	665	1.97	1.00	1.26	0.05	0.775
	Surgeon in training	226	1.95	1.00	1.17	0.08	
Southampton	Expert surgeon	665	1.75	1.00	1.15	0.04	0.415
	Surgeon in training	226	1.81	1.00	1.15	0.08	
Clinical	Expert surgeon	665	4.56	5.00	0.87	0.03	0.428
	Surgeon in training	226	4.54	5.00	0.84	0.06	
Other	Expert surgeon	665	1.68	1.00	1.24	0.05	0.876
	Surgeon in training	226	1.67	1.00	1.18	0.08	
At what time frame prior to incision do you give antibiotic prophylaxis?							
>2 hours	Expert surgeon	596	1.88	1.00	1.28	-	0.059
	Surgeon in training	184	2.02	1.50	1.23	-	
1-2 hours	Expert surgeon	596	2.19	2.00	1.30	-	0.330
	Surgeon in training	184	2.25	2.00	1.20	-	
0-1 hours	**Expert surgeon**	**596**	**3.68**	**4.00**	**1.33**	**-**	**0.005**
	Surgeon in training	**184**	**3.38**	**4.00**	**1.37**	**-**	
At incision	**Expert surgeon**	**596**	**2.70**	**3.00**	**1.40**	**-**	**<0.001**
	Surgeon in training	**184**	**3.29**	**3.00**	**1.29**	**-**	
Other	Expert surgeon	596	1.43	1.00	1.02	-	0.263
	Surgeon in training	184	1.52	1.00	1.07	-	
What solution agent do you use for surgical site preparation?							
Alcoholic povidone iodine	Expert surgeon	596	3.05	3.00	1.47	0.06	0.667
	Surgeon in training	184	3.10	3.00	1.41	0.10	
Alcoholic chlorhexidine	**Expert surgeon**	**596**	**3.12**	**3.00**	**1.42**	**0.06**	**0.076**
	Surgeon in training	**184**	**3.33**	**4.00**	**1.33**	**0.10**	
Aqueous povidone iodine	Expert surgeon	596	2.61	3.00	1.33	0.05	0.489
	Surgeon in training	184	2.68	3.00	1.32	0.10	
Aqueous chlorhexidine	Expert surgeon	596	2.13	2.00	1.22	0.05	0.414
	Surgeon in training	184	2.21	2.00	1.26	0.09	
Other	Expert surgeon	596	1.37	1.00	0.91	0.04	0.570
	Surgeon in training	184	1.46	1.00	0.99	0.07	
What solution agent do you use for surgical hand washing?							
Alcoholic povidone iodine	**Expert surgeon**	**596**	**2.39**	**2.00**	**1.50**	**0.06**	**0.027**
	Surgeon in training	**184**	**2.67**	**3.00**	**1.51**	**0.11**	
Alcoholic chlorhexidine	Expert surgeon	596	2.55	2.00	1.52	0.06	0.454
	Surgeon in training	184	2.63	3.00	1.39	0.10	
Aqueous povidone iodine	**Expert surgeon**	**596**	**2.40**	**2.00**	**1.43**	**0.06**	**0.018**
	Surgeon in training	**184**	**2.67**	**3.00**	**1.36**	**0.10**	
Aqueous chlorhexidine	Expert surgeon	596	2.51	2.00	1.47	0.06	0.602
	Surgeon in training	184	2.57	3.00	1.40	0.10	
Other	Expert surgeon	596	1.54	1.00	1.19	0.05	0.631
	Surgeon in training	184	1.55	1.00	1.11	0.08	
Do your patients have routine assessment of their perioperative nutritional status?							
Nutrition assessment	**Expert surgeon**	**563**	**3.32**	**3.00**	**1.15**	**0.05**	**0.085**
	Surgeon in training	**173**	**3.16**	**3.00**	**1.07**	**0.08**	
Do you use the following to maintain targeted normothermia?							
Standard blankets	Expert surgeon	563	3.44	4.00	1.31	0.06	0.937
	Surgeon in training	173	3.50	4.00	1.11	0.08	
Active warming	Expert surgeon	563	3.53	4.00	1.26	0.05	0.914
	Surgeon in training	173	3.61	4.00	0.98	0.07	
Warmed fluids	Expert surgeon	563	3.06	3.00	1.15	0.05	0.066
	Surgeon in training	173	3.23	3.00	1.02	0.08	

Group Descriptives							
Response category	Group	N	Mean	Median	SD	SE	P-value
Heated mattress	Expert surgeon	563	2.48	2.00	1.29	0.05	0.737
	Surgeon in training	173	2.43	2.00	1.21	0.09	
Other	Expert surgeon	563	1.36	1.00	0.91	0.04	0.207
	Surgeon in training	173	1.47	1.00	1.01	0.08	
What surgical drapes do you use to prepare your surgical field?							
Iodinated	Expert surgeon	563	2.56	2.00	1.48	0.06	0.210
	Surgeon in training	173	2.71	3.00	1.44	0.11	
Non-iodinated	Expert surgeon	563	3.43	4.00	1.46	0.06	0.957
	Surgeon in training	173	3.44	4.00	1.42	0.11	
Other	Expert surgeon	563	1.48	1.00	1.05	0.04	0.522
	Surgeon in training	173	1.50	1.00	0.99	0.08	
Would you use any of the following for deep or subcutaneous tissue irrigation?							
Saline	Expert surgeon	563	3.71	4.00	1.21	0.05	0.269
	Surgeon in training	173	3.87	4.00	1.03	0.08	
Povidone iodine	Expert surgeon	563	1.94	1.00	1.15	0.05	0.399
	Surgeon in training	173	2.06	1.00	1.26	0.10	
Hydrogen peroxide	Expert surgeon	563	2.12	2.00	1.08	0.05	0.714
	Surgeon in training	173	2.17	2.00	1.14	0.09	
Other	Expert surgeon	563	1.53	1.00	1.07	0.05	0.343
	Surgeon in training	173	1.62	1.00	1.10	0.08	
Prior to closure do you replace any of the following for sterile items?							
Instruments	Expert surgeon	563	2.54	2.00	1.38	0.06	0.274
	Surgeon in training	173	2.65	3.00	1.32	0.10	
Gloves	Expert surgeon	563	3.06	3.00	1.36	0.06	0.414
	Surgeon in training	173	3.17	3.00	1.25	0.10	
Do you use triclosan-coated antimicrobial sutures for primary closure?							
Triclosan sutures	**Expert surgeon**	**488**	**1.86**	**1.00**	**1.32**	**0.06**	**0.045**
	Surgeon in training	**149**	**2.11**	**1.00**	**1.42**	**0.12**	
After primary skin closure, which type of wound dressing do you use?							
Basic layer	**Expert surgeon**	**563**	**3.90**	**4.00**	**1.03**	**0.04**	**0.012**
	Surgeon in training	**173**	**3.72**	**4.00**	**0.98**	**0.07**	
Advanced dressings	**Expert surgeon**	**563**	**2.12**	**2.00**	**1.07**	**0.05**	**<0.001**
	Surgeon in training	**173**	**2.48**	**2.00**	**1.03**	**0.08**	
Skin glue	**Expert surgeon**	**563**	**2.08**	**2.00**	**1.21**	**0.05**	**<0.001**
	Surgeon in training	**173**	**2.45**	**3.00**	**1.13**	**0.09**	
NPWT	**Expert surgeon**	**563**	**2.29**	**2.00**	**1.03**	**0.04**	**<0.001**
	Surgeon in training	**173**	**2.62**	**3.00**	**0.98**	**0.07**	
No dressing	Expert surgeon	563	1.56	1.00	1.01	0.04	0.111
	Surgeon in training	173	1.72	1.00	1.12	0.09	
Other	**Expert surgeon**	**563**	**1.23**	**1.00**	**0.72**	**0.03**	**<0.001**
	Surgeon in training	**173**	**1.52**	**1.00**	**1.01**	**0.08**	
How frequently do you give postoperative antibiotic prophylaxis to prevent SSI for routine operations in your specialty?							
Postoperative antibiotics	Expert surgeon	561	3.03	3.00	1.35	0.06	0.681
	Surgeon in training	172	3.08	3.00	1.27	0.10	
Which methods of follow-up do you use to assess for SSI?							
Face-to-face	**Expert surgeon**	**548**	**4.12**	**4.00**	**1.05**	**0.05**	**<0.001**
	Surgeon in training	**167**	**3.89**	**4.00**	**0.99**	**0.08**	
Telephone	Expert surgeon	548	2.33	2.00	1.16	0.05	0.504
	Surgeon in training	167	2.22	2.00	0.99	0.08	
Video	Expert surgeon	548	1.77	1.00	1.11	0.05	0.653
	Surgeon in training	167	1.71	1.00	1.01	0.08	
Photo at discharge	Expert surgeon	548	2.13	2.00	1.21	0.05	0.336
	Surgeon in training	167	2.04	1.00	1.21	0.09	
Paper questionnaire	Expert surgeon	548	1.72	1.00	1.14	0.05	0.937
	Surgeon in training	167	1.71	1.00	1.11	0.09	
Community nurse led follow-up	Expert surgeon	548	2.51	3.00	1.28	0.05	0.100
	Surgeon in training	167	2.66	3.00	1.17	0.09	
No follow-up	**Expert surgeon**	**548**	**1.86**	**1.00**	**1.18**	**0.05**	**<0.001**
	Surgeon in training	**167**	**2.19**	**2.00**	**1.25**	**0.10**	
Other	**Expert surgeon**	**548**	**1.23**	**1.00**	**0.77**	**0.03**	**<0.001**
	Surgeon in training	**167**	**1.47**	**1.00**	**1.02**	**0.08**	

18.6 PRISMA-DTA Checklist

Section/topic	#	PRISMA-DTA Checklist Item	Reported on page #
TITLE / ABSTRACT			
Title	1	Identify the report as a systematic review (+/- meta-analysis) of diagnostic test accuracy (DTA) studies.	88
Abstract	2	Abstract: See PRISMA-DTA for abstracts.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	88
Clinical role of index test	D1	State the scientific and clinical background, including the intended use and clinical role of the index test, and if applicable, the rationale for minimally acceptable test accuracy (or minimum difference in accuracy for comparative design).	88-89
Objectives	4	Provide an explicit statement of question(s) being addressed in terms of participants, index test(s), and target condition(s).	89
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	89
Eligibility criteria	6	Specify study characteristics (participants, setting, index test(s), reference standard(s), target condition(s), and study design) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	89-90
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	90
Search	8	Present full search strategies for all electronic databases and other sources searched, including any limits used, such that they could be repeated.	Appendix 8.7
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	90
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	90-92
Definitions for data extraction	11	Provide definitions used in data extraction and classifications of target condition(s), index test(s), reference standard(s) and other characteristics (e.g. study design, clinical setting).	90-91
Risk of bias and applicability	12	Describe methods used for assessing risk of bias in individual studies and concerns regarding the applicability to the review question.	91
Diagnostic accuracy measures	13	State the principal diagnostic accuracy measure(s) reported (e.g. sensitivity, specificity) and state the unit of assessment (e.g. per-patient, per-lesion).	91-92
Synthesis of results	14	Describe methods of handling data, combining results of studies and describing variability between studies. This could include, but is not limited to: a) handling of multiple definitions of target condition. b) handling of multiple thresholds of test positivity, c) handling multiple index test readers, d) handling of indeterminate test results, e) grouping and comparing tests, f) handling of different reference standards	91-92

Section/topic	#	PRISMA-DTA Checklist Item	Reported on page #
Meta-analysis	D2	Report the statistical methods used for meta-analyses, if performed.	91-92
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	92
RESULTS			
Study selection	17	Provide numbers of studies screened, assessed for eligibility, included in the review (and included in meta-analysis, if applicable) with reasons for exclusions at each stage, ideally with a flow diagram.	92-93
Study characteristics	18	For each included study provide citations and present key characteristics including: a) participant characteristics (presentation, prior testing), b) clinical setting, c) study design, d) target condition definition, e) index test, f) reference standard, g) sample size, h) funding sources	93 and 95
Risk of bias and applicability	19	Present evaluation of risk of bias and concerns regarding applicability for each study.	95
Results of individual studies	20	For each analysis in each study (e.g. unique combination of index test, reference standard, and positivity threshold) report 2x2 data (TP, FP, FN, TN) with estimates of diagnostic accuracy and confidence intervals, ideally with a forest or receiver operator characteristic (ROC) plot.	96
Synthesis of results	21	Describe test accuracy, including variability; if meta-analysis was done, include results and confidence intervals.	96-98
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression; analysis of index test: failure rates, proportion of inconclusive results, adverse events).	98-101
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence.	102-104
Limitations	25	Discuss limitations from included studies (e.g. risk of bias and concerns regarding applicability) and from the review process (e.g. incomplete retrieval of identified research).	104
Conclusions	26	Provide a general interpretation of the results in the context of other evidence. Discuss implications for future research and clinical practice (e.g. the intended use and clinical role of the index test).	104-105
FUNDING			
Funding	27	For the systematic review, describe the sources of funding and other support and the role of the funders.	N/A

18.7 Search strategy for Medline, Embase and CINAHL

(exp (Telemedicine)/ OR (remote consultation).mp OR (teleconsultation).mp OR (teleconsultation).mp OR (mobile health).mp OR (telehealth).mp OR (ehealth).mp OR (mhealth).mp OR (e*health).mp OR (e health).mp OR (m*health).mp OR (m health).mp OR (telephon*).mp OR (photograph*).mp OR (video*).mp OR (mobile app*).mp)

AND

(exp (surgical wound infection)/ OR (surgical wound dehiscence).mp OR surgical site infection).mp OR (postoperative infection).mp OR (SSI).mp OR (wound infection).mp OR (surgical wound complication).mp OR (post-surgical infection).mp OR (post operative infection).mp OR (post-operative infection).mp)

18.8 Agreement by response categories to items 1-6

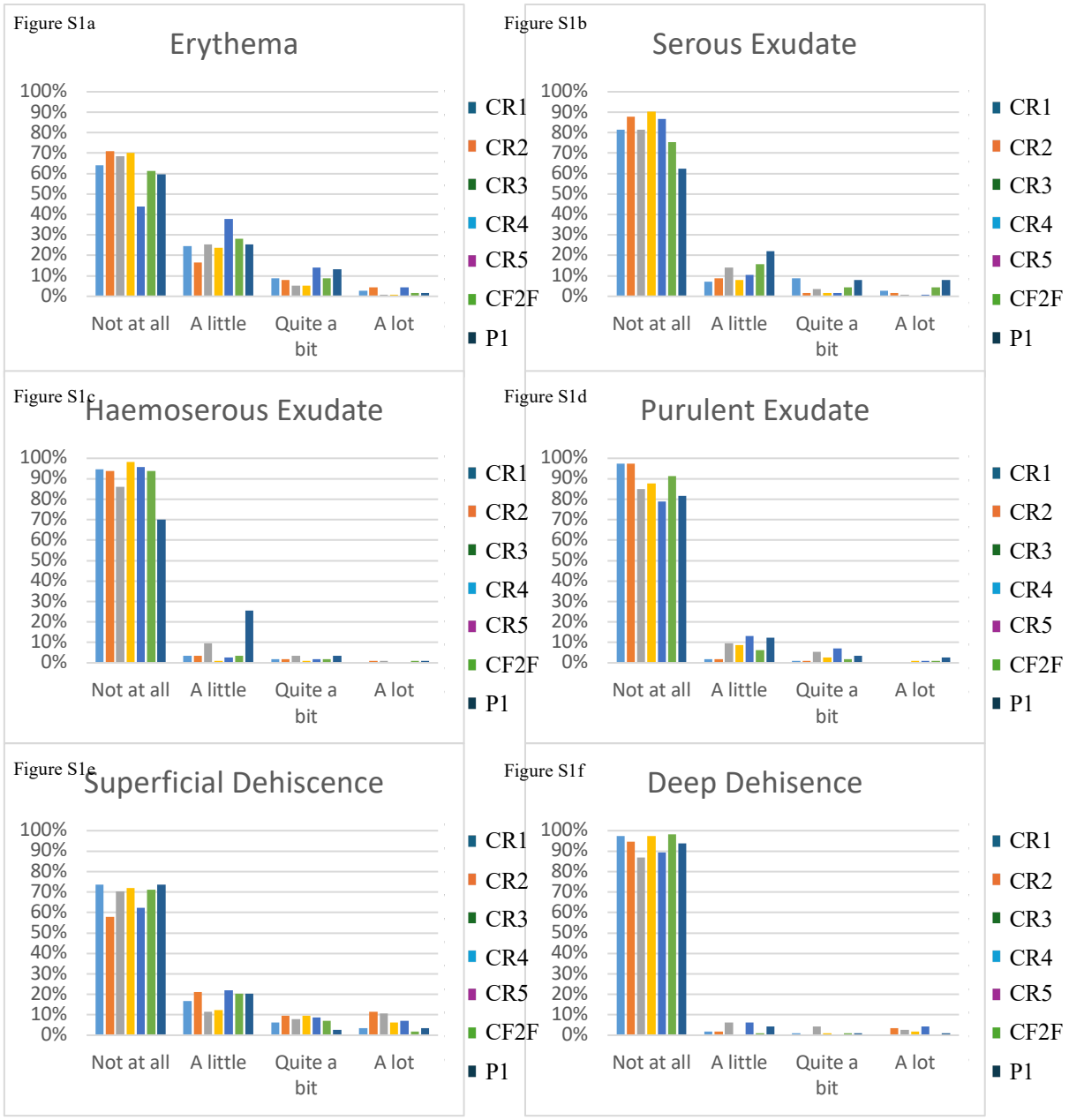
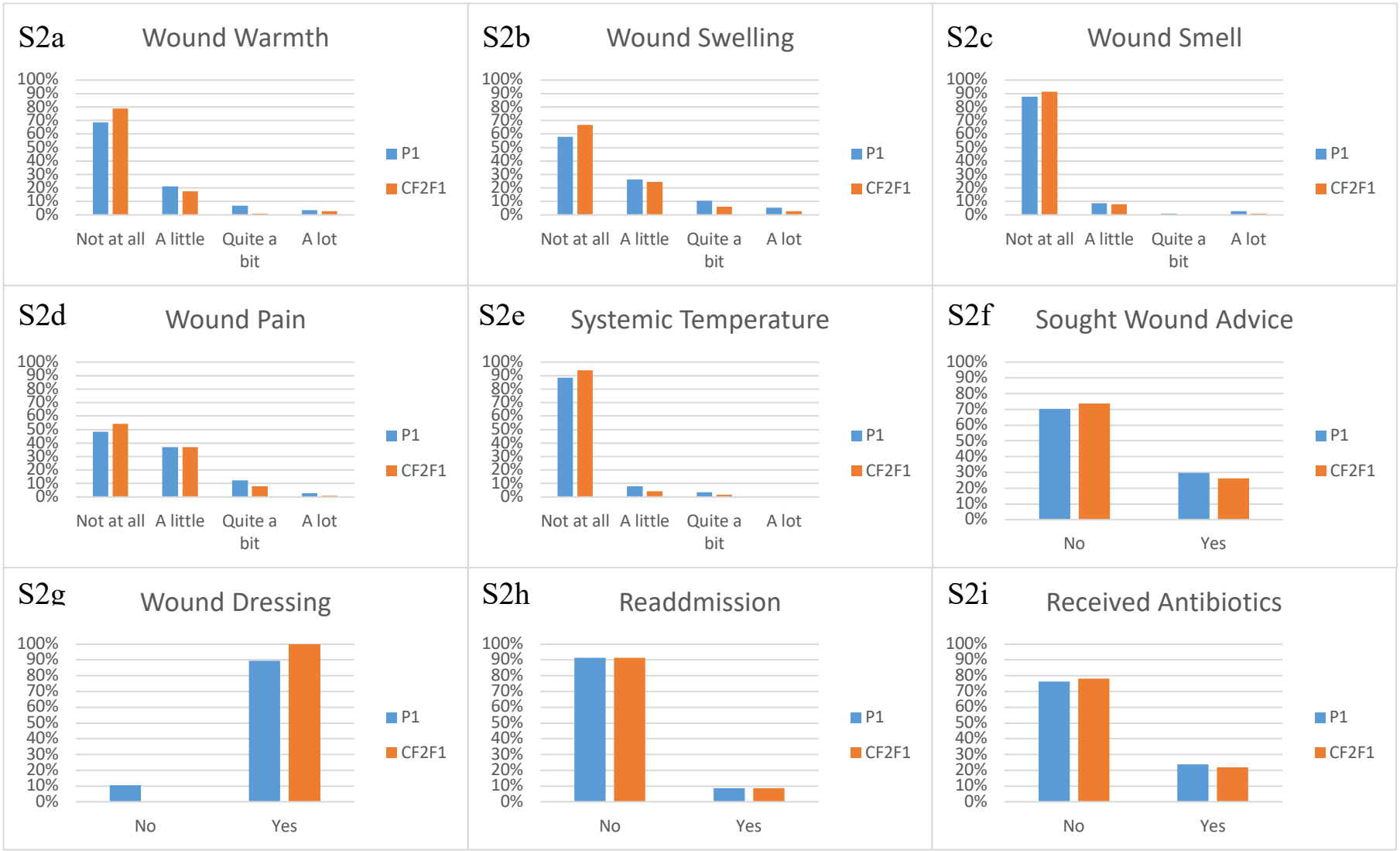


Figure S1a-f: Agreement by response categories to items 1-6. CR; remote clinician, CF2F; face-to-

18.9 Agreement by response categories to items 7-19



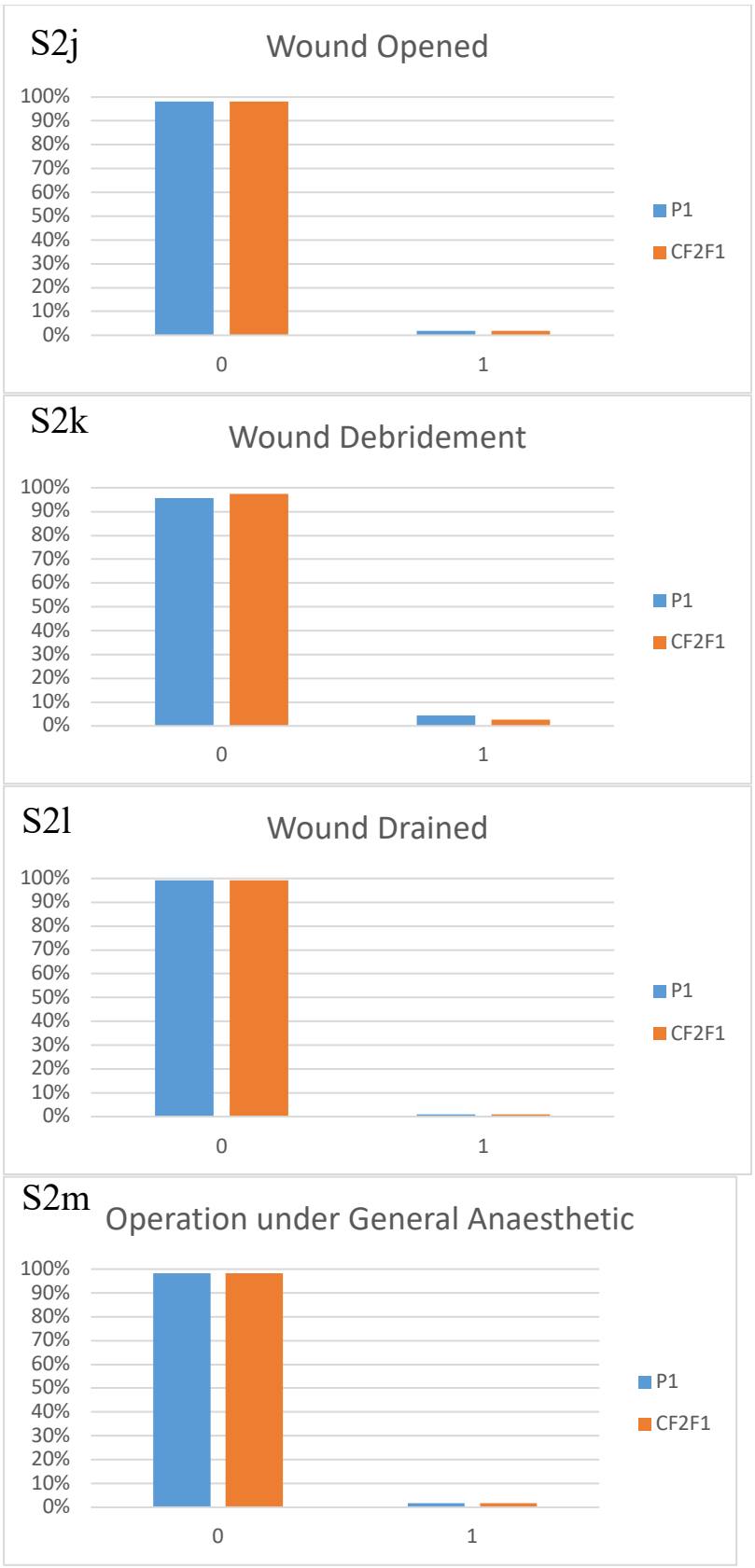


Figure S2a-m: Agreement by response categories to items 7-19. CR; remote clinician, CF2F; face-to-face clinician, P1; patient self assessment

18.10 Agreement by response categories to items 1-6

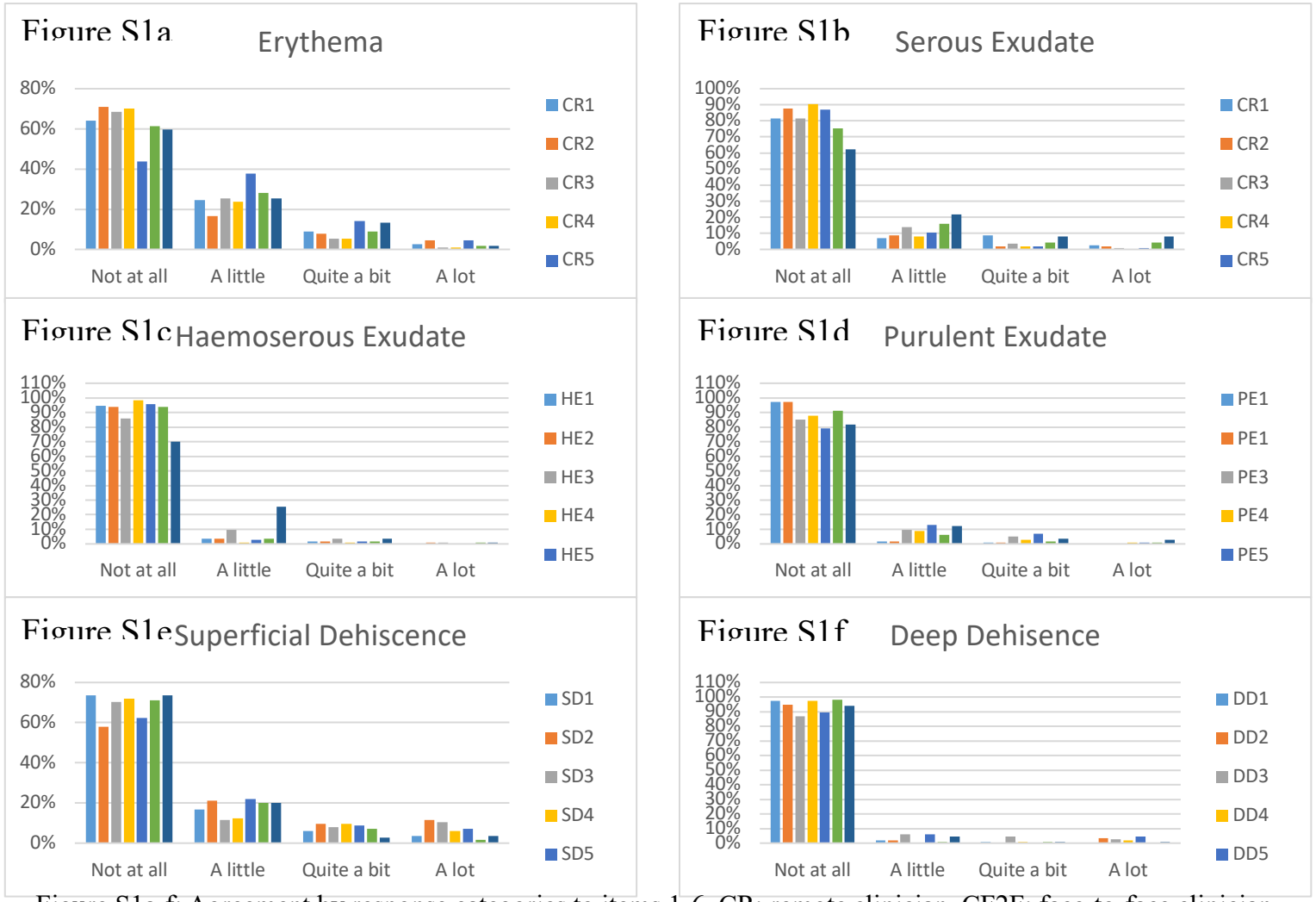
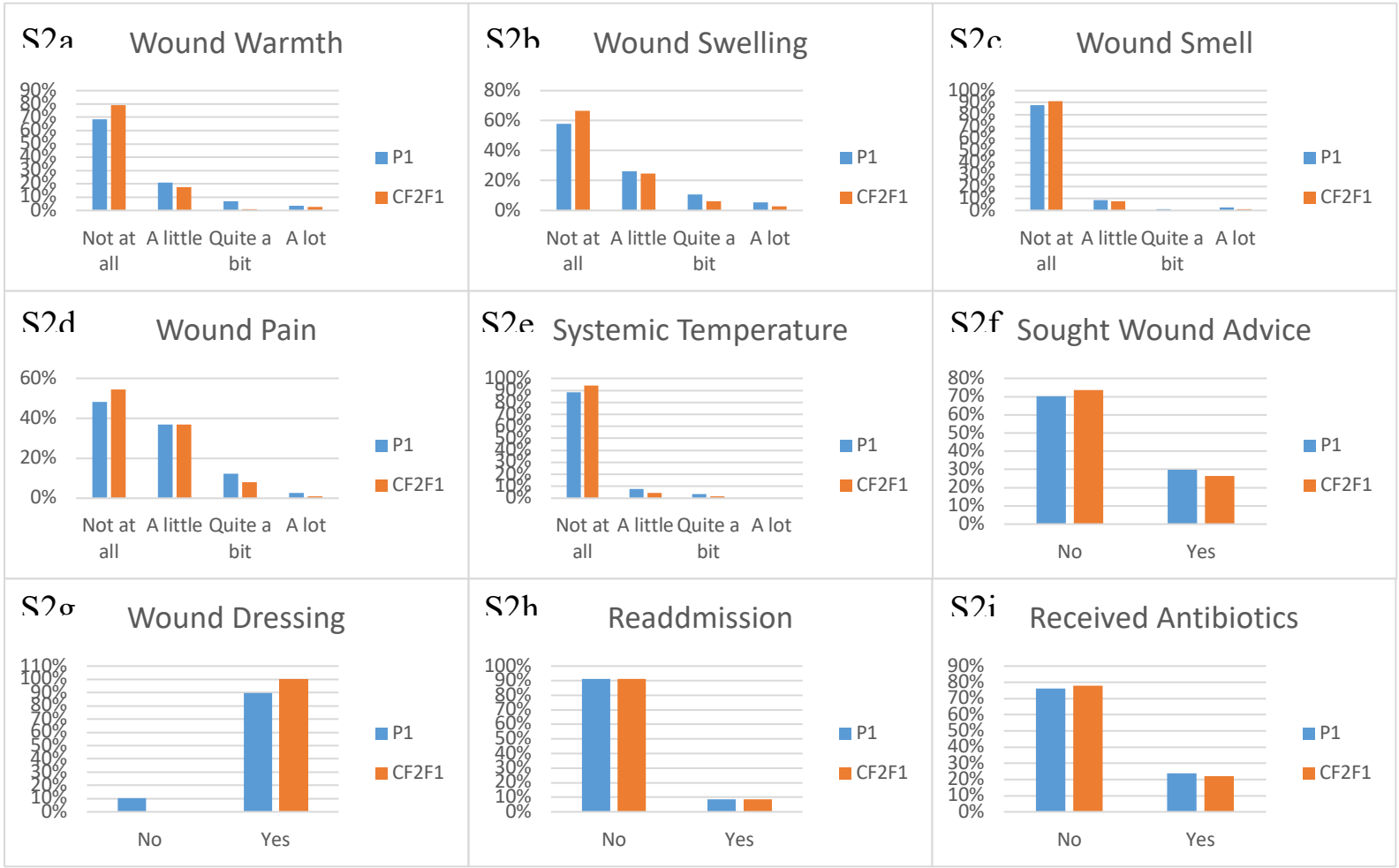


Figure S1a-f: Agreement by response categories to items 1-6. CR; remote clinician, CF2F; face-to-face clinician, P; patient self assessment

18.11 Agreement by response categories to items 7-19



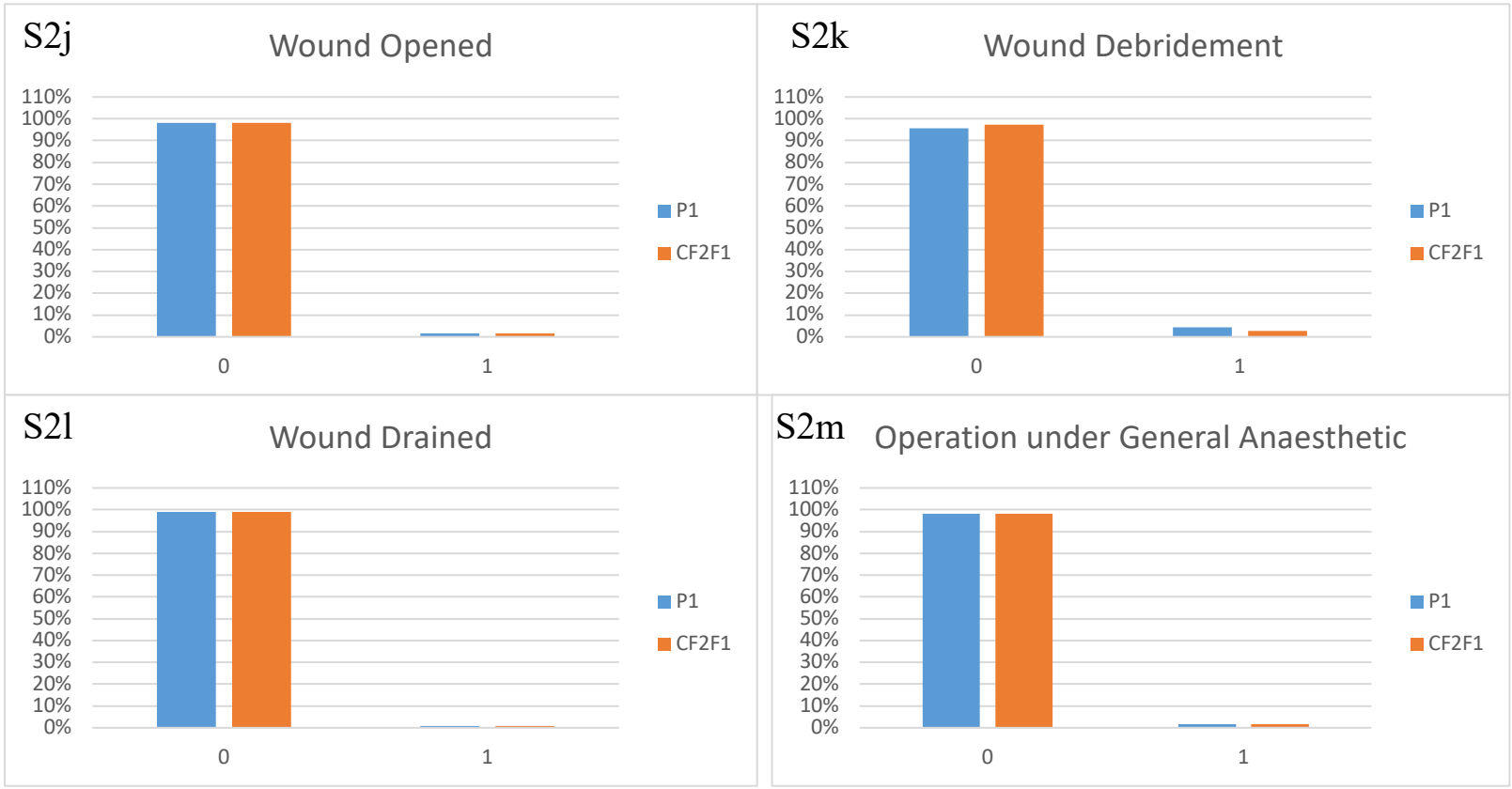


Figure S2a-m: Agreement by response categories to items 7-19. CR; remote clinician, CF2F; face-to-face clinician, P; patient self assessment

18.12 Inter-rater reliability for items 1-6 for all five remote clinical and patient responders using both ICC and κ.

	ICC	Lower	Upper	P value	Kappa	Lower	Upper	P value
Erythema								
CR1	0.906	0.830	0.947	<0.001	0.662	0.543	0.780	<0.001
CR2	0.758	0.571	0.863	<0.001	0.478	0.337	0.618	<0.001
CR3	0.417	-0.053	0.678	0.037	0.471	0.333	0.609	<0.001
CR4	0.636	0.347	0.797	<0.001	0.404	0.265	0.543	<0.001
CR5	0.740	0.533	0.855	<0.001	0.495	0.353	0.637	<0.001
Patient	0.697	0.562	0.791	<0.001	0.651	0.524	0.778	<0.001
Serous Exudate								
CR1	0.893	0.808	0.940	<0.001	0.700	0.572	0.829	<0.001
CR2	0.797	0.639	0.885	<0.001	0.453	0.259	0.646	<0.001
CR3	0.328	-0.215	0.628	0.093	0.437	0.296	0.578	<0.001
CR4	0.361	-0.148	0.644	0.066	0.425	0.245	0.605	<0.001
CR5	0.374	-0.123	0.652	0.058	0.234	0.098	0.370	<0.001
Patient	0.741	0.592	0.831	<0.001	0.583	0.429	0.737	<0.001
Haemoserous Exudate								
CR1	0.876	0.820	0.914	<0.001	0.651	0.413	0.889	<0.001
CR2	0.853	0.740	0.917	<0.001	0.750	0.516	0.985	<0.001
CR3	0.462	0.225	0.627	<0.001	0.263	0.031	0.494	<0.001
CR4	0.649	0.492	0.757	<0.001	0.326	0.005	0.646	<0.001
CR5	0.693	0.555	0.788	<0.001	0.450	0.090	0.810	<0.001
Patient	0.342	0.058	0.543	<0.001	0.255	0.097	0.412	<0.001
Purulent Exudate								

CR1	0.882	0.788	0.934	<0.001	0.266	-0.044	0.576	<0.001
CR2	0.732	0.524	0.849	<0.001	0.413	0.151	0.676	<0.001
CR3	0.604	0.284	0.781	0.001	0.385	0.171	0.599	<0.001
CR4	0.779	0.603	0.877	<0.001	0.366	0.151	0.580	<0.001
CR5	0.612	0.303	0.784	<0.001	0.231	0.043	0.418	0.001
Patient	0.230	-0.079	0.455	<0.001	0.453	0.211	0.694	<0.001
Superficial Dehiscence								
CR1	0.935	0.883	0.964	<0.001	0.795	0.695	0.895	<0.001
CR2	0.957	0.923	0.976	<0.001	0.514	0.399	0.628	<0.001
CR3	0.575	0.232	0.765	0.002	0.597	0.486	0.707	<0.001
CR4	0.902	0.824	0.945	<0.001	0.609	0.485	0.733	<0.001
CR5	0.852	0.735	0.918	<0.001	0.631	0.507	0.754	<0.001
Patient	0.793	0.700	0.857	<0.001	0.710	0.571	0.848	<0.001
Deep Dehiscence								
CR1	0.796	0.635	0.887	<0.001	0.663	0.128	1.000	<0.001
CR2	0.655	0.388	0.805	<0.001	0.242	-0.125	0.608	<0.001
CR3	0.402	-0.081	0.669	0.044	0.130	-0.101	0.362	0.001
CR4	0.937	0.887	0.965	<0.001	0.156	-0.103	0.415	<0.001
CR5	0.796	0.635	0.887	<0.001	0.327	-0.201	0.856	<0.001
Patient	0.728	0.607	0.812	<0.001	0.292	-0.161	0.746	<0.001

18.13 Inter-rater reliability for items 7-19 for patient responders using both ICC and κ.

	ICC	Lower	Upper	P value	Kappa	Lower	Upper	P value
Warmth	0.681	0.508	0.793	<0.001	0.478	0.277	0.679	<0.001
Swelling	0.735	0.591	0.828	<0.001	0.533	0.354	0.713	<0.001
Smell	0.824	0.728	0.886	<0.001	0.615	0.360	0.871	<0.001
Pain	0.818	0.719	0.882	<0.001	0.647	0.497	0.798	<0.001
Temp	0.823	0.727	0.885	<0.001	0.610	0.335	0.885	<0.001
Wound advice	0.933	0.897	0.957	<0.001	0.869	0.745	0.993	<0.001
Dressing	0.000	-0.542	0.352	0.500	0.000	0.000	0.000	-
Readmission	0.934	0.898	0.957	<0.001	0.876	0.706	1.045	<0.001
Antibiotics	0.828	0.735	0.888	<0.001	0.705	0.515	0.896	<0.001
Wound opened	1.000	1.000	1.000	-	1.000	1.000	1.000	<0.001
Wound debridement	0.664	0.482	0.782	<0.001	0.491	-0.109	1.091	<0.001
Pus Drained	1.000	1.000	1.000	-	1.000	1.000	1.000	<0.001
Operation	1.000	1.000	1.000	-	1.000	1.000	1.000	<0.001

18.14 Intra-rater reliability for items 1-6 for all five remote clinical and patient responders using both ICC and κ.

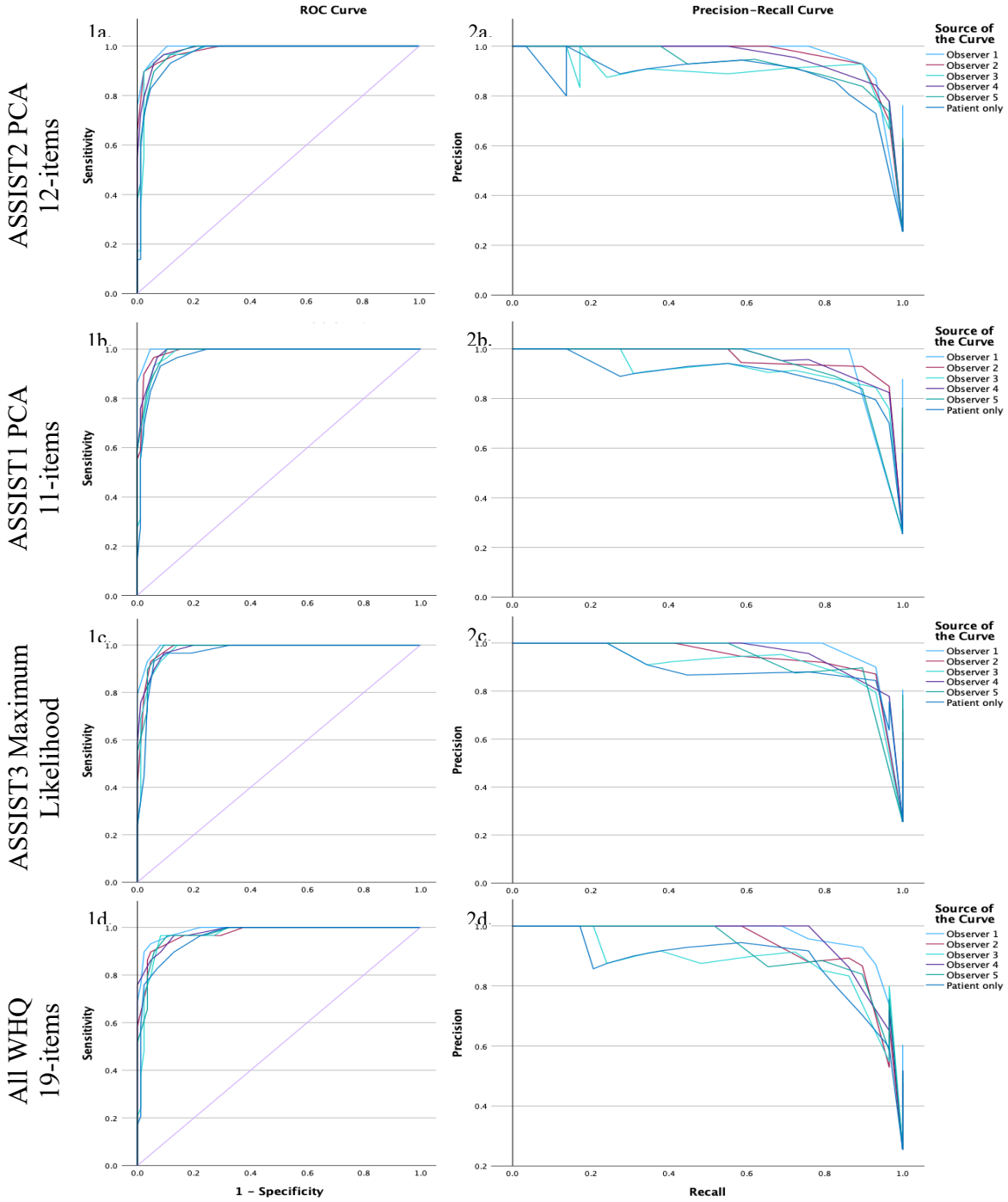
	ICC	Lower	Upper	P value	Kappa	Lower	Upper	P value
Erythema								
CR1	0.902	0.824	0.946	<0.001	0.777	0.602	0.952	<0.001
CR2	0.750	0.559	0.859	<0.001	0.553	0.297	0.808	<0.001
CR3	0.411	-0.047	0.671	<0.001	0.213	0.014	0.412	0.041
CR4	0.586	0.235	0.773	<0.001	0.297	0.112	0.482	0.002
CR5	0.740	0.533	0.855	<0.001	0.488	0.304	0.673	<0.001
Patient	0.615	0.308	0.785	<0.001	0.582	0.424	0.740	<0.001
Serous Exudate								
CR1	0.893	0.809	0.940	<0.001	0.692	0.512	0.872	<0.001
CR2	0.795	0.639	0.884	<0.001	0.517	0.143	0.891	<0.001
CR3	0.325	-0.208	0.624	<0.001	0.186	-0.001	0.372	0.084
CR4	0.354	-0.139	0.637	<0.001	0.219	-0.083	0.521	0.039
CR5	0.374	-0.123	0.652	<0.001	0.230	-0.228	0.687	0.111
Patient	0.606	0.292	0.780	<0.001	0.345	0.090	0.600	0.002
Haemoserous Exudate								
CR1	1.000	.	.	.	1.000	1.000	1.000	<0.001
CR2	0.853	0.741	0.917	<0.001	0.487	0.067	0.907	<0.001
CR3	0.183	-0.482	0.549	<0.001	0.240	-0.013	0.493	0.036
CR4	-0.044	-0.875	0.418	<0.001	-0.022	-0.052	0.008	0.882
CR5	0.000	.	.	.	.[e]	.[d]	.[d]	.[d]
Patient	0.230	-0.382	0.571	<0.001	0.258	0.007	0.508	0.026
Purulent Exudate								

CR1	0.884	0.791	0.935	<0.001	0.648	0.627	0.670	<0.001
CR2	0.723	0.513	0.843	<0.001	0.385	0.006	0.764	<0.001
CR3	0.608	0.288	0.784	<0.001	0.278	0.022	0.535	0.021
CR4	0.753	0.535	0.866	<0.001	0.523	0.295	0.752	<0.001
CR5	0.612	0.303	0.784	<0.001	0.323	0.096	0.550	0.001
Patient	0.643	0.359	0.801	<0.001	0.731	0.524	0.937	<0.001
Superficial Dehiscence								
CR1	0.932	0.878	0.962	<0.001	0.862	0.706	1.018	<0.001
CR2	0.957	0.924	0.976	<0.001	0.813	0.709	0.916	<0.001
CR3	0.575	0.235	0.764	<0.001	0.345	0.096	0.594	0.002
CR4	0.902	0.824	0.945	<0.001	0.662	0.480	0.843	<0.001
CR5	0.852	0.735	0.918	<0.001	0.627	0.429	0.824	<0.001
Patient	0.811	0.660	0.894	<0.001	0.577	0.360	0.793	<0.001
Deep Dehiscence								
CR1	0.796	0.636	0.886	<0.001	0.657	0.032	1.282	<0.001
CR2	0.656	0.391	0.806	<0.001	0.469	0.133	0.804	<0.001
CR3	0.398	-0.075	0.665	<0.001	0.190	-0.161	0.540	0.098
CR4	0.937	0.887	0.965	<0.001	0.820	0.628	1.013	<0.001
CR5	0.796	0.635	0.887	<0.001	0.657	0.032	1.282	<0.001
Patient	-0.033	-0.854	0.425	<0.001	0.655	0.101	1.209	<0.001

18.15 Intra-rater reliability for items 7-19 for patient responders using both ICC and κ.

	ICC	Lower	Upper	P value	Kappa	Lower	Upper	P value
Warmth	0.852	0.734	0.918	<0.001	0.592	0.429	0.754	<0.001
Swelling	0.491	0.086	0.716	0.012	0.311	0.070	0.552	0.004
Smell	0.965	0.938	0.981	<0.001	0.844	0.708	0.979	<0.001
Pain	0.623	0.324	0.790	<0.001	0.294	0.074	0.514	0.005
Temp	0.750	0.552	0.861	<0.001	0.505	0.252	0.758	<0.001
Wound advice	0.747	0.546	0.859	<0.001	0.594	0.343	0.845	<0.001
Dressing	0.156	-0.516	0.530	0.284	0.078	-0.209	0.366	0.519
Readmission	0.714	0.486	0.841	<0.001	0.554	0.207	0.901	<0.001
Antibiotics	0.932	0.878	0.962	<0.001	0.873	0.701	1.045	<0.001
Wound opened	0.796	0.635	0.887	<0.001	0.657	0.032	1.282	<0.001
Wound debridement	0.796	0.635	0.887	<0.001	0.657	0.032	1.282	<0.001
Pus Drained	0.000	.	.	.	.[f]	.[d]	.[d]	.[d]
Operation	0.000	.	.	.	.[f]	.[e]	.[e]	.[e]

18.16 Receiver operator characteristic and precision recall curves for each index test with all observers plotted.



18.17 Resource use for patients with SSI

Review															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Nurse face-to-face review	Review			28.50			0.3100		8.8350		89	786.3150	0.0000	786.3150	2536.50
Nurse Telephone	Review			13.17			0.1550		2.0408		3	6.1225	0.0000	6.1225	39.50
Vascular Telephone Review	Review			35.75			0.1550		5.5413		1	5.5413	0.0000	5.5413	35.75
ID telephone review	Review			56.50			0.1550		8.7575		2	17.5150		17.5150	113.00
ID face-to-face review	Review			56.50			0.3100		17.5150		1	17.5150		17.5150	56.50
ID face-to-face OPAT nurse review	Review			26.50			0.3100		8.2150		1	8.2150		8.2150	26.50
ED review	Review			53.00			0.3100		13.8000		8	110.4000	0.0000	110.4000	424.00
Vascular face-to-face clinic	Review			55.50			0.3100		17.2050		5	86.0250	0.0000	86.0250	277.50
GP review telephone	Review			41.13			0.1550		6.3752		3	19.1255	0.0000	19.1255	123.39
GP Precription	Review			29.00							61				1769.00

Transfer															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Transfer	Review			225.00			0.2747		18.2368		1	18.2368		18.2368	225.00

Admission															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Low-intensity ward days	Review			586.89	1	1	37.9000		37.9000		190	7201.0000		7201.0000	111509.10
High-intensity ward days	Review			1621.16	1	1	89.5000		89.5000		5	447.5000		447.5000	8105.80

Other Consumables															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Foley catheter	Product	Rubber (silicone)	0.0016	3.09	1	1	3.1800	1.0740	0.0051	0.0017	3	0.0153	0.0052	0.0204	9.27
	Packaging	LDPE	0.0023		1	1	2.6010	0.1720	0.0060	0.0004	3	0.0179	0.0012	0.0191	0.00
	Packaging	Paper	0.0010		1	1	0.9190	0.1720	0.0009	0.0002	3	0.0028	0.0005	0.0033	0.00
Syringe 20ml	Product	LDPE	0.0129	0.11	1	1	0.3000	1.0740	0.0330	0.0139	1	0.1650	0.0693	0.2343	0.55
	Packaging	Paper	0.0004		1	1	0.9190	0.1720	0.0004	0.0001	1	0.0018	0.0003	0.0022	0.00
	Packaging	LDPE	0.0007		1	1	2.6000	0.1720	0.0018	0.0001	1	0.0091	0.0006	0.0097	0.00
Cannula	Product	stainless steel	0.0610	0.71	1	1	0.3000	1.0740	0.2130	0.0655	13	2.7690	0.8517	3.6207	9.23
	Packaging	LDPE	0.0050		1	1	2.6006	0.1720	0.0130	0.0009	13	0.1690	0.0112	0.1802	0.00
	Packaging	Paper	0.0040		1	1	0.9190	0.1720	0.0037	0.0007	13	0.0478	0.0089	0.0567	0.00
Bionector	Product	Polyurethane	0.0100	0.51	1	1	0.3000	1.0740	0.1530	0.0107	13	1.9890	0.1396	2.1286	6.63
	Packaging	LDPE	0.0030		1	1	2.6006	0.1720	0.0078	0.0005	13	0.1014	0.0067	0.1081	0.00
	Packaging	Paper	0.0020		1	1	0.9190	0.1720	0.0018	0.0003	13	0.0239	0.0045	0.0284	0.00
Tegaderm	Product	LDPE	0.0100	0.14	1	1	1.5400	1.0740	0.2156	0.0107	16	3.4496	0.1718	3.6214	2.24
	Packaging	LDPE	0.0030		1	1	2.6006	0.1720	0.0078	0.0005	16	0.1248	0.0083	0.1331	0.00
0.9% NaCL 5ml Flush	Product	Pharmaceuticals	0.0180	0.62	1	1	0.3000	1.0740	0.1860	0.0193	13	2.4180	0.2513	2.6693	8.06
	Packaging	LDPE	0.0030		1	1	2.6006	0.1720	0.0078	0.0005	13	0.1014	0.0067	0.1081	0.00
2% chlorhexadine in 70% alcohol skin wipe	Product	Polypropylene	0.0014	0.02	1	1	0.3000	1.0740	0.0060	0.0015	13	0.0780	0.0195	0.0975	0.26
	Packaging	Aluminium	0.0010		1	1	9.1220	0.1720	0.0091	0.0002	13	0.1186	0.0022	0.1208	0.00
Tourniquet	Product	Silicone	0.0075	0.06	1	1	0.3000	1.0740	0.0180	0.0081	13	0.2340	0.1047	0.3387	0.78
MCS	Product	LDPE	0.0130	0.11	1	1	0.3000	1.0740	0.0330	0.0140	52	1.7160	0.7260	2.4420	5.72
	Packaging	LDPE	0.0030		1	1	2.6006	0.1720	0.0078	0.0005	52	0.4057	0.0268	0.4325	0.00
EDTA tube (FBC)	Product	Polypropylene	0.0080	0.08	1	1	0.3000	1.0740	0.0240	0.0086	84	2.0160	0.7217	2.7377	6.72
SST (Biochemistry)	Product	Polypropylene	0.1000	0.33	1	1	0.3000	1.0740	0.0990	0.1074	87	8.6130	9.3438	17.9568	28.71
Anticoagulant EDTA (G&S)	Product	Polypropylene	0.0200	0.07	1	1	0.3000	1.0740	0.0210	0.0215	24	0.5040	0.5155	1.0195	1.68
Sodium Citrate tube (Coagulation)	Product	Polypropylene	0.0080	0.20	1	1	0.3000	1.0740	0.0600	0.0086	50	3.0000	0.4296	3.4296	10.00
Glucose POCT	Product	Polypropylene	0.0120	0.24	1	1	0.3000	1.0720	0.0720	0.0129	160	11.5200	2.0582	13.5782	38.40
Blood culture	Product	Polypropylene	0.0360	4.60	1	1	0.3000	1.0740	1.3800	0.0387	11	15.1800	0.4253	15.6053	50.60
Arterial blood gas	Product	Polypropylene	0.0057	0.74	1	1	0.3000	1.0740	0.2220	0.0061	34	7.5480	0.2081	7.7561	25.16
	Packaging	LDPE	0.0006		1	1	2.6000	0.1720	0.0016	0.0001	34	0.0530	0.0035	0.0565	0.00

Other Consumables															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Blunt Fill Needle with filter	Product	stainless steel	0.0010	0.13	1	1	0.3000	1.0740	0.0390	0.0011	2	0.0780	0.0021	0.0801	0.26
	Packaging	Paper	0.0003		1	1	0.9190	0.1720	0.0003	0.0001	2	0.0006	0.0001	0.0007	0.00
	Packaging	LDPE	0.0003		1	1	2.6006	0.1720	0.0008	0.0001	2	0.0016	0.0001	0.0017	0.00

Imaging															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
CXR	Review			63.00			0.3100		0.7300		11	8.0300		8.0300	693.00
MSK XR	Review			126.00			0.3100		0.7300		7	5.1100		5.1100	882.00
CT Head	Review			174.00			0.3100		4.0000		2	8.0000		8.0000	348.00
CT angiogram	Review			361.00			0.3100		2.6100		10	26.1000		26.1000	3610.00
USS	Review			95.00			0.3100		0.5300		7	3.7100		3.7100	665.00
CTPA	Review			361.00			0.3100		2.6100		1	2.6100		2.6100	361.00
PET CT	Review			1587.00			0.3100		2.6100		1	2.6100		2.6100	1587.00

Pharmaceuticals															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Flucloxacillin 500mg PO	Product	Pharmaceuticals		0.11	1	1	0.1550		0.0167		672	11.1972		11.1972	72.24
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	672	1.0053	0.0190	1.0243	0.00
Flucloxacillin 1g PO	Product	Pharmaceuticals		0.22	1	1	0.1550		0.0333		55	1.8329		1.8329	11.83
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	55	0.0823	0.0016	0.0838	0.00
Flucloxacillin 1g IV	Product	Pharmaceuticals		3.45	1	1	0.1550		0.5348		29	15.5078		15.5078	100.05
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	29	1.8100	0.1197	1.9298	0.00
Flucloxacillin 2g IV	Product	Pharmaceuticals		6.00	1	1	0.1550		0.9300		40	37.2000		37.2000	240.00
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	40	2.4966	0.1651	2.6617	0.00
Metronidazole 400mg PO	Product	Pharmaceuticals		0.06	1	1	0.1550		0.0098	0.0000	231	2.2677	0.0000	2.2677	14.63

Pharmaceuticals															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0021	0.0000	231	0.4937	0.0093	0.5030	0.00
Metronidazole 500mg IV	Product	Pharmaceuticals		3.59	1	1	0.1550		0.5568		8	4.4547		4.4547	28.74
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	8	0.4993	0.0330	0.5323	0.00
Doxycycline 100mg	Product	Pharmaceuticals		0.11	1	1	0.1550		0.0167		28	0.4666		0.4666	3.01
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	28	0.0419	0.0008	0.0427	0.00
Co-trimoxazole 960mg PO	Product	Pharmaceuticals		0.24	1	1	0.1550		0.0367	0.0000	308	11.3144	0.0000	11.3144	73.00
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	308	0.4608	0.0087	0.4695	0.00
Clarithromycin 500mg IV	Product	Pharmaceuticals		11.15	1	1	0.1550		1.7283		42	72.5865	0.0000	72.5865	468.30
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	42	2.6214	0.1734	2.7948	0.00
Gentamicin 240mg IV	Product	Pharmaceuticals		3.60	1	1	0.1550		0.5580		1	0.5580		0.5580	3.60
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	1	0.0624	0.0041	0.0665	0.00
Gentamicin 320mg IV	Product	Pharmaceuticals		7.22	1	1	0.1550		1.1198		2	2.2396		2.2396	14.45
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	2	0.1248	0.0083	0.1331	0.00
Teicoplanin 400mg IV	Product	Pharmaceuticals		7.32	1	1	0.1550		1.1346		4	4.5384		4.5384	29.28
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	4	0.2497	0.0165	0.2662	0.00
Teicoplanin 800mg IV	Product	Pharmaceuticals		18.16	1	1	0.1550		2.8148		18	50.6664		50.6664	326.88
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	18	1.1235	0.0743	1.1978	0.00
Teicoplanin 2g IV	Product	Pharmaceuticals		36.60	1	1	0.1550		5.6730		3	17.0190		17.0190	109.80
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	3	0.1872	0.0124	0.1996	0.00
Cefuroxime 750mg IV	Product	Pharmaceuticals		2.52	1	1	0.1550		0.3906		6	2.3436		2.3436	15.12
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	6	0.3745	0.0248	0.3993	0.00
Piperacillin and Tazobactam 4.5g IV	Product	Pharmaceuticals		15.75	1	1	0.1550		2.4413		9	21.9713		21.9713	141.75
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	9	0.5617	0.0372	0.5989	0.00
Linezolid 600mg PO	Product	Pharmaceuticals		32.72	1	1	0.1550		5.0711		49	248.4856		248.4856	1603.13
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	49	0.0733	0.0014	0.0747	0.00
Linezolid 600mg IV	Product	Pharmaceuticals		44.50	1	1	0.1550		6.8975		5	34.4875		34.4875	222.50
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	5	0.3121	0.0206	0.3327	0.00
Meropenem 1g IV	Product	Pharmaceuticals		16.00	1	1	0.1550		2.4800		13	32.2400		32.2400	208.00
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	13	0.8114	0.0537	0.8651	0.00
Meropenem 2g IV	Product	Pharmaceuticals		32.00	1	1	0.1550		4.9600		96	476.1600		476.1600	3072.00

Pharmaceuticals															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	96	5.9919	0.3963	6.3882	0.00
Ertapenem1g IV	Product	Pharmaceuticals		31.65	1	1	0.1550		4.9058		49	240.3818		240.3818	1550.85
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	49	3.0584	0.2023	3.2606	0.00
Ciprofloxacin 750mg PO	Product	Pharmaceuticals		1.05	1	1	0.1550		0.1629		56	9.1227		9.1227	58.86
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	56	0.0838	0.0016	0.0854	0.00
Co-amoxiclav 625mg PO	Product	Pharmaceuticals		0.29	1	1	0.1550		0.0443		63	2.7900		2.7900	18.00
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0021	0.0000	63	0.1346	0.0025	0.1372	0.00
Co-amoxiclav 1.2g IV	Product	Pharmaceuticals		2.75	1	1	0.1550		0.4263		4	1.7050		1.7050	11.00
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	4	0.2497	0.0165	0.2662	0.00
Aztreonam 2g IV	Product	Pharmaceuticals		18.82	1	1	0.1550		2.9171		3	8.7513		8.7513	56.46
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	3	0.1872	0.0124	0.1996	0.00
Moxifloxacin 400mg PO	Product	Pharmaceuticals		2.49	1	1	0.1550		0.3853		13	5.0093		5.0093	32.32
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	13	0.0194	0.0004	0.0198	0.00
Paracetamol 1g PO	Product	Pharmaceuticals		0.05	1	1	0.1550		0.0079		353	2.8014		2.8014	18.07
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	353	0.5281	0.0100	0.5380	0.00
Paracetamol 1g IV	Product	Pharmaceuticals		1.35	1	1	0.1550		0.2093		26	5.4405		5.4405	35.10
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	26	1.6228	0.1073	1.7301	0.00
Co-codamol 30.500mg	Product	Pharmaceuticals		0.04	1	1	0.1550		0.0063		95	0.5993		0.5993	3.87
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	95	0.1421	0.0027	0.1448	0.00
Codeine Phosphate 30mg PO	Product	Pharmaceuticals		0.04	1	1	0.1550		0.0055	0.0000	120	0.6576	0.0000	0.6576	4.24
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	120	0.1795	0.0034	0.1829	0.00
Codeine Phosphate 60mg PO	Product	Pharmaceuticals		0.07	1	1	0.1550		0.0106	0.0000	1	0.0106	0.0000	0.0106	0.07
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	1	0.0015	0.0000	0.0015	0.00
Dihydrocodeine	Product	Pharmaceuticals		0.09	1	1	0.1550		0.0141		3	0.0423		0.0423	0.27
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	3	0.0045	0.0001	0.0046	0.00
Oxycodone 10mg MR	Product	Pharmaceuticals		0.17	1	1	0.1550		0.0260	0.0000	6	0.1559	0.0000	0.1559	1.01
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	6	0.0090	0.0002	0.0091	0.00
Oxycodone 10mg IR	Product	Pharmaceuticals		0.25	1	1	0.1550		0.0380	0.0000	1	0.0380	0.0000	0.0380	0.25
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	1	0.0015	0.0000	0.0015	0.00

Pharmaceuticals															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
MST 5mg	Product	Pharmaceuticals		0.05	1	1	0.1550		0.0085		10	0.0850		0.0850	0.55
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	10	0.0150	0.0003	0.0152	0.00
MST 10mg	Product	Pharmaceuticals		0.09	1	1	0.1550		0.0134		10	0.1343		0.1343	0.87
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	10	0.0150	0.0003	0.0152	0.00
MST 15mg	Product	Pharmaceuticals		0.15	1	1	0.1550		0.0235		61	1.4340		1.4340	9.25
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	61	0.0913	0.0017	0.0930	0.00
Morphine 10mg/5ml Oral Solution	Product	Pharmaceuticals		0.08	1	1	0.1550		0.0116	0.0000	653	7.5940	0.0000	7.5940	48.99
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	504	3.3917	2.5982	5.9899	0.00
Morhpine 1mg/ml PCA infusion	Product	Pharmaceuticals		0.18	1	1	0.1550		0.0271	0.0000	399	10.8283	0.0000	10.8283	69.86
	Packaging	Glass	0.0005		1	1	1.4020	1.0740	0.0007	0.0005	399	0.2686	0.2058	0.4744	0.00
Morphine 10mg/10ml x1ml	Product	Pharmaceuticals		1.75	1	1	0.1550		0.2713	0.0000	6	1.4919	0.0000	1.4919	9.63
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	6	0.0370	0.0284	0.0654	0.00
Levobupivicaine 0.25% 25mg/20ml (1ml)	Product	Pharmaceuticals		0.21	1	1	0.1550		0.0328	0.0000	3	0.0820	0.0000	0.0820	0.53
	Packaging	LDPE	0.0002		1	1	1.4020	1.0740	0.0003	0.0003	3	0.0008	0.0006	0.0015	0.00
Nefopam 30mg PO	Product	Pharmaceuticals		0.04	1	1	0.1550		0.0068	0.0000	122	0.8341	0.0000	0.8341	5.38
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	122	0.1825	0.0034	0.1860	0.00
Dalteparin 18,000 units	Product	Pharmaceuticals		10.16	1	1	0.1550		1.5754		22	34.6592		34.6592	223.61
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	22	1.3731	0.0908	1.4640	0.00
Dalteparin 12500 units	Product	Pharmaceuticals		7.06	1	1	0.1550		1.0940		2	2.1880		2.1880	14.12
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	2	0.1248	0.0083	0.1331	0.00
Dalteparin 5000 units	Product	Pharmaceuticals		2.82	1	1	0.1550		0.4376		167	73.0734		73.0734	471.44
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	167	10.4234	0.6894	11.1127	0.00
Pregabalin 300mg	Product	Pharmaceuticals		0.13	1	1	0.1550		0.0199	0.0000	22	0.4378	0.0000	0.4378	2.82
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	22	0.0329	0.0006	0.0335	0.00
Pregabalin 225mg	Product	Pharmaceuticals		0.11	1	1	0.1550		0.0177	0.0000	1	0.0177	0.0000	0.0177	0.11
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	1	0.0015	0.0000	0.0015	0.00
Pregabalin 100mg	Product	Pharmaceuticals		0.07	1	1	0.1550		0.0103	0.0000	6	0.0619	0.0000	0.0619	0.40
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	6	0.0090	0.0002	0.0091	0.00
Pregabalin 50mg	Product	Pharmaceuticals		0.05	1	1	0.1550		0.0074	0.0000	1	0.0074	0.0000	0.0074	0.05

Pharmaceuticals															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	1	0.0015	0.0000	0.0015	0.00
Gabapentin 300mg PO	Product	Pharmaceuticals		0.03	1	1	0.1550		0.0042		101	0.4289		0.4289	2.77
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0021	0.0000	101	0.2159	0.0041	0.2199	0.00
Iloprost 50mcg	Product	Pharmaceuticals		75.00	1	1	0.1550		11.6250	0.0000	1	11.6250	0.0000	11.6250	75.00
	Packaging	LDPE	0.0002		1	1	1.4020	1.0740	0.0003	0.0003	1	0.0003	0.0003	0.0006	0.00
Ondansetron 4mg IV	Product	Pharmaceuticals	0.0002	5.99	1	1	0.1550		0.9285	0.0000	18	16.7121	0.0000	16.7121	107.82
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	18	0.1211	0.0928	0.2139	0.00
Ondansetron 8mg IV	Product	Pharmaceuticals	0.0002	5.67	1	1	0.1550		0.8795	0.0000	6	5.2768	0.0000	5.2768	34.04
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	6	0.0404	0.0309	0.0713	0.00
Cyclizine 50mg IV	Product	Pharmaceuticals		1.95	1	1	0.1550		0.3019		25	7.5485		7.5485	48.70
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	25	1.5604	0.1032	1.6636	0.00
Metoclopramide 10mg IV	Product	Pharmaceuticals		0.90	1	1	0.1550		0.1395		1	0.1395		0.1395	0.90
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	1	0.0624	0.0041	0.0665	0.00
Harmanns 1L	Product	Pharmaceuticals		2.21	1	1	0.1550		0.4108		4	0.4108	0.0000	0.4108	7.74
	Packaging	LDPE	0.0500		1	1	2.6010	0.1720	0.1301	0.0086	4	0.1301	0.0011	0.1312	0.00
	Packaging	LDPE	0.0102		1	1	2.6000	0.1720	0.0265	0.0018	4	0.0928	0.0061	0.0990	0.00
NaCl 1L	Product	Pharmaceuticals		2.65	1	1	0.1550		0.4108		3	1.2323	0.0000	1.2323	7.95
	Packaging	LDPE	0.0500		1	1	2.6010	0.1720	0.1301	0.0086	3	0.3902	0.0034	0.3935	0.00
	Packaging	LDPE	0.0102		1	1	2.6000	0.1720	0.0265	0.0018	3	0.0796	0.0053	0.0848	0.00
0.9% NaCL 500ml	Product	Pharmaceuticals	0.5278	1.71	1	1	0.3000		0.5130		31	15.9030	0.0000	15.9030	53.01
	Packaging	LDPE	0.0200		1	1	2.6000	0.1720	0.0520	0.0034	31	1.6120	0.1066	1.7186	0.00
	Packaging	LDPE	0.0102		1	1	2.6000	0.1720	0.0265	0.0018	31	0.8221	0.0544	0.8765	0.00
NaCl 250ml	Product	Pharmaceuticals		1.85	1	1	0.1550		0.2868		1	0.2868	0.0000	0.2868	1.85
	Packaging	LDPE	0.0500		1	1	2.6010	0.1720	0.1301	0.0086	1	0.1301	0.0011	0.1312	0.00
	Packaging	LDPE	0.0102		1	1	2.6000	0.1720	0.0265	0.0018	1	0.0265	0.0018	0.0283	0.00
Glucose 5% infusion 500ml	Product	Pharmaceuticals	0.5278	1.88	1	1	0.3000		0.5640		1	0.5640	0.0000	0.5640	1.88
	Packaging	LDPE	0.0200		1	1	2.6000	0.1720	0.0520	0.0034	1	0.0520	0.0034	0.0554	0.00
	Packaging	LDPE	0.0102		1	1	2.6000	0.1720	0.0265	0.0018	1	0.0265	0.0018	0.0283	0.00
Senna 15mg PO	Product	Pharmaceuticals		0.08	1	1	0.1550		0.0124	0.0000	5	0.0620	0.0000	0.0620	0.40
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	5	0.0075	0.0001	0.0076	0.00

Pharmaceuticals															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Phosphates enema 128ml	Product	Pharmaceuticals	0.1280	30.78	1	1	0.1550		4.7709	0.0000	1	4.7709	0.0000	4.7709	30.78
	Packaging	Aluminium	0.0460		1	1	9.1220	0.1720	0.4196	0.0079	1	0.4196	0.0079	0.4275	0.00
Lactulose 15ml	Product	Pharmaceuticals		0.25	1	1	0.1550		0.0388	0.0000	37	1.4338	0.0000	1.4338	9.25
	Packaging	Paper	0.0069		1	1	0.9190	0.1720	0.0063	0.0012	37	0.2347	0.0439	0.2786	0.00
Macrogol	Product	Pharmaceuticals		4.64	1	1	0.1550		0.7186		51	36.6481		36.6481	236.44
	Packaging	Paper	0.0089		1	1	9.1220	0.1720	0.0814	0.0015	51	4.1526	0.0783	4.2309	0.00
Zopiclone 7.5mg PO	Product	Pharmaceuticals		0.08	1	1	0.1550		0.0125	0.0000	12	0.1495	0.0000	0.1495	0.96
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	12	0.0180	0.0003	0.0183	0.00
Nicotine 21mg Transderm patch	Product	Pharmaceuticals		1.64	1	1	0.1550		0.2542	0.0000	4	1.0168	0.0000	1.0168	6.56
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	4	0.0060	0.0001	0.0061	0.00
Bumetanide 1mg	Product	Pharmaceuticals		0.06	1	1	0.1550		0.0086		7	0.0601		0.0601	0.39
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0021	0.0000	7	0.0150	0.0003	0.0152	0.00
Insulin aspart biphasic - novomix 30 flexpen 40 units	Product	Pharmaceuticals		0.82	1	1	0.1550		0.1265		23	2.9090		2.9090	18.77
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	23	1.4356	0.0949	1.5305	0.00
Lidocaine Hydrochloride 10mg/ml (1%) 1ml	Product	Pharmaceuticals	0.0063	0.11	1	1	0.3000		0.0336		3	0.1008	0.0000	0.1008	0.34
	Packaging	Polypropylene	0.0013		1	1	3.1050	0.1720	0.0040	0.0002	3	0.0121	0.0007	0.0128	0.00
Alteplase 2mg (10mg vial)	Product	Pharmaceuticals		172.80	1	1	0.1550		26.7840	0.0000	3	80.3520	0.0000	80.3520	518.40
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	3	0.0202	0.0155	0.0357	0.00

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Cost
Consultant anaesthetist	Review			113.00	1						26				2966.25
Consultant Radiologist	Review			113.00	1						4				452.00
Registrar	Review			53.00	1						28				1497.25
Consultant surgeon	Review			111.00	1						26				2913.75
Band 5 staff	Review			43.00	3						36				1558.75

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Cost
5F Nylex Sheath Terumo	Product	Nylon/polyamide	0.0480	12.96	1	1	0.4100	1.0740	5.3136	0.0516	3	15.9408	0.1547	16.0955	38.88
	Packaging	Paper	0.0010		1	1	0.9200	0.1720	0.0009	0.0002	3	0.0028	0.0005	0.0033	0.00
	Packaging	LDPE	0.0010		1	1	2.6000	0.1720	0.0026	0.0002	3	0.0078	0.0005	0.0083	0.00
Omnipaque 300 mg/ml (100ml) (total weight)	Product	Iohexol	0.1680		1	1	0.3000		0.0000	0.0000	3	0.0000	0.0000	0.0000	0.00
	Packaging	Polypropylene	0.0240		1	1	0.3000	0.1720	0.0072	0.0041	3	0.0216	0.0124	0.0340	0.00
6F Angioseal Terumo	Product	collagen	0.0040	166.80	1	1	0.4100		68.3880		3	205.1640	0.0000	205.1640	500.40
	Product	Nylon/polyamide	0.0700		1	1		1.0740		0.0752	3	0.0000	0.2255	0.2255	0.00
	Packaging	LDPE	0.0220		1	1	2.6000	0.1720	0.0572	0.0038	3	0.1716	0.0114	0.1830	0.00
Scalpel 15	Product	Steel		0.27	1	1	0.3000		0.0810	0.0448	3	0.2430	0.1344	0.3774	0.81
Needle 21G green	Product	Polypropylene + steel		0.08	1	1	0.3000		0.0240	0.0448	3	0.0720	0.1344	0.2064	0.24
Towel paper	Product	Paper		1.51	1	1			0.0906	0.0448	3	0.2718	0.1344	0.4062	4.53
Gallipot 120ml (x2)	Product	Polypropylene			1	1			0.0906	0.0448	3	0.2718	0.1344	0.4062	0.00
Sponge bowl 500ml (x2)	Product	Polypropylene			1	1	0.3000		0.0906	0.0448	3	0.2718	0.1344	0.4062	0.00
Kidney bowl 700ml	Product	Polypropylene			1	1			0.0906	0.0448	3	0.2718	0.1344	0.4062	0.00
Bowl sponge	Product	rubber			1	1			0.0906	0.0448	3	0.2718	0.1344	0.4062	0.00
Needle containment device	Product	Polypropylene		1.55	1	1	0.3000		0.4650	0.0448	3	1.3950	0.1344	1.5294	4.65
10ml Syringe (x3)	Product	Polypropylene		0.30	1	1	0.3000		0.0900	0.0448	3	0.2700	0.1344	0.4044	0.90
Foam prep spone 5cm x 4cm x 3cm	Product	Polypropylene +	1.0010	0.34	1	1	0.3000	1.0740	0.1020	0.0448	3	0.3060	0.1344	0.4404	1.02
Chloraprep tint 10.5ml	Product	Polypropylene		1.10	1	1			0.1100	0.0448	3	0.3300	0.1344	0.4644	3.30
	Product	Chlorhexadine gluconate 2% w/v and isopropyl alcohol 70% v/v			1	1	0.3000		0.1100	0.0448	3	0.3300	0.1344	0.4644	0.00
PIL chloraprep tint	Product	Paper			1	1			0.1100	0.0448	3	0.3300	0.1344	0.4644	0.00
Guidewire bowl	Product	Polypropylene		2.53	1	1	0.3000		0.7590	0.0448	3	2.2770	0.1344	2.4114	7.59
Needle 25G orange	Product	Polypropylene + steel		0.08	1	1	0.3000		0.0240	0.0448	3	0.0720	0.1344	0.2064	0.24
Sponge stick medium 15cm	Product	Polypropylene +		0.34	1	1	0.3000		0.1020	0.0448	3	0.3060	0.1344	0.4404	1.02
Gauze swab 10cm x 10cm x4 (5 pack)	Product	Cotton		0.55	1	1	0.3000		0.1650	0.0448	3	0.4950	0.1344	0.6294	1.65

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Cost
Trolley cover 140x140cm	Product	LDPE		4.50	1	1	0.3000		1.3500	0.0448	3	4.0500	0.1344	4.1844	13.50
20ml syringe (x2)	Product	Polypropylene		0.14	1	1	0.3000		0.0420	0.0448	3	0.1260	0.1344	0.2604	0.42
18G needle introducer 70mm	Product	Steel + LDPE + polypropylene		1.80	1	1	0.3000		0.5400	0.0448	3	1.6200	0.1344	1.7544	5.40
Cover fluoro medium blue	Product	Polypropylene		1.54	1	1	0.3000		0.4620	0.0448	3	1.3860	0.1344	1.5204	4.62
Drape 200x330cm	Product	LDPE		10.70	1	1	0.3000		3.2100	0.0448	3	9.6300	0.1344	9.7644	32.10
Clamp towl	Product	Cotton			1	1				0.0448	3	0.0000	0.1344	0.1344	0.00
Label waterproof 2 across 45x10mm (x40)	Product	Paper		0.01	1	1	0.3000		0.0030	0.0448	3	0.0090	0.1344	0.1434	0.03
		Paper	0.0130		1	1	0.9200	0.1720	0.0120	0.0022	3	0.0359	0.0067	0.0426	0.00
	Packaging	LDPE	0.0460		1	1	2.6000	0.1720	0.1196	0.0079	3	0.3588	0.0237	0.3825	0.00
Guidewire	Product	Nitinol (nickel titanium)	0.0090	30.72	1	1	0.3000	1.0740	9.2160	0.0097	3	27.6480	0.0290	27.6770	92.16
	Packaging	Paper	0.0050		1	1	0.9200	0.1720	0.0046	0.0009	3	0.0138	0.0026	0.0164	0.00
	Packaging	LDPE	0.0040		1	1	2.6000	0.1720	0.0104	0.0007	3	0.0312	0.0021	0.0333	0.00
Inflation device (basixCOMPAK)	Product	Polycarbonate	0.1661	22.02	1	1	0.3000	1.0740	6.6060	0.1784	3	19.8180	0.5352	20.3532	66.06
	Packaging	Paper	0.0039		1	1	0.9200	0.1720	0.0036	0.0007	3	0.0108	0.0020	0.0128	0.00
	Packaging	LDPE	0.0500		1	1	2.6000	0.1720	0.1300	0.0086	3	0.3900	0.0258	0.4158	0.00
Giving set (merit Disposal Depot)	Product	Polyurethane	0.1298		1	1	0.3000	1.0740	0.0389	0.1394	3	0.1168	0.4182	0.5350	0.00
	Packaging	Paper	0.0042		1	1	0.9200	0.1720	0.0039	0.0007	3	0.0116	0.0022	0.0138	0.00
	Packaging	LDPE	0.0150		1	1	2.6000	0.1720	0.0390	0.0026	3	0.1170	0.0077	0.1247	0.00
Torque device (terumo - radifocus)	Product	Polypropylene	0.0010	6.60	1	1	0.3000	1.0740	1.9800	0.0011	3	5.9400	0.0032	5.9432	19.80
	Packaging	Paper	0.0010		1	1	0.9200	0.1720	0.0009	0.0002	3	0.0028	0.0005	0.0033	0.00
	Packaging	LDPE	0.0010		1	1	2.6000	0.1720	0.0026	0.0002	3	0.0078	0.0005	0.0083	0.00
Biogel Surgeon Gloves 7.5 latex	Product	Rubber	0.0070	1.06	1	1	0.3000	1.0740	0.3180	0.0075	3	0.9540	0.0226	0.9766	3.18
	Packaging	Paper	0.0060		1	1	0.9200	0.1720	0.0055	0.0010	3	0.0166	0.0031	0.0197	0.00
	Packaging	LDPE	0.0060		1	1	2.6000	0.1720	0.0156	0.0010	3	0.0468	0.0031	0.0499	0.00
Gammex latex gloves 7	Product	Latex	0.0070	0.81	1	1	0.3000	1.0740	0.2430	0.0075	3	0.7290	0.0226	0.7516	2.43
	Packaging	Paper	0.0040		1	1	0.9200	0.1720	0.0037	0.0007	3	0.0110	0.0021	0.0131	0.00
	Packaging	LDPE	0.0030		1	1	2.6000	0.1720	0.0078	0.0005	3	0.0234	0.0015	0.0249	0.00

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Cost
Biogel Surgeon Gloves 6	Product	Rubber	0.0070	1.06	1	1	0.3000	1.0740	0.3180	0.0075	3	0.9540	0.0226	0.9766	3.18
	Packaging	Paper	0.0060		1	1	0.9200	0.1720	0.0055	0.0010	3	0.0166	0.0031	0.0197	0.00
	Packaging	LDPE	0.0060		1	1	2.6000	0.1720	0.0156	0.0010	3	0.0468	0.0031	0.0499	0.00
Gammex latex gloves 6	Product	Latex	0.0070	0.81	1	1	0.3000	1.0740	0.2430	0.0075	3	0.7290	0.0226	0.7516	2.43
	Packaging	Paper	0.0040		1	1	0.9200	0.1720	0.0037	0.0007	3	0.0110	0.0021	0.0131	0.00
	Packaging	LDPE	0.0030		1	1	2.6000	0.1720	0.0078	0.0005	3	0.0234	0.0015	0.0249	0.00
500ml NaCL	Product	Pharmaceuticals	0.5278	1.71	1	1	0.1550		0.0818	0.0000	3	0.2454	0.0000	0.2454	5.13
	Packaging	LDPE	0.0250		1	1	2.6000	0.1720	0.0650	0.0043	3	0.1950	0.0129	0.2079	0.00
Waste disposal bag	Product	LDPE	0.0230		1	1	2.6000	1.0740	0.0598	0.0247	3	0.1794	0.0741	0.2535	0.00
Surgical gown	Product	LDPE	0.0350		1	1	2.6000	1.0740	0.0910	0.0376	8	0.7280	0.3007	1.0287	0.00
	Packaging	Paper	0.0270		1	1	0.9200	0.1720	0.0248	0.0046	8	0.1987	0.0372	0.2359	0.00
	Packaging	LDPE	0.0051		1	1	2.6000	0.1720	0.0133	0.0009	8	0.1061	0.0070	0.1131	0.00
Small drape 75x75	Product	Polypropylene	0.0430	5.28	1	1	3.1050	1.0740	16.3944	0.0462	9	147.5496	0.4156	147.9652	47.52
	Packaging	Paper	0.0010		1	1	0.9200	0.1720	0.0009	0.0002	9	0.0083	0.0015	0.0098	0.00
	Packaging	LDPE	0.0100		1	1	2.6000	0.1720	0.0260	0.0017	9	0.2340	0.0155	0.2495	0.00
Mayo stand cover 80X144	Product	Polypropylene	0.2090	1.11	1	1	3.1050	1.0740	3.4466	0.2245	9	31.0190	2.0202	33.0391	9.99
	Packaging	Paper	0.0010		1	1	0.9200	0.1720	0.0009	0.0002	9	0.0083	0.0015	0.0098	0.00
	Packaging	LDPE	0.0100		1	1	2.6000	0.1720	0.0260	0.0017	9	0.2340	0.0155	0.2495	0.00
Trolley cover	Product	Polypropylene	0.2040	2.83	1	1	3.1050	1.0740	8.7872	0.2191	9	79.0844	1.9719	81.0562	25.47
	Packaging	Paper	0.0010		1	1	0.9200	0.1720	0.0009	0.0002	9	0.0083	0.0015	0.0098	0.00
	Packaging	LDPE	0.0100		1	1	2.6000	0.1720	0.0260	0.0017	9	0.2340	0.0155	0.2495	0.00
Drape pack 100x85 183x183 350x152 200x152	Product	Polypropylene	0.8790	11.40	1	1	3.1050	1.0740	2.7293	0.9440	9	24.5637	8.4964	33.0601	102.60
	Packaging	Paper	0.0010		1	1	0.9200	0.1720	0.0009	0.0002	9	0.0083	0.0015	0.0098	0.00
	Packaging	LDPE	0.0100		1	1	2.6000	0.1720	0.0260	0.0017	9	0.2340	0.0155	0.2495	0.00
Vascular general set	Product	Stainless steel	4.5600		2040	1	0.3700	0.5690	0.0008	2.5946	5	0.0041	12.9732	12.9773	0.00
Suction connecting tube	Product	Polypropylene	0.1114	0.98	1	1	0.3000	1.0740	0.2940	0.1196	8	2.3520	0.9571	3.3091	7.84
	Packaging	Paper	0.0020		1	1	0.9190	0.1720	0.0018	0.0003	8	0.0147	0.0028	0.0175	0.00

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Cost
	Packaging	LDPE	0.0026		1	1	2.6000	0.1720	0.0068	0.0004	8	0.0541	0.0036	0.0577	0.00
Temperature probe	Product	polyurethane	0.0120	1.58	1	1	0.3000	1.0740	0.4740	0.0129	7	3.3180	0.0902	3.4082	11.06
	Packaging	Paper	0.0016		1	1	0.9190	0.1720	0.0015	0.0003	7	0.0103	0.0019	0.0122	0.00
	Packaging	LDPE	0.0014		1	1	2.6000	0.1720	0.0036	0.0002	7	0.0255	0.0017	0.0272	0.00
Tegaderm 7cmx8xm	Product	LDPE	0.0041	0.33	1	1	0.3000	1.0740	0.0990	0.0044	15	1.4850	0.0661	1.5511	4.95
	Packaging	LDPE	0.0019		1	1	2.6000	0.1720	0.0049	0.0003	15	0.0741	0.0049	0.0790	0.00
Anaesthesia face mask Pre-filled inflatable size 4	Product	PVC	0.0212	1.33	1	1	0.3000	1.0740	0.3990	0.0228	8	3.1920	0.1822	3.3742	10.64
	Packaging	LDPE	0.0058		1	1	2.6000	0.1720	0.0151	0.0010	8	0.1206	0.0080	0.1286	0.00
Laryngoscope (metal combi MAC 3m 110mm)	Product	Steel	0.1350	3.60	1	1	0.3000	1.0740	1.0800	0.1450	7	7.5600	1.0149	8.5749	25.20
	Packaging	LDPE	0.0010		1	1	2.6000	0.1720	0.0026	0.0002	7	0.0182	0.0012	0.0194	0.00
Syringe 50ml	Product	Polypropylene	0.0309	0.37	1	1	0.3000	1.0740	0.1110	0.0332	7	0.7770	0.2323	1.0093	2.59
	Packaging	Paper	0.0015		1	1	0.9190	0.1720	0.0014	0.0003	7	0.0096	0.0018	0.0115	0.00
	Packaging	LDPE	0.0036		1	1	2.6000	0.1720	0.0094	0.0006	7	0.0655	0.0043	0.0699	0.00
Guedel Airway Size 4	Product	LDPE	0.0390	0.22	1	1	0.3000	1.0740	0.0660	0.0419	7	0.4620	0.2932	0.7552	1.54
	Packaging	LDPE	0.0010		1	1	2.6000	0.1720	0.0026	0.0002	7	0.0182	0.0012	0.0194	0.00
Syringe 5ml	Product	Polypropylene	0.0044	0.07	1	1	0.3000	1.0740	0.0210	0.0047	10	0.2100	0.0473	0.2573	0.70
	Packaging	Paper	0.0003		1	1	0.9190	0.1720	0.0003	0.0001	10	0.0028	0.0005	0.0033	0.00
	Packaging	LDPE	0.0003		1	1	2.6000	0.1720	0.0008	0.0001	10	0.0078	0.0005	0.0083	0.00
Syringe 2ml	Product	Polypropylene	0.0025	0.04	1	1	0.3000	1.0740	0.0120	0.0027	9	0.1080	0.0242	0.1322	0.36
	Packaging	Paper	0.0003		1	1	0.9190	0.1720	0.0003	0.0001	19	0.0052	0.0010	0.0062	0.00
	Packaging	LDPE	0.0002		1	1	2.6000	0.1720	0.0005	0.0000	19	0.0099	0.0007	0.0105	0.00
Syringe 10ml	Product	Polypropylene	0.0068	0.10	1	1	0.3000	1.0740	0.0300	0.0073	13	0.3900	0.0949	0.4849	1.30
	Packaging	Paper	0.0007		1	1	0.9190	0.1720	0.0006	0.0001	13	0.0084	0.0016	0.0099	0.00
	Packaging	LDPE	0.0005		1	1	2.6000	0.1720	0.0013	0.0001	13	0.0169	0.0011	0.0180	0.00
Syringe 20ml	Product	Polypropylene	0.0129	0.11	1	1	0.3000	1.0740	0.0330	0.0139	19	0.6270	0.2632	0.8902	2.09
	Packaging	Paper	0.0004		1	1	0.9190	0.1720	0.0004	0.0001	19	0.0070	0.0013	0.0083	0.00
	Packaging	LDPE	0.0007		1	1	2.6000	0.1720	0.0018	0.0001	19	0.0346	0.0023	0.0369	0.00
Sodium Chloride 0.9% 10ml	Product	Pharmaceuticals	0.0125	0.21	1	1	0.3000		0.0630		19	1.1970	0.0000	1.1970	3.99
	Packaging	Polypropylene	0.0015		1	1	3.1050	0.1720	0.0047	0.0003	19	0.0885	0.0049	0.0934	0.00

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Cost
Sodium Chloride 0.9% 5ml	Product	Pharmaceuticals	0.0063	0.30	1	1	0.3000		0.0900		14	1.2600	0.0000	1.2600	4.20
	Packaging	Polypropylene	0.0013		1	1	3.1050	0.1720	0.0040	0.0002	14	0.0565	0.0031	0.0596	0.00
Optilube	Product	Pharmaceuticals	0.0060	0.04	1	1	0.3000		0.0120		7	0.0840	0.0000	0.0840	0.28
	Packaging	Average plastics	0.0040		1	1	3.1160	0.1720	0.0125	0.0007	7	0.0872	0.0048	0.0921	0.00
Gloves	Product	Rubber	0.0080	0.08	1	1	0.3000	1.0740	0.0240	0.0086	8	0.1920	0.0687	0.2607	0.64
Water for injections 20ml	Product	Pharmaceuticals		0.61	1	1	0.3000		0.1830		7	1.2810	0.0000	1.2810	4.27
	Packaging	PET	0.0020		1	1	4.0320	0.1720	0.0081	0.0003	7	0.0564	0.0024	0.0589	0.00
Box packaging 20 ampoules	Packaging	Cardboard	0.0304		1	1	0.8840	0.1720	0.0269	0.0052	7	0.1881	0.0366	0.2247	0.00
Propofol 200mg	Product	Pharmaceuticals		0.96	1	1	0.1550		0.1488		9	1.0416	0.0000	1.0416	6.72
	Packaging	Glass	0.1220		1	1	1.4020	1.0740	0.1710	0.1310	9	1.1973	0.9172	2.1145	0.00
Ondansetron 4mg	Product	Pharmaceuticals	0.0002	5.99	1	1	0.1550		0.9285	0.0000	8	7.4276	0.0000	7.4276	47.92
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	8	0.0538	0.0412	0.0951	0.00
NaCl 1L	Product	Pharmaceuticals		2.65	1	1	0.1550		0.4108		8	3.2860	0.0000	3.2860	21.20
	Packaging	LDPE	0.0500		1	1	2.6010	0.1720	0.1301	0.0086	8	1.0404	0.0688	1.1092	0.00
Sevoflurane 0.5 FiO2	Product	Pharmaceuticals		6.21	1	1	70.9400		70.9400		25.25	1791.2350	0.0000	1791.2350	156.80
Fentanyl 50mcg/ml 2ml	Product	Pharmaceuticals	0.0002	1.43	1	1	0.3000		0.4290		7	3.0030	0.0000	3.0030	10.01
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	7	0.0471	0.0361	0.0832	0.00
Box packaging (10 ampoules)	Packaging	Cardboard	0.0046		1	1	0.8840	0.1720	0.0041	0.0008	7	0.0285	0.0055	0.0340	0.00
	Packaging	LDPE	0.0077		1	1	2.6000	0.1720	0.0200	0.0013	7	0.1401	0.0093	0.1494	0.00
Ketamine 50mg	Product	Pharmaceuticals		0.51	1	1	0.1550		0.0784		1	0.0784	0.0000	0.0784	0.51
	Packaging	Glass	0.1220		1	1	1.4020	1.0740	0.1710	0.1310	1	0.1710	0.1310	0.3021	0.00
Dexamethasone 6.6mg	Product	Pharmaceuticals		2.44	1	1	0.1550		0.3788	0.0000	6	2.2729	0.0000	2.2729	14.64
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	6	0.0404	0.0309	0.0713	0.00
neostigmine 2.5mg +Glycopyrronium 0.5mg /1ml	Product	Pharmaceuticals		1.15	1	1	0.1550		0.1783	0.0000	5	0.8913	0.0000	0.8913	5.75
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	5	0.0336	0.0258	0.0594	0.00
Metaraminol 0.5mg/1ml	Product	Pharmaceuticals		0.75	1	1	0.1550		0.1159	0.0000	411	47.6513	0.0000	47.6513	308.25
	Packaging	Glass	0.0010		1	1	1.4020	1.0740	0.0013	0.0010	411	0.5532	0.4238	0.9769	0.00

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Cost
Tracheal tube 7	Product	Polyvinyl Chloride	0.0614	0.96	1	1	0.3000	1.0740	0.2880	0.0659	4	1.1520	0.2638	1.4158	3.84
	Packaging	Paper	0.0008		1	1	0.9190	0.1720	0.0007	0.0001	4	0.0029	0.0006	0.0035	0.00
	Packaging	LDPE	0.0028		1	1	2.6000	0.1720	0.0073	0.0005	4	0.0291	0.0019	0.0310	0.00
Large vascular set	Product	Stainless steel	4.5600		2040	1	0.3700	0.5690	0.0008	2.5946	5	0.0041	12.9732	12.9773	0.00
Small Vascular set	Product	Stainless steel	3.7300		2040	1	0.3700	0.5690	0.0007	2.1224	4	0.0027	8.4895	8.4922	0.00
Micro instruments	Product	Stainless steel	1.4870		2040	1	0.3700	0.5690	0.0003	0.8461	4	0.0011	3.3844	3.3855	0.00
Inadine 9.5cm x 9.5cm	Product	Polyethylene glycol	0.0070	0.54	1	1	0.3000	1.0740	0.1620	0.0073	1	0.1620	0.0073	0.1693	0.54
	Packaging	Aluminium	0.0030		1	1	9.1220	0.1720	0.0295	0.0006	1	0.0295	0.0006	0.0300	0.00
	Packaging	Cardboard	0.0020		1	1	0.8840	0.1720	0.0016	0.0003	1	0.0016	0.0003	0.0020	0.00
Kaltostat 15cm x 25cm	Product	Polysaccharide	0.0070	4.80	1	1	0.3000	1.0740	1.4400	0.0073	1	1.4400	0.0073	1.4473	4.80
	Packaging	Aluminium	0.0030		1	1	9.1220	0.1720	0.0295	0.0006	1	0.0295	0.0006	0.0300	0.00
	Packaging	Cardboard	0.0020		1	1	0.8840	0.1720	0.0016	0.0003	1	0.0016	0.0003	0.0020	0.00
Gauze Pack	Product	Cotton	0.0050	1.70	1	1	0.3000	1.0740	0.0015	0.0055	3	0.0046	0.0165	0.0211	5.10
	Packaging	Paper	0.0020		1	1	0.9190	0.1720	0.0020	0.0004	3	0.0061	0.0011	0.0072	0.00
Wool bandage	Product	Wool	0.0050	2.33	1	1	0.3000	1.0740	0.0015	0.0055	1	0.0015	0.0055	0.0070	2.33
	Packaging	Paper	0.0020		1	1	0.9190	0.1720	0.0020	0.0004	1	0.0020	0.0004	0.0024	0.00
Crepe bandage	Product	Cotton	0.0050	0.55	1	1	0.3000	1.0740	0.0015	0.0055	2	0.0031	0.0110	0.0141	1.10
	Packaging	Paper	0.0020		1	1	0.9190	0.1720	0.0020	0.0004	2	0.0041	0.0008	0.0048	0.00
Atracurium 50mg/5ml (1mg)	Product	Pharmaceuticals		0.06	1	1	0.1550		0.0093		290	2.7006	0.0000	2.7006	17.42
	Packaging	Glass	0.0001		1	1	1.4020	1.0740	0.0002	0.0001	290	0.0529	0.0405	0.0933	0.00
Box packaging 5 vials	Packaging	Cardboard	0.0001		1	1	0.8840	0.1720	0.0001	0.0000	290	0.0251	0.0049	0.0300	0.00
	Packaging	Paper	0.0002		1	1	0.9190	0.1720	0.0001	0.0000	290	0.0421	0.0079	0.0500	0.00
Morphine 10mg/10ml (1ml)	Product	Pharmaceuticals		0.18	1	1	0.1550		0.0271	0.0000	55	1.4919	0.0000	1.4919	9.63
	Packaging	Glass	0.0005		1	1	1.4020	1.0740	0.0007	0.0005	55	0.0370	0.0284	0.0654	0.00
Silicone catheter	Product	Rubber (silicone)	0.0016	4.93	1	1	3.1800	1.0740	0.0051	0.0017	2	0.0102	0.0034	0.0136	9.86
	Packaging	LDPE	0.0023		1	1	2.6010	0.1720	0.0060	0.0004	2	0.0120	0.0008	0.0128	0.00
	Packaging	Paper	0.0010		1	1	0.9190	0.1720	0.0009	0.0002	2	0.0018	0.0003	0.0022	0.00
Femoro-distal set	Product	Stainless steel	2.9950		2040	1	0.3682	0.5690	0.0005	1.7042	4	0.0022	6.8166	6.8188	0.00
LMA size 4	Product	Polyvinyl Chloride	0.0650	8.99	1	1	0.3000	1.0740	2.6970	0.0698	1	2.6970	0.0698	2.7668	8.99

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Cost
	Packaging	Paper	0.0080		1	1	0.9200	0.1720	0.0074	0.0014	1	0.0074	0.0014	0.0087	0.00
	Packaging	LDPE	0.0280		1	1	2.6000	0.1720	0.0728	0.0048	1	0.0728	0.0048	0.0776	0.00
Paracetamol 1g IV	Product	Pharmaceuticals		1.35	1	1	0.1550		0.2093		1	0.2093	0.0000	0.2093	1.35
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	1	0.0624	0.0041	0.0665	0.00
tegaderm 8.5x11.5cm	Product	LPDE	0.0060	1.14	1	1	0.3000	1.0740	0.3420	0.0064	2	0.6840	0.0129	0.6969	2.28
	Packaging	Paper	0.0043		1	1	0.9190	0.1720	0.0040	0.0007	2	0.0079	0.0015	0.0094	0.00
	Packaging	LDPE	0.0027		1	1	2.6000	0.1720	0.0070	0.0005	2	0.0140	0.0009	0.0150	0.00
Ultrasound probe cover	Product	LDPE	0.0872	4.13	1	1	0.3000	1.0740	1.2390	0.0937	2	2.4780	0.1873	2.6653	8.26
	Product	paper cover	0.0045		1	1	0.9190	0.1720	0.0041	0.0008	2	0.0083	0.0015	0.0098	0.00
	Packaging	Paper	0.0038		1	1	0.9190	0.1720	0.0035	0.0007	2	0.0070	0.0013	0.0083	0.00
	Packaging	LDPE	0.0025		1	1	2.6000	0.1720	0.0065	0.0004	2	0.0130	0.0009	0.0139	0.00
CVP line - 4 lumen catheter 8.5Fr/12.5cm	Product	Polyurethane	0.0378	39.42	1	1	0.3000	1.0740	11.8260	0.0406	2	23.6520	0.0812	23.7332	78.84
	Packaging	Paper	0.0032		1	1	0.9190	0.1720	0.0029	0.0006	2	0.0059	0.0011	0.0070	0.00
	Packaging	Polypropylene	0.0400		1	1	3.1050	0.1720	0.1242	0.0069	2	0.2484	0.0138	0.2622	0.00
Autofusion IV fluid infusion set 180cm tubing, 3 way connector, 120cm extension tubing, rotating luer connector	Product	Polypropylene	0.0496	1.05	1	1	0.3000	1.0740	0.3150	0.0533	2	0.6300	0.1065	0.7365	2.10
	Packaging	Paper	0.0007		1	1	0.9190	0.1720	0.0006	0.0001	2	0.0013	0.0002	0.0015	0.00
	Packaging	LDPE	0.0007		1	1	2.6000	0.1720	0.0018	0.0001	2	0.0036	0.0002	0.0039	0.00
Blue monofilament non-absorbable suture	Product	Steel + nylon	0.0040	1.01	1	1	0.3000	1.0740	0.3030	0.0043	2	0.6060	0.0086	0.6146	2.02
	Packaging	Paper	0.0005		1	1	0.9190	0.1720	0.0005	0.0001	2	0.0009	0.0002	0.0011	0.00
	Packaging	LDPE	0.0005		1	1	2.6000	0.1720	0.0013	0.0001	2	0.0026	0.0002	0.0028	0.00
Eco HEF + tube + connectors	Product	Polypropylene	0.0317	1.23	1	1	0.3000	1.0740	0.3690	0.0340	2	0.7380	0.0681	0.8061	2.46
	Packaging	LDPE	0.0003		1	1	2.6000	0.1720	0.0008	0.0001	2	0.0016	0.0001	0.0017	0.00
Blunt Fill Needle with filter	Product	Steel	0.0010	0.13	1	1	0.3000	1.0740	0.0390	0.0011	22	0.8580	0.0236	0.8816	2.86
	Packaging	Paper	0.0003		1	1	0.9190	0.1720	0.0003	0.0001	22	0.0061	0.0011	0.0072	0.00
	Packaging	Pharmaceuticals	0.0003		1	1	2.6000	0.1720	0.0008	0.0001	22	0.0172	0.0011	0.0183	0.00
Lidocaine Hydrochloride 10mg/ml (1%) 5ml	Product	Pharmaceuticals	0.0063	0.56	1	1	0.3000		0.1680		7	1.1760	0.0000	1.1760	3.92

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Cost
	Packaging	Polypropylene	0.0013		1	1	3.1050	0.1720	0.0040	0.0002	7	0.0283	0.0016	0.0298	0.00
0.9% NaCL 500ml	Product	Pharmaceuticals	0.5278	1.71	1	1	0.3000		0.5130		6	3.0780	0.0000	3.0780	10.26
	Packaging	LDPE	0.0200		1	1	2.6000	0.1720	0.0520	0.0034	6	0.3120	0.0206	0.3326	0.00
	Packaging	LDPE	0.0102		1	1	2.6000	0.1720	0.0265	0.0018	6	0.1591	0.0105	0.1696	0.00
Noradrenaline 4mg/50ml (1ml)	Product	Pharmaceuticals		0.22	1	1	0.1550		0.0344	0.0000	175	6.0218	0.0000	6.0218	38.85
	Packaging	Glass	0.0001		1	1	1.4020	1.0740	0.0001	0.0001	175	0.0236	0.0180	0.0416	0.00
Magnesium 6mg	Product	Pharmaceuticals		2.17	1	1	0.1550		0.3365	0.0000	3	1.0095	0.0000	1.0095	6.51
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	3	0.0202	0.0155	0.0357	0.00
Heparin 1000u / 1ml	Product	Pharmaceuticals		1.49	1	1	0.1550		0.2302	0.0000	19	4.3733	0.0000	4.3733	28.22
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	19	0.1279	0.0979	0.2258	0.00
Hartmans 1L	Product	Pharmaceuticals		2.21	1	1	0.1550		0.3426		8	2.7404	0.0000	2.7404	17.68
	Packaging	LDPE	0.0500		1	1	2.6000	0.1720	0.1300	0.0086	8	1.0400	0.0688	1.1088	0.00
Levobupivicaine 0.125% 25mg/20ml (1ml)	Product	Pharmaceuticals		0.11	1	1	0.1550		0.0164	0.0000	120	1.9679	0.0000	1.9679	12.70
	Packaging	LDPE	0.0002		1	1	1.4020	1.0740	0.0003	0.0003	120	0.0404	0.0309	0.0713	0.00
Fistula set	Product	Stainless steel	2.8000		2040	1	0.3682	0.5690	0.0005	1.5932	1	0.0005	1.5932	1.5937	0.00
Sterile Biogel gloves x2	Product	Rubber	0.0180	1.06	1	1	3.1800	1.0740	3.3708	0.0193	4	13.4832	0.0773	13.5605	4.24
	Packaging	Paper	0.0060		1	1	0.9200	0.1720	0.0055	0.0000	4	0.0221	0.0001	0.0222	0.00
	Packaging	LDPE	0.0060		1	1	2.6000	0.1720	0.0156	0.0001	4	0.0624	0.0004	0.0628	0.00
Chloraprep tint	Product	Polypropylene	0.0120	1.10	1	1	3.1050	1.0740	3.4155	0.0129	3	10.2465	0.0387	10.2852	3.30
	Product	Chlorhexadine gluconate 2% w/v and isopropyl alcohol 70% v/v	0.0140		1	1	0.1550		0.1705		3	0.5115	0.0000	0.5115	0.00
	Packaging	Paper	0.0040		1	1	0.9200	0.1720	0.0037	0.0007	3	0.0110	0.0021	0.0131	0.00
	Packaging	LDPE	0.0070		1	1	2.6000	0.1720	0.0182	0.0012	3	0.0546	0.0036	0.0582	0.00
Ioban drapes 60 x 35cm	Product	LDPE	0.5200	6.34	1	1	2.5742	1.0740	1.3386	0.5585	2	2.6771	1.1170	3.7941	12.68
	Packaging	LDPE	0.0450		1	1	2.6006	0.1720	0.1170	0.0077	2	0.2341	0.0155	0.2495	0.00
	Packaging	Paper	0.0280		1	1	0.9194	0.1720	0.0257	0.0048	2	0.0515	0.0096	0.0611	0.00
3/0 monocryl curve [3213H]	Product	Stainless steel	0.0002	2.56	1	1	0.3683	1.0740	0.0001	0.0002	4	0.0003	0.0009	0.0012	10.24
	Packaging	LDPE	0.0004		1	1	2.6010	0.1720	0.0010	0.0001	4	0.0042	0.0003	0.0044	0.00

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Cost
	Packaging	Aluminium Foil	0.0010		1	1	9.1220	0.1720	0.0091	0.0002	4	0.0365	0.0007	0.0372	0.00
impra tunneler	Product	Stainless steel	2.4948		2040	1	0.3680	0.5690	0.0005	1.4195	2	0.0009	2.8390	2.8399	0.00
10 beaver blade	Product	Stainless steel	0.0004	3.12	1	1	0.3680	1.0740	0.0001	0.0004	3	0.0004	0.0013	0.0017	9.36
	Packaging	Aluminium Foil	0.0005		1	1	9.1220	0.1720	0.0046	0.0001	3	0.0137	0.0003	0.0139	0.00
11 blade	Product	Stainless steel	0.0004	3.12	1	1	0.3680	1.0740	0.0001	0.0004	2	0.0003	0.0009	0.0012	6.24
	Packaging	Aluminium Foil	0.0005		1	1	9.1220	0.1720	0.0046	0.0001	2	0.0091	0.0002	0.0093	0.00
2.0 vicryl 320H	Product	Stainless steel	0.0002	3.93	1	1	0.3680	1.0740	1.4462	0.0002	7	10.1237	0.0015	10.1252	27.51
	Packaging	LDPE	0.0004		1	1	2.6010	0.1720	0.0010	0.0001	7	0.0073	0.0005	0.0078	0.00
	Packaging	Aluminium foil	0.0010		1	1	9.1220	0.1720	0.0091	0.0002	7	0.0639	0.0012	0.0651	0.00
5.0 surgipro VP-705	Product	Polypropylene	0.0002	4.01	1	1	3.1050	1.0740	0.0006	0.0002	2	0.0012	0.0004	0.0017	8.02
	Packaging	LDPE	0.0004		1	1	2.6010	0.1720	0.0010	0.0001	2	0.0021	0.0001	0.0022	0.00
	Packaging	LDPE	0.0004		1	1	2.6010	0.1720	0.0010	0.0001	2	0.0021	0.0001	0.0022	0.00
7.0 Prolene 8735H	Product	Polypropylene	0.0002	2.76	1	1	3.1050	1.0740	0.0006	0.0002	2	0.0012	0.0004	0.0017	5.52
	Packaging	LDPE	0.0004		1	1	2.6010	0.1720	0.0010	0.0001	2	0.0021	0.0001	0.0022	0.00
	Packaging	LDPE	0.0004		1	1	2.6010	0.1720	0.0010	0.0001	2	0.0021	0.0001	0.0022	0.00
6.0 prolene W8807	Product	Polypropylene	0.0002	2.76	1	1	3.1050	1.0740	0.0006	0.0002	2	0.0012	0.0004	0.0017	5.52
	Packaging	LDPE	0.0004		1	1	2.6010	0.1720	0.0010	0.0001	2	0.0021	0.0001	0.0022	0.00
	Packaging	LDPE	0.0004		1	1	2.6010	0.1720	0.0010	0.0001	2	0.0021	0.0001	0.0022	0.00
Opsite large 10x30cm	Product	LDPE	0.0096	0.42	1	1	2.6010	1.0740	0.0250	0.0103	2	0.0499	0.0206	0.0706	0.84
	Packaging	LDPE	0.0012		1	1	2.6010	0.1720	0.0031	0.0002	2	0.0062	0.0004	0.0067	0.00
	Packaging	Paper	0.0069		1	1	0.9190	0.1720	0.0063	0.0012	2	0.0127	0.0024	0.0151	0.00
light handles	Product	LDPE	0.0030	0.53	1	1	2.6010	1.0740	0.0078	0.0032	9	0.0702	0.0290	0.0992	4.77
	Product	PET (Foam)	0.0020		1	1	4.0324	1.0740	0.0081	0.0021	9	0.0726	0.0193	0.0919	0.00
	Packaging	LDPE	0.0035		1	1	2.6010	0.1720	0.0091	0.0006	9	0.0819	0.0054	0.0873	0.00
diathermy + tip cleaner	Product	PVC	0.0680	1.75	1	1	3.4130	1.0740	0.2321	0.0730	3	0.6963	0.2191	0.9153	5.25
	Packaging	Paper	0.0045		1	1	0.9190	0.1720	0.0041	0.0008	3	0.0124	0.0023	0.0147	0.00
	Packaging	LDPE	0.0040		1	1	2.6010	0.1720	0.0104	0.0007	3	0.0312	0.0021	0.0333	0.00
skin marker pen	Product	LDPE	0.0050	0.42	1	1	2.6010	1.0740	0.0130	0.0054	3	0.0390	0.0161	0.0551	1.26
	Packaging	LDPE	0.0038		1	1	2.6010	0.1720	0.0099	0.0007	3	0.0297	0.0020	0.0316	0.00
	Packaging	Paper	0.0012		1	1	0.9190	0.1720	0.0011	0.0002	3	0.0033	0.0006	0.0039	0.00

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Cost
magnetic discard a apd	Product	Rubber (silicone)	0.8000	203.58	1036	1	3.1800	0.5690	0.0025	0.4552	3	0.0074	1.3656	1.3730	610.74
Diathermy quiver	Product	Polypropylene	0.0620	0.49	1	1	3.1050	1.0740	0.1925	0.0666	3	0.5775	0.1998	0.7773	1.47
	Packaging	LDPE	0.0045		1	1	2.6010	0.1720	0.0117	0.0008	3	0.0351	0.0023	0.0374	0.00
	Packaging	Paper	0.0025		1	1	0.9190	0.1720	0.0023	0.0004	3	0.0069	0.0013	0.0082	0.00
small fogarty inserts	Product	rubber	0.0040	11.50	1	1	3.1800	1.0740	0.0127	0.0043	2	0.0254	0.0086	0.0340	23.00
	Packaging	Paper	0.0010		1	1	0.9190	0.1720	0.0009	0.0002	2	0.0018	0.0003	0.0022	0.00
	Packaging	LDPE	0.0015		1	1	2.6010	0.1720	0.0039	0.0003	2	0.0078	0.0005	0.0083	0.00
Vascular shods	Product	Rubber	0.0010	2.02	1	1	3.1800	1.0740	0.0032	0.0011	2	0.0064	0.0021	0.0085	4.04
	Product	PET (Foam)	0.0020		1	1	4.0320	1.0740	0.0081	0.0021	2	0.0161	0.0043	0.0204	0.00
	Packaging	LDPE	0.0015		1	1	2.6010	0.1720	0.0039	0.0003	2	0.0078	0.0005	0.0083	0.00
	Packaging	Paper	0.0010		1	1	0.9190	0.1720	0.0009	0.0002	2	0.0018	0.0003	0.0022	0.00
Gallipots	Product	Polypropylene	0.0190	0.10	1	1	3.1050	1.0740	0.0590	0.0204	9	0.5310	0.1837	0.7146	0.90
	Packaging	LDPE	0.0018		1	1	2.6010	0.1720	0.0047	0.0003	9	0.0421	0.0028	0.0449	0.00
	Packaging	Paper	0.0012		1	1	0.9190	0.1720	0.0011	0.0002	9	0.0099	0.0019	0.0118	0.00
Scanlan Tunneler Sheath	Product	Rubber (silicone)	0.0652	18.38	1	1	3.1800	1.0740	0.2073	0.0700	2	0.4147	0.1400	0.5547	36.76
	Packaging	LDPE	0.0440		1	1	2.6010	0.1720	0.1144	0.0076	2	0.2289	0.0151	0.2440	0.00
	Packaging	Paper	0.0240		1	1	0.9190	0.1720	0.0221	0.0041	2	0.0441	0.0083	0.0524	0.00
aldon bag	Product	PVC	0.0650	1.24	1	1	3.4130	1.0740	0.2218	0.0698	3	0.6655	0.2094	0.8750	3.72
	Packaging	LDPE	0.0420		1	1	2.6010	0.1720	0.1092	0.0072	3	0.3277	0.0217	0.3494	0.00
	Packaging	Paper	0.0230		1	1	0.9190	0.1720	0.0211	0.0040	3	0.0634	0.0119	0.0753	0.00
Foley catheter	Product	Rubber (silicone)	0.0016	3.09	1	1	3.1800	1.0740	0.0051	0.0017	1	0.0051	0.0017	0.0068	3.09
	Packaging	LDPE	0.0023		1	1	2.6010	0.1720	0.0060	0.0004	1	0.0060	0.0004	0.0064	0.00
	Packaging	Paper	0.0010		1	1	0.9190	0.1720	0.0009	0.0002	1	0.0009	0.0002	0.0011	0.00
Bard Hickman catheter Silicone 10.8	Product	Silicone	0.0740	201.60	1	1	0.3000	1.0740			1	0.0000	0.0000	0.0000	201.60
	Packaging	LDPE	0.0040		1	1		0.1720			1	0.0000	0.0000	0.0000	0.00
Softpore 5cm x 25cm	Product	LDPE	0.0110	0.16	1	1	0.3000	1.0740	0.0480	0.1718	1	0.0480	0.1718	0.2198	0.16
	Packaging	Paper	0.0040		1	1	0.9190	0.1720	0.0037	0.0007	1	0.0037	0.0007	0.0044	0.00
Glycopyrronium Bromide 200mcg/ml - 1ml	Product	Pharmaceuticals		1.65	1	1	0.3000		0.4950		1	0.4950	0.0000	0.4950	1.65
	Packaging	Glass	0.0030		1	1	1.4020	1.0740	0.0042	0.0032	1	0.0042	0.0032	0.0074	0.00

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Cost
Plastic blister pack (5 ampoules)		PET	0.0010		1	1	4.0320	0.1720	0.0040	0.0002	1	0.0040	0.0002	0.0042	0.00
Box packaging (10 ampoules)	Packaging	Cardboard	0.0079		1	1	0.8840	0.1720	0.0070	0.0014	1	0.0070	0.0014	0.0083	0.00
	Packaging	LDPE	0.0040		1	1	2.6000	0.1720	0.0104	0.0007	1	0.0104	0.0007	0.0111	0.00
Dexamethasone 3.3mg	Product	Pharmaceuticals		2.40	1	1	0.1550		0.3718	0.0000	4	1.4874	0.0000	1.4874	9.60
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	4	0.0269	0.0206	0.0475	0.00
Ephedrine 30mg/10ml	Product	Pharmaceuticals		12.41	1	1	0.1550		1.9234	0.0000	2	3.8468	0.0000	3.8468	24.82
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	2	0.0135	0.0103	0.0238	0.00
Mixed retractors set	Product	Stainless steel	4.6500		2040	1	0.3682	0.5690	0.0000	0.0000	1	0.0000	0.0000	0.0000	0.00
6x4 swab pack	Product	Cotton	0.0800	4.03	1	1	0.3000	1.0740	1.2090	0.0859	6	7.2540	0.5155	7.7695	24.18
	Packaging	Paper	0.0045		1	1	0.9190	0.1720	0.0041	0.0008	6	0.0248	0.0046	0.0295	0.00
Rocuronium bromide 50mg/5ml	Product	Pharmaceuticals		2.80	1	1	0.3000		0.8400		1	0.8400	0.0000	0.8400	2.80
	Packaging	Glass	0.0030		1	1	1.4020	1.0740	0.0042	0.0032	1	0.0042	0.0032	0.0074	0.00
Plastic blister pack (5 ampoules)	Packaging	PET	0.0010		1	1	4.0320	0.1720	0.0040	0.0002	1	0.0040	0.0002	0.0042	0.00
Box packaging (10 ampoules)	Packaging	Cardboard	0.0079		1	1	0.8840	0.1720	0.0070	0.0014	1	0.0070	0.0014	0.0083	0.00
	Packaging	LDPE	0.0040		1	1	2.6000	0.1720	0.0104	0.0007	1	0.0104	0.0007	0.0111	0.00
Levobupivicaine 25mg/10ml	Product	Pharmaceuticals	0.0002	2.12	1	1	0.3000		0.6348		1	0.6348	0.0000	0.6348	2.12
	Packaging	Glass	0.0048		1	1	1.4020	1.0740	0.0067	0.0052	1	0.0067	0.0052	0.0119	0.00
Box packaging (10 ampoules)	Packaging	Cardboard	0.0046		1	1	0.8840	0.1720	0.0041	0.0008	1	0.0041	0.0008	0.0049	0.00
	Packaging	LDPE	0.0077		1	1	2.6000	0.1720	0.0200	0.0013	1	0.0200	0.0013	0.0213	0.00
Cyclizine 50mg/1ml	Product	Pharmaceuticals	0.0005	2.18	1	1	0.1550		0.3376		1	0.3376	0.0000	0.3376	2.18
	Packaging	Glass	0.0065		1	1	1.4020	1.0740	0.0091	0.0070	1	0.0091	0.0070	0.0161	0.00
Box packaging 5 vials	Packaging	Cardboard	0.0049		1	1	0.8840	0.1720	0.0043	0.0008	1	0.0043	0.0008	0.0052	0.00
	Packaging	Paper	0.0079		1	1	0.9190	0.1720	0.0073	0.0014	1	0.0073	0.0014	0.0086	0.00
Amputation set	Product	Stainless steel	4.7830		2040	1	0.3700	0.5690	0.0009	2.7215	1	0.0009	2.7215	2.7224	0.00
Desouter set	Product	Stainless steel	4.0710		2040	1	0.3700	0.5690	0.0007	2.3164	1	0.0007	2.3164	2.3171	0.00
18x18 swab pack	Product	Cotton	0.0800	1.29	1	1	0.3000	1.0740	0.3870	0.0859	1	0.3870	0.0859	0.4729	1.29
	Packaging	Paper	0.0045		1	1	0.9190	0.1720	0.0041	0.0008	1	0.0041	0.0008	0.0049	0.00

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Cost
Aquacel ribbon 2cm x 45cm	Product	Polyurethane	0.0117	1.67	1	1	0.3000	1.0740	0.5010	0.0125	3	1.5030	0.0375	1.5405	5.01
	Packaging	Paper	0.0069		1	1	0.9190	0.1720	0.0063	0.0012	3	0.0190	0.0036	0.0226	0.00
	Packaging	Cardboard	0.0042		1	1	0.8840	0.1720	0.0037	0.0007	3	0.0111	0.0022	0.0132	0.00
Midazolam 2m/2ml (1ml)	Product	Pharmaceuticals		0.47	1	1	0.1550		0.0721	0.0000	2	0.1442	0.0000	0.1442	0.93
	Packaging	Glass	0.0005		1	1	1.4020	1.0740	0.0007	0.0005	2	0.0013	0.0010	0.0024	0.00
Lignocaine 1% 100mg/10ml	Product	Pharmaceuticals		0.63	1	1	0.1550		0.0978	0.0000	1	0.0978	0.0000	0.0978	0.63
	Packaging	LDPE	0.0240		1	1	2.6006	0.1720	0.0624	0.0041	1	0.0624	0.0041	0.0665	0.00

Dressings															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Inadine 5cm x 5cm	Product	Polyethylene	0.0019	0.37	1	1	0.3000	1.0740	0.1110	0.0021	10	1.1100	0.0207	1.1307	3.70
	Packaging	Aluminium	0.0027		1	1	9.1220	0.1720	0.0244	0.0005	10	0.2444	0.0046	0.2490	0.00
	Packaging	Cardboard	0.0007		1	1	0.8840	0.1720	0.0006	0.0001	10	0.0059	0.0011	0.0071	0.00
Inadine 9.5cm x 9.5cm	Product	Polyethylene	0.0068	0.54	1	1	0.3000	1.0740	0.1620	0.0073	17	2.7540	0.1237	2.8777	9.18
	Packaging	Aluminium	0.0032		1	1	9.1220	0.1720	0.0295	0.0006	17	0.5012	0.0095	0.5106	0.00
	Packaging	Cardboard	0.0019		1	1	0.8840	0.1720	0.0016	0.0003	17	0.0280	0.0054	0.0335	0.00
Softpore 5cm x 15cm PO	Product	Polyethylene	0.0090	0.12	1	1	0.3000	1.0740	0.0360	0.0097	10	0.3600	0.0967	0.4567	1.20
	Packaging	Paper	0.0045		1	1	0.9190	0.1720	0.0041	0.0008	10	0.0409	0.0077	0.0486	0.00
Softpore 5cm x 25cm	Product	Polyethylene	0.0110	0.16	1	1	0.3000	1.0740	0.0480	0.1718	11	0.5280	1.8902	2.4182	1.76
	Packaging	Paper	0.0040		1	1	0.9190	0.1720	0.0037	0.0007	11	0.0404	0.0076	0.0480	0.00
Softpore 10cm x 15cm	Product	Polyethylene	0.0017	0.09	1	1	0.3000	1.0740	0.0270	0.0018	17	0.4590	0.0307	0.4897	1.53
	Packaging	Paper	0.0045		1	1	0.9190	0.1720	0.0041	0.0008	17	0.0695	0.0130	0.0826	0.00
Softpore 10cm x 30cm	Product	Polyethylene	0.0246	0.19	1	1	0.3000	1.0740	0.0570	0.0264	47	2.6790	1.2426	3.9216	8.93
	Packaging	Paper	0.0019		1	1	0.9190	0.1720	0.0018	0.0003	47	0.0830	0.0155	0.0986	0.00
Softpore 10cm x 35cm	Product	Polyethylene	0.0190	0.27	1	1	0.3000	1.0740	0.0810	0.0204	10	0.8100	0.2041	1.0141	2.70
	Packaging	Paper	0.0060		1	1	0.9190	0.1720	0.0055	0.0010	10	0.0551	0.0103	0.0655	0.00

Dressings															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Mepore 11cm x 15cm	Product	Polyethylene	0.0015	0.97	1	1	0.3000	1.0740	0.2910	0.0016	6	1.7460	0.0096	1.7556	5.82
	Packaging	LDPE	0.0039		1	1	2.6006	0.1720	0.0103	0.0007	6	0.0616	0.0041	0.0656	0.00
	Packaging	Cardboard	0.0025		1	1	0.8840	0.1720	0.0022	0.0004	6	0.0131	0.0025	0.0156	0.00
Opsite large 10x30cm	Product	LDPE	0.0096	0.42	1	1	2.6010	1.0740	0.0250	0.0103	2	0.0499	0.0206	0.0706	0.84
	Packaging	LDPE	0.0012		1	1	2.6010	0.1720	0.0031	0.0002	2	0.0062	0.0004	0.0067	0.00
	Packaging	Paper	0.0069		1	1	0.9190	0.1720	0.0063	0.0012	2	0.0127	0.0024	0.0151	0.00
Mepilex border dressing 10cm x 12.5cm	Product	Polyurethane	0.0085	3.17	1	1	0.3000	1.0740	0.9510	0.0091	36	34.2360	0.3272	34.5632	114.12
	Packaging	Paper	0.0064		1	1	0.9190	0.1720	0.0059	0.0011	36	0.2118	0.0396	0.2514	0.00
	Packaging	Cardboard	0.0076		1	1	0.8840	0.1720	0.0067	0.0013	36	0.2425	0.0472	0.2897	0.00
Allevyn GB lite 5cm x 5cm	Product	Polyurethane	0.0011	0.60	1	1	0.3000	1.0740	0.1800	0.0012	2	0.3600	0.0024	0.3624	1.20
	Packaging	Paper	0.0009		1	1	0.9190	0.1720	0.0008	0.0002	2	0.0016	0.0003	0.0019	0.00
	Packaging	Cardboard	0.0009		1	1	0.8830	0.1720	0.0008	0.0002	2	0.0016	0.0003	0.0020	0.00
Allevyn GB 10cm x 10cm	Product	Polyurethane	0.0117	1.29	1	1	0.3000	1.0740	0.3870	0.0125	30	11.6100	0.3754	11.9854	38.70
	Packaging	Paper	0.0069		1	1	0.9190	0.1720	0.0063	0.0012	30	0.1903	0.0356	0.2259	0.00
	Packaging	Cardboard	0.0036		1	1	0.8840	0.1720	0.0032	0.0006	30	0.0948	0.0006	0.0954	0.00
Allevyn GB 10cm x 20cm	Product	Polyurethane	0.0117	2.10	1	1	0.3000	1.0740	0.6300	0.0125	15	9.4500	0.1877	9.6377	31.50
	Packaging	Paper	0.0069		1	1	0.9190	0.1720	0.0063	0.0012	15	0.0951	0.0178	0.1129	0.00
	Packaging	Cardboard	0.0036		1	1	0.8840	0.1720	0.0032	0.0006	15	0.0474	0.0006	0.0480	0.00
Allevyn foam 10cm x 20cm	Product	Polyurethane	0.0180	2.62	1	1	0.3000	1.0740	0.7860	0.0193	5	3.9300	0.0967	4.0267	13.10
	Packaging	Paper	0.0060		1	1	0.9190	0.1720	0.0055	0.0010	5	0.0276	0.0052	0.0327	0.00
Allevyn Classic 12.5cm x 12.5cm	Product	Polyurethane	0.0044	0.80	1	1	0.3000	1.0740	0.2400	0.0047	17	4.0800	0.0047	4.0847	13.60
	Packaging	Paper	0.0042		1	1	0.9190	0.1720	0.0039	0.0007	17	0.0656	0.0007	0.0664	0.00
	Packaging	Cardboard	0.0036		1	1	0.8840	0.1720	0.0032	0.0006	17	0.0537	0.0006	0.0543	0.00
UrgoTul 10cm x 10cm	Product	Polyester	0.0021	1.88	1	1	0.1550	1.0740	0.0003	0.0022	2	0.0006	0.0044	0.0051	3.76
	Packaging	Aluminium	0.0040		1	1	9.1220	0.1720	0.0363	0.0007	2	0.0726	0.0014	0.0739	0.00
	Packaging	Cardboard	0.0019		1	1	0.8840	0.1720	0.0017	0.0003	2	0.0034	0.0007	0.0041	0.00
Leukomed 10cm x 20cm	Product	Polyurethane	0.0230	8.78	1	1	0.3000	1.0740	2.6340	0.0247	1	2.6340	0.0247	2.6587	8.78
	Packaging	Paper	0.0090		1	1	0.9190	0.1720	0.0083	0.0015	1	0.0083	0.0015	0.0098	0.00
tegaderm 8.5x11.5cm	Product	LDPE	0.0060	1.14	1	1	0.3000	1.0740	0.3420	0.0064	10	3.4200	0.0644	3.4844	11.40

Dressings															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
	Packaging	Paper	0.0043		1	1	0.9190	0.1720	0.0040	0.0007	10	0.0395	0.0074	0.0469	0.00
	Packaging	LDPE	0.0027		1	1	2.6000	0.1720	0.0070	0.0005	10	0.0702	0.0046	0.0748	0.00
Aquacell Ag 10cm x 10cm	Product	Polyurethane	0.0017	3.45	1	1	0.3000	1.0740	0.0000	0.0018	26	0.0000	0.0469	0.0469	0.00
	Packaging	Aluminium	0.0045		1	1	9.1220	0.1720	0.0406	0.0008	26	1.0557	0.0199	1.0756	0.00
	Packaging	Cardboard	0.0025		1	1	0.8840	0.1720	0.0022	0.0004	26	0.0564	0.0110	0.0674	0.00
Aquacell extra 10cm x 10cm	Product	Polyurethane	0.0015	1.67	1	1	0.3000	1.0740	0.0000	0.0016	10	0.0000	0.0159	0.0159	0.00
	Packaging	LDPE	0.0039		1	1	2.6006	0.1720	0.0103	0.0007	10	0.1026	0.0068	0.1094	0.00
	Packaging	Cardboard	0.0025		1	1	0.8840	0.1720	0.0022	0.0004	10	0.0218	0.0042	0.0260	0.00
Atraumen 5cm x 5cm	Product	Polyethylene	0.0007	0.22	1	1	0.1550	1.0740	0.0001	0.0008	1	0.0001	0.0008	0.0009	0.22
	Packaging	Aluminium	0.0022		1	1	9.1220	0.1720	0.0198	0.0004	1	0.0198	0.0004	0.0202	0.00
	Packaging	Cardboard	0.0004		1	1	0.8840	0.1720	0.0003	0.0001	1	0.0003	0.0001	0.0004	0.00
Atraumen 10cm x 20cm	Product	Polyethylene	0.0045	0.38	1	1	0.3000	1.0740	0.1140	0.0049	5	0.5700	0.0243	0.5943	1.90
	Packaging	Aluminium	0.0094		1	1	9.1220	0.1720	0.0854	0.0016	5	0.4268	0.0080	0.4349	0.00
	Packaging	Cardboard	0.0014		1	1	0.8840	0.1720	0.0013	0.0002	5	0.0064	0.0012	0.0076	0.00
Cutimed sorbact gel 7.5cm x 7.5cm	Product	Polyurethane	0.0017	1.56	1	1	0.3000	1.0740	0.4680	0.0018	19	8.8920	0.0343	8.9263	29.64
	Packaging	Aluminium	0.0045		1	1	9.1220	0.1720	0.0406	0.0008	19	0.7714	0.0145	0.7860	0.00
	Packaging	Cardboard	0.0025		1	1	0.8840	0.1720	0.0022	0.0004	19	0.0412	0.0080	0.0493	0.00
Flaminal forte gel dressing 15g	Product	Pharmaceuticals	0.0017	4.43	1	1	0.3000	1.0740	0.0000	0.0018	10	0.0000	0.0180	0.0180	0.00
	Packaging	LDPE	0.0045		1	1	2.6006	0.1720	0.0116	0.0008	10	0.1158	0.0077	0.1234	0.00
	Packaging	Cardboard	0.0025		1	1	0.8840	0.1720	0.0022	0.0004	10	0.0217	0.0042	0.0259	0.00
Medihoney sheet 5cm x 5cm	Product	Pharmaceuticals	0.0117	1.63	1	1	0.3000	1.0740	0.4890	0.0125	10	4.8900	0.1251	5.0151	16.30
	Packaging	Paper	0.0069		1	1	0.9190	0.1720	0.0063	0.0012	10	0.0634	0.0119	0.0753	0.00
Urgo K-soft 10cm x 4.5m	Product	Polyester	0.0246	0.55	1	1	0.3000	1.0740	0.1650	0.0264	16	2.6400	0.4230	3.0630	8.80
	Packaging	LDPE	0.0019		1	1	2.6006	0.1720	0.0050	0.0003	16	0.0800	0.0053	0.0853	0.00
Urgo K-Lite 10cm x 5.25m	Product	Nilon	0.0246	1.02	1	1	0.3000	1.0740	0.3060	0.0264	16	4.8960	0.4230	5.3190	16.32
	Packaging	LDPE	0.0019		1	1	2.6006	0.1720	0.0050	0.0003	16	0.0800	0.0053	0.0853	0.00
Crepe bandage	Product	Cotton	0.0051	0.55	1	1	0.3000	1.0740	0.0015	0.0055	3	0.0046	0.0165	0.0211	1.65
	Packaging	Paper	0.0022		1	1	0.9190	0.1720	0.0020	0.0004	3	0.0061	0.0011	0.0072	0.00

Dressings															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Profore bandage 10cm x 4.5m	Product	Cotton	0.0246	0.62	1	1	0.3000	1.0740	0.1860	0.0264	10	1.8600	0.2644	2.1244	6.20
	Packaging	LDPE	0.0019		1	1	2.6006	0.1720	0.0050	0.0003	10	0.0500	0.0033	0.0533	0.00
Gauze Pack	Product	Cotton	0.0051	1.71	1	1	0.3000	1.0740	0.0015	0.0055	2	0.0031	0.0110	0.0141	3.42
	Packaging	Paper	0.0022		1	1	0.9190	0.1720	0.0020	0.0004	2	0.0041	0.0008	0.0048	0.00
0.9% NaCL solution 240ml	Product	Pharmaceuticals	0.0620	2.74	1	1	0.3000	0.1720	0.8220	0.0107	6	4.9320	0.0640	4.9960	16.44
Normosol irrigation 25ml sachet	Product	Pharmaceuticals	0.0250	0.73	1	1	0.3000		0.2190		7	1.5330	0.0000	1.5330	5.11
	Packaging	LDPE	0.0030		1	1	2.6006	0.1720	0.0078	0.0005	7	0.0546	0.0036	0.0582	0.00
Sodium chloride 0.9% irrigation solution 20ml irripod (Crest medical) - 25 unit dose	Product	Pharmaceuticals		0.73	1	1	0.3000		0.2190		2	0.4380	0.0000	0.4380	1.46
	Packaging	LDPE	0.0060		1	1	2.6006	0.1720	0.0156	0.0010	2	0.0312	0.0021	0.0333	0.00
Dressit Sterile dressing pack	Product	LDPE	0.0390	0.58	1	1	0.3000	1.0740	0.1740	0.0419	66	11.4840	2.7645	14.2485	38.28
	Packaging	LDPE	0.0070		1	1	2.6006	0.1720	0.0182	0.0012	66	1.2015	0.0795	1.2810	0.00
	Packaging	Paper	0.0080		1	1	0.9190	0.1720	0.0074	0.0014	66	0.4852	0.0908	0.5760	0.00
Gloves	Product	Rubber	0.0080	0.14	1	1	0.0520	1.0740	0.0073	0.0086	66	0.4805	0.5671	1.0476	9.24

18.18 Supplementary material 18: Resource use for patients without SSI

Review															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Nurse Telephone	Review			13.17	1	1	0.1550		2.0408		2	4.0817		4.0817	26.33
Vascular Telephone Review	Review			35.75	1	1	0.1550		5.5413		1	5.5413		5.5413	35.75

Imaging															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
USS doppler lower limbs	Review			95.00	1	1	0.3000		0.5300		6	3.1800		3.1800	570.00

Other Consumables															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Anticoagulant EDTA (G&S)	Product	LDPE	0.0200	0.07	1	1	0.3000	1.0740	0.0210	0.0215	1	0.0210	0.0215	0.0425	0.07
Sodium Citrate tube (Coagulation)	Product	LDPE	0.0080	0.20	1	1	0.3000	1.0740	0.0600	0.0086	3	0.1800	0.0258	0.2058	0.60

Pharmaceuticals															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Codeine Phosphate 15mg PO	Product	Pharmaceuticals		0.03	1	1	0.1550		0.0044	0.0000	56	0.2449	0.0000	0.2449	1.58
	Packaging	Aluminium	0.0002		1	1	9.1220	0.1720	0.0015	0.0000	56	0.0838	0.0016	0.0854	0.00

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)

2% chlorhexadine in 70% alcohol skin wipe	Product	Polypropylene	0.0014	0.02	1	1	0.3000	1.0740	0.0060	0.0015	1	0.0060	0.0015	0.0075	0.02
	Packaging	Aluminium	0.0010		1	1	9.1220	0.1720	0.0091	0.0002	1	0.0091	0.0002	0.0093	0.00
	Packaging	Paper	0.0003		1	1	0.9190	0.1720	0.0003	0.0001	1	0.0003	0.0001	0.0003	0.00
	Packaging	LDPE	0.0003		1	1	2.6000	0.1720	0.0008	0.0001	1	0.0008	0.0001	0.0008	0.00
Syringe 20ml	Product	Polypropylene	0.0129	0.11	1	1	0.3000	1.0740	0.0330	0.0139	1	0.0330	0.0139	0.0469	0.11
	Packaging	Paper	0.0004		1	1	0.9190	0.1720	0.0004	0.0001	1	0.0004	0.0001	0.0004	0.00
	Packaging	LDPE	0.0007		1	1	2.6000	0.1720	0.0018	0.0001	1	0.0018	0.0001	0.0019	0.00
Gloves	Product	Rubber	0.0080	0.14	1	1	0.0520	1.0740	0.0073	0.0086	16	0.1165	0.1375	0.2540	2.24

Procedures															
Product	Component	Material	Weight (kg)	Cost (£)	Number of uses	Number of scenarios per use	Emissions factor	Waste stream Emission Factor	Production	Waste	Number	Production total	Waste total	Total emissions	Total Cost (£)
Allevyn GB 7.5cm x 7.5cm	Product	Silicone	0.0030	0.89	1	1	0.3000	1.0740	0.2670	0.0034	10	2.6700	0.0345	2.7045	8.90
	Packaging	Paper	0.0030		1	1	0.9190	0.1720	0.0024	0.0005	10	0.0242	0.0045	0.0288	0.00
	Packaging	Cardboard	0.0030		1	1	0.8840	0.1720	0.0032	0.0006	10	0.0316	0.0061	0.0378	0.00
Allevyn GB 10cm x 10cm	Product	Silicone	0.0120	1.29	1	1	0.3000	1.0740	0.3870	0.0125	30	11.6100	0.3754	11.9854	38.70
	Packaging	Paper	0.0070		1	1	0.9190	0.1720	0.0063	0.0012	30	0.1903	0.0356	0.2259	0.00
	Packaging	Cardboard	0.0030		1	1	0.8840	0.1720	0.0032	0.0006	30	0.0948	0.0184	0.1133	0.00
Allevyn GB 10cm x 25cm	Product	Silicone	0.0120	2.96	1	1	0.3000	1.0740	0.8880	0.0125	10	8.8800	0.1251	9.0051	29.60
	Packaging	Paper	0.0070		1	1	0.9190	0.1720	0.0063	0.0012	10	0.0634	0.0119	0.0753	0.00
	Packaging	Cardboard	0.0040		1	1	0.8840	0.1720	0.0032	0.0006	10	0.0316	0.0061	0.0378	0.00
Allevyn foam 10cm x 20cm	Product	Polyurethane	0.0180	2.62	1	1	0.3000	1.0740	0.7860	0.0193	20	15.7200	0.3866	16.1066	52.40
	Packaging	Paper	0.0060		1	1	0.9190	0.1720	0.0055	0.0010	20	0.1103	0.0206	0.1309	0.00
Softpore 10cm x 15cm	Product	Polyethylene	0.0017	0.09	1	1	0.3000	1.0740	0.0270	0.0018	18	0.4860	0.0325	0.5185	1.62
	Packaging	Paper	0.0009		1	1	0.9190	0.1720	0.0008	0.0002	1	0.0008	0.0002	0.0010	0.00
Inadine 5cm x 5cm	Product	Polyethylene	0.0019	0.37	1	1	0.3000	1.0740	0.1110	0.0021	10	1.1100	0.0207	1.1307	3.70
	Packaging	Aluminium	0.0027		1	1	9.1220	0.1720	0.0244	0.0005	10	0.2444	0.0046	0.2490	0.00
	Packaging	Cardboard	0.0007		1	1	0.8840	0.1720	0.0006	0.0001	10	0.0059	0.0011	0.0071	0.00
Inadine 9.5cm x 9.5cm	Product	Polyethylene	0.0068	0.54	1	1	0.3000	1.0740	0.1620	0.0073	10	1.6200	0.0728	1.6928	5.40
	Packaging	Aluminium	0.0032		1	1	9.1220	0.1720	0.0295	0.0006	10	0.2948	0.0056	0.3004	0.00
	Packaging	Cardboard	0.0019		1	1	0.8840	0.1720	0.0016	0.0003	10	0.0165	0.0032	0.0197	0.00
Aquacel ribbon 1cm x 45cm	Product	Polyurethane	0.0210	1.31	1	1	0.3000	1.0740	0.3930	0.0226	10	3.9300	0.2255	4.1555	13.10

	Packaging	Aluminium	0.0050		1	1	9.1220	0.1720	0.0456	0.0009	10	0.4561	0.0086	0.4647	0.00
Dressit Sterile dressing pack	Product	LDPE	0.0390	0.58	1	1	0.3000	1.0740	0.1740	0.0419	51	8.8740	2.1362	11.0102	29.58
	Packaging	LDPE	0.0070		1	1	2.6006	0.1720	0.0182	0.0012	51	0.9284	0.0614	0.9898	0.00
	Packaging	Paper	0.0080		1	1	0.9190	0.1720	0.0074	0.0014	51	0.3750	0.0702	0.4451	0.00

18.19 Emissions sources for Greenhouse Gas Protocol Scopes 1, 2, 3 and outside of scope

Greenhouse Gas Protocol Scope	Factors Covered	Reference(s)
Scope 1	There were no fossil fuels, anaesthetic agents or NHS fleet vehicles to be accounted for in this analysis.	N/A
Scope 2	The Department for Environment, Food and Rural Affairs (DEFRA) and Business, Energy and Industrial Strategy (BEIS) GHG conversion factors were applied to data collected on electricity to provide $kgCO_2e$ within this scope. Electricity data accounted for lighting in both remote and clinic models, and for personal computer use	Department for Environment Food and Rural Affairs / Business Energy and Industrial Strategy. Greenhouse Gas Reporting: Conversion Factors 2023 Gov.UK2023 [Available from: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023.
Scope 3	DEFRA/BEIS GHG conversion factors for water use in addition to waste incineration factors were integrated with resource data providing emissions mapping. Water data collected accounted for handwashing in clinic models. The NHS supply chain online catalogue provided individual clinic item costings. No business travel or metered dose inhaler emissions were utilised within this study. For remote review, time to complete assessment was applied to clinician cost and staff services emissions factor. For clinic review, recorded appointment review time were multiplied by cost and the staff services emissions factor. No additional medical devices, freight transport, business services, construction, food and catering, commissioned services, manufacturing, or commuting services' emissions were utilised or calculated within this study.	Department for Environment Food and Rural Affairs / Business Energy and Industrial Strategy. Greenhouse Gas Reporting: Conversion Factors 2023 Gov.UK2023 [Available from: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023. National Health Service. NHS Supply Chain Online Catalogue 2023 [Available from: https://www.supplychain.nhs.uk/.
Outside of Scope	Patient travel emissions were evaluated by collecting mode of transport, return mileage from home postcode to clinic postcode, and application of the emissions factor for method of transport (DEFRA/BEIS conversion factors).[311]	Department for Environment Food and Rural Affairs / Business Energy and Industrial Strategy. Greenhouse Gas Reporting: Conversion Factors 2023 Gov.UK2023 [Available from: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023.

18.20 References used for emissions and economic analysis

	Emissions Reference	Cost Reference
Travel	Department for Environment Food and Rural Affairs / Business Energy and Industrial Strategy. Greenhouse Gas Reporting: Conversion Factors 2023 Gov.UK2023 [Available from: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023.	HMRC. Travel – mileage and fuel rates allowances, 2024. [Available from: https://www.gov.uk/government/publications/rates-and-allowances-travel-mileage-and-fuel-allowances/travel-mileage-and-fuel-rates-and-allowances] APCOA Parking charges
Staff Consulting	The Centre got Sustainable Healthcare. Sustainability in Quality Improvement: Measuring Environmental Impact. 2023. [Available from: https://www.susqi.org/templates]	Jones K, Weatherly H, Birch S, Castelli A, Chalkley M, Dargan A, et al. Unit Costs of Health and Social Care 2023 Manual. Personal Social Services Research Unit (University of Kent) & Centre for Health Economics (University of York), Kent, UK; 2024.
Pharmaceuticals	The Centre got Sustainable Healthcare. Sustainability in Quality Improvement: Measuring Environmental Impact. 2023. [Available from: https://www.susqi.org/templates]	Joint Formulary Committee. British National Formulary. 87th Ed. London: BMJ and Pharmaceutical Press; 2024
Other Consumables	Department for Environment Food and Rural Affairs / Business Energy and Industrial Strategy. Greenhouse Gas Reporting: Conversion Factors 2023 Gov.UK2023 [Available from: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023.	National Health Service. NHS Supply Chain Online Catalogue 2023 [Available from: https://www.supplychain.nhs.uk/]
Investigations	The Centre got Sustainable Healthcare. Sustainability in Quality Improvement: Measuring Environmental Impact. 2023. [Available from: https://www.susqi.org/templates]	National Institute for Health and Care Research. Interactive Costing Tool 2022/2023, 2023.
Healthcare activity units (bed days)	Sustainable Development Unit: Inpatient Bed Days. 2015. [Available from: https://networks.sustainablehealthcare.org.uk/sites/default/files/resources/4._Sustainable_Care_Pathways_Guidance_-_Inpatient_Bed_Day_Module_-_Oct_2015.pdf]	Guest JF, et al. Modelling the annual NHS costs and outcomes attributable to healthcare-associated infections in England. BMJ Open. 2020 Jan 22;10(1):e033367. doi: 10.1136/bmjopen-2019-033367.
Anaesthetic gases	Pierce T. Anaesthetic gases calculator, Association of Anaesthetists. 2024. [Available from: https://anaesthetists.org/Home/Resources-publications/Environment/Guide-to-green-anaesthesia/Anaesthetic-gases-calculator]	Pierce T. Anaesthetic gases calculator, Association of Anaesthetists. 2024. [Available from: https://anaesthetists.org/Home/Resources-publications/Environment/Guide-to-green-anaesthesia/Anaesthetic-gases-calculator]

18.21 Cost-emissions formulas used in data analysis

Outcome	Formula	Description
Mean Incremental Cost-Emissions Ratio	$ICER = \frac{\Delta £}{\Delta tCO_2e}$	Represents the difference in costs associated with difference in emissions associated with two interventions
Emissions Benefit	$Emissions\ Change_{A,B} = kgCO_2e_A - kgCO_2e_B$	The change in emissions generated for healthcare activity using intervention A compared to intervention B
Carbon Offsetting Value	$COV_1 = \frac{\Delta kgCO_2e}{kgCO_2e\ UK\ tree}$ $COV_{10} = \frac{\Delta kgCO_2e}{kgCO_2e\ UK\ tree}$	The emissions benefit gained implementing an intervention expressed in terms of $kgCO_2e$ sequestered by a UK variety tree over one year and 10 years

19 CHAPTER 9: LIST OF ABBREVIATIONS/INDEX

A

AAA – Abdominal Aortic Aneurysm

AI – Artificial Intelligence

AIDS – Acquired Immunodeficiency Syndrome

ANOVA – Analysis of Variance

APC – Antigen Presenting Cell

ASA – American Society of Anaesthesiologists

AUROC – Area Under the Receiver Operator Characteristic Curve

B

BEIS – Department for Business, Energy and Industrial Strategy

BMI – Body Mass Index

BNF – British National Formulary

C

CCTV – Closed-Circuit Television

CDC – Centres for Disease Control and Prevention

CEA – Carotid Endarterectomy

CROSS – Checklist for Reporting of Survey Studies

CFU – Colony Forming Unit

CHERRIES – Checklist for Reporting Results of Internet E-Surveys

CHG – Chlorhexidine Gluconate

CI – Confidence Interval

CKD – Chronic Kidney Disease

CO_2e – Carbon Dioxide Equivalent

CoNS – Coagulase Negative Staphylococci

COPD – Chronic Obstructive Pulmonary Disease

CT – Computed Tomography

CVA – Cerebrovascular Accident

D

DEFRA – Department for Environment, Food and Rural Affairs

DOR – Diagnostic Odds Ratio

E

eC – Environmental Cost

ECG – Electrocardiogram

ECM – Extracellular Matrix

EHR – Electronic Health Record

EVAR – Endovascular Aortic Repair

F

fC – Financial Cost

FGF – Fibroblast Growth Factor

FN – False Negative

FP – False Positive

G

GA – General Anaesthetic

GAG – Glycosaminoglycan

GDPR – General Data Protection Regulation

GHG – Greenhouse Gas

GICS – Gentamicin Impregnated Collagen Sponge

H

HCAI – Healthcare Associated Infection

HIC – High Income Country

HIV – Human Immunodeficiency Virus

HVAC – Heating, Ventilation and Air Conditioning

I

ICC – Intraclass Correlation Coefficient

IHD – Ischaemic Heart Disease

IQR – Interquartile Range

ISWCAP – International Surgical Wound Complications Advisory Panel

K

K-S – Kolmogorov-Smirnov

KMO - Kaiser-Meyer-Olkin

L

LCA – Life Cycle Analysis

LED – Light Emitting Diode

M

MLLA – Major Lower Limb Amputation

MRSA – Methicillin Resistant Staphylococcus Aureus

N

NASA – National Aeronautics and Space Administration

NHS – National Health Service

NICE – National Institute of Health and Care Excellence

NIHR – National Institute for Health and Care Research

NPV – Negative Predictive Value

NPWT – Negative Pressure Wound Therapy

NVR – National Vascular Registry

NWCSP – National Wound Care Strategy Programme

O

OR – Odds Ratio

P

PCA – Principal Components Analysis

PDGF – Platelet Derived Growth Factor

PPV – Positive Predictive Analysis

PRC – Precision Recall Curve

PSS – Personal and Social Services

PSSRU – Personal Social Services Research Unit

PVI – Povidone Iodine

R

RCT – Randomised Controlled Trial

RFS – Remote First Screening

RFT – Remote First Treatment

ROC – Receiver Operator Characteristic

RR – Risk Ratio

S

SAP – Surgical Antibiotic Prophylaxis

SD – Standard Deviation

SDU – Sustainable Development Unit

SES – Socioeconomic Status

SSC – Study Steering Committee

SSI – Surgical Site Infection

STARD – Standards for Reporting of Diagnostic Accuracy

T

TGF – Transforming Growth Factor

TIA – Transient Ischaemic Attack

TIVA – Total Intravenous Anaesthesia

TN – True Negative

TNF – Tumour Necrosis Factor

TP – True Positive

TRIPOD – Transparent Reporting of a Multivariable Prediction Model for Prognosis or Diagnosis

U

UK – United Kingdom

UKHSA – United Kingdom Health Security Agency

USA – United States of America

UV – Ultraviolet

V

VEGF - Vascular Endothelial Growth Factor

W

WHO – World Health Organisation

WHQ – Wound Healing Questionnaire