Simulation in Medical Training

JANUARY 2017

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Abstract

Introduction

Whilst simulating clinical scenarios for the purposes of training is not a new concept, changes to the structure of medical training and working hours, technological advance and patient safety concerns have been responsible for intense interest and development of the use of simulation based medical education in recent years. The evidence base for the use of simulation is growing, with a number of studies demonstrating both learner satisfaction and improvements in self-reported confidence, as well as improvement in professional skill and knowledge. There are fewer studies which demonstrate an objective improvement in patient outcome however. Three linked studies in simulation are presented which explore the role of simulation in contemporary postgraduate medical training.

1) **Temporary pacing**

The first examined the use of simulation to teach the uncommon but potentially life threatening skill of temporary transvenous pacemaker insertion to trainees in General (Internal) Medicine. This demonstrated a significant increase in procedural success and learner self-reported confidence in their ability to complete the procedure, but a significant increase in the time required to do so following a single session intervention. The benefits of confidence appeared to decay somewhat over several months, although remained well above baseline.

2) **ECG interpretation**

The second examined the use of a novel online electrocardiography (ECG) interpretation simulator for medical students and foundation doctors. No significant difference was demonstrated in ECG interpretation between those using the simulation package and those who underwent traditional tutorial based training. There was a non-significant trend towards preference of the tutorial method.

3) Survey of attitudes to simulation

The third surveyed trainees across the United Kingdom to determine their experience of simulation, potential to access this learning modality and attitudes towards its incorporation into their training curricula. There appears to be considerable variation by region, specialty and seniority of what is available to trainees. The majority do feel that simulation has the potential to play a positive role within training but that curriculum integration, access and appropriate facilitation are issues which need to be addressed fully to optimise the benefit.

Conclusions

There is evidence to support the use of simulation as a means to increase the knowledge and skill of doctors in training, although there is less evidence of direct improvement to patient outcome as a result. Trainees themselves do perceive simulation as a valuable adjunct to learning in the clinical environment when well-integrated into the curriculum, but there are variations in the accessibility and quality of what is offered. Future work should focus on addressing these issues.

Acknowledgements

I would like to acknowledge all of the staff, both technical and administrative of the Hull Institute for Learning and Simulation, and also the staff of the Medical Education department at Sheffield Teaching Hospitals, without whom these studies would not have been possible. This work was supported by the Yorkshire and Humber Deanery (now Health Education Yorkshire and the Humber) clinical leadership programme, and also a grant from the Sheffield Hospitals Charitable Trust. I would like to acknowledge the collaboration of Dr Eirini Kasfiki (temporary pacing) and Dr Graham Fent (ECG simulator) in the projects described here, although the analysis of data presented here is my own. Dr Makani Purva and Prof. Julian Gunn have been my supervisors through this process, supporting me with advice, guidance and technical expertise. Finally, thanks to Morag.

List of figures and tables

Abbreviations

A(I)M	Acute Internal Medicine
AAMC	Association of American Medical Colleges
ACC	American College of Cardiology
ACCS	Acute Care Common Stem
AHA	American Heart Association
ALS	Advanced Life Support
ASPiH	Association for Simulation Professionals in Healthcare
ATLS	Advanced Trauma Life Support
CCT/CST	Certificate of Completion of Training/Certificate of Specialist Training
CHFG	Clinical Human Factors Group
CMT	Core Medical Training
CSV	Comma Separated Values
CT(1-2)	Core Trainee (Year 1-2)
DGH	District General Hospital
DoH	Department of Health
DOPS	Directly Observed Procedural Skills
ECG	Electrocardiogram
EWTD	European Working Time Directive
FY	Foundation Year
FY1	Foundation Year 1
FY2	Foundation Year 2
G(I)M	General Internal Medicine
GCP	Good Clinical Practice
GMC	General Medical Council

HCP	Healthcare Professional
HEYH	Health Education Yorkshire and Humber
JRCPTB	Joint Royal Colleges of Physicians Training Board
LETB	Local Education and Training Board
MiniCEX	Mini Clinical Examination Exercise
MIST-VR	Minimally Invasive Surgical Trainer - Virtual Reality
NES	NHS Education for Scotland
NFC	Near Field Communication
NHS	National Health Service
NIMDTA	Northern Ireland Medical and Dental Training Agency
NMC	Nursing and Midwifery Council
NRES	National Research Ethics Service
NTS	National Training Survey (General Medical Council)
OSATS	Objective Structured Assessment of Technical Skills
RA	Right Atrium
RFID	Radio Frequency Identification
RV	Right Ventricle
SBME	Simulation Based Medical Education
SBT	Simulation Based Training
SHO	Senior House Officer
SSH	Society for Simulation in Healthcare
ST(1-8)	Specialty Trainee (Year 1-8)
TER	Transfer Effectiveness Ratio
TH	Teaching Hospital
ToT	Transfer of Training

TPW	Temporary Pacing Wire
UK	United Kingdom
US(A)	United States of America
VAK	Visual, Auditory, Kinaesthetic (Learning Styles)

Statement of originality

The work presented here is my own. Whilst others have assisted in the design of studies and data collection as described above, the analysis and presentation is my own. The thesis has been reviewed with suggestions by my supervisors.

Funding

The majority of the study design and data collection was completed whilst I was employed by Health Education Yorkshire and Humber as a clinical leadership and simulation fellow. This research was supported by a grant (<£5000) from the Sheffield Hospitals Charitable Trust for the purchase of equipment to conduct the data collection.

Our group were contacted directly by the makers of the Epicardio simulator to invite an evaluation of the product. During this period, they supplied a licence for use of the software free of charge. Epicardio however had no influence on the study design, data collection methods or analysis and publication of results. No other external companies provided any funding or support for this work.

Outputs from this work

The following publications have arisen from this and closely related work,

Fent G, Gosai J, Purva M. Teaching the interpretation of electrocardiograms: Which method is best? *Journal of Electrocardiology*. 2014;48(2):190–3.

Fent G, Gosai J, Purva M. A randomized control trial comparing use of a novel electrocardiogram simulator with traditional teaching in the acquisition of electrocardiogram interpretation skill. *Journal of Electrocardiology*. 2016;49(2):112–6.

Gosai JN, Pathmanathan S, Chowdhury F. Integrating awareness of the role of human factors in medical errors into a curriculum for foundation doctors: learning from clinical incidents. *METRIC*. 2015;1(2):9–11.

Gosai JN, Gunn JP. Simulation training for the trainee cardiologist: the evidence mounts. *Eurointervention*. 2016;11(13):1454–5.

Gosai J, Purva M, Gunn J. Simulation in cardiology: state of the art. *European Heart Journal*. 2015 Jan 13;36(13):777–83.

Gosai J, Chowdhury F, Burns A. The doctor who performs poorly in simulation: An approach. *Medical Teacher*. 2015 Dec 9;37(5):49–500.

1 Introduction

1.1 Introduction to simulation

1.1.1 What is simulation?

Simulation is the term used to describe the imitation of a behaviour or process using some suitably analogous situation or apparatus(1). Simulation as a technique can be applied for the purpose of studying a phenomenon which is difficult or undesirable to work with in real life. Thus, there are applications appropriate to a variety of industries and settings such as modelling and testing of systems, protocols or emergency preparedness procedures in environments where the cost, risk or ethical implications of practicing in the real world would be unacceptable, for example modelling the effect of a major disaster on transportation systems(2,3). The work described here is concerned with the application of simulation as an educational method for healthcare professionals; recreating scenarios from clinical practice for training. Specifically, this work will examine the role of simulation in postgraduate medical education; applied to those who have already gained the primary medical qualification and are now involved in the delivery of clinical care to patients. There is intense interest in developing simulation for all healthcare professionals, at both undergraduate and postgraduate level, and increasingly in multidisciplinary simulation.

Whilst the focus of this work is not on multidisciplinary simulation, or the integration of simulation curricula for different professions, it is worth noting at this stage that training with a focus on a single group of professionals does carry limitations. This is especially true when considering the interface between human factors and task performance. The ability to achieve technical competence in the performance of any one skill within a simulated environment should not be confused with the ability to complete this task in the more complex real clinical environment. Team working is fundamental to the way that healthcare is delivered in the United Kingdom, and hence should be considered as a fundamental component in the way that professionals are trained. Simulation used to evaluate and train team working is described extensively in the literature and is potentially one of the most valuable applications for the technique, although the majority of the description in this work will focus primarily on individual performance.

What we now recognise as the concept of simulation has in fact been practised in some forms for centuries. The game of chess is widely thought to be the first (or at least an early) attempt at military battle simulation, derived from the Indian game Chaturanga prior to the 6th century(4). Flight simulation is one of the most widely recognisable applications for simulation technology, with primitive devices which replicated the controls of real aircraft appearing as early as 1909, only a few years after the first powered flight. From these primitive designs, progress was made through the world wars into the 1950s when devices we would recognise as a modern flight simulator became available(5). In the 1940s, along with the technological advances of flight simulation, there was a growing interest into what we now recognise as the non-technical element to pilot training and in 1949 in the UK the Ergonomics Research Society was formed, followed in 1957 in the USA by the Human Factors Society(6). It is not uncommon when describing medical simulation to those with limited experience for the link between commercial aviation and flight simulation to be made. There is a move however to steer away from this within the community of simulation educators; our patterns of work and the situations we face are markedly different, and maintaining a strong association between the two disciplines may be unhelpful.

Medical simulation as an educational tool is currently receiving a large amount of attention. What we recognise nowadays as simulation training has, of course been used as a technique for many years, and the majority of us will have undergone resuscitation training, benefitting from the early work of Åsmund S Laerdal, who founded his publishing house in the 1940s, later expanding into toys, and subsequently developing resuscitation manikins(7). Since then, simulation has been widely adopted in the specific arena of resuscitation training, although its uptake in the wider field of medical education has lagged behind this(8).

In 2008, the UK Chief Medical Officer's report by Sir Liam Donaldson made direct comparison between healthcare and the aviation industry's training models for crisis management, citing high profile examples of emergency scenarios in aviation where the rehearsed and calm actions of the pilots have averted or mitigated disaster. This is attributed to the well-established training programme run by the aviation industry using flight simulation (and in particular simulation or emergency procedures) as a key component of this(9).

Several other factors are likely to have contributed to the recent increase in interest in medical simulation. Amongst these, importantly is the reduction in working hours of medical trainees, leading to shortened overall training experience and direct patient contact(10–12). Also, the move in recent years towards more competency-based medical training curricula in which trainees are expected to demonstrate experience and competency in specific medical situations, which they may not experience in the course of routine training(13). Indeed, many medical training curricula now include the use of simulation as an acceptable form of evidence towards achievement of the curriculum objectives. In addition, there may be an increasing expectation from patients that they are treated by experienced and capable teams of health care professionals, raising the conundrum of how those health care professionals gain their experience and skill in the first place(14). There may also be cost implications – in one US study of surgical resident training, it was estimated that training residents in the operating theatre may cost $53 million per year, some of which could be saved if the surgical residents' baseline level of skills were improved using simulation training prior to their entry to the operating theatre(15).

A comprehensive literature search was performed at the outset of this work to examine the existing literature on medical simulation and the related concepts discussed in this thesis. PubMed was searched using the search term "medical simulation" without restriction on time limits. The titles of all returned results were scanned and abstracts read for all relevant results. Full texts were obtained for all relevant references and read. Reference lists for each paper were examined and further relevant works obtained from these. Additionally, references and standard texts were obtained through completion of a Masters degree in education, including references on fundamental concepts in pedagogy and reflective learning. Specific literature searches were also conducted relevant to each study theme, including the practice of temporary pacemaker insertion, acquisition of electrocardiogram interpretation skills and the conduct of surveys. Periodically throughout the course of this project, additional searches were carried out to include work published during the writing of this thesis, and to review the literature around specific topics arising in discussion not covered by the existing literature review.

1.1.2 Fidelity

One of the key concepts used within simulation is that of fidelity. Whilst the cockpit and response of an aircraft may be reproduced almost verbatim within a flight simulator, the same is not true of clinical situations. Crudely, fidelity refers to the degree of accuracy with which a simulation replicates the clinical environment it seeks to ape. Erroneously, it has been used as a descriptor of the technology of the simulator being used however this does not fully explain the concept. Improved graphical representations, additional physiological features or data collection abilities do not automatically confer improved learning experiences(16,17). Fidelity has been broken down into three components; the realism of the environment, the realism of the equipment being used and the psychological engagement of the learner(18). Without the consideration of all of these aspects, the educational benefit of simulation is questionable. Not every simulation will require painstaking recreations of clinical environments or simulators which can replicate every aspect of the procedure or scenario of focus (19,20). The uncanny valley hypothesis was described in 1970, initially applied to the field of robotics. This describes the phenomenon that as the appearance of a robot becomes more human, the emotional response of some of those who interact with it will become progressively more empathetic until a point where this changes to strong revulsion. After this point, further improvements in the resemblance to humans will result in a rapid rise again of the empathy towards the recreation. 'Uncanny' refers to the likeness of the robot being very close to but not identical to the human form, and 'valley' as the sharp fall and recovery in empathy which occurs at this point (21,22). This is an interesting concept, given the advances in simulators in recent years towards realism. Several studies have demonstrated that the indiscriminate use of high-technology simulators without further consideration of the learning objectives confers no benefit to learners over the use of more straightforward devices. Indeed, in certain scenarios, lower technology alternatives may provide a more accurate analogue(16,17,19,20,23–26). One example of this is in the teaching of communication skills, where the nuance of dialogue, including non-verbal cues, will be more faithfully reproduced using an actor or simulated patient rather than a manikin. Psychological engagement of learners in simulation can be a challenging process; a suspension of disbelief is required for learner *immersion* into the simulation. If the behaviour of the learner in simulation is different to their normal clinical practice as a result of their recognition that it is a false situation, the mental models produced may not be transferable back to the clinical environment, or worse, they may be encouraged to engage in risky behaviours as a result of a lack of engagement. Learners will approach simulation with a spectrum of prior experience and preconceptions, and briefing prior to the simulation is an essential component of setting the scene. This includes highlighting the similarities and dissimilarities between what they are about to experience and real-life clinical practice, and clarifying the learning outcomes anticipated.

1.1.3 Taxonomy in simulation

Medical simulation can be delivered in a number of ways. It is important to distinguish simulations which occur in virtual reality – entirely based within computer software - from physical reality simulation, where the simulation equipment comprises physical components designed to replicate real world objects (or patients) which may be more acceptable and confer subjective benefits in terms of perception of value. Further to this, simulation activity can be classified into that which aims to teach a specific procedure or task (often broken down into constituent parts to become "part tasks", and that which aims to recreate clinical scenarios (often referred to as immersive simulation). Immersive simulation is often delivered using physiological manikins and/or actors. Simulation delivery need not be confined to a single methodology in isolation. Indeed, there are numerous examples of successful simulation programmes in operation which blend several different approaches. This is usually referred to as "hybrid simulation"(27). A mixture of methods is combined to obtain the intended result, utilising the strengths of each technique. A risk with this approach, however, is that the increased complexity this entails may result in a paradoxical reduction in the environmental fidelity.

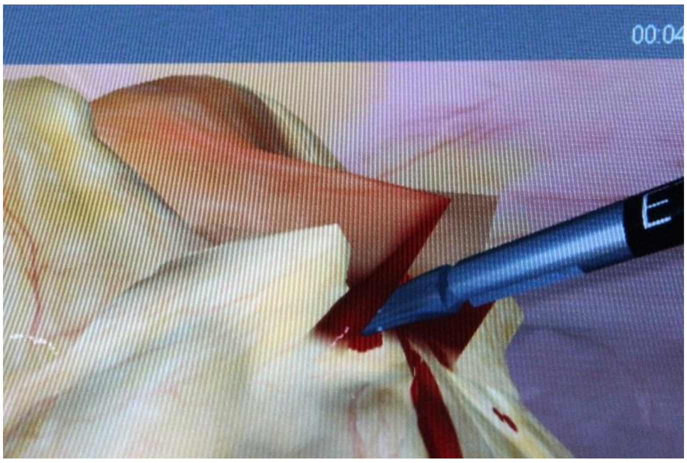


Figure 1 An example of a virtual reality surgical simulation: Simbionix Lapmentor™

(Picture courtesy of Hull Institute for Learning and Simulation)

In addition to commercially available simulators, devices can be created or customised according to need. Creative use of materials such as animal carcasses, gelatine and latex can be used to good effect to create models which are inexpensive and tailored to need.

'Serious gaming' is the term given to computer software which replicates real-world environments, to achieve learning outcomes (as distinct from games designed purely for entertainment). Some of these may take the form of simulations, where the learner plays in their own role and others allow the learner to assume a different role. One potential advantage of serious games is that they occur entirely in virtual reality, and often do not necessitate the purchase of specialist equipment. They can be completed at a time and pace suitable to the learner and feedback is automated within the system, allowing progress when pre-set goals are achieved. Elements of assessment of learning both in terms of knowledge and skill may be incorporated within, and there is some evidence to suggest that motor skills gained using computer games transfers to improved motor performance in technical tasks(28–33). Assessment and modification of underlying cognitive processes and deeper learning through serious games remains a challenge, although an approach where asymmetric tutor involvement is incorporated could address this. There is also some concern that in the absence of facilitation, engagement and motivation of learners may vary; serious games are more likely to appeal to those who have experience of computer gaming, although the gamification of clinical situations may encourage users to perform reckless or wilfully harmful actions(34).

1.1.4 Faculty and quality

The delivery of simulation is contingent upon educators who are able to deliver it. In addition to the clinical knowledge of the subject area being taught, it is also important that they have expertise in the use of the simulators themselves and in the practice of delivering feedback and debriefing after simulations(35). Given this set of requirements, the pool from which to draw faculty is relatively small, although expanding, and there is an enthusiastic network of simulation educators. Programs, including our own Train the Trainers in Simulation and Postgraduate Certificate in Clinical Simulation at Hull have been developed to assist those who are interested in developing their own simulation programs to get started. In the UK, the Association for Simulated Practice in Healthcare (ASPiH) was formed in 2009 with the intention of providing a communication network, standards for best practice and research in simulation.

Given the growth of simulation, inclusion within training curricula and potential role in the assessment and certification of healthcare practitioners, there is increasing scrutiny in the quality of simulation education which is delivered. The Society for Simulation in Healthcare (SSH) in North America have an accreditation/certification program for both individual educators and simulation centres(36). These are voluntary programs of recognition which aim to propagate best practice in simulation and maintain confidence in the education which is delivered. This may be particularly relevant when simulation is used for summative assessment purposes, which will be discussed later, but there is a concern that mandating this for all those who deliver simulation education may discourage some from becoming involved. Co-facilitation is the term used to describe the use of more than one facilitator to deliver an educational activity and in this context, may be a useful way of assisting novice faculty to develop their confidence in delivering simulation.

1.2 Postgraduate medical training in the United Kingdom

When describing the application of any educational method in medical training, it is imperative to consider the context in which it sits. Postgraduate medical training in the UK has undergone a number of significant changes in structure and emphasis within the 21st century. There is an intended linear career path from undergraduate study through to independent practitioner level. Those that graduate with a primary medical degree enter into a period of foundation training. This is typically two years full-time equivalent practice, with posts in a variety of specialties (with the intention of providing a broad base of training). For the first year, provisional registration with the General Medical Council (GMC) is granted, and on satisfactory completion, full registration.

After the foundation programme, the process of specialisation commences, with a choice to be made between primary and secondary care. Those pursuing a career in general practice follow a 3-year programme to become general practitioners, with rotations in hospital and community settings. Those pursuing a secondary care career will typically enter either a ‘core’ training scheme which includes rotations through multiple subspecialties within a wider field (for example Core Medical Training - CMT), followed by entry to a training scheme for the intended subspecialty or will directly enter training leading to specialist qualification in the case of smaller fields. Each entry point is competitive; typically requiring application, assessment and interview, as well as evidence of successful completion of the previous stages.

The length of training from the time of graduation to independent practitioner status varies widely, with a minimum full time equivalent commitment of five years in the case of general practice, and a maximum of eleven years for some secondary care specialties. The actual length of time taken may be markedly longer than this if there are breaks in training, posts which are not recognised to count towards completion of specialist training, or periods of less than full time work.

There has been a move towards competency-based curricula across the spectrum for medical training. This has many implications, and a full exploration of the rationale and consequences of this is outside the scope of this work, but on a practical level it does mean that the current generation of medical trainees must comply with a prescriptive and clearly defined set of requirements in order to achieve progression. The explicit requirement to be able to demonstrate experience and in some cases competence in the management of uncommon clinical scenarios may prove difficult to achieve for some in the face of shortened training times and the move towards consultant delivered care. This can be especially problematic when such situations arise out of hours and supervision is not readily available. The ability to recreate these scenarios reliably using simulation may go some way towards bridging this gap.

Recently, a wide-ranging review of medical training has been completed, with the report entitled “The Shape of Training”. Recommendations have been made to change the way that doctors in the UK are trained, with an increased focus on the role of the generalist. The full detail of implementation of this is uncertain at this time, but is likely to result in further modifications to the career structure. One recommendation is that training in what are currently recognised as the subspecialties occurs only after completion of generalist training, which may result in the requirement to acquire specialist skills in a compressed time period(37).

1.3 Drivers towards increasing use of simulation

1.3.1 The European Working Time Directive (EWTD)

The European Working Time Directive (2003/88/EC) has now been implemented in full in the UK. This has reduced the amount of time that staff are permitted to be compelled to work to 48 hours per week averaged over a period of 26 weeks. Staff may opt to work longer hours, up to a maximum of 56 hours per week averaged over the same period. However this is voluntary and cannot be relied upon when training curricula are being set(11,12,38–41). Prior to the introduction of this directive, the maximum working week for doctors was 56 hours per week, and in the 1990s, working weeks in excess of 90 hours are well documented. There is a clear link between both shift length and total hours worked and the commission of error. Put simply, fatigued staff are less effective in their roles and cognitive functions such as decision-making and situational awareness decay markedly(42–44). Shortened working hours have not been universally welcomed however; in particular, the Royal College of Surgeons have called strongly for working hours for trainees to be increased again, and citing the reduction in overall time spent training, procedure numbers and experience as potentially harmful for the consultants of the future acquiring sufficient expertise(45). It is in this context that simulation, particularly for the acquisition of procedural skills and competency in infrequently encountered clinical situations has risen to prominence. Intensive simulation training could potentially be used to replace some of these ‘missing hours’, particularly in procedure heavy specialties, although it is recognised that simulation will not be able to fully replace real patient experience.

1.3.2 Patient safety

One of the often-quoted differences between pilot and clinician training is that the baseline expectation when flying a plane is that the passengers will disembark safely at the end of the journey whereas the patients that require our services are unwell, often critically so and that our intervention can only be of benefit to them in reducing the likelihood of their death or disability. Unfortunately, a number of patients will experience harm as a result of healthcare error or suboptimal treatment, and the reasons for this have come under increasing scrutiny. The report "To Err Is Human", published in 1990 is one of the landmark pieces of work in this field, highlighting the contribution that human factors (used synonymously with the terms non-technical skills and ergonomics) plays in these errors(46–48). Retrospective analysis of clinical incidents often demonstrates that there is no deficiency in technical skills or knowledge, but that there were deficiencies in non-technical skills resulting in inappropriate decision-making. Frequently, it is not one single error which results in harm to a patient but a series of opportunities are missed to avert a problem occurring. The "Swiss Cheese" model proposed by Reason is frequently used to describe this(49). An example of this can be seen in the events which led to the death of Elaine Bromiley. In this case, a lady was scheduled to undergo elective sinus surgery but at the induction of anaesthesia was unable to be intubated despite the efforts of four experienced consultants. Her life could have been saved if a cricothyroidotomy had been performed, however a failure of situational awareness, decision making and team communication prevented this from happening, despite multiple opportunities to save her life. There are lessons to be learnt from this for health professionals, specifically the contribution of human factors to decision making and error. The sequence of events has been recreated in an educational video, and in her legacy the Clinical Human Factors Group (CHFG) has been set up by her husband to propagate awareness and training in human factors for healthcare professionals(50). Simulation allows us to recreate clinical scenarios, including real-life situations in which human factors errors have occurred. These can then be used to deliver training and also to investigate latent errors within systems(51).

1.3.3 Technological advance

Computing technology has advanced at a rapid pace. This has resulted in each new generation of simulators being more technologically sophisticated than the last. For those that exist within virtual reality, graphical representations of the real world are much improved and more accurate sensors can translate user input into the system a more lifelike fashion. The addition of haptic feedback has also been a critical step in enhancing the experience(52,53). Manikin technology has also benefited greatly from computing advances, the latest generation of manikins are battery-powered and can be controlled wirelessly from a range of up to 10 metres, and feature such technologies as RFID and NFC which enable the interaction of peripheral equipment with the simulator. An example of this is the mounting of an RFID reader and flow rate sensor within a cannula embedded within a manikin arm. This allows automated data collection when an injection is given on the drug used, the dose administered and the flow rate. A wide range of manikin simulators are available, many specialised for specific purposes. Whilst the general-purpose adult manikin remains the most versatile, others can be obtained tailored to paediatric, obstetric, trauma and other specific requirements.

In addition to the simulators themselves, video recording is commonly used during simulation scenarios. Multiple cameras and microphones capture the simulation and record this to a central storage unit. The footage can then be used to assist when giving feedback, and can be shared with learners either via optical disc or uploaded to a web server. Portable camera assemblies are available for use during *in situ* simulation events and many systems allow additional data to be fed into the system such as outputs from the simulator. These advances in technology have increased the complexity of the simulations which we are able to deliver. This can be daunting for novice faculty, and has led to the creation of technician roles specific to simulation.

1.3.4 Healthcare technologies

So far, I have focused on those in training grades. The pace of medical advance however remains rapid and new technologies and procedures are introduced frequently. Simulation can be used as a method to assist in familiarisation with these. Within Cardiology, interventional procedures such as transcatheter valve replacements and coronary sinus electrode placement have become commonplace. The techniques required to master the skills are highly specialised and in response, simulation devices have emerged alongside the introduction of equipment. The trend towards minimally invasive surgical procedures has facilitated simulator development; there is a disconnect inherent with this type of procedure where the tissues are not visualised directly, but either via real-time video acquisition in the instrumentation or radiologically. The Department of Health (DoH) recommends that before any healthcare professional performs a procedure on a patient for the first time, they should first practise in simulation(54).

Complex systems can be simulated to improve both safety and quality; it may be more cost-effective to engage modelling in the design stage of new healthcare services and forecast need using sophisticated models. On an organisational level, much emergency and disaster planning is conducted in this fashion. One example of this is emergency planning for a recent Ebola pandemic(55).

1.4 Educational theories relevant to simulation

Fundamentally, simulation should be considered a technique to deliver education. Therefore, much of the educational theory which is used when discussing simulation predates the widespread adoption of simulation in medical education. Whilst the practical aspects of delivering simulation may be very different from other forms of teaching, focussing simply on the technology without considering the underlying learning is unlikely to result in the desired outcomes. As a form of experiential learning, the obvious analogue to simulation is real-life clinical experience. As discussed above however, this is dependent upon the psychological engagement of the learner, and replication of normal behaviour from the clinical setting. The work of Thorndike and Woodworth over 100 years ago demonstrated that the creation of mental models for one situation can be transferred to others(56). This suggests that simulation does not have to be an exact analogue of the clinical environment, but that the learning outcomes should be tailored to the intended benefits.

Training should be done under the supervision of a mentor, teacher or peer who should provide feedback (debriefing) on performance and guidance, including points to focus on at the next repetition. This feedback is critical to performance improvement; there is consensus in education that delivering simulation alone has little or no effect on learning, and may in fact encourage the acquisition and propagation of poor practice. Feedback is the mechanism by which errors in performance are identified and addressed(57).

The way that feedback is delivered and its content is important. A comprehensive review of the evidence for simulation identifies a number of elements which should be included in any debrief, citing the work of Rudolph et al to recommend that identifying performance issues, describing them, exploring the underlying thinking behind decisions made and actions taken and attempting to modify practice are all incorporated(57,58). The practical methods of giving feedback have been studied extensively; there have been a number of models proposed. A meta-analysis of simulation debriefing found that the methods used were often incompletely reported however the use of video recording and playback does not appear to confer benefit. The use of expert modelling appears to show promise, and the length of debriefing should be tailored as appropriate to the simulation(59,60). Tools have been developed for the assessment of the debriefing itself, which can facilitate educator development in their own practice in providing feedback on performance(61–63).

1.4.1 Bloom's taxonomy and cognitive schemata

Bloom's taxonomy is one of the most widely applied classification systems for learning objectives within education. There are three domains within the taxonomy; *cognitive*, *affective* and *psychomotor*. Each of these is further subdivided into levels arranged as a hierarchy from lower to higher order thinking skills(64). When planning learning objectives for simulation, it can be useful to consider this system with regard to the intended outcome. In the psychomotor domain, the lowest level is that of *perception* where sensory cues are introduced to guide motor response, rising to *origination* which is the ability to generate new motor responses in order to tackle a previously unseen problem. Within the *cognitive* domain, the ability to remember facts is at the lowest level, rising to the analysis, evaluation and creation of new information at the highest levels. The *affective* domain concerns emotional response to situations, from passively receiving at the lowest level to being able to assign values, organise and characterise information received and use this in future situations. This taxonomy has been used as the basis for the description of the schemata we use in daily clinical practice. These are described as Sensory, Motor and Abstract which develop as we gain experience and assist in the reduction of cognitive load. Mental patterns are formed based on prior experience of complex situations, which are then processed automatically and rapidly. The expert practitioner will have well developed and balanced schemata in each domain, as a reflection of prior abstract learning and exposure, but is still at risk of fixation errors when confronted with situations which are superficially similar to ones encountered before. This expertise may take up to ten years to develop. There is also the risk of decay in the knowledge (abstract) domain when skills are not practised regularly.

1.4.2 Adult learners and learning styles

When considering healthcare professional education, we are largely describing adult learners. This group has several characteristics which distinguish them from students. They will have accumulated life experience and prior knowledge, and are motivated to use these in practical learning activities. They will have gained insight and realistic perspective as a result of their experiences, and will have established values and beliefs. Typically, the adult learner will be intrinsically motivated by a need or desire to learn and will engage with material which is relevant to their needs and which progresses towards their personal goals. It must also be recognised that the adult learner may be constrained by external logistical considerations such as work schedules, commitments outside of work and conflicting demands on time. These factors are important to consider when planning simulation activities for healthcare professionals. Developing a simulation based purely on educator know-how or technical feasibility is unlikely to engage adult learners.

This also raises the concept of learning styles. There are a number of theories which propose that not all individuals learn in the same way. The VAK model proposes that sensory preference for visualisation, auditory or tactile stimuli alters the way that a learner responds to teaching. The Honey and Mumford model is a modification based on Kolb's experiential learning model, although preferences are assumed to be dynamic dependent on situation. Despite the identification of different learning styles, there has been little work on whether modification of teaching style to reflect these makes any difference to educational outcomes. A few studies have attempted to assess the impact of learning style on learning from simulation, demonstrating no evidence of difference(65–69).

1.4.3 Reflective practice, experiential learning and debriefing

The concept of reflective practice was introduced by Schön in 1983, based upon the theories of reflection put forward by Dewey(70). The key concept is that professionals are able to improvise when faced with challenges, then consider and evaluate their actions afterwards. This may occur either in a cyclical fashion (reflection *on action*), or synchronously (reflection *in action*) with the aim of correcting error and improving subsequent performance. This is not simply a recollection of events, which may be associated with emotional attachment, but a critical appraisal (which does include emotional reactions) of the sequence of events and decisions, comparing the intended outcome with the actual outcome. Alternate approaches are considered and evaluated, blending the actual experience with theoretical knowledge.

Kolb's experiential learning theory is often used as the model for how simulation should be delivered. It is described as a continuous cycle, with *concrete experience* as the cornerstone(71). Reflection on action is employed following the experience, and the underlying schemata are examined and modified as necessary. These new models are then tested and consolidated the next time the situation is encountered. Structured debriefing is used to frame the reflection and model modification. A facilitated debrief is more effective in achieving this than individual reflection alone, utilising the expertise of the tutor to add to the reflections of the learner(58,62,72,73). Applied to simulation, after a (simulated) experience, the learner is debriefed to examine the events, their own reactions and decisions, and areas of suboptimal performance. These are then abstracted from that specific situation and the learner is encouraged to form new models. The cycle is then completed when the learner is exposed to a similar situation to reinforce changes in practice. This model does depend upon the learner engaging with the simulation in the same way as they engage during clinical practice as discussed above in the section on fidelity.

There is good evidence to suggest that SBME without associated debriefing is not effective. A meta-analysis of 117 studies concluded that outcomes of knowledge, process skill, time, skills, product skills, behaviour and patient effect are all significantly improved with the addition of debriefing, and one study demonstrated that simulation without debriefing had no effect on non-technical skills(59,74). The process of simulation debriefing itself is an area of intense study. A number of different approaches have been proposed, including immediate and delayed debrief, the use of video playback and self-debriefing, but in the meta-analysis described above, no significant difference was found when any particular approach was employed. The only exception to this is that the use of an expert educator does appear to confer significant advantages when compared with learner self-debrief or generic pre-set instructional material. Video recording and playback is now widely used for debriefing in simulation, however, there is no evidence for its benefit over oral debriefing alone. Multiple models for the practice of debrief, such as the good judgement approach, 3-D approach and Pendleton's rules have been proposed, but there is limited evidence to recommend any one approach.

1.4.4 Transfer of training

Another theory relevant to the practice of simulation is transfer of training (ToT). The central principle is that learning in one context can transfer to other similar but not identical situations. The underlying cognitive theories are similar to those of Kolb; underlying mental models are formed which can be applied to a variety of situations. This allows us to extrapolate the learning from simulation beyond the actual situation recreated, assuming that the cognitive schemata which result such as emergency response are common to multiple, diverse clinical situations. If we accept this premise that transfer will occur between simulation and real life clinical practice, a *transfer effectiveness ratio* (TER) may be calculated, an attempt to quantify the improvement in clinical practice which may occur as a direct result of time spent in simulation. This may be expressed either as a change in measured outcome such as error rate or procedure time, or as a function of the time saved during the learning curve in clinical practice as a result of using simulation. If effective ToT and favourable TER are demonstrated, this is compelling evidence for the use of SBME in training, particularly for novice practitioners.

1.4.5 Mastery learning and the acquisition of expertise

The acquisition of expert level performance has been studied in professional sport, music and medical practice. Some individuals are able to perform at a high level, rising above their peers with similar levels of experience. This is likely to be a product of both innate ability and deliberate practice. The cognitive load for novice performers in a skill is high, as they seek to avoid mistakes. As they gain experience, many of the actions become automated and subconscious until eventually a plateau is reached where no further improvement can occur, and performance levels are reproducible. Modification of behaviour by the time that actions have become automated is extremely challenging. The time periods involved to develop expert levels are performance may be prolonged for professional skills, and it has been suggested that 10 years is required to reach this stage, or alternatively 10,000 hours' specific practice in the skill in question (although this is a heavily disputed view)(75,76). Those who perform a procedure at a high volume have better outcomes than those who do so infrequently, and deliberate practice with reflection can play an important role in skill acquisition and maintenance(77,78). Review of performance is another factor which aids in the acquisition of expertise, most commonly by watching videoed performances back to identify errors and focussing practice on these areas. For these reasons, again simulation has been postulated as having the potential to assist clinicians developing technical skills to expert level, providing a safe environment in which to make mistakes, review performance, and the ability to stop the procedure and re-run parts of the task as necessary.

1.5 Technical and non-technical skills

The distinction between technical and non-technical skills has roots in Bloom's taxonomy as discussed above, but is also partly a function of simulator design. Part task trainers which focus exclusively on the technical steps required to complete a procedure are widely available. Learning outcomes for technical skills exercises may be straightforward, with a focus on deliberate practice and assessment of their achievement based on objective measures. Simulation design for non-technical skills is concerned with the recreation of entire clinical scenarios and environments, often in teams and frequently involving the use of actors or manikins. Learning outcomes here may be more complex, and objective assessment of their achievement is challenging. These two domains within simulation are not mutually exclusive; hybrid simulation designs can be used to blend both the technical and non-technical aspects of clinical scenarios.

1.6 Assessment of performance in practice

The topic of assessment of clinicians in training and in practice is large and complex; assessment is fundamental to the way our education and professional system is constructed, and this is further amplified by the move towards competency based curricula. Miller described a hierarchy for assessments of medical practitioners(79). This attempts to recognise that working activities are not constrained to the domains described by Bloom but rather a combination of cognitive, psychomotor and affective skills need to be demonstrated. He has described the lowest level as ‘knows’, demonstrating a recall of facts with ‘knows how’ as a demonstration of competence above this, ‘shows how’ demonstrates performance, and finally at the top level is ‘does’ evidenced by assessment in practice. Any assessment tool is by default a sample of the behaviour of the assessed; usually reflecting performance on specified occasions and often with forewarning. Reliability describes the ability of these samples to represent the overall performance of the candidate being assessed. Generally, the assessments we use to measure clinicians are described as either formative or summative. Formative assessments are usually intended to be used as part of an iterative process during a period of teaching as a method of checking progress, identifying learning needs and improving the quality of teaching. They should be used in a feed forward cycle, with the results used proactively to determine what happens next. Summative assessments are used to evaluate learning and make judgement on competency, measured against an accepted standard (criterion referenced). Typically, summative assessment carries a grade, and in the context of healthcare professionals, are related to career progression and continued licence to practice.

Given the potential consequences of summative assessments, validity of the test itself is a crucial factor. Validity in assessment is the measure of whether the assessment is able to assess and achieve what is intended. Within this, content, face and construct validity should be considered. Exam technique is one facet of this; there are those who perform poorly during summative assessments despite formative evidence of good progress, and those who can excel when assessed with little apparent effort or prior aptitude(80,81). It is also relevant to consider examiners. A knowledge based examination may be truly objective (although in almost all cases will only be a sample of all the required knowledge), but any assessment looking at behaviours or attitudes (and to a lesser extent technical skills) is reliant on subjective judgements by examiners. Inter-examiner reliability is poor in a wide range of assessments which are used, and whilst the '*hawk-dove effect*' can be corrected for when more than one examiner scores each candidate, and each will rank the candidates in the same order (with different absolute scores), evidence suggests that other factors such as prior knowledge of the candidate, shared background and gender play a part in marks awarded (82,83).

The actual assessments in use in postgraduate medicine in the UK follow the domains of Bloom's taxonomy. A mixture of workplace (in practice) and examination based assessment is used. A portfolio approach has been adopted, comprising of multiple assessments linked explicitly to curriculum items to demonstrate competency. These assessments are intended to be used in both a formative and summative capacity; assessments are completed at the request of the trainee for inclusion in the portfolio throughout training, ideally with an ipsative aim (albeit referenced to standards), and a minimum standard of achievement is expected at annual review(84,85). This granular approach to assessment is the subject of some controversy; there is some evidence to suggest that global ratings are as useful in discriminating between individuals as considering each individual assessment facet individually. On the other hand, there is concern that global ratings are potentially wasteful, leading to an averaging of performance scoring across multiple domains and hence reducing the formative benefits (86,87).

1.7 Assessment of performance in simulation

Facilitated debriefing in simulation implies at least an informal external assessment of performance. The facilitator will usually make some judgement of the learner level of performance and relate this to either established standards (criterion reference) or the performance of peers (normative referenced)(59,88). Frequently, this is not formally recorded or carried forward beyond the reflection of the learner however it has been proposed that workplace based assessments may be recorded based on simulation performance, especially for simulated scenarios which are uncommon and that the learner may not experience in clinical practice. This is a divisive subject for simulation educators. The psychological safety of the learner is a key consideration here; one of the defining features of simulation is that no harm can occur to patients when mistakes are made, and hence learners may try new approaches. If an assessment is being made, this may restrict the freedom of the learner to do so and also places the educator in the role of assessor(89–95). This may impact upon the interaction between educator and learner at the time of debriefing, limiting the discussion and hence the potential learning from the experience. On the other hand, however, are the duties placed upon the educator as a healthcare professional. If conduct which could be harmful to patients were observed during simulation and no satisfactory resolution is reached during debriefing, there may be an onus on the educator to act upon this to prevent potential patient harm. This may take the form of further assessment or simulation sessions, or alternatively an attempt at direct correlation between simulation performance and clinical performance, with liaison with clinical supervisors.

One of the challenges with assessment in simulation is the validity of tool used. The Mini-CEX assessment tool has been validated for use in clinical environments but even then, a significant subjectivity from raters can be shown(96,97). There has been no validation for its use in simulation, although this is common practice. The OSATS assessment of surgical performance is amongst the few which have been validated for use in simulation (98–102). Many of these are objective skill based assessments, which assess metrics which are either direct measurements or can be scored pseudo-objectively by expert observers. No other workplace based assessments which are in common use have been validated for use in simulated environments.

There is increasing interest in the use of simulation for summative assessment and certification(93,103,104). There are many potential advantages of this, including reproducibility of scenarios and the ability to tailor simulation scenarios directly to the factors being assessed. Construct validity of the assessment of performance in simulation relies on the assumption that learner performance in simulated environments is truly reflective of real clinical practice. The perfect scenario in assessment terms would be where the participant could not tell the difference between the simulation and real life. An example of this is the use of unannounced simulated patients used in general practice. In reality, although great care is taken to create an accurate analogue, there may still be discrepancies such as location, equipment, paperwork, time and staffing, which may alter learner response. Learners may not attach the same urgency to actions, or situational changes, may engage in riskier or untried behaviour, or may simply fail to consider the activity serious or relevant to their clinical practice and disengage from the process. This is perhaps less likely with preannounced assessments but little evidence exists on the subject. In North America, clinicians can already opt to have part of their professional certification assessments in simulation and with the development of robust, simulation specific assessment tools, this is likely to increase(105).

1.7.1 The use of video recording and its use in debriefing

In addition to the reproducibility of scenarios during simulation, another advantage is the ability to record video and audio of the events that occur and play this back in the debriefing. This may allow the demonstration of acts such as non-verbal communication behaviours which can be difficult to otherwise debrief. The cognitive overload that occurs during crises can distort the recollection of events that happened, and evidence from critical scenario debriefing suggests that details and timescales of events are often poorly recalled. It must be considered, however, that the presence of video recording equipment itself may alter the response of the learner. They may experience unease when simulations are recorded or observed by their peers, which may in turn influence performance. Several studies have failed to demonstrate the superiority of video debriefing over oral debriefing alone; and video recording poses the technical challenges of equipment usage and storage(106–110). The use of video playback during the debrief is itself a skilled process; simply playing back entire scenarios whilst discussing events over the top of it is unlikely to be a useful learning exercise however carefully chosen snippets can help illustrate relevant points, especially where there is discord between learner and educator. In some cases, it is possible to provide the learner with access to the footage to take away with them for review at their convenience but this should not replace debriefing by an educator.

1.8 The evidence for using simulation

Many consider simulation a useful learning methodology only if transfer of the knowledge and skills gained can be demonstrated to the clinical environment. The theoretical basis for this has been described above, however, prior to widespread adoption of simulation in clinical practice, studies demonstrating benefit of the technique are required. Ideally, studies should demonstrate that medical simulation has a positive impact on efficiency, quality or patient safety, although multiple other measures have been used.

1.8.1 Research methods in simulation

Kirkpatrick described a model for evaluation of training in 1959, which is still widely used today (111). This is usually represented as a four-level hierarchy, with reaction at the lowest level, learning above this, evaluation above this, and results at the highest level. This is broadly translatable to the T1, T2, T3 framework, which is applied to translational medical research. This is used to describe the translation of scientific findings (T1) to implications for practice (T2) and onwards to population health (T3). When applied to simulation, the reaction of learners is commonly assessed using evaluation questionnaires, to establish whether the educational programme was well received. Learning is assessed by means of knowledge or skill assessment following the educational intervention. This may take the form of an exam or practical assessment. Behaviours assessment is the first level where transfer from the simulation environment to normal clinical practice is assessed. This involves the evaluation of learner behaviour following an educational intervention when they return to the workplace, ideally with either a before and after comparison or a control group. This can be considered equivalent to T2 translation. Outcome assessment in the context of simulation interventions refers to actual benefits experienced by the patients or healthcare systems as a result of the intervention. This is equivalent to T3 translation. Given the complexity of healthcare systems and number of professionals that patients will interact with as well as multiple other variables in the outcome of any illness, assessments of the effectiveness of simulation can be extremely challenging to construct(112). The assessment levels described by Miller correspond to T1 research, with the exception of the top level which is measured in the workplace and hence could be considered as T2 level research. What is difficult to ascertain from research evidence published in the field is how representative of normal clinical behaviour the observed behaviour is. If those being observed are truly blinded to the observations being made (such as an unannounced notes review or 'mystery shopper' consultation) then this can be assumed. If there is pre-warning of the observation, this may introduce unpredictable performance adjustments by those being observed, not necessarily corrected for in the presence of a control group. It then falls somewhere between a 'shows' and a 'does' assessment, making it difficult to assess whether any improvement in skill demonstrated will actually persist beyond the observed session. Many studies have used lower levels of assessment, including using simulations as the tool for assessment itself. Learner reaction should not be dismissed entirely as an evaluation strategy; the motivation of adult learners depends on their acceptance of techniques, and they are unlikely to engage with that which they find disagreeable. Self-reported confidence is another outcome which is frequently measured in the evaluation of simulation. This probably falls somewhere between reaction and knowledge in the Kirkpatrick hierarchy. Unfortunately, multiple studies have demonstrated a poor correlation between self-reported confidence and physician self-assessment of skill with external assessments of knowledge and performance.

1.8.2 Assessing the transfer of skills

Some studies test the educational effectiveness of their simulation with another simulation. Whilst this approach clearly has the potential to demonstrate that training to use a simulator improves skill in the use of that simulator, it cannot explicitly demonstrate that that improved skill will be demonstrated by the operator when performing the real live procedure.

Some studies have taken a more direct approach to transfer of skills, such as Calatayud et al, who studied surgeons' performance of laparoscopic cholecystectomy with one group undergoing a "warm up" using simulation, and the other group having no warm up. Surgical performance was assessed using the validated OSATS tool, and demonstrated a significant difference in score between those that had undergone pre-procedural warm-up and those that hadn't. Even with this study seeming to demonstrate a significant improvement in the scores however, this is far from convincing evidence of transfer of skills from simulation to the clinical environment. Only 10 surgeons were recruited to the study, but more importantly this was designed specifically to look at whether warm up enhanced surgical performance. As a result, the measurement of surgical performance occurred immediately after the use of the simulation, and the simulation delivery was designed only to allow the surgeons to warm up, i.e. no training to improve their existing skills was provided(113).

A more promising study, conducted by Wayne and colleagues used a retrospective case control methodology to assess the protocol compliance of cardiac arrest teams led by residents who had undergone simulation training (n=20) in addition to standard resuscitation training compared to residents who had only undergone standard training (n=28). In this study, a large and significant increase in protocol compliance was demonstrated in the simulation group (68% vs. 44%, $p<0.01$). No significant difference in successful resuscitation rates was demonstrated however (45% survival in the simulation group vs. 46.4% in the non-simulation group, $p = 0.92$). This seeming discordance in results of the study – a significant increase in one parameter which may be a direct result of the training received which does not automatically correspond with a direct increase in patient survival from cardiac arrest is a good representation of the difficulty of conducting research in this area and expecting to demonstrate definitive evidence of improved patient outcome. In this particular area (in-hospital resuscitation), patient survival (22/48) was broadly in line with that demonstrated in other studies. It would even be possible to draw the conclusion from this study that increasing compliance with resuscitation protocols does not significantly alter cardiac arrest survival, however caution should be exercised about drawing such conclusions from such a small study. In order to demonstrate transfer of knowledge or skill from simulation to the clinical environment by measuring patient outcomes, to correct for the vast array of potential confounding variables either the sample size required would be vast, or else the clinical effect to be studied should be one which has the potential to be altered dramatically by the educational intervention(114). A good example of this is the study conducted by Rosenthal et al where 49 medical interns were enrolled, and it was established at baseline that they had little to no skill in emergency airway management. Following an intensive simulation programme, they were re-tested using both simulation and in the clinical environment, and demonstrated improved skill in both(115).

Seymour and colleagues conducted a randomised, controlled trial of virtual reality training in laparoscopic cholecystectomy, using the MIST-VR system which primarily aims to train surgeons in the technical skills required to perform laparoscopic procedures (specifically the control of instruments on screen during laparoscopy). Although numbers were small (n=16), all participants were relative novices. The group (n=8) trained using the simulation system for between 3 and 8 hours performed significantly better when then asked to complete a real-life cholecystectomy in the operating theatre compared to the group who had undergone no simulation training despite no significant difference in baseline performance(116). Other industries, in particular the aviation industry have taken this approach, and have successfully demonstrated that following the intensive simulation of one specific procedure (for example landing a plane), transfer of this skill can be demonstrated in the real-life environment(117–119). If the early learning can be done in simulation when the operator is most likely to cause inadvertent harm, then they will approach their first patients less likely to injure them.

There have been a considerable number of studies completed focussing on procedural simulation. It may be that it is relatively more straightforward to simulate procedures, and then to measure the real-world equivalent using tools such as the OSATS, complications experienced or other measures of competence which correlate with outcome (for example total time, radiation time and contrast volume are commonly used measures in studies of angiographic performance). In addition, many studies undertake video recorded procedures, which are then reviewed by blinded observers and scored using validated scoring tools (or at least expert agreed measures). In other cases, an agreed "gold standard" exists, such as the resuscitation protocol compliance discussed above. However, it is also apparent that a number of simulation studies use assessment tools which have been designed by the research team themselves in order to conduct the study without any validation.

Another commonly used method to evaluate simulation and its educational value is to make the assumption that real world clinical competence correlates with competence using the simulation, and therefore a simulation that is able to discriminate between novice and expert performance (as defined by the clinical experience of the subject) can be validated, and in some cases considered suitable for competence assessment(120).

1.8.3 Retention of knowledge and skills

Little is known about the duration which the knowledge gained from simulation teaching persists, regardless of whether it actually transfers into the clinical arena or not. The evidence in this area is far more limited and often conflicting, comprising small scale studies and varying methodology. Wayne et al conducted a study assessing the retention of resuscitation skill amongst internal medicine residents, with a follow up study by Didwania et al. Whilst they demonstrated no decay in skill over 14 months, they have failed to adjust for the baseline level of skill, although this is addressed somewhat in a related paper by the same authors who demonstrate that in a crossover study the simulation training does significantly improve skill (assessed by simulation), whereas clinical experience alone does not(121,122). In comparison with this, however, Gass and Curry demonstrated that retention of knowledge after basic resuscitation training was less than 6 months(123).

Schwid compared examination scores in a group of anaesthesia residents 10 months after computer simulation training, and compared their scores with a group who had undergone textbook learning and demonstrated significantly higher scores in the simulation group (mean 34.9 points vs. 29.2 points, p=0.001, n=45) although performed no initial testing to demonstrate whether this difference was present immediately after the learning, and a similar study of pharmacy students (albeit only assessing retention of knowledge at 25 days) failed to demonstrate superiority of simulation over textbook learning in either initial increases in knowledge or retention of this(124,125). A further study, however did demonstrate increased confidence and knowledge following simulation training of uncommon obstetric emergencies which decayed over 12 months. Further simulation training at that time point again increased knowledge and confidence(126).

1.9 The place for simulation

The Department of Health has supported the increase in adoption and use of simulation as a learning technology, but stresses that it should not and cannot entirely replace other forms of learning in healthcare education(54). This is partly a function of the cost and logistical challenges of simulation; compared to other modes of teaching, it is expensive and time consuming for both learners and educators. For this reason, the use of simulation to deliver education for any group or topic should be justified. One of the aims of this work is to establish the current place and potential future directions for SBME in postgraduate medical training in the UK, and this will be discussed later.

1.9.1 Disadvantages of using simulation

Simulation, by definition, attempts to recreate real situations, scenarios and procedures without the presence of a patient. Inevitably, therefore, there will be an element of unreality. Procedural skills are often broken down into component parts, and unless using a hybrid approach, a procedure simulator will offer no human interaction. In addition, any equipment malfunction during the simulation can break the immersion, and disrupt any learning that has occurred. Equipment purchase can be costly, and with rapid improvements in either medical practice or simulation technology can quickly become outdated. Software updates and additional scenarios are often available, but frequently at extra cost. One example of this is seen with the Simbionix Angiomentor™ system in use locally, which was purchased at considerable cost but allows practice of procedures only by the femoral route, whereas there has been a move in recent years to radial arterial access. Updating the simulators for the Yorkshire and Humber region alone would entail a cost of several hundred thousand pounds. The risk of broken immersion here is probably the most serious, if the learner perceives that what is happening is an artificial feature of the simulation, their responses will be different to those in clinical practice, potentially breaking the opportunity for transfer of training. Ingraining of poor practice may occur in the absence of adequate supervision where simulator design is poor, and this will not necessarily be reflected in the output metrics from the simulator such as total procedure time, radiation time or contrast volume. Unlearning these undesirable behaviours can be difficult. Additionally, skills learned on a single occasion will decay if regular practice is not maintained.

There is a substantial learning curve for both learners and facilitators. The technology itself and acquisition of debriefing skill can be daunting to educators, and if not used frequently, these skills themselves may decay. Increased use of pre-prepared learning packages and simulation scenarios may remove some freedom from the teachers and learners to tailor their own learning. Mentorship and peer tutoring programmes may help with this somewhat, and the use of virtual reality simulation can allow asynchronous learning to occur. The logistics of arranging staff time to train, especially if entire team training is desired, can be challenging in acute care areas where there is little 'downtime'. There needs to be high level management support to enable such activities and ensure success.

1.9.2 Adoption of simulation

The Association for Simulated Practice in Healthcare (ASPiH) has conducted a large-scale scoping exercise to determine the current status of SBME in the United Kingdom in 2014. A total of 87 simulation centres were identified in the UK. Approximately 80% of these centres are using simulated patients and advanced manikin simulators, and between 25-30% are using virtual reality trainers. The virtual reality trainers are the least used resources, and interprofessional learning is infrequently seen. The key barriers identified to further expansion of the use of simulation were time related; both the time for educators to teach and develop scenarios, and learner release from job plans, possibly as a consequence of poor management 'buy-in'(127).

Locally, in the Yorkshire and Humber region, there has been considerable financial investment at both undergraduate and postgraduate level into the provision of buildings and equipment to deliver SBME. Health Education Yorkshire and Humber (HEYH) has invested around £20 million in the creation of new simulation centres and equipping them. This investment has been supported by an extensive leadership fellowship programme to drive forward adoption and research in simulation through the development and running of new programmes and the advertising of their availability.

Professional and governing bodies now recognise simulation as a valid component in the training and maintenance of skills. The Nursing and Midwifery Council (NMC) accept the use of simulation training for up to 300 of the required 2300 practice hours for preregistration nursing students (128). The General Medical Council (GMC) has recognised simulation as a potentially advantageous educational delivery method, however, in the most recent report of the Curriculum and Assessment

System Activity (May 2014) have stopped short of mandating the inclusion of simulation in training curricula as a result of concerns regarding equity of access to simulation facilities and obtaining trainer time to support this(129). The Royal College of Physicians routinely incorporates simulated patients into the summative assessment process to gain membership of the college.

1.10 Summary and challenges

As a technique in healthcare professional education, simulation offers many potential advantages over both non-experiential learning methods and on the job learning. The proposed mechanisms by which learning occurs are plausible and based in educational theory when the technique is applied appropriately. There remains however a lack of available evidence for objective improvement in patient outcomes, and there are considerable logistical and financial barriers to increased adoption. This is an area of rapidly growing interest, with several drivers at a time of reduced overall training times, competency based curricula and an active focus on improved patient safety.

1.11 Aims

The aim of this work is to investigate the place of simulation-based medical education applied to postgraduate medical training, with a focus on Cardiology and the place which it currently occupies within the broader curriculum. In particular, I will examine a) the role of simulation in training operators in temporary pacemaker insertion; b) the utility of simulation in teaching ECG interpretation; and c) attitudes to simulation.

2 Evaluating the use of simulation to train inexperienced operators in temporary transvenous cardiac pacing

2.1 Temporary transvenous pacing

Implantation of a temporary transvenous pacing wire (TPW) is a procedural skill where one or more electrodes is introduced to the endocardium of the heart through a percutaneous access port into the venous system, and connected to an external pace generator device. It is frequently performed in an emergency to treat brady- and tachy-arrhythmias(130). Evidence suggests that this is an increasingly rare procedure. In one local district general hospital, an audit revealed that 18 such procedures were performed within a 12-month period, of which 9 were performed in hours by the on-site cardiologists and 9 out of hours by general physician registrars and consultants (unpublished data, Gosai and Louis, 2011). At the same site, there were in excess of 10 registrars, all of whom may rotate annually. In one 12-month period at the Northern General Hospital in Sheffield, a tertiary site with on call Cardiology, 46 TPW insertions were recorded on the database of procedures performed in the catheter suite, although this is likely to be an under-estimate as a number of these procedures are performed in the coronary care ward and not recorded in the same place (unpublished data, Gosai, 2016). When a TPW implant is required, it is often performed by low volume operators, with a repeat procedure required in excess of 10% of cases, and bacteraemia ensuing in 6%(131,132).

This is a procedure which requires some skill and practice to master, as well as to be aware of the potential serious complications and anatomical variation(133–135). A wide range is reported for complication rates, but even at the most conservative end, at 10%, this is a procedure that carries a high risk(136–138). Additionally, the patient population requiring a TPW are likely to be a high risk group (139). The use of modified permanent pacing systems has gained traction as an alternative in recent years(140). Suggestions to further reduce the need to perform TPW implants have included provision of capacity for permanent pacemaker implantation 24 hours a day (141). Nonetheless, until viable alternatives are in place, the management of these patients with life threatening arrhythmia remains a challenge.

Personal experience and discussions with colleagues in General Internal Medicine (G(I)M) and cardiology has identified a shortfall in the training and clinical service provision for temporary pacemaker insertion, especially outside office hours in District General Hospitals (DGH). Locally, cardiology services are maintained across a variety of sites, with a teaching hospital (TH) and tertiary referral centre which has a 24-hour cardiology service, comprising of a registrar on site at all times, and consultants on call from home. In the surrounding area are several DGHs, the majority of which offer an on-site cardiologist during office hours, and out of hours admissions to their units covered by physicians trained in G(I)M, with a G(I)M training registrar on site at all times, and the consultant physician able to attend at short notice. No formal pathway exists for direct admission of patients at risk of needing a TPW to the TH site. This pattern is replicated across the UK. At the time of writing, the British Heart Rhythm Society have announced a consultation and plan to publish recommendations in this area.

G(I)M trainees themselves express concern about the lack of opportunities to perform and maintain competence in this skill, and indeed a recent UK survey reports 61% of general medical registrars had not performed any TPW insertions prior to becoming a registrar, only 14% having received formal training. Only 18% felt confident to perform this procedure independently and, 84% would not be certain that their on call consultant would be competent to perform the procedure(142–146). Nonetheless, in the current system, they will be expected to assess and institute the acute management of these patients.

The JRCPTB have now removed temporary cardiac pacing by transvenous wire as an essential skill required to be demonstrated by core medical training doctors to progress to ST3+ training, and for ST3+ registrars to gain CCT. It does, however remain a desirable skill, and they recommend that practice in skills labs or simulation is considered(147). It remains an essential skill for those training in Acute Internal Medicine (A(I)M) to demonstrate competence in by the time of completion of training.

Studies examining the practice of TPW implantation have demonstrated a reduction in procedure times and complications for cardiologists and experienced physicians when compared to inexperienced operators and non-cardiologists. Procedure time correlates with infection risk(148). At the present time, there are few courses available which teach temporary cardiac pacing, using variable methods of teaching and levels of simulation. No dedicated task trainer is available on the market for temporary transvenous pacing (although simulators are available for permanent pacemaker implantation), and no validating evidence exists that simulation based training in temporary pacing is of value. At the time of researching the background to this project, we were unable to find any course running regularly in the UK which gives attendees hands on practice either in simulation or on real patients in TPW implant.

2.2 Measurement of Quality in Pacemaker Insertion

No validated evidence beyond expert consensus exists on how we should measure quality in pacemaker implantation. It is a “core procedure” in the Cardiology specialty training curriculum from the JRCPTB, with a requirement that all cardiology trainees reaching completion of training achieve at least “level 2” competence in permanent pacing (“able to perform procedure with limited supervision/assistance”), and “level 3” competence in temporary pacing (“competent to perform the procedure unsupervised and deal with complications”)(149). This is assessed using a modification to the widely used DOPS assessment tool which uses a series of expert agreed criteria to measure the quality of the procedure(150–152). A minimum of two independent observers are required for each trainee. There are recognised complications for the procedure, including infection, bleeding, failure of positioning, pneumothorax and cardiac perforation. None of these are assessed using the DOPS template in use.

Evaluation metrics for temporary pacing are therefore difficult. There are no published, validated measures which could be used as acceptable metrics to determine the effect of a teaching session. The actions which lead to complications of the procedure such as infection, cardiac perforation and pneumothorax have not been clearly identified. Whilst we do know that experienced implanters experience fewer complications, what has yet to be defined is what those operators do which results in fewer complications. Shorter overall procedure and radiation times are the only measurement which has been shown to correlate with complication rates, although whether this is a direct causative factor or a reflection of operator experience improving both is uncertain.

For the purposes of this work, there was also the issue of what could actually be measured. Whilst infection is one of the most serious complications, it is frequently only seen some time after the initial procedure, and there is no clear association between wire manipulation technique and the development of infection when standard aseptic techniques are used. Similarly, pneumothorax and cardiac perforation commonly become apparent some time after the procedure, and at present are not accurately simulated. Rajappan has defined three techniques for ventricular electrode placement, but there are no data to suggest the superiority of one over another; and, in many cases, a combination of techniques are required to achieve position(153). There are some data on the effect of final position within the ventricle for permanent pacing, but these data were collected for long term paced patients, and no studies have examined the effect of electrode position in temporary pacing which is likely to be in situ for only a few days.

2.3 Aims

The aim of this work was to develop a single session teaching programme for inexperienced physician trainees in the insertion of temporary transvenous pacing wires using 'hands on' simulation, and to evaluate the effect upon learner confidence and skill in performing this procedure.

2.4 Objectives

1. To develop a course to deliver simulation based training in temporary transvenous pacemaker insertion which is as accurate a representation of the real-life procedure as possible using current generation simulation technology.
2. To assess the utility of such a course in the training of medical registrars to perform this procedure.
3. To assess the acceptability of such a course by trainees.
4. To evaluate whether attendance on such a course improves the confidence of medical registrars when faced with a clinical situation when temporary pacing is contemplated or attempted.
5. To evaluate whether attending this course has the potential to improve skill in TPW implant.

2.5 Methods

2.5.1 Research governance

Ethical approval to proceed with this study was sought from the University of Sheffield Medical School Research Ethics Committee (Ref: SMBRER264) (Appendix 2.1). All research was carried out in accordance with the conditions of the ethics committee.

2.5.2 Design of the course

Good practice was considered to be compliance with the standards for temporary pacing as set out in the JRCPTB Cardiology curriculum, and Good Medical Practice Guidance issued by the UK General Medical Council(149,154).

The content of the teaching was designed to align with the standards for competency in TPW insertion as defined by the American College of Cardiology and American Heart Association(155). No equivalent UK or European guidance was available. In addition, the opinions of experienced cardiologists were sought to include any locally relevant information. It was therefore decided to include the following:

- Indications and contraindications to the procedure
- Alternatives, including chronotropic drugs, transcutaneous pacing and permanent pacing
- Relevant anatomy of the heart, including variations
- Anaesthesia and sedation
- Aseptic technique
- Venous access
- Familiarisation with the equipment used
- Patient preparation and facilities
- Radiation use and safety
- Wire manipulation and positioning under fluoroscopy
- Connection and parameter testing
- Identification and management of complications
- Aftercare and removal

The course was structured with a welcome to participants and gaining informed, written consent to participate in the study. The initial video recorded assessments were then conducted.

The course comprised a small group plenary session covering the theoretical aspects of the procedure. This was presented in a style to allow participants to ask questions at any stage, and with regular checks of understanding to ensure comprehension before moving forwards. A copy of the presentation materials was forwarded to each participant for future reference. Participants were then shown the computer based threshold simulator. This was then followed by a short break before moving on to the practical skills session.

The practical skills session commenced with an introduction to the simulator and the key differences between the simulator and human physiology. This was followed by a faculty demonstration of the process of a TPW implant, with descriptions of each stage of the process and demonstration of the different approaches available. Each participant was then asked to perform an implant, with mentoring of their technique. All the participants had the opportunity to do this, and repeat the process with progressively lower levels of instruction and advice until they and the facilitators were confident that they had mastered the procedure. During this time, the other participants were invited to watch and discuss the technique and provide feedback. Most participants required between two and five repetitions in order to master the procedure. Further time for free practice was built onto the end of the end of the session, before a final attempt directly observed by faculty without instruction.

After the practical session had ended, the repeat filmed assessments were conducted, and the post-course questionnaire administered..

2.5.3 Simulation application

Although no dedicated simulator exists for the training of temporary pacemaker insertion, existing angiographic simulation equipment has a module which can replicate the actions required in the implantation of permanent pacemakers. This was included in the Simbionix Angiomentor™ Express system (Simbionix limited, Airport City, Israel). Using this facility, but altering the choice of pacing catheter used to a generic angiographic catheter rather than a specific permanent pacing electrode, allowed replication of the procedure required to implant a TPW. This has been reviewed and tested by experienced pacemaker implanters and found to provide acceptable fidelity.

A simple screen based simulation of threshold testing was designed to be implemented alongside the Simbionix simulator. Introducer sheaths, temporary pacing electrodes and pace generators were also procured for demonstration use.

2.5.4 Study design

A single arm, uncontrolled, observational study design was chosen. The reason for the use of this design was largely pragmatic; one of the major challenges associated with similar projects has been recruitment of participants, in particular for multiple attendances. Our experience has been that this is particularly true of trainees in the medical specialties, who are frequently working in complex shift pattern rotas. This design was intended to maximise potential recruitment and data collection. Inclusion criteria were medical trainees at ST3 or above level training in either G(I)M or Acute (Internal) Medicine (A(I)M, who had performed fewer than 20 TPW implants. Participants were identified through invitations sent out by training programme directors for these two specialties throughout the Yorkshire and Humber region. Courses were run at two sites, in Sheffield and Hull. No individual was identified that had implanted more than 20 TPWs. Invitations to the course were delivered to all current trainees in the Yorkshire and Humber region at the grade of ST3 and above, training in the specialties of acute internal medicine (AIM) and general internal medicine (GIM). This was achieved with permission from the head of the school of medicine, and distribution via regional training programme directors.

Prior to the start of the course, participants were asked to confirm informed, written consent. Each was assigned a unique identifying code. A questionnaire (Appendix 2.2) was administered to establish their baseline experience of TPW implants (including watching the procedure), and confidence to perform the procedure. The questionnaires used were modelled on the existing evaluation questionnaires in use at the Hull Institute for Learning and Simulation for other courses. A mixture of question types was employed, using closed questions to establish the participant baseline level of experience in TPW implantation, and to establish initial reaction to the course in the post course questionnaire. This was followed by a grid of five option Likert-type bipolar questions to establish participants' self-reported confidence in aspects of temporary pacing. These questions were replicated on the pre-course and post-course questionnaires to allow a direct within subject comparison of self-reported confidence immediately following the course, and at follow up several months later. Finally, at the end of the post-course and follow up questionnaire, a space was provided for any other comments from participants to enable them to raise any other thoughts or comments. This mix of question types was chosen to allow the questionnaires to be simple for participants to complete, but with the scope to capture comments and thoughts. It was decided to allow a neutral option for the confidence questions rather than an even number in order to enable those respondents neutral in confidence to express this. Five rather than seven possible responses were allowed due to the relatively small expected sample size in order to reduce extreme response bias(156).

Participants were then asked to use the simulator to attempt a TPW positioning. The controls of the simulator were explained for those unfamiliar, but not the actual procedure. This attempt was video recorded and assigned a randomisation tag. The video recordings did not include the participants themselves, only the simulator screen. In the initial conception of the study, an attempt was made to define features of the technique employed by a series of operators including experienced and inexperienced operators. No features were identified which appeared to correlate with operator experience. There is some data that simulator fluoroscopy time and total procedure time correlate with operator experience in angiographic procedures(157,158).

Following the course, the participants were asked to complete a second questionnaire with the same confidence questions, and an evaluation of the course (Appendix 2.3). They then underwent a second video recorded attempt. They were also given a link to an online questionnaire to be completed in the event of experiencing a clinical scenario where a patient may have needed a TPW implant (Appendix 2.5). Between 3 and 6 months after the end of the course, all participants were invited to arrange a time to return to one of the skills centres in Sheffield or Hull for a reassessment of skills. They were also invited to complete a further questionnaire assessing confidence (which was hosted online) (Appendix 2.4). For each video recorded procedure, a reading was taken from the Simbionix simulator for procedure time and fluoroscopy screening time. The videos were assigned a random order for analysis and analysed by a single, blinded observer for final wire position and comments on the technique.

2.5.5 Data collection, storage and confidentiality

All information collected during the study were held on a secure NHS computer with password protection, and backed up in approved form. The films were kept in digital format, similarly protected. Study documents (paper and electronic) were retained in a secure office at the Hull Institute of Learning and Simulation Hull Royal Infirmary, Hull and East Yorkshire NHS Trust. The Clinical Skills Facility complied with all aspects of the Data Protection Act 1998 and operationally this included appropriate storage, restricted access and disposal arrangements for candidates' personal details.

2.5.6 Data analysis

Statistical advice was sought from the University of Sheffield Statistical Services Unit. Given no prior data exist in this area, it was not possible to perform a sample size calculation. Nominally, a sample size of 24 was planned. All data were compiled into a spreadsheet. A descriptive analysis was completed of the questionnaire data using NVivo 10 (QSR International, Melbourne), as well as a thematic analysis of free-text comments received. Wilcoxon signed rank analysis was used to evaluate the significance of difference between the confidence questionnaires returned before the course, at the end of the course, and at follow up.

The data from the video analysis were transferred to SPSS version 22 (IBM Inc., Armonk, NY). A Shapiro-Wilks test ($p<0.05$) and visual inspection of histograms and Q-Q plots confirmed that the data were not normally distributed. Wilcoxon signed rank analysis was used to determine whether there was any significant difference between total and radiation time from between the pre and post course attempts. Due to the poor recruitment to follow up assessment, no further statistical analysis of the follow up assessment videos was made.

2.5.7 Issues of assessing performance

No patient contact or involvement was required for this study. It was anticipated that the majority of doctors who took part in this would have had little or no knowledge or experience in this field, and this was explained to the participants at the time of consent. It was stated that the participants were not being directly assessed and that results from this study would not be directed to their educational supervisors or any other agency responsible for their training.

Given that this study was not designed to provide an assessment of competence of participants, and no assessment of competence was given to participants, those that took part in this study would not be able to use attendance to demonstrate competence in the procedure for clinical practice. This was made clear to participants, and they were advised that should they require training in temporary pacemaker insertion, this should be sought in the usual way. Any candidate observed to perform actions which would be considered hazardous if attempted in clinical practice was informed of this. If such action took place during the training course, remedial training was provided. If such action took place during a subsequent assessment, they were informed of this in writing (by email), and that they should undergo further supervised training before attempting this procedure on a patient.

Participation in this research, however, aimed to validate this method of training for temporary pacemaker insertion and if so, plans will be made to run this as a formal training course, where assessment of competence may be made.

2.6 Results

2.6.1 Recruitment

A total of 40 candidates attended one of nine courses run over a six-month period. 18 were A(I)M trainees, and 21 were G(I)M. One was about to commence a Cardiology programme (with no prior experience).

2.6.2 Experience

Of those attending, eight had made a previous attempt at inserting a pacing wire (20%). None had done more than four. For all but one of those who had attempted a TPW insertion, this had been greater than 12 months prior to attendance at the course. Thirty had seen the procedure done at least once (75%).

2.6.3 Confidence and evaluation

At the start of the course, candidates were asked to rate their confidence in five areas of temporary pacing, using a rating scale of 1 (not at all confident) to 5 (very confident). These questions were repeated at the end of the course and the results are displayed below (Table 1).

Thirty-one would if faced with the situation where a temporary pacing may be needed seek help from a cardiologist either locally or regionally (n=32).

The same set of confidence questions were asked as prior to the start of the course, and again at follow up (follow up at median 140 days, range 61-216 days).

		n	Mean	Median	Standard Deviation	p	p
I would be able to insert a TPW unsupervised	Pre	37	1.16	1	0.44	<0.01	
	Post	40	2.8	3	0.99		0.024
	Follow up	21	1.95	2	0.97		
I would attempt this procedure in an emergency	Pre	37	1.54	1	0.73	<0.01	
	Post	40	3.35	3	1.03		0.134
	Follow up	21	2.9	3	1.07		
I could identify immediate complications	Pre	37	2.14	2	1.06	<0.01	
	Post	40	3.95	4	0.60		0.005
	Follow up	21	3.45	3	0.83		
I could deal with immediate complications	Pre	37	1.86	2	0.98	<0.01	
	Post	39	3.72	4	0.69		0.001
	Follow up	21	2.7	3	0.86		
Most current consultant physicians could perform this procedure	Pre	37	2.02	2	1.04		

Table 1 Pre vs post course and follow up confidence
(1=not at all confident, 5=very confident)

In addition, at the end of the course, four general evaluation questions were added to the questionnaire (Table 2 and 3).

	Yes	No
Was this course useful to you?	40	0
Did you find this course enjoyable?	40	0
Would you recommend this to a colleague	40	0

Table 2 Post course evaluation

Mean	4.28
Standard deviation	0.60
Upper	5
Lower	3

Table 3 Did the simulation feel like a good representation of the procedure?

Wilcoxon signed ranks analysis demonstrated an increase in confidence ($p<0.01$ for all four questions asked) from the pre-course questions to the post course questions. At follow up, there was a significant deterioration for each domain apart from the one asking whether an emergency attempt would be made (Figure 2).

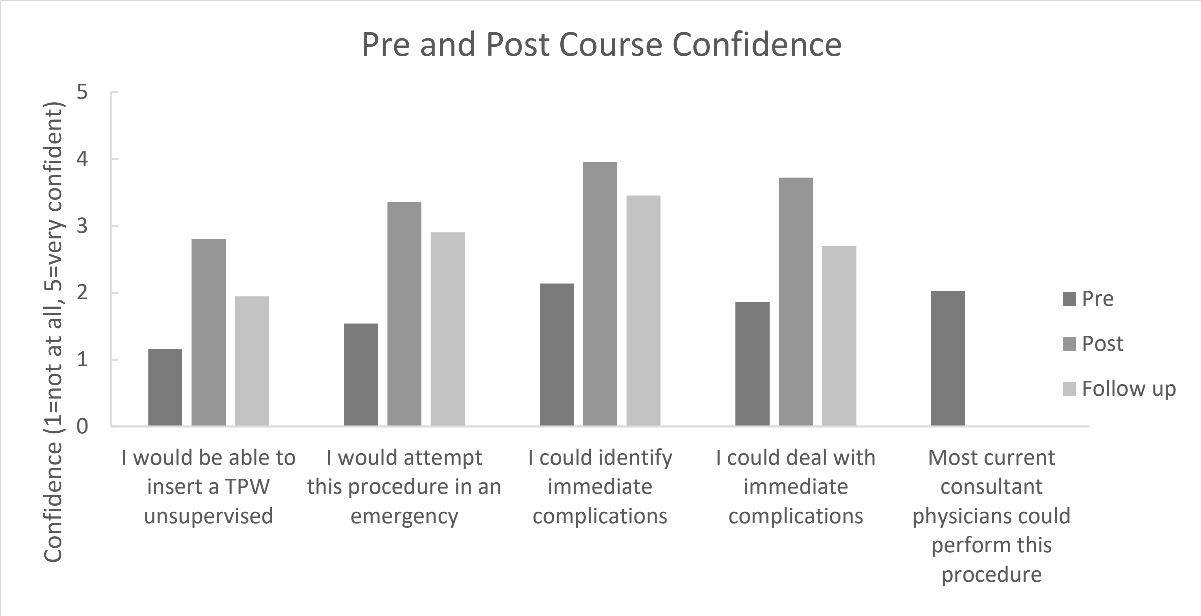


Figure 2 Pre and post course confidence (median scores)

Comments received from those at the end of the course (n=17) were constructive and positive. Key themes identified within the comments were of the relevance of this course to the acute or general medical registrar (11 references), the quality of facilitation (8 references), increase in confidence (7 references) and suggestions of components to be added to the course (5 references). A full list of comments received is available in Appendix 2.6.

In the follow up questionnaire, one of the 21 who responded had inserted a pacing wire (under supervision); the other 20 had not. Three had watched one being inserted. Twelve had encountered at least one patient where insertion of a pacing wire may have been indicated (5 of these on more than one occasion). For these patients, management strategies were: local implantation of temporary pacing (4), chronotropic drugs (7), permanent pacemaker implant (2), transcutaneous pacing (1) and palliative therapy (1). Fourteen respondents did not expect to be able to achieve competence in temporary pacing by the time they achieved CCT, four expected to achieve competence under supervision, and one expected to achieve the ‘competent to perform the procedure independently and deal with complications' certification (an acute medicine trainee). Only a few comments were left. These were broadly themed as follows;

1. Utility of the course in providing some exposure to temporary pacing for those with no experience of this procedure, increasing confidence in dealing with paced patients
2. Difficulty in accessing opportunities to practice this skill and frustration at this lack of opportunity.

A full list of comments received is available in Appendix 2.6.

For the survey to be completed when participants had encountered a patient potentially in need of TPW insertion, three responses were received. All three patients had a temporary pacing wire inserted, all for bradycardia and these were implanted by a cardiology registrar or consultant at the same hospital. Two of these patients received both transcutaneous pacing and chronotropic drugs prior to the pacing wire insertion. No complications were recorded.

2.6.4 Skills assessment

At the start of the course, 24/40 participants positioned the wire within the right ventricle (60%). 16/40 (40%) positioned the wire within the right atrium. At the end of the course, all 40 achieved a final position within the right ventricle. The four participants who attended follow up all achieved a final position within the right ventricle (two of these had initially failed to cross the tricuspid valve at initial assessment).

Mean total procedure time was 55.0 seconds pre course, with a mean radiation time of 40.6 seconds. Excluding those that did not enter the ventricle, mean total procedure time was 52.6 seconds, with a mean radiation time of 36.9 seconds. Mean total procedure time was 141.0 seconds post course, with a mean radiation time 134.6 seconds. Total procedure time increased for all but one participant between the start and the end of the course, and radiation time increased for all but two. Mean total procedure time for those that attended follow up was 122.2 seconds, with a mean radiation time of 99.5 seconds (Figures 3 and 4).

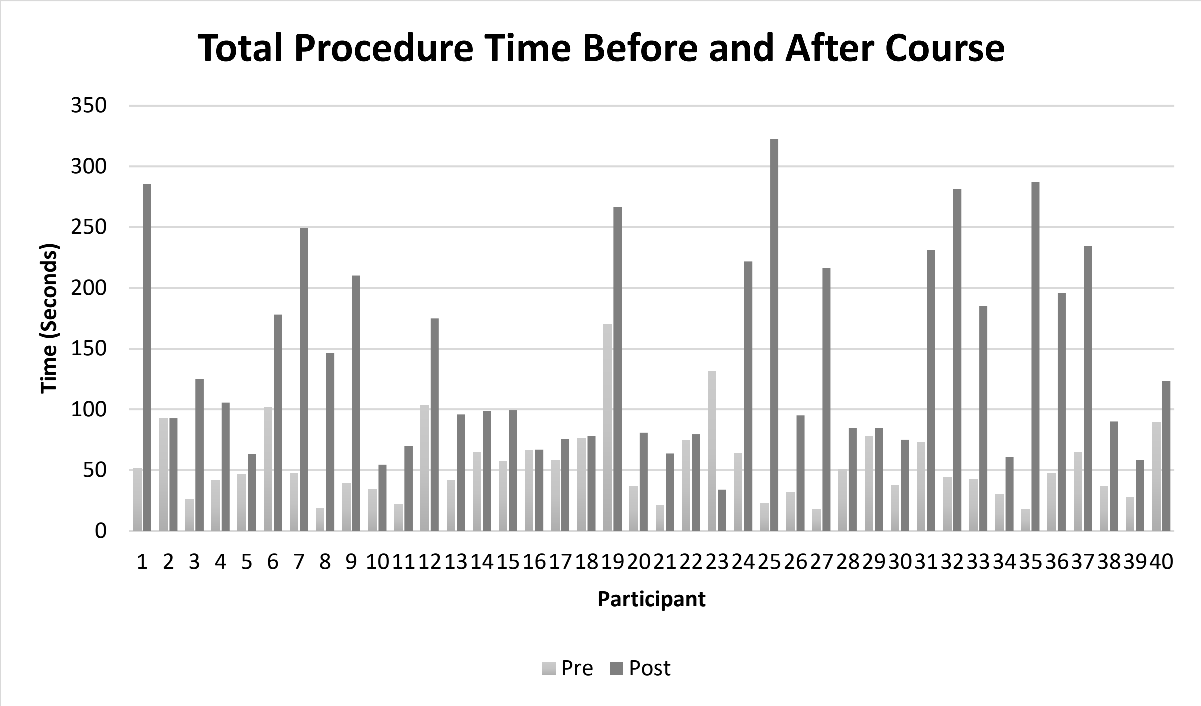


Figure 3 Total procedure time

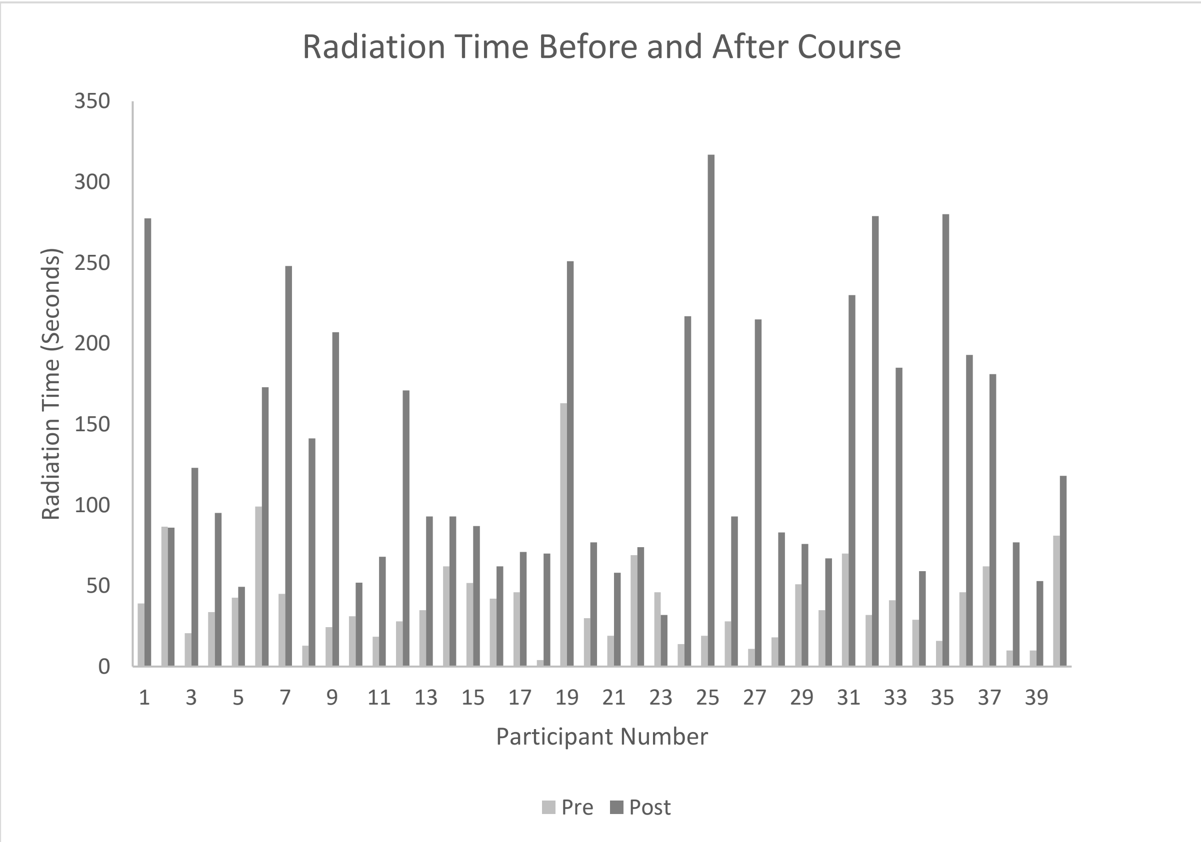


Figure 4 Radiation time

Wilcoxon signed rank analysis revealed that there was a significant difference in both total time and radiation time ($p<0.001$).

Excluding those who failed to cross the tricuspid valve on the initial attempt, the difference in time was smaller (total time 52.6 seconds pre-and 131.2 post, difference 78.6 seconds, radiation time 39.9 seconds pre and 124.9 seconds post, difference 85 seconds). Wilcoxon signed rank analysis revealed that there was a significant difference in both total time and radiation time ($p<0.001$ for both). Final wire position and approach is described below in Table 4.

	Pre	Post
RA	16	0
RV Apex	3	31
RV, other than apex	21	9
No attempt to cross valve made	16	0
Direct approach	22	11
Loop approach	2	21
Drop down	0	8

Table 4 Wire position and approach

It was observed in the post course videos on a number of occasions that participants achieved a feasible position within the right ventricle, but continued to manipulate the catheter in order to achieve a final position that was frequently very similar to the original one. No instruction was being given at this stage. This behaviour was not observed in the initial video assessment.

2.7 Discussion

This study demonstrated that attendance at a single session simulation course for TPW insertion resulted in a significant increase in self-reported confidence in ability to perform the procedure and deal with complications. It also showed that successful procedure completion in simulation is improved by attendance, but that procedural times are significantly increased.

When the invitations were delivered, there was a greater than expected response, with the initial target of 24 recruits surpassed easily. Consistent with previously published studies, the level of experience in TPW implantation was low. For that reason, it is unsurprising that self-reported confidence in TPW implantation was low at baseline and that when faced with patients who may have required the procedure, participants were likely to explore alternative solutions for patient management.

Attendance at the course resulted in a significant increase in confidence, which decayed over a period of several months but remained above baseline. This was coupled with a significant increase in the number of participants able to successfully position a TPW in simulation. All but one participant took longer to complete the procedure following the course than at the start of it, and this included a longer radiation time. The increase in procedure time could not be explained only by the improved success rates. The course was well received by those that attended, and learners felt that this did give them some experience in an area where they had had no previous experience.

Following the course, few of those who had attended reported being able to put this skill into practice, and some appeared frustrated at the lack of ability to do so. Two thirds did not expect to achieve competence by the time of completion of specialist training. When the potential need for a TPW implant had arisen, none of the participants who reported this had actually performed the procedure themselves. Only one participant reported implanting a TPW at any point following the course.

The increase in procedure and radiation time does not necessarily indicate a worsening of performance of the procedure as a result of attendance at the course. The videos taken pre course showed that almost all employed a direct approach to crossing the tricuspid valve. The assessment of skills demonstrated that at the end of the course, a number of the participants used alternative approaches to position the wire, including the direct approach, loop and drop down. All three formed part of the teaching material supplied, but no direction on which to choose was given. There is no data on the superiority of one approach over another. It is suspected that the increased time was at least in part a result of a more considered approach being employed based on increased appreciation of the anatomy and simulator behaviour. It was also interesting to observe that some achieved a potentially acceptable position within the right ventricle relatively early in the procedure, and then elected to continue to manipulate the catheter until they were satisfied. It is suspected that this is a function of the assessment method itself; in the knowledge that this was a filmed procedure, there was a drive to chase perfection on the imaging. We did not specify what features we would be examining the videos to assess in the evaluation of this course, and the participants were given no guidance during this final assessment on what to aim for, but it is suspected that these individuals assumed a scoring system based on approach and final position. This may have led to a modification in the observed performance based on the presence of observation, and hence questions the validity of the assessments made. It was not possible to isolate the cases in which this was potentially true, and therefore correct for this in any way. Had the nature of the assessment been described clearly to participants from the outset, these results may have been different. Whilst other studies have demonstrated a reduction in radiation and total procedure time using simulation, the nature of the assessments and whether the assessment criteria were explicitly defined to the trainees is not stated(159). Some studies of simulation using catheter based procedures have attempted to define scoring systems for the procedure, using observed expert practice to set standards, or modifications to existing assessment tools, although there is little evidence that existing performance assessment tools are valid in measuring what they set out to(160). It is also interesting to note that one other study which randomised novice operators to either simulation or no simulation training for coronary angiography demonstrated an increase in fluoroscopy time and complications for the simulation group(161).

These findings raise challenging questions both about the methods used within this study, and more widely about the justification for training medical registrars in TPW implantation and the implications this has for patient care.

2.7.1 Measuring performance change after a single session

Much of the existing data on the use of simulation based learning for the acquisition of procedural skill competency have utilised either a mastery learning approach, or the use of repetitive practice(162–165). One study did demonstrate an improvement in performance in cardiac catheterisation following a single simulator session, although the participants in that study had a reasonable amount of prior experience(163). Other studies demonstrated an improvement in bronchoscopy and cricothyroidotomy performance following only an average of 60 minutes of simulation experience in novice operators(166,167). In the landmark trial of central venous catheter insertion simulation training, 92 residents underwent simulation based training in the procedure, and a significant reduction in catheter-related blood stream infection was demonstrated in the period following this training when compared to the period prior. Participants in this study had two two-hour simulation sessions (168). There is a discordance between this and what is seen locally and nationally with regards to the provision of skills training. Across Yorkshire and the Humber, existing practical skills training for trainees in internal medicine comprises single sessions focussed on individual skills such as chest drain insertion, central line insertion and lumbar puncture. Attempts have been made to standardise and centralise the delivery of skills teaching to ensure a consistent experience and quality standards. One consequence of this is a limit to the amount of teaching that can actually be delivered. Groups of trainees and faculty attend fixed sessions, and trainees are often allocated only to a single session. The reasons behind this are primarily logistical; delivering simulation can be a faculty and resource intensive exercise, and when the availability of trainees is factored in, it is often a more practical proposition to offer a small number of fixed sessions. This is especially true of those activities which require access to specific simulation facilities or equipment.

There have however been a number of studies which have demonstrated that repeated practice is more effective than single sessions in the transfer of skill from simulation to clinical practice and in the acquisition of expertise in technical skills amongst novice operators.

There is, therefore, a disconnection between the methods used in existing research studies and the reality of what is available to trainees in the UK. The present study does little to add to this, demonstrating an increase in self-reported confidence with little objective evidence of improved performance, aside from successful placement. Other studies where novice operators have been introduced to endovascular procedures and demonstrated an improvement in performance have followed a repeated practice and mastery learning approach, which may suggest that a single session is inadequate for training in TPW implantation.

It would be useful to evaluate whether repeated practice did lead to a shortening of procedure times in this procedure. Shorter procedure times are associated with more experienced operators and were also affected with a lower rate of infective complications(148). Studies have shown that repeated practice in simulation of endovascular procedures leads to a shortening of total and radiation time(163,169,170), and that operator experience does appear to correlate with performance in simulation(171). This again raises problems in terms of recruitment and follow up. When invited back to a repeat skills assessment, only four of the 40 original participants were able to attend. 21 were able to complete an online follow up questionnaire. The logistics of this study were such that the majority of doctors who took part did not work in the hospitals where the simulation equipment was located. In order therefore to gain meaningful results, initial recruitment to the study would need large numbers of participants and strategies to facilitate follow up and account for drop out. The same is true of arranging repeated practice for educational purposes; trainees require the ability to attend sessions in order to make this work. In practical terms, the availability of resources such as the simulator used in this course are likely to limit this. In the Yorkshire and Humber region, there are three such devices, all of which are located in central teaching hospitals.

One of the limiting factors which emerged from the survey described in chapter four was the location of equipment and ability to access it by trainees. These factors have been highlighted as barriers to the use of simulation in another study examining the uptake of simulators for self-directed learning(172). There is evidence however that regionalising simulation programmes costs less than provision at individual institutions(173). The use of several, shorter sessions of an hour or two as described in other studies utilising mastery learning is more challenging when those participating struggle to access the training.

2.7.2 The rationale for providing medical registrars with teaching on TPW insertion

Temporary pacing has become an uncommonly required, albeit potentially lifesaving procedure. This study raises questions about who should perform the procedure, and where. If it is to be continued at district general hospitals, who should be trained to perform the procedure and how? As therapy for cardiovascular disease advances, the patient population who may require this procedure will change. My own personal procedure log reveals between one and three procedures per month during clinical practice, with some exceptions. Data on the decay of unpractised technical skills are sparse and conflicting, with some studies appear to suggest that considerable decay is seen from between 4 and 12 months after initial training, but others demonstrating retention beyond 12 months(167,174).

An important question about the justification for training general physicians in this skill therefore arises. There is clear evidence that case volume and operator experience correlates with surgical performance(77). The efficacy of a single session in allowing trainees to gain competence appears questionable, and the logistics of running a more comprehensive programme based on repeated practice and mastery learning appear challenging at a time of high demand on trainee time and multiple potential opportunities. Most participants in this study did not expect to obtain competence in this skill by the completion of specialist training, and only one expected to gain competence to practice unsupervised. Furthermore, the discordance between the increase in confidence seen and the increase in procedure time may suggest that a single session could instil false confidence in an operator. It has been demonstrated that an increase in confidence does not correlate with an increase in competence(175–177), although self-assessment of skills may be more reliable amongst those already experienced(178). In addition to this concern, the ability to practise in real life following the training and to maintain competence with the opportunity to use the skill regularly similarly seems to be limited, and the decay in skill over time unquantified. The procedure itself does carry considerable risks, and again there is data to suggest that invasive catheter procedures performed by more experienced operators carry a lower complication rate. There is a concern that providing an inadequate amount of training to inexperienced operators may in fact encourage them to make an attempt at the procedure, at a time or location where adequate support is not available and therefore potentially expose the patient to harm when an operator with no training would not contemplate trying but would proceed immediately to seek alternative options. The ACC/AHA guidance on competence in TPW insertion recommends that a minimum of 10 supervised procedures are required before competence can be determined, in operators who are already competent in the skill of right heart catheterisation. They are explicit that a short workshop session is not adequate to confer competence. The lack of opportunities for practice reported by the participants in this study suggests that without significant investment this is unfeasible to apply for the medical registrar(155). The learner time, educator resources and equipment used in delivering this training could potentially be diverted elsewhere, or indeed focussed solely on those training in Cardiology. Issues of competence assessment have also not been addressed. If the aim of the training is to enable medical registrars to practise independently when required, some form of competence assessment would be required. Given the infrequency with which this procedure is performed in daily clinical practice, assessment using simulation would appear to be the pragmatic solution to enable this but would require prospective validation. This is outside the scope of this study but would require consideration prior to roll out. There has been some work in the use of simulation to assess competence in endovascular procedures already (179).

TPW insertion has persisted as a requirement for all A(I)M trainees to demonstrate competence in prior to completion of specialist training, and is described as a desirable skill for those in G(I)M. Those who set curricula may have a justifiable reason for this continued inclusion, although at present this is not supported by training opportunities. There is no dedicated Cardiology service out of hours in many hospitals which maintain an acute medical take, which does mean that patients who experience life threatening cardiac rhythm disturbances may do so in a location with no TPW capability. This currently results in transfers occurring, occasionally across prolonged distances to a site with the ability to perform TPW insertion. There are of course wider issues in addition to this; aftercare of a patient with a TPW in place requires nursing staff experienced in the maintenance of these devices, and the availability of a suitable monitored area for them to be cared in. It may be more prudent to ensure adequate training in non-invasive rhythm management strategies such as transcutaneous pacing is available. This has been successfully demonstrated to be a feasible proposition using commonly available simulation equipment(180).

One of the most potentially useful applications of simulation-based learning is in training healthcare staff in uncommonly encountered situations. This study has demonstrated that such an approach for TPW insertion is technically feasible, acceptable and increases learner confidence. In order to further validate whether this approach does have genuine effectiveness in training staff to perform this procedure, a larger study is recommended utilising mastery learning models, and ideally assessment of performance when performing the procedure on real patients, with a more comprehensive assessment of skill decay over time. Whether this approach is justifiable given the context of the frequency of the procedure and the resource implications that implementation of such a programme to all medical trainees would entail is uncertain. It may be more prudent to examine the models of care and patient pathways for those at risk of rhythm disturbance, and examining whether adoption of a model similar to that implemented for patients suffering acute ST-segment elevation myocardial infarction is more appropriate in this case.

2.7.3 Limitations of the study

In this study, we examined a specific aspect of the procedure employed in the implantation of TPW, whilst the clinical procedure is a complex skill requiring the completion of several steps for successful implantation to be achieved. Skills such as handwashing and aseptic technique, central venous access and assessment of electrical pacing parameters are all elements which could be feasibly simulated and assessed. Future work should build upon this study and encompass these aspects of the procedure as part of the assessment of skills.

2.7.4 Final conclusions

This study demonstrated a significant increase in procedural success rates and self-reported confidence in temporary pacemaker insertion, at a cost of increased procedure and radiation time, after a single SBT session, compared with before. This course was well received and proved popular. There is evidence from the literature however that a mastery learning approach may be preferable to a single session and should be explored. The study raises the issue of whether the general physician should be expected to master and maintain skill in this procedure in preparation for the infrequent situations when the need arises, or whether educational time and resources should be focussed elsewhere to maximise impact.

3 Evaluating the use of an online ECG simulation programme compared to tutorial for the acquisition of ECG interpretation skill in medical students and junior doctors

3.1 Introduction

An accessible method of delivering SBT is through the use of entirely computerised learning packages. These require no specific equipment, or facilities to be used, and once initialised, require little input from educators to facilitate. For the learners, the ability to access learning materials on demand at a time and place convenient to them, and to work at their own pace, are major advantages in accessing the education. This is especially true in the era of modern internet connectivity and web based technology which facilitates delivery.

There have been a number of studies on the use of computer aided instruction which have demonstrated an improvement in the knowledge and skills of learners(181–187). To date, there have been few studies examining the use of computerised simulation systems in the teaching of electrocardiogram (ECG) acquisition skills.

3.1.1 The ECG

The Electrocardiogram (ECG) is a commonly used and important diagnostic test in the investigation of cardiovascular disease. Interpretation is a complex and important skill to master for doctors working across a wide range of clinical specialties. It is a low cost, accessible investigation which can be performed rapidly at the bedside, and has the potential to offer definitive diagnosis in a number of serious conditions(188). ECG interpretation is traditionally taught at medical school and beyond in the form of bedside sessions, didactic teaching and self-study, though there is considerable variation in time allocation and teacher experience (189,190).

ECG interpretation amongst medical students and junior doctors, using independent verification by qualified cardiologists, has been demonstrated to be poor, including those in specialties in which ECG interpretation forms part of the core role. Correct identification of potentially life-threatening conditions occurred in only 57% in a group of medical students in the US and 46.4% in a group of South African Emergency Medicine trainees(191–194). Computerised ECG interpretation (ECG-C) algorithms are now integrated into many ECG machines. The diagnostic accuracy of these in determining cardiac rhythm was recently demonstrated to be 88% overall, although correct interpretation of non-sinus rhythm was only 53.5%(195). Another study examining automated recognition of ST segment myocardial infarction demonstrated 58% sensitivity and 100% specificity using ECG-C(196). These data suggest that ECG-C interpretations should be independently verified by a qualified clinician competent in ECG interpretation, alongside clinical assessment of the patient(197,198). A 2004 study retrospectively analysed ECGs performed on 1085 patients with an ECG-C interpretation of atrial fibrillation. This found that 382 ECGs (35%) had been incorrectly interpreted by ECG-C and, of these, the incorrect interpretation was not identified by the requesting physician in 92 patients leading to inappropriate anti-arrhythmic and anti-coagulant prescription in in 39 patients (3.6% of the total)(199). Another study of 1057 ECGs demonstrated correct ECG-C identification of atrial fibrillation in 79.5% of cases, and of those cases erroneously diagnosed, 7.8% were not corrected by the ordering physicians(200). A retrospective analysis of ECGs for 268 patients discharged from hospital with a diagnosis of atrial fibrillation or flutter (by clinician and not ECG-C interpretation) revealed inaccurate diagnosis in 16%(201).

3.1.2 Importance of ECG interpretation

Although it is difficult accurately to estimate the overall true number of adverse clinical events due to incorrect ECG interpretation, one paper suggested that 10,000 deaths annually in the USA alone would be a conservative figure, although this is a crude estimate which does not account for multiple interpreters reviewing the ECG and further diagnostic testing being performed (202). An economic analysis has demonstrated that an improvement in recognition of atrial fibrillation and flutter may save $1.3M per 1000 patients, although this is a modelled extrapolation from a smaller sample size(203).

There are published American guidelines on knowledge and minimum practice to attain clinical competency and standardised approach to ECG interpretation(204,205). To be deemed clinically competent in ECG interpretation, a reader should either be a qualified cardiologist, have interpreted 500 ECGs under the supervision of an expert or achieve accreditation by way of passing a standardised ECG examination. However, it is recognised that this may be difficult to achieve in practice, especially in smaller centres.

3.1.3 Existing methods of teaching ECG interpretation

Little work has been conducted to assess which teaching method is most effective for teaching ECG interpretation. A survey of US Clerkship Directors in Internal Medicine revealed the most frequent format for teaching ECG interpretation to medical students was lectures (75%) followed by teaching rounds (44%)(206). A large study randomised 223 US medical students to receive either workshop-based, lecture-based or self-directed learning (SDL) and assessed performance in a baseline pre-course, immediate post-course and one-week post course ECG interpretation test. In order to standardise the content and quality of teaching materials, each group covered the same content, used identical example ECGs and were given the same learning objectives. All teaching materials were created and delivered by the same educators to ensure they were of equivalent quality. The workshop and lecture-based groups received two hours of teaching and the SDL group were provided with a course manual and instructed to study for two hours. The same university instructor was responsible for delivery of teaching. No statistical difference was found between the three groups in the baseline test, but in the immediate post-course tests, scores in the workshop and lecture groups were significantly better than the SDL group with mean scores 57.3%, 56.8% and

48.8% respectively (p-value 0.003) with a similar, significant effect also being present in the retention test(207).

3.1.4 Web based methods

Web-based ECG learning packages are widely available. The usefulness of one such learning programme for medical students was assessed by a Swedish group. A cohort of 32 students completed a web-based ECG interpretation package in addition to traditional lecture based teaching and were tested in an ECG interpretation exercise five months later. They compared their results to a control group of 30 students who received the same lecture based teaching, but were not given access to the web learning. The mean score for those who completed the web based learning package (n=17) in an eight-question interpretation exercise was 61% versus 51% in the control group (n=25, p = 0.03). However, there were significant confounding factors, including self-selection bias and small sample size. In addition, the control group received additional teaching on cardiac physiology including some ECG interpretation. Interestingly, the test of ECG interpretation was administered five months after commencing the course, which could indicate that this method of teaching is associated with a sustained benefit in learning(208).

Although web-based packages offer a potentially useful learning opportunity, caution must be exercised as to where material is accessed. A recent study analysed 119 videos on YouTube offering tutorials on ECG interpretation. All of these videos were watched by an expert panel of two physicians who graded each video against pre-specified criteria in terms of usefulness, source and characteristics. This demonstrated that 47.1% were considered 'very useful', 39.5% 'useful', and 13.4% 'misleading' or containing inaccurate information. Of the videos classified as 'very useful', 90% were uploaded by universities or hospitals and only 45% were uploaded by individuals. The study demonstrated how popular this resource is with each of the 119 videos having been viewed an average of 12,197 times, however, given that there was no difference in number of views or number of 'likes' and 'dislikes' by viewers between 'very useful' and 'misleading' videos, it would seem that viewers are unable to discriminate between useful and misleading content themselves. Although of benefit in some cases, this highlights the potential dangers associated with non-peer-reviewed or verified content(209).

3.1.5 Factors affecting ECG learning

Other factors may have a role to play in the effectiveness of teaching ECG interpretation. An extensive study assessing the effects of both teaching format and type of assessment was performed. A total of 534 fourth year medical students were divided into six groups who received three differing levels of intensity learning; two SDL groups, two lecture groups (facilitated by an expert Cardiac Electrophysiologist) and two small group peer teaching groups (where more advanced medical students facilitated sessions). One of each group type underwent formative assessment and the other underwent summative assessment, both assessments taking place after six weeks. No significant difference was shown in performance (defined as obtaining at least 3/5 correct answers in an ECG interpretation exercise) attributable to intensity level of learning, a significant improvement was found in students undergoing summative rather than formative assessment (OR 5.14; 95% CI 3.26 to 8.09). Furthermore, summative rather than formative assessment increased the likelihood of spending extra time studying as well as using additional learning material. This does suggest that summative assessment can be a potent driver for learning with intensity level of learning seemingly less of a significant factor at undergraduate level, though whether this leads to a long-term sustained effect is unclear(210).

Another study assessed the effect of instructional format upon the acquisition of ECG interpretation skills. Sixty-six first year medical students were divided into two equal groups and received a two-hour ECG teaching session. ECG interpretation was assessed immediately after the session. One group was encouraged to use a 'contrastive approach' where morphological ECG differences were compared, whilst the other group used a 'non-contrastive' approach where the same ECG examples were presented in isolation. The facilitator for both groups was the same. This showed significantly better performance in the contrastive group who attained 46% accuracy compared with the non-contrastive instructional format who attained 30% accuracy ($p<0.05$)(211).

3.2 Aims

The aim of this project was to determine the effect of a single session, novel, online ECG simulation package versus a single tutorial session, upon ECG interpretation skills in medical students and Foundation Year 1 doctors. Retention of knowledge after an interval of 3 months and learner responses to teaching method are also evaluated.

3.3 Objectives

1. To develop a 1-hour ECG simulation package based on a novel software platform (Epicardio) to teach basic ECG interpretation at a level suitable for Phase 3 medical students and Foundation Year 1 doctors.

2. To develop a 1-hour ECG small group teaching presentation to teach basic ECG interpretation at a level suitable for Phase 3 medical students and Foundation Year 1 doctors.

3. To assess performance of phase 3 medical students and Foundation Year 1 doctors in a formal assessment of ECG interpretation immediately after teaching and 1 month after them receiving teaching via the ECG simulation package or via traditional small group teaching.

4. To assess for any statistically significant difference in performance between 2 groups.

5. To assess acceptability of both courses to participants.

3.4 Methods

3.4.1 Research governance

Ethical permission to proceed with this study was sought from the University of Sheffield Medical School Research Ethics Committee (Ref: 001793). A copy of the ethics approval letter can be found in Appendix 3.1. Permission to proceed with research and approach learners was obtained from the University of Sheffield Medical School, Hull York Medical School, Sheffield Teaching Hospitals NHS Trust and Hull and East Yorkshire Hospitals NHS Trust.

3.4.2 The Epicardio™ Simulator

The Epicardio™ (Epicardio LTD, Richmond, UK) simulator has been developed by a UK based team including software development specialists and a medical lead. It comprises an underlying computer model based on simulated myocyte clusters, each of which is programmed to respond physiologically. Using this model, normal sinus rhythm, pathologic conditions and electrophysiological interventions can be simulated to display a real-time ECG and 3D graphical representation of the heart with depolarisation and repolarisation on screen. It is accessed via a web interface, using a supplied username and password. Installation of a browser plugin is required, which limits compatibility to systems running Microsoft Windows and Apple OSX. Tablet computers and smart phones running Android or Apple iOS, and smartphones were not supported.

3.4.3 Conflict of interest statement

None of the research team working on the present project had any affiliation with the Epicardio development team. No potential benefit, financial or otherwise is known for any of the researchers. We were approached indirectly with the opportunity to evaluate the utility of the software, and conducted this research independently of any external interference or influence.

3.4.4 Study design and protocol

A head-to-head, randomised controlled study design was chosen, the primary outcome being results of a knowledge based assessment. Participants were medical students from the medical schools at the University of Sheffield and Hull-York in their 3rd or 4th year of medical studies, and Foundation Year 1 doctors working at Sheffield Teaching Hospitals NHS Trust and Hull and East Yorkshire Hospitals NHS Trust. The purpose of the small group teaching arm was to act as a control group, against which the group receiving teaching via the simulation package were compared.

The purposes of having both medical students and doctors taking the course were: a) to validate the assessment tool (i.e. Foundation Year One doctors would be expected to perform better than students given their levels of expertise and experience); and b) to validate the simulator package as a tool which could be used to teach basic ECG interpretation to a variety of different healthcare professionals with differing levels of experience and baseline knowledge.

3.4.5 Outcome Measures

3.4.5.1 Primary outcome measure

- Performance in formal assessment of ECG interpretation test immediately and one month following teaching
- Self-reported performance in ECG interpretation pre and post teaching course assessed via questionnaire

3.4.5.2 Secondary outcome measure

- Acceptability of traditional and simulation courses as reported in questionnaire of those taking part

3.4.6 Study Subject Selection

Subjects were third and fourth year medical students and FY1 doctors. Those who had had formal ECG teaching within the previous academic year were excluded. Medical students were recruited by placing an advert on the University online message boards. For the doctors, this was incorporated into the weekly mandatory teaching programme. Written informed consent was taken from all participants and those who did not consent were excluded from the study. For the FY1 doctors, who were all scheduled to have an ECG teaching session as part of their mandatory teaching programme, those that declined to participate in the study were offered attendance at the teaching session, but did not take part in the assessment, and no other data were collected on them.

3.4.6.1 Randomisation

Those who consented to participation were randomly allocated by simple computer generated randomisation to either simulation or tutorial session.

3.4.6.2 Sample size

The sample size required was 82 participants in each teaching group, using the University of British Columbia power calculation tool. This assumes mean scores of 5.68 and 6.14/10 in assessments, with a standard deviation of 1.05 in the control. These values are based upon performance in a similar study using a 9 question assessment(211). Allowing for an anticipated 10% dropout rate, the aim was to recruit a total of 180 participants.

3.4.6.3 Exclusion Criteria

- No exclusion criteria were identified other than prospective participants who do not give their consent to take part in the research.

3.4.6.4 Subject Withdrawal

- Participants may elect to withdraw from the study at any time without having to specify a reason by contacting any of the investigators via email, telephone or in writing.
- Any data collected from them will be destroyed immediately and not included in the study reporting.

3.4.7 Data collection, Source Data and Confidentiality

All data collected during the study were kept strictly confidential on a secure NHS computer with password protection and backed up in electronic form according to local guidelines. Study documents (paper and electronic) were retained in a secure office at the Hull Institute of Learning and Simulation, Hull Royal Infirmary, Hull and East Yorkshire NHS Trust for a period of five years from the end of the study. The Clinical Skills Facility complied with all aspects of the Data Protection Act 1998 and operationally, this included appropriate storage, restricted access and disposal arrangements for candidates' personal details. Access to data was restricted only to those directly involved in the study, and for research governance inspections. Participant contact details (used only to invite participation to the follow up questionnaire) was stored separately to assessment results.

3.4.8 Devising teaching materials and an appropriate test of ECG Interpretation Skills

The Foundation Programme curriculum sets out a number of competencies expected of a doctor in their first year of postgraduate training(212). For 12-lead ECG interpretation, they are expected to be able to correctly identify a normal ECG pattern, bundle branch block and ventricular hypertrophy, acute ST-segment myocardial infarction, bradyarrhythmias, broad and narrow complex tachyarrhythmia, hyperkalaemia, ventricular fibrillation and ventricular tachycardia.

These diagnoses were used to design both the small group and ECG simulator teaching sessions. Additionally, they were used to devise 2 separate ECG interpretation tests to be taken immediately and 3 months after teaching. The assessment format used was a ten-question single best answer multiple choice question (MCQ) format, with five options for each example. The questions were aligned to cover the topics defined as core knowledge in ECG interpretation by the Foundation curriculum. Each question featured a sample ECG which clearly displayed the intended diagnosis with the instruction to pick the single best answer. The intention in using this assessment format was to clearly define the level of knowledge in ECG diagnosis rather than the clinical reasoning and application which would be assessed using an extended matching item (EMI) design. Due to the nature of the subject matter and the intention to compare ECG interpretation skill between the test groups, this format was expected to provide the most appropriate measure of this domain, and was also most directly comparable to other studies in the area assessing the knowledge gained during ECG learning. Table 5 lists the diagnoses tested in the test taken immediately after teaching:

Question	Diagnosis tested
1	Normal sinus rhythm
2	Right bundle branch block
3	Inferior ST-segment elevation
4	Mobitz type 2 2:1 atrioventricular
5	Atrial flutter
6	Ventricular tachycardia
7	Hyperkalaemia
8	Left ventricular hypertrophy
9	Ventricular fibrillation
10	Sinus bradycardia

Table 5 ECG Diagnoses assessed

None of the test ECGs were shown to participants prior to the test. The test was taken under exam conditions. At 3 months, a further 10 question ECG assessment test was sent electronically to study participants via email and it was requested that they refrain from referring to notes or teaching materials whilst completing this. The maximum score for each test was 10, with one point awarded for each correct answer. Immediately after the teaching session, all participants were also asked three questions about their reaction to the teaching – confidence in ECG interpretation following the session, usefulness of the session in teaching ECG interpretation and whether they felt the session improved ECG interpretation skills. A copy of the questionnaire and test answer sheet is included in appendix 3.2.

Prior to the knowledge assessment, all participants were asked to complete three evaluation questions to assess reaction to the course and self-reported confidence in ECG interpretation. These were presented as five item Likert-type questions. Three general questions were chosen, with a space below to allow free text comments. This was intended to capture immediate reaction to the session which the participants had just attended, and perceived utility of that method. These questions were chosen to be quick to answer given the time constraints of the sessions, and provide some data on the acceptability of the methods used.

3.4.9 Small group teaching arm

The small group teaching was delivered as a small group tutorial session, led by one of two Cardiology registrars with at least three years' experience. This was structured to resemble the existing ECG teaching within the curriculum as closely as possible. A presentation covering each topic was prepared and rehearsed, to ensure coverage of the intended curriculum and that it could be delivered consistently within 45 minutes.

The presentation was introduced with aims of the session, followed by basic terminology of ECG interpretation and a scheme for interpreting and reporting the ECG. This was followed by example cases of each ECG abnormality, with explanations of the abnormality. The delivery of the presentation was intended to be relaxed, with ample time for questions both within and immediately after the session to clarify any points.

3.4.10 ECG Simulator teaching arm

Participants were given 45 minutes to work through an interactive computer program with an interactive 3D animation of the conductive tissue of the heart and text explanations of each diagnosis. Each participant was allocated a computer for the exercise. They were not permitted to ask questions regarding ECG interpretation (technical support was provided). They were given a password allowing them to access the software at any point in the 3 months following the initial teaching session and assessment if they wished.

3.4.11 Data Analysis

Data were compiled into a spreadsheet using Microsoft Excel version 15 (Microsoft Corporation, Redmond). Data were transferred to SPSS (IBM Inc., Armonk, NY) for statistical analysis. Qualitative comments were analysed in NVivo 10 (QSR International, Melbourne). Shapiro-Wilk's test ($p < 0.05$), visual inspection of histograms, box plots and Q-Q plots did not demonstrate that test scores for both groups were not normally distributed. An independent t-test with bootstrapping was used to compare mean test scores between groups. Independent t-tests were used to compare mean questionnaire scores.

Simple descriptive analysis and thematic analysis was conducted on the evaluation questionnaires. Thematic analysis is a systematic tool to approach the analysis of qualitative data in order to identify and interpret themes expressed by multiple respondents. The six-stage process described by Braun and Clarke was employed. Initially, all responses were read through several times to ensure data familiarization. Initial codes were generated which were then organized and re-analysed for themes. Initial themes were then proposed and the data organised into these themes. These themes were reviewed and revised as necessary before the final report was generated(213).

3.5 Results

3.5.1 Demographics

One hundred and sixty eight participants were recruited between January and May 2015, of which 47 were junior doctors and 121 were medical students (Table 6). Eighty five participants were randomised to the simulator group, and 83 to the lecture group. One participant withdrew from the study without giving a reason, and their data were discarded.

	Participants	Teaching sessions	Mean number per session	Range of group sizes	FY1 doctors (%)	Medical students
Simulator	85	85	1	-	18 (21)	67 (79)
Lecture	83	14	5.9	1-21	29 (35)	54 (65)

Table 6 Participant demographics

3.5.2 Assessment scores

Mean scores in the ECG interpretation test taken immediately after teaching are summarised below in Table 7. Mean scores were higher in the lecture than the simulator group, though this difference was not statistically significant (7.07 vs. 6.62; P = 0.12).

	Number	Mean score	Standard deviation	95% confidence interval (lower)	95% confidence interval (upper)	P value
Simulator	85	6.62	1.73	6.25	6.99	0.12
Lecture	83	7.07	1.88	6.68	7.46	

Table 7 Scores in ECG interpretation exercise immediately following teaching session

FY1 scores in the test were significantly higher than those of medical students (7.85 vs. 6.45; p=0.001). Sub-analysis of the results of the FY1 doctors demonstrated similar results between the lecture and ECG simulator groups (7.83 vs. 7.89; p=0.4). Sub-analysis of the medical student cohort demonstrated marginally higher (though not statistically significant) mean scores in the lecture versus the ECG simulator group (6.67 vs. 6.28; p=0.28).

3.5.3 Post-teaching questionnaires

Results of the post-teaching questionnaire are summarised in Table 8. There was no difference in self-reported confidence in ECG interpretation between the lecture and ECG simulator groups, mean scores for the usefulness of teaching and self-reported improvement in ECG interpretation were higher in the lecture group, though neither reached statistical significance.

	ECG group (n=85)	Lecture group (n= 83)	P
After attending this session, how confident do you feel in ECG interpretation?	3.1	3.05	0.64
Do you feel the session you attended was a useful way of teaching ECG interpretation?	3.65	3.91	0.08
Do you feel the session improved your ECG interpretation skills?	3.58	3.8	0.09

Table 8 Post teaching questionnaires

A second ECG interpretation test which was sent via email link three months after teaching to the 130 participants for whom full contact details were available. Twenty four participants completed this, of whom 17 were medical students and 7 were FY1 doctors; 14 were from the lecture group and 10 were from the simulator group. There was no significant difference in mean scores in the lecture versus the simulator groups (5.79 vs. 5.3; P=0.55). These results are shown in Table 9.

	Number	Mean	Standard deviation	Standard error	95% confidence interval (lower)	95% confidence interval (upper)	P value
Simulator	10	5.3	1.77	0.56	4.14	6.33	0.55
Lecture	14	5.79	2.15	0.58	4.6	6.83	

Table 9 Scores in ECG interpretation test at 3 months

3.5.3.1 Qualitative evaluation

Qualitative feedback given in the form of brief written comments after teaching in the simulator group was encouraging and demonstrated that both medical students and FY1 doctors found it a useful and acceptable means of teaching ECG interpretation. Typical statements are presented in Table 10. A full list of comments is available in Appendix 3.3.

"The visuals were good. The software taught me ways of differentiating between similar diagnoses"
"The 3D animation helped me to understand cardiac axis"
"I was able to work at my own pace"
"More audio or video clips rather than written explanations would have improved the software"

Table 10 Example comments

A qualitative analysis of these comments was performed. Text was coded by themes. The major themes identified are shown in Table 11.

Facilitation quality
Visual representation of concepts
Interactivity
Time and tempo of teaching
Level of teaching
Specific components
Technical issues in accessing the simulator
“I would like to have been able to ask questions”

Table 11 Themes identified in feedback

Analysis of the coded results revealed participant perceptions of the strengths and weaknesses of both methods of teaching. These are described in more detail below.

3.5.3.2 Facilitation quality

Facilitation quality was predominantly described by the lecture group. The majority of participants valued the knowledge of facilitators and interactive nature of the sessions – being able to answer specific questions and clarify any points as needed, including some comments referencing being able to ask questions which they did not feel comfortable asking ‘on the wards’. Group sizes were identified as good. In contrast, the simulation was identified as lacking explanation in some areas, and lacking clinical correlation. The ability to work at the pace of the individual learner and to visualise the electrical activity of the heart alongside the ECG were identified as strengths. Several participants noted that the addition of a voiceover to explain the on-screen content would be a useful addition.

3.5.3.3 Visual representation

Visual representation was described as an area of strength in the simulation group. The ability to see a representation of the electrical activation of the heart with the surface ECG alongside was valuable to some, however there were some areas which could be improved on, such as in the explanation of cardiac axis and some of the visual effects were found confusing. In the lecture group, some of the example ECGs used were unclear, and multiple examples may have been preferable.

3.5.3.4 Interactivity

Some participants in the simulation group would have preferred a more interactive session; being able to ask questions whilst going through the teaching and have alternate explanations to the one presented on screen. This included worked examples, and practice questions in addition to the didactic learning material. There were also comments on the lack of group interactivity.

3.5.3.5 Time and tempo

This was one of the most prevalent themes arising from the simulation group. Multiple participants commented that there was insufficient time to fully utilise the simulator. Only a small number requested more time from the lecture group.

3.5.3.6 Level of teaching

There were several participants who felt that the level of baseline knowledge assumed was inappropriately advanced, and who were expecting a more basic session with explanation of basic physiological principles. No participants commented that the level of teaching was too basic.

3.5.3.7 Specific components

There were a higher than expected number of comments (17) specifically referencing that the explanation of cardiac axis was unclear or confusing, from both the simulation and the lecture arm.

3.5.3.8 Technical issues

Four participants described problems accessing or operating the simulation programme. Facilitators were present to address technical difficulties, and it is likely that without this, the numbers unable to access and use all of the features would have been considerably higher.

3.6 Discussion

This study demonstrated no significant difference in ECG interpretation scores amongst medical students and junior doctors between those taught by lecture and those taught by a web-based ECG simulation programme. As expected, FY1 doctors outperformed medical students in their ability to correctly report common ECG abnormalities. There was a nonsignificant trend towards preference for the lecture teaching over simulation in terms of improving confidence, utility of teaching and perception of the ability for the teaching session to improve ECG interpretation overall. Few participants completed a follow up questionnaire at 3 months, so it is not possible to assess the retention of knowledge between groups. The lack of a facilitator to deliver explanations and answer questions, plus the inflexibility of the approach in adapting the level of teaching and timing were major themes in the evaluation of the simulator. Analysis of the qualitative data did not reveal any differences in the themes identified by the groups, although far fewer FY1 doctors opted to leave any comments than medical students. There are insufficient data to suggest any fundamental difference in learning style or preference between the groups. Of those who had been in the simulator group initially and who completed the second assessment (n=10), only one had accessed the tool following the teaching, despite all being given a username and password to do so if they wished.

3.6.1 Asynchronous online learning and facilitation

From the qualitative data, there are some issues related to the simulation which are inherent to this form of teaching, some which could potentially be addressed through modifications to the tool. The Epicardio simulator was designed to be accessed as an online learning resource with no real-time input from facilitators required; all of the learning material is written into the package which is then delivered in a standard format. In the present study, the facilitation of the lecture group was described positively by many of those who had undergone this form of teaching, with the ability to ask questions and have points clarified being specific advantages. The addition of either real time facilitation or some form of asynchronous facilitation available such as discussion forums would change the nature of the Epicardio programme fundamentally and remove a major potential advantage of the tool; the absence of need to rely on facilitator time. Similarly, in delivering online pre-set learning materials, altering the level at which the teaching is delivered based on the needs of an individual learner or group can be challenging. The inclusion of all levels from fundamental principles upwards may be cumbersome and unappealing, but setting the initial level of teaching at too advanced a stage may alienate some.

The ability of the learner to work through the simulation at their own pace was raised as a positive factor, and on the same subject, the time restriction imposed prior to assessment in this study were reported frequently. For the logistical purposes of this study, the fixed teaching time was imposed upon learners. Technical support was required frequently, and the study design required learners to access the programme and then undergo the assessment under examination conditions. This may be a somewhat artificial way to use such a programme however; by design, it can be accessed from wherever the learner wishes and does not need to be completed in a single setting. In comparison, delivering a lecture is always likely to be constrained to specifics of time and location. Within the same time period however, the same amount of material was covered reliably by lecture, and assessment scores were not significantly different. The apparent low usage of the simulation programme after the session (albeit from a small subset of the sample) is of concern however. As discussed above, self-directed learning is associated with variable participation and outcomes. Evidence from other areas such as institutions offering MOOCs demonstrates that online courses are frequently not completed when there is little incentive or driver for the learner to do so. The only factor which has been shown to improve knowledge is the use of summative assessment(207,214,215).

Some of the concerns raised by the participants in this study could be addressed by modification of the simulation package. Several learners felt that audio commentary would be a useful addition, potentially reflecting their intrinsic learning style preference. There were also comments regarding specific aspects of the teaching which could be addressed, and technical issues in accessing and using the simulator. Whilst these are not unsurmountable, they do represent a requirement for ongoing maintenance and support to run such a programme. Institutions without expertise may not simply be able to purchase access to the Epicardio programme and expect it to be able to run without any input.

One area in which the simulation programme has the potential to outperform the lecture based approach is in the standardisation of teaching programmes. Content can be mapped accurately to curricula, and peer reviewed for accuracy by experts in the field before being delivered in a homogenised fashion, which is less possible when using individual teachers. This may be especially advantageous in smaller centres and other areas without local expertise, where scheduling teaching sessions may be problematic.

3.6.2 Limitations

A major limitation of the present study was the absence of a pre-test – post-test design. Ideally, a baseline level of knowledge would have been established, although the process of establishing baseline ECG interpretation may in itself have modified the results one hour later. The groups were randomly allocated, in order to minimise the influence of any selection bias and it was assumed that baseline skills were equivalent in both groups. What is not measurable from this approach is the absolute change in knowledge effected by either approach. In the questionnaires, participants responded favourably to both arms when asked whether they perceived teaching had improved confidence, was useful and had improved ECG interpretation skills. These ratings showed a non-significant increase for the lecture arm over the simulation.

There was inequality in the recruitment of medical students and FY1 doctors, with the latter comprising 28% of the total recruitment and a greater proportion of FY1 doctors in the lecture group compared to the simulation group. Whilst we were able to recruit the majority of the doctors working at the two hospital sites, they are fewer in number than medical students. Regionally, in addition to the teaching hospital sites from which we recruited, FY1 trainees are rotated to a number of district general hospitals and community placements. Logistically, it would have been unfeasible to acquire permission to recruit from each site, whereas whilst the medical students do rotate through placements, the recruitment to the study was approved centrally by the Universities. We were able to demonstrate that for both groups individually, and overall there was no significant difference for teaching method, however there was a nonsignificant difference favouring lecture teaching for medical students which was not reflected in the FY1s. The absence of a pre-teaching assessment does not allow us to evaluate the contribution of baseline knowledge explicitly, however the significantly increased score achieved by the FY1s does add validity to the assessment method chosen. This is a reflection of the increased experience and day to day clinical roles which are likely to include ECG interpretation as a core component. As described above, there is also evidence that summative assessment is a driver to learning, and the FY1s having completed their undergraduate training and summative examinations associated with that may also be a contributory factor. It would be interesting to investigate further whether doctors more advanced in their career who do not routinely interpret ECGs perform worse than their more junior colleagues.

Overall assessment scores in the study were higher than predicted in the sample size calculation (estimated scores 5.6 & 6.14, actual scores 6.62 and 7.07 across groups). The sample size estimation was based on data from a previous study using a similar methodology, although no directly comparable studies to this one have been published. One key difference however was that Hatala et el studied first year Canadian medical students completing a period of cardiac physiology study, whilst the present study employed a mixed group of medical students and junior doctors. This overall higher performance of our group is not unexpected and likely explained by the increased experience of the group in the present study. Future studies should take the results of the current study into account.

The limited data from the three month follow up assessment appeared to show a decay in scores from an overall mean 6.85 to 5.55. These results should be interpreted with caution because only 24 participants completed this. The second assessment was not taken under the same controlled conditions as the initial assessment, and no score matching was possible due to the data anonymisation to evaluate whether those that completed the follow up were those that scored lower initially or whether there had been a true deterioration.

3.6.3 Future work

Further work may focus on the utility of a hybrid approach, which was not investigated here. There were advantages to both teaching methods, both from the learner and the institutional perspective. This was a direct head-to-head comparison without summative assessment however in practice, a blended learning approach with elements of both face to face tutorials, self-directed learning and formative and summative assessment may be preferable. ECG interpretation is a complex and important skill, and it is unlikely to be taught in a single session during medical training. There is likely to be a stepwise approach with progression through training, with activities such as teaching rounds and clinical presentations alongside theoretical learning. In this context, allowing medical students and junior doctors access to web based self-directed learning materials to supplement facilitated sessions and assessed by means of formative and summative assessment methods may be a useful addition to what is currently offered.

3.6.4 Final conclusions

This study demonstrated that teaching ECG interpretation via an online simulation course is feasible, and there is no evidence to suggest that this approach is inferior to face to face tutorial. Further development of this tool may increase learner satisfaction with using it, although they do continue to value the input of real-time facilitation, the addition of which would require a fundamental change to the way it operates. The adoption of a hybrid approach should be investigated further.

4 A survey of medical trainees' experiences and perceptions of SBME

4.1 Introduction

There has been considerable investment in developing simulation for trainees in all medical specialties around the United Kingdom. Whilst there have been attempts to quantify the amount of provision available and the usage of simulation facilities, there is little or no evidence concerning how trainees actually perceive the education that they are receiving. Many studies examine the reaction of learners to simulation but these are conducted with the aim of establishing reaction to a specific learning activity. There are other surveys, most prominently that run annually by the GMC which intend to examine all aspects of medical trainees' experiences but these typically do not examine any specific aspect in great depth. Some work has examined how non-medical professional groups and subsets of medical trainees perceive the use of SBME in their training, but to date there has been no published work offering a comparison across specialties and differing levels of experience.

4.2 Aim

The aim of this work was to establish how medical trainees feel about the introduction and integration of simulation-based training into their training by conducting a survey to establish their experiences and perceptions.

4.3 Methods

4.3.1 Research governance

Ethical approval to proceed with this study was sought from the University of Sheffield Medical School Research Ethics Committee (Ref: SMBRER277). A copy of the ethics approval letter is in Appendix 4.1.

4.3.2 Development of a questionnaire

A comprehensive literature search was performed to identify whether any suitable existing research tool existed. None was found. It was therefore decided to develop a new instrument to survey the participants. Evidence suggests that a response rate of between 40% and 10% of distributed questionnaires could be expected. The use of incentives does appear to impact positively upon completion rates (216–219). One of the main barriers identified to improved completion rates of online surveys by clinicians was the time taken to complete surveys, and hence it was decided to ensure that completion time for the survey should not exceed 10 minutes.

4.3.2.1 Demographic data

Questions were designed to explore demographic details of the participants including grade, seniority and region. Grades and seniority were based upon the guidance for approved training programmes published by the GMC. The regions targeted were derived from the list of training regions supplied by the JRCPTB. The questions for inclusion were chosen to provide a balance between collecting data to answer the research questions and keeping the questionnaire brief whilst not collecting information which would allow the identification of any individual respondent.

4.3.2.2 Experience of simulation

In order to determine the experience of SBME that respondents had received, the inventory of simulation activity running within the Yorkshire and Humber region was used. Activity was divided into four categories; scenarios, ward environment, procedure training and life support courses. It was decided to further subdivide procedural training into supervised and unsupervised to reflect that in some locations, procedure simulators can be accessed by trainees without the need to be booked onto a formal training course. They may utilise self-directed learning to work through technique.

In addition to personal experience as a learner, a question was added to ask respondents whether they had been involved in the delivery of simulation as a facilitator, and if so whether this was for undergraduate or postgraduate learners.

4.3.2.3 Attitudes to simulation

The final set of questions was compiled to determine learner reflection on simulation for those who had undergone such an experience, and those who had not. This was intended to capture the experience of these trainees, and how they perceived the experience as a component of their training. Two questions were aimed at those who had previously had simulation training, and the final question to all those responding in order to attempt to capture reasons (logistical or opinion related) for not being involved.

4.3.3 Pilot of the questions

The questions were piloted in a group of clinicians with a specific interest in patient safety and simulation attending an event to promote simulation. The intention was to gauge the performance of the questions amongst this group, and whether any unexpected issues arose.

4.3.3.1 Demographics

A total of 19 respondents completed the pilot questions. Primary (nonclinical) interests were Simulation 8 (42%), Medical Management 4 (21%), Medical Service Improvement 5 (26%), Patient

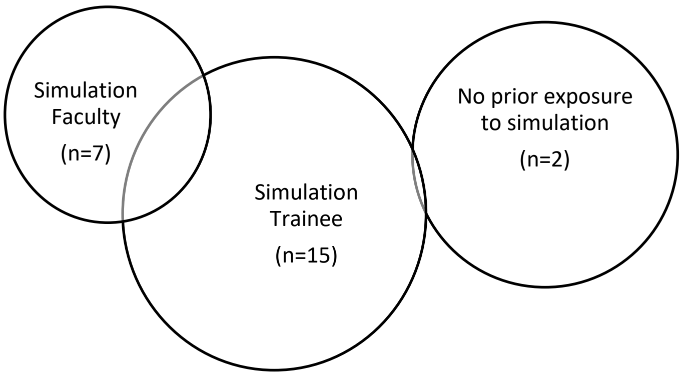


Figure 5 Prior engagement with simulation

Safety 2 (11%). Parent clinical specialty was Internal Medicine 7 (37%), Surgery 3 (16%), Obstetrics and Gynaecology 1 (5%), Paediatrics 2 (10%), Anaesthesia 2 (10%) and Psychiatry 4 (21%).

4.3.3.2 Experience and perceptions of simulation

Of the group, two participants had no prior experience of simulation training (10%), fifteen had participated in simulation training in the role of candidate, and seven had participated as faculty, implying that there was a degree of crossover in this group (Figure 5). It may have been more advantageous to add a "both" option to this question in order to define the exact size of the crossover.

In perception and attitudes towards simulation, question responses were assigned numerical value from 1-5, with 1 = strongly disagree, and 5 = strongly agree (with 3 = neutral). This was used to create a mean and standard deviation for each question response, and paired t-tests were used to assess for significant differences between the two.

Mean response to Q1 "simulation has a key part to play in patient safety", and Q2 "simulation training has the potential to improve quality in healthcare" was 4.16 for both at baseline, with a non-significant rise seen for both to 4.32 on repeat questioning (p=0.19). Mean response to Q3 "before doing any procedure, it should be practised using a simulator" was lower at 3.53, with a non-significant fall on repeat questioning to 3.26 (p=0.06). Support for increased usage of simulation training was high, with a mean response to the question Q4 “I would welcome more simulation training in my specialty” of 3.95 at baseline, rising to 4.26 on repeat questioning (p=0.02) (Figure 6).

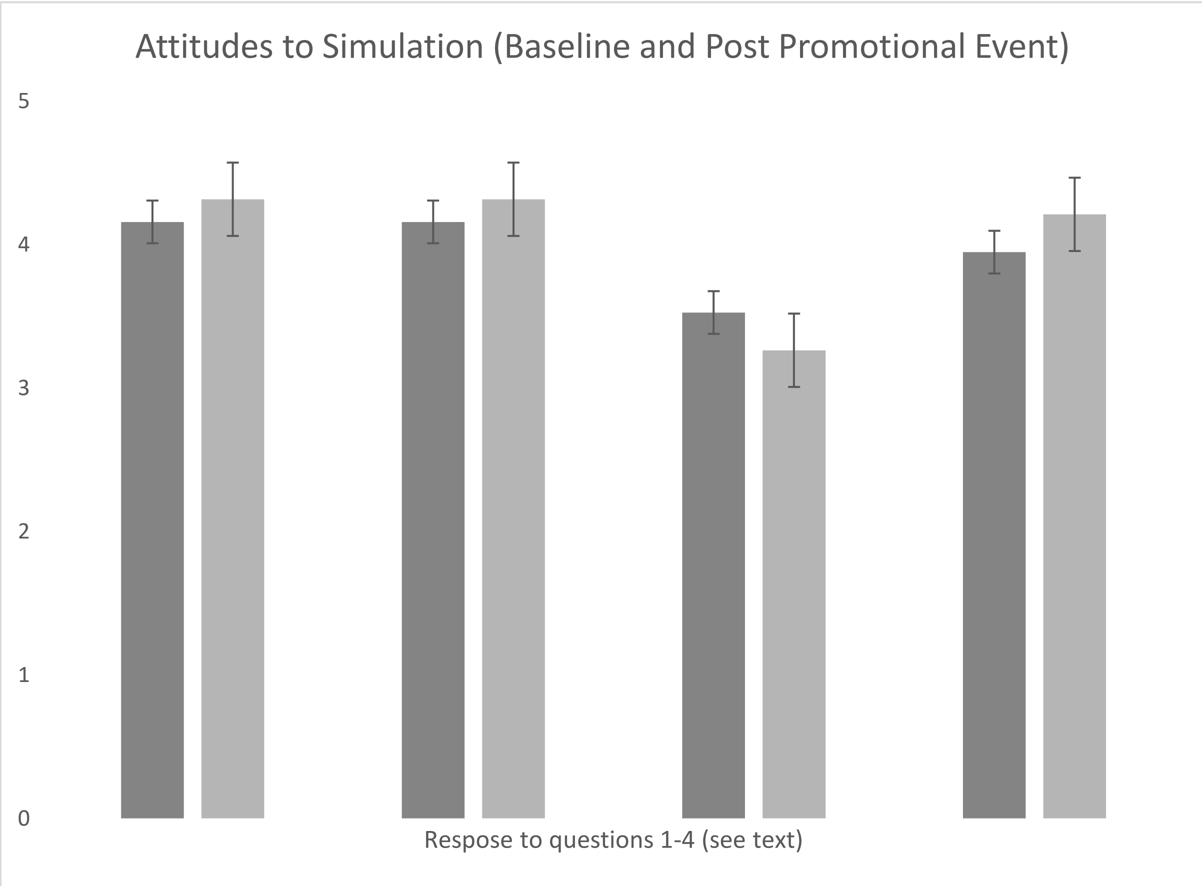


Figure 6 Attitudes to simulation

4.3.4 Delivering the survey

A web-based platform was used to deliver this survey (SurveyMonkey, Palo Alto, California). This was chosen as a recognisable service. The web-based delivery and collection of responses allowed respondents to participate from any time or location, using a variety of internet-enabled devices. The option to send individual personalised email collection links was available, but due to the requirement that email invitations had to be forwarded via postgraduate deans this was not feasible, and hence a generic link was made available. The full text of the final questions delivered is available in Appendix 4.2, and the invitation sent to trainees in Appendix 4.3.

Invitations were extended to the postgraduate deans of all 13 Local Education and Training Boards (LETBs) covered by Health Education England, plus NHS Education Scotland (NES), the Wales Deanery and the Northern Ireland Medical & Dental Training Agency (NIMDTA). For a 95% confidence level with a confidence interval of 5, the sample size was calculated at 374 in order to give a representative sample of the target population.

Positive replies were received from Yorkshire and Humber, West Midlands, London (North West and South Regions), Thames Valley and South West England. The dean of NIMDTA declined to circulate the study, citing concerns about the number of communication requests to be passed on received. No response was received from the deans of other regions. A follow up email was sent but again no response was received.

4.3.5 Data analysis

Data were received from the survey collection tool in the comma separated values (CSV) format. This was manipulated in Microsoft Excel 2013 (Microsoft corporation, Redmond, WA) and prepared for analysis. A visual check of the data was performed to ensure accuracy and completeness. Numeric data were imported into SPSS version 21 (IBM corporation, Armonk, NY), and text responses were imported into NVivo 10 (QSR International, Doncaster, Australia). Descriptive analysis was carried out to identify the demographics of the respondents. Chi-squared and Pearson rank correlation analyses were used to identify trends within the data.

4.3.6 Qualitative analysis

Qualitative analysis of the free text responses was carried out. Ninety-three respondents had elected to complete this field. Initially, a ‘broad brush’ analysis was carried out, with a word frequency query for the 50 most commonly used terms of 4 letters or greater. Word frequency tables and word association diagrams were constructed, and a full thematic analysis of the responses was conducted. The same six stage process for thematic analysis was used as described in section 2.5.6.

4.4 Results

4.4.1 Demographics

A total of 682 responses were received. After the study information and consent question, 674 (98.8%) consented to participate. Eight (1.2%) did not consent, and the survey was closed. Of the 674 who did consent to proceed, 18 did not complete any further questions. For context, the General Medical Council estimates that there are around 65,000 doctors in training grades in the UK (220). The 2014 mandatory GMC national training survey which is distributed to all trainees collected 53,077 responses (of 54,068 invited, 98.2%), and the 2015 reports over 53,000 responses (although does not give specific numbers).

Responses were recorded from all medical grades (Table 12).

Grade	N	%
FY1	88	13.4
FY2	76	11.6
ST1	94	14.4
ST2	59	9.0
ST3	72	11.0
ST4-5	113	17.3
ST6+	120	18.3
Staff Grade/Associate Specialist	4	0.6
Research fellow	8	1.2
Consultant	10	1.5
Clinical fellow	8	1.2
Lecturer	1	0.2
GP	1	0.2
Manager	1	0.2
Total	655	

Table 12 Grade of respondents

Respondents identified themselves as currently practising in a total of 20 regions (19 within UK, 1 overseas) (Table 13).

Region	N	%	Number of responses to 2015 GMC NTS	Response rate per region (%)
Yorkshire and Humber	189	28.9	4531	4.17
West Midlands	292	44.6	4306	6.78
Wales	3	.5		
Thames Valley	1	.2		
South West England	51	7.8	3466	1.47
South East England	8	1.2		
South Central England	1	.2		
Severn	1	.2		
Scotland	2	.3		
Oxford	2	.3		
North West England	1	.2		
North East England	3	.5		
Midlands	1	.2		
Mersey	1	.2		
South London	6	.9		
North West London	70	10.7	2411	2.90
North Central & East London	10	1.5		
East of England	1	.2		
East Midlands	11	1.7		
Overseas	1	.2		
Total	655		14714	3.83

Table 13 Region of respondents

Specialty and subspecialty information was collected from respondents. These categories were taken to align with the specialty groups identified by the Royal Colleges and GMC as specialty career pathways for the purposes of training (Table 14).

Specialty	N	%
Foundation Programme	73	11.2
Anaesthetics	81	12.4
General Practice	59	9.0
Laboratory Specialties	32	4.9
Surgical	142	21.7
Medicine	182	27.8
Paediatrics	28	4.3
Psychiatry	13	2.0
Public Health	4	.6
Radiology	10	1.5
Broad Based Training	1	.2
Dental	1	.2
Education	1	.2
Emergency Medicine	27	4.1
Total	654	

Table 14 Specialty of respondents

Those in the medical and surgical specialty groups were further asked to describe their subspecialty (Table 15).

Major Specialty	Subspecialty	N
Medicine	Acute Medicine	23
	Cardiology	17
	Elderly Medicine	22
	Diabetes & Endocrine	3
	Gastroenterology	5
	Genito-Urinary Medicine	3
	Haematology	7
	Infectious Disease	1
	Neurology	3
	Oncology	3
	Palliative Care	3
	Renal	8
	Respiratory	18
	Rheumatology	4
Surgical Specialties	Urology	14
	Cardiothoracic	2
	Colorectal	1
	Core Surgical Training	8
	Ear, Nose and Throat	10
	Neurosurgery	1
	General Surgery	22
	Paediatric Surgery	2
	Plastic Surgery	8
	Trauma and Orthopaedics	20
	Vascular Surgery	7

Table 15 Subspecialty of respondents

A breakdown of the grade and specialty of those who responded to the survey is shown in Figures 7 and 8.

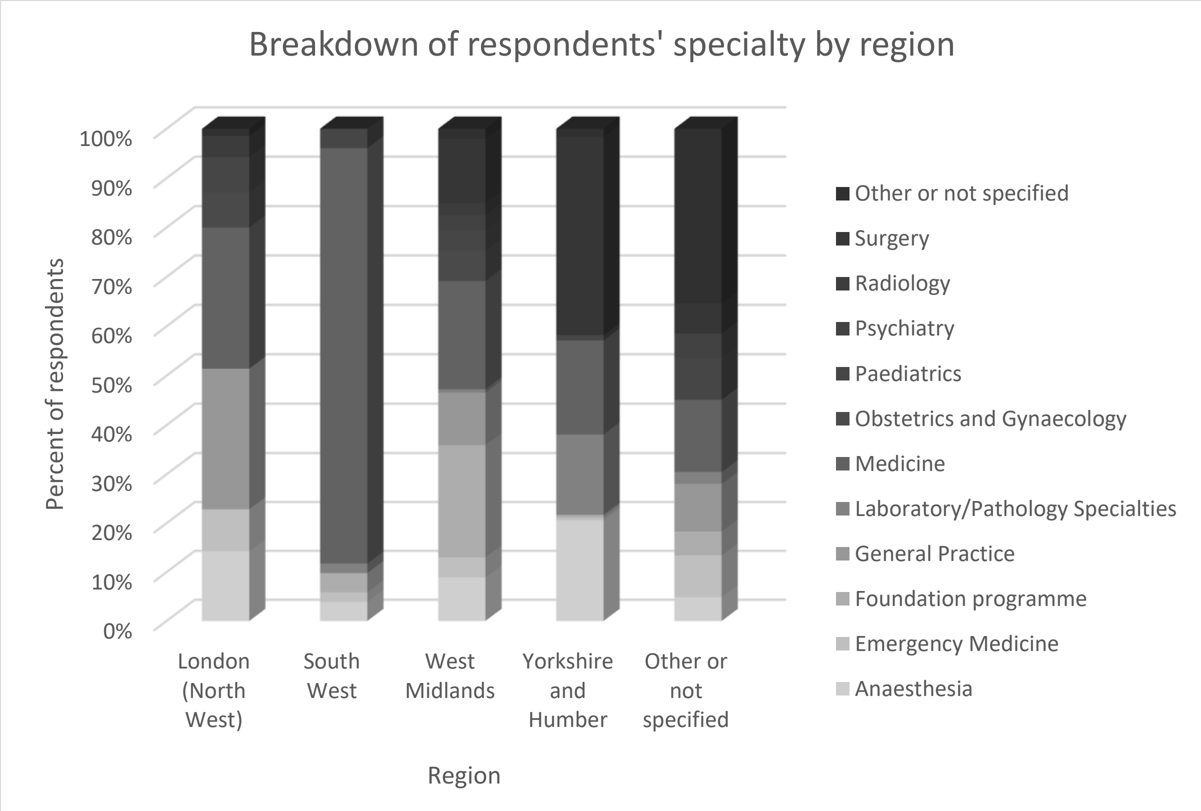


Figure 7 Specialty of respondents by region

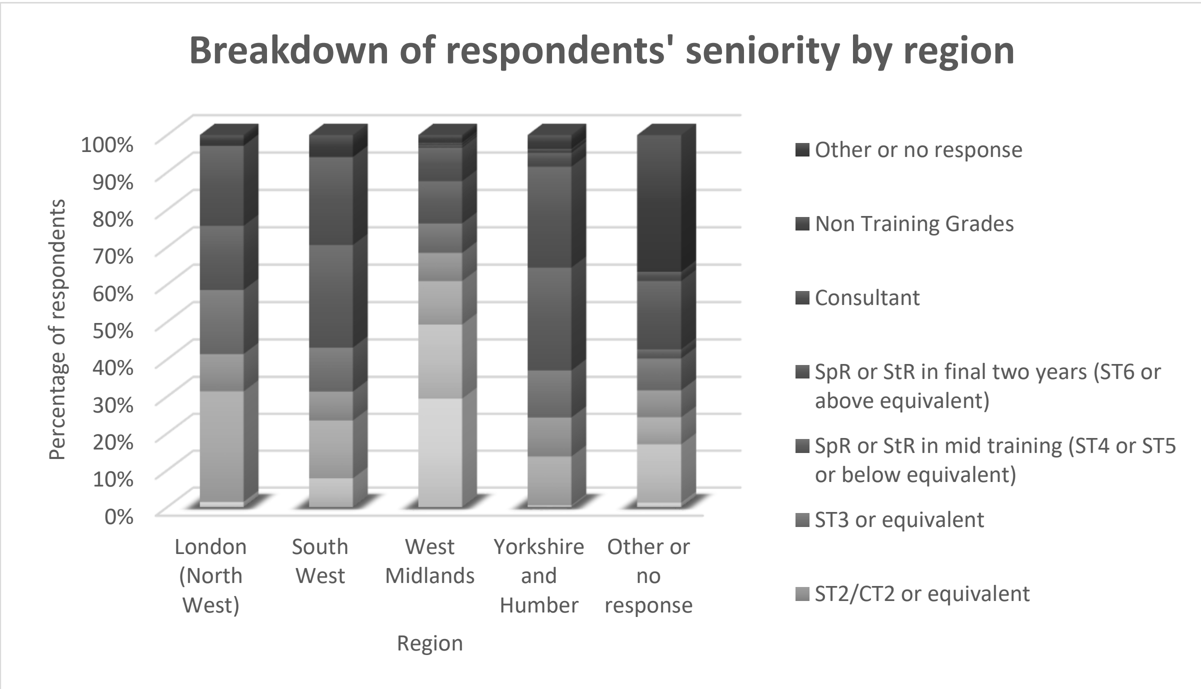


Figure 8 Seniority of respondents by region

4.4.2 Experience of simulation

Respondents were asked to describe their experience of previous simulation training at any stage in their career to date (Table 16).

Type of SBT	Have experienced (n)
Simulated scenarios (emergencies, consultations etc.)	535
Simulated ward environment	169
Specific procedure training supervised directly by an experienced operator	243
Specific procedure training (unsupervised)	97
Life support course	540
Other	29

Table 16 Experience of simulation

For those regions with greater than 20 respondents, chi square analysis was performed to determine whether there was a significant difference in the experience of their trainees (Table 17).

Region	Undergone Simulation Scenarios (n, %)	% Undergone Simulated Ward	% Undergone Supervised Procedure Training	% Undergone Unsupervised Procedure Training	% Undergone life support course
Yorkshire and Humber	136 (72.0%)	47(24.9%)	94(49.7%)	50(26.5%)	147(77.8%)
West Midlands	247 (86.6%)	95(32.5%)	82(28.1%)	31(10.6%)	237(81.1%)
South West	41 (80.4%)	8(15.7%)	23(45.1%)	5(9.8%)	46(90.2%)
London (North West)	64 (91.4%)	13(18.6%)	25(35.7%)	5(7.1%)	66(94.3%)
Chi Square	0.001	0.013	<0.001	<0.001	0.007

Table 17 Analysis of experience by region

A similar analysis was conducted to evaluate the correlation between seniority and simulation experience (Table 18).

Grade	Undergone Simulation Scenarios (n, %)	% Undergone Simulated Ward	% Undergone Supervised Procedure Training	% Undergone Unsupervised Procedure Training	% Undergone life support course
FY1	81(92.0%)	38(43.2%)	13(14.8%)	7(8%)	67(76.1%)
FY2	69(90.8%)	28(36.8%)	19(25%)	4(5.3%)	70(92.1%)
ST1	82(87.2%)	24(25.5%)	33(35.1%)	13(13.8%)	85(90.4%)
ST2	54(91.5%)	16(27.1%)	27(45.8%)	8(13.6%)	53(89.8%)
ST3	58(80.6%)	13(18.1%)	33(45.8%)	15(20.8%)	56(77.8%)
ST4-5	80(70.8%)	23(20.4%)	54(47.8%)	21(18.6%)	86(76.1%)
ST6+	87(72.5%)	24(20%)	53(44.2%)	25(20.8%)	97(80.8%)
Consultant	7(70%)	1(10%)	4(40%)	1(10%)	7(70%)
Chi Square	<0.001	0.001	<0.001	0.27	0.008
Correlation (Pearson)	R=-0.209	-1.82	0.202	0.131	-0.069

Table 18 Analysis of experience by grade

There was an inverse relationship between seniority and the type of courses attended, with a fall in the number participating in emergency scenario training and simulated ward environments from ST2 onwards, but a rise in those participating in procedural skill training (Figure 9).

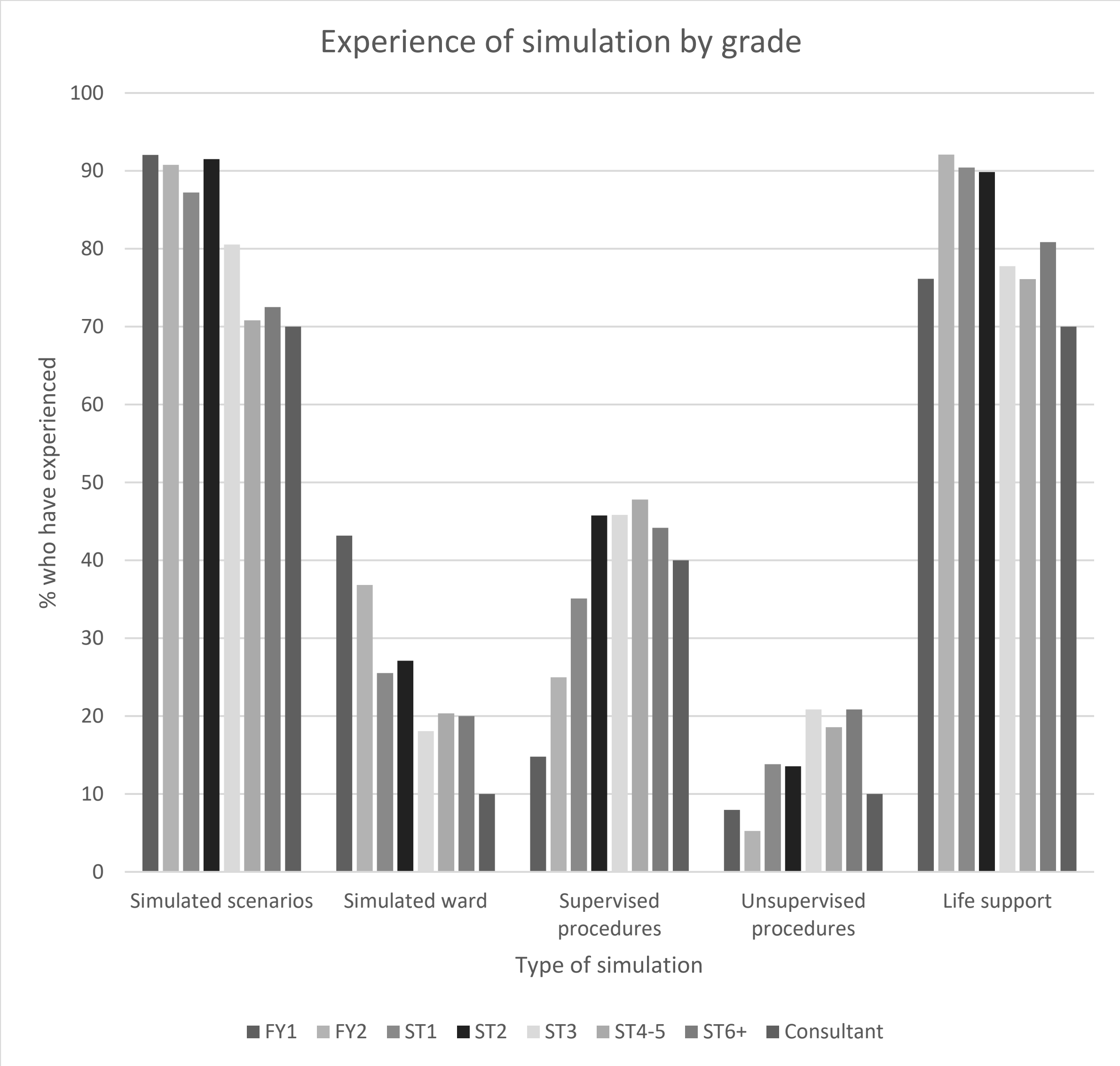


Figure 9 Experience by grade

Other simulated experiences described by respondents included cadaveric procedures, virtual histology, human factors training and specific procedure simulators.

4.4.3 Simulator availability

Respondents were asked to describe their awareness of the availability of simulation equipment for learning in their area (Figure 10).

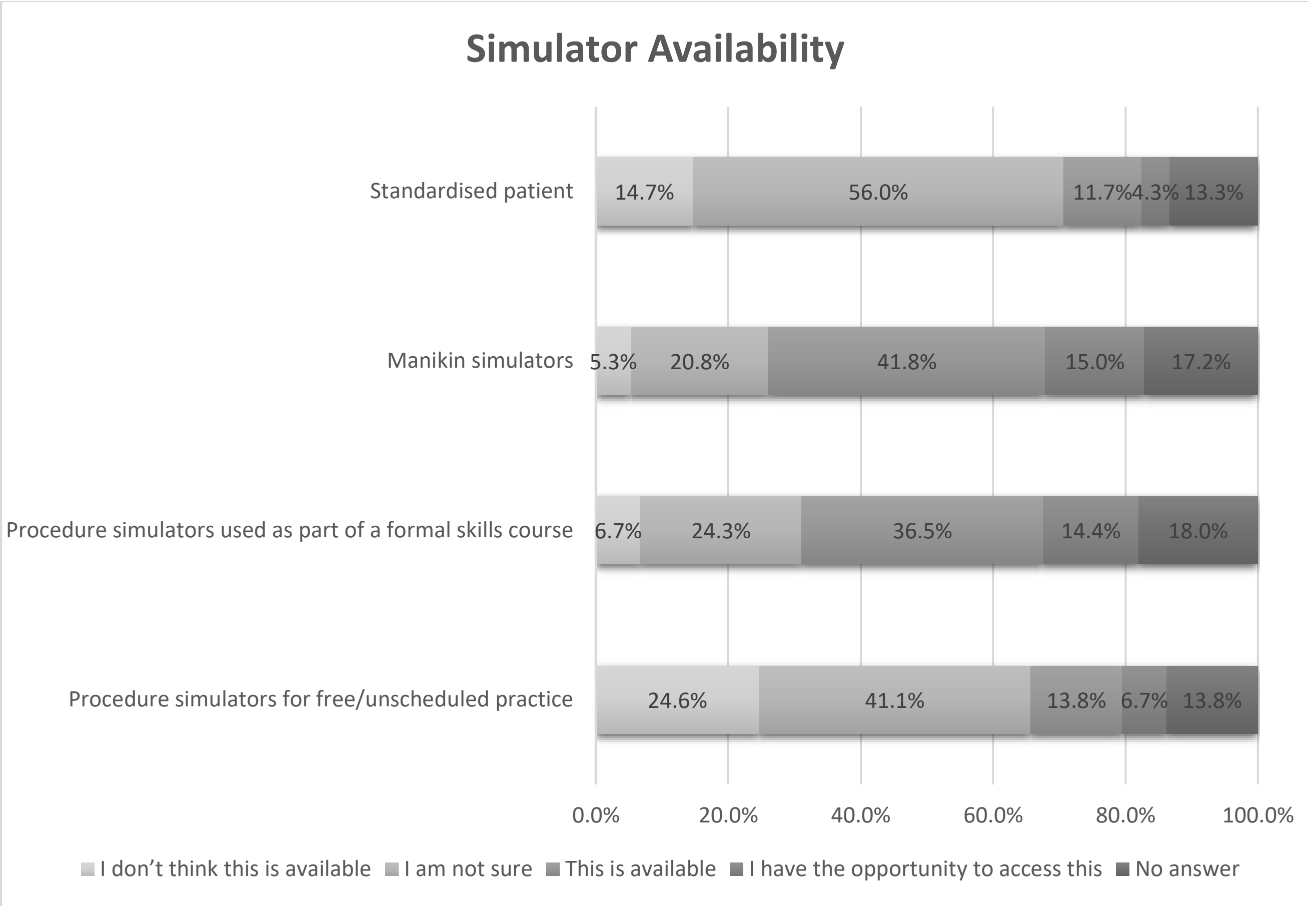


Figure 10 Simulator availability

4.4.4 Facilitation experience

Respondents were asked to describe any experience with facilitation of simulation activity for other learners (Figure 11).

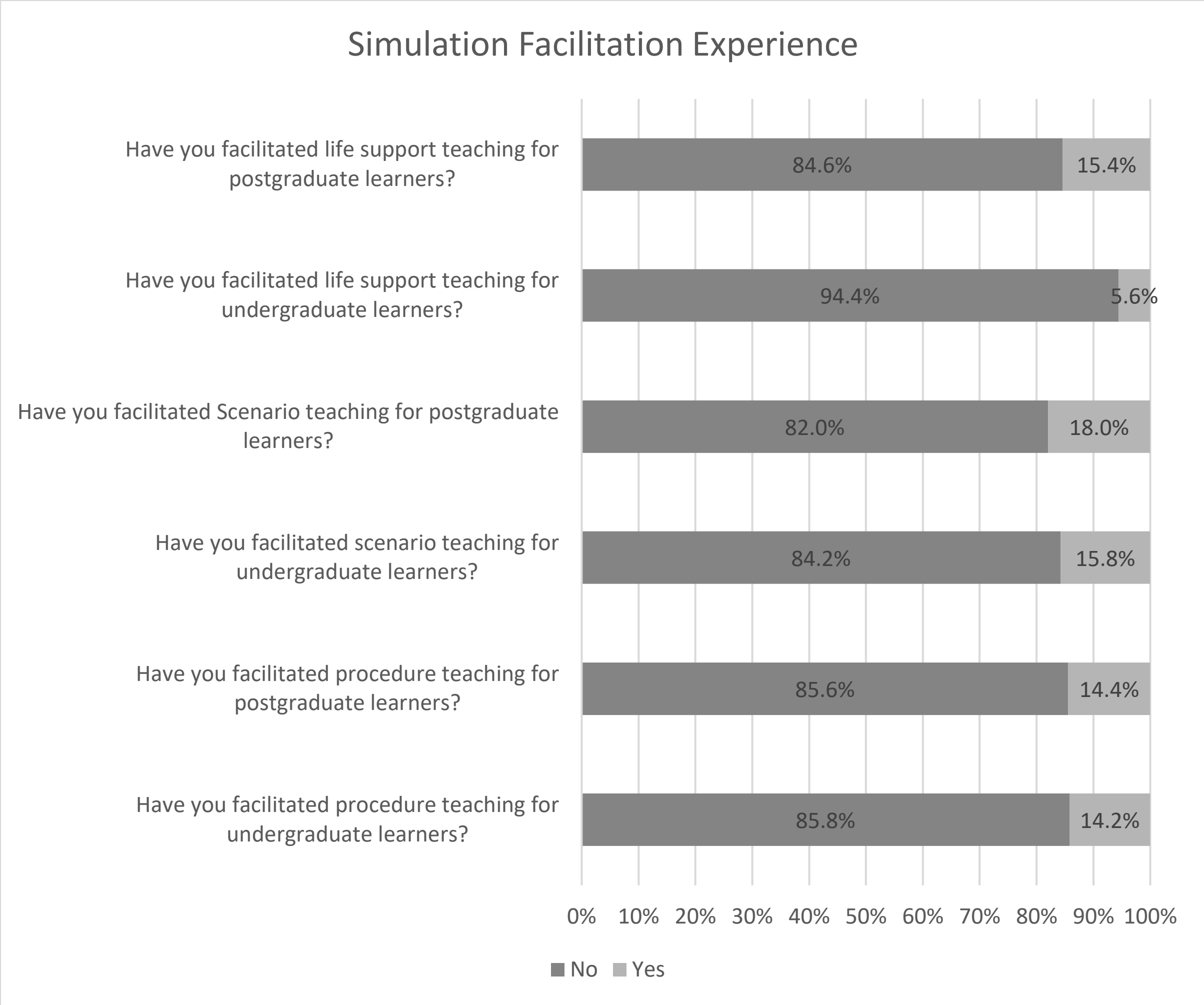
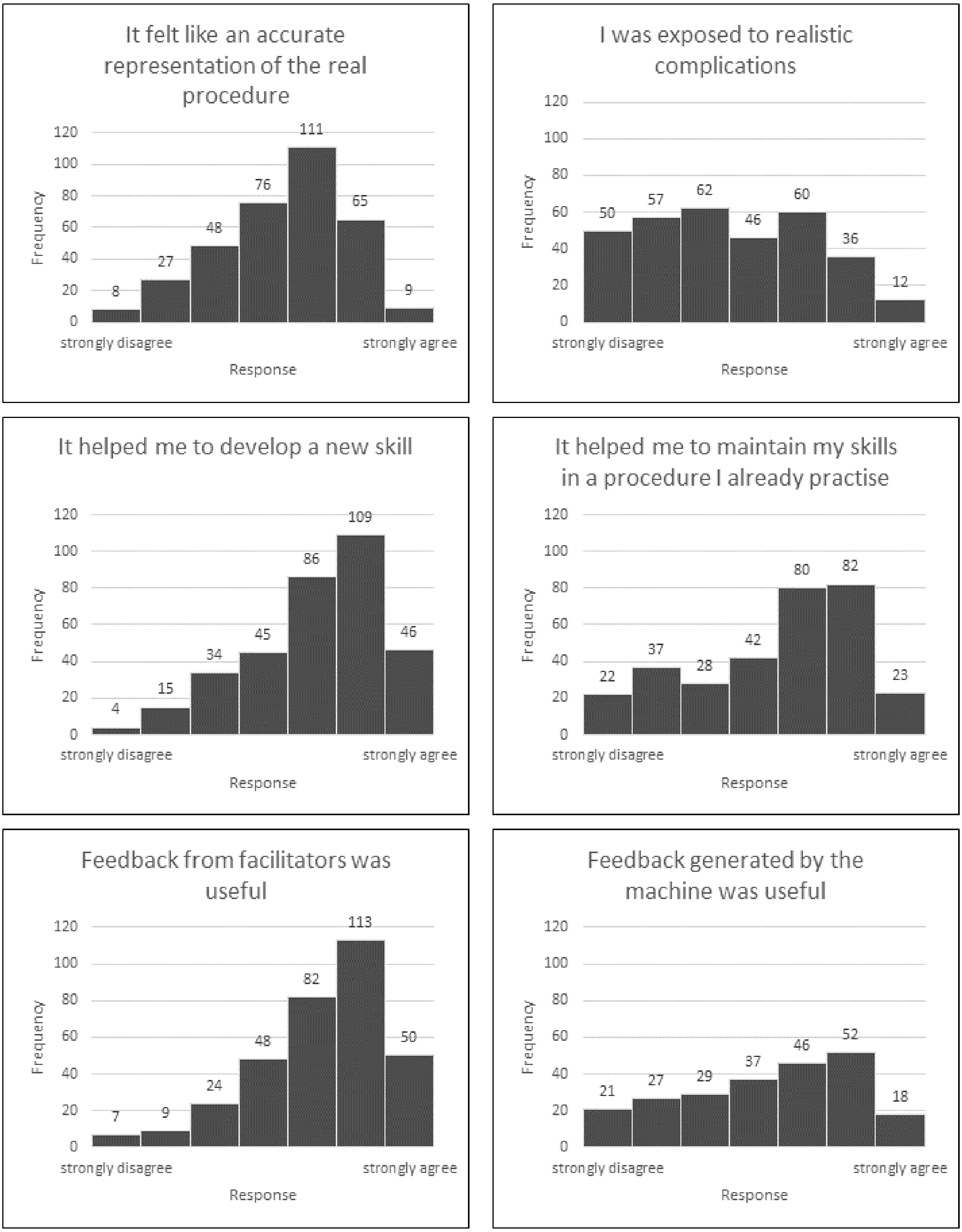


Figure 11 Simulator facilitation experience

There was a weak positive correlation between the number of course types accessed as a learner and the number of course types facilitated (R^2 = 0.314, Pearson). For breadth of simulation teaching, respondents had participated in a mean 0.36 types of courses for undergraduate learners, and 0.48 for postgraduate learners ($p<0.001$).

4.4.5 Perceptions of simulation experience for procedures

Participants were asked to consider their experience of simulated procedures, ranking on a scale from 1 (strongly disagree) to 7 (strongly agree) their opinions on the accuracy and utility of the procedural skills they had undergone (Figures 12-18).



Figures 12-17 Response to simulated procedures

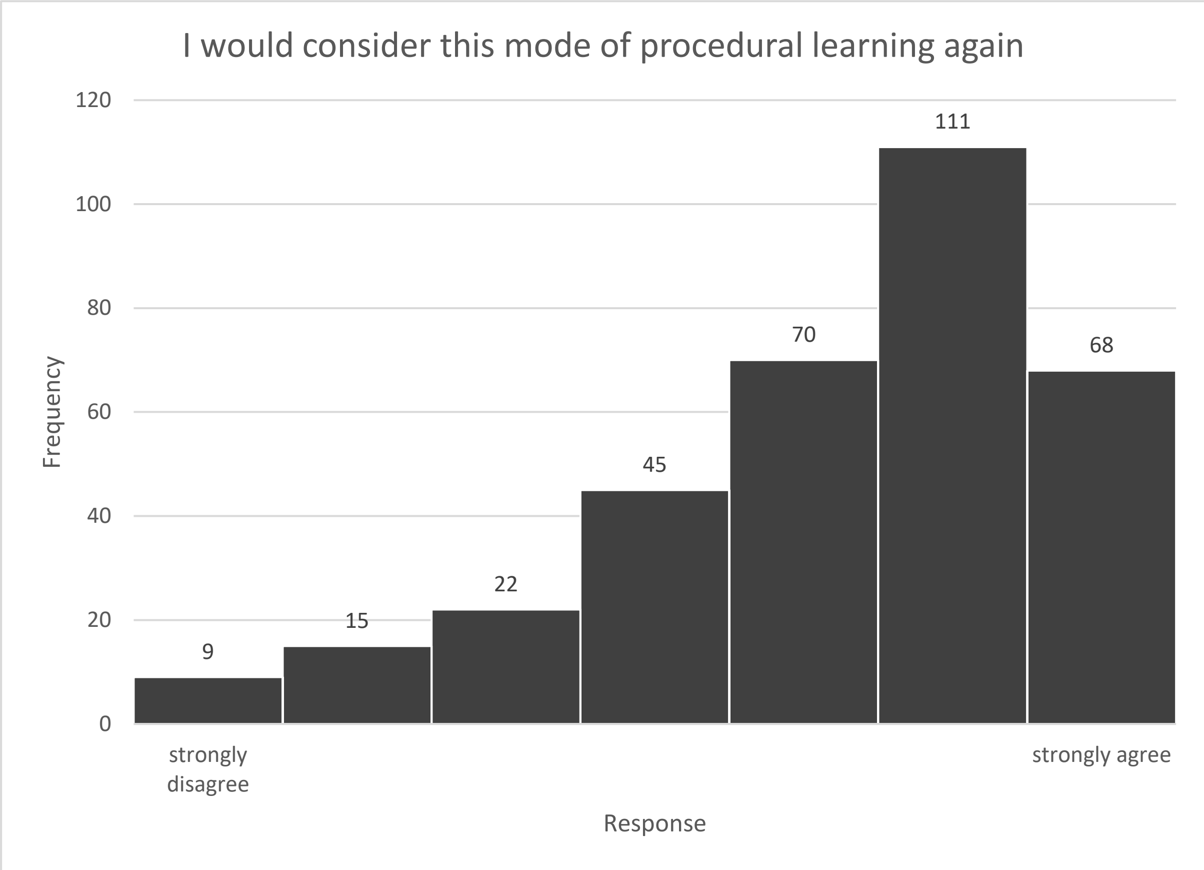


Figure 18 Willingness to consider procedural simulation again

4.4.6 Perceptions of simulation experience for scenarios

Participants were asked to consider their experience of simulated emergency scenarios, ranking on a scale from 1 (strongly disagree) to 7 (strongly agree) their opinions on the accuracy and utility of the experience (Figures 19-26).

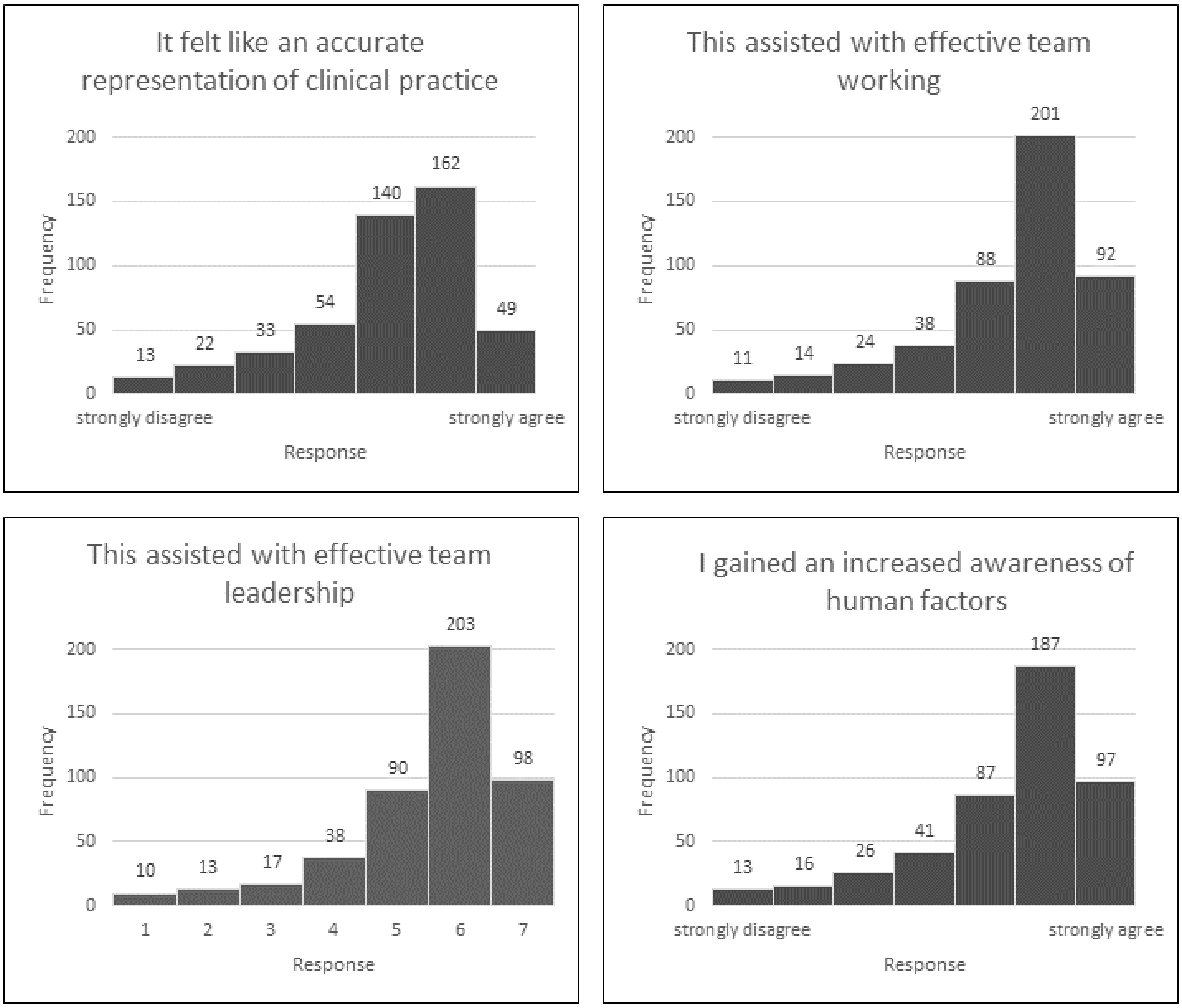


Figure 19-22 Response to simulated scenarios

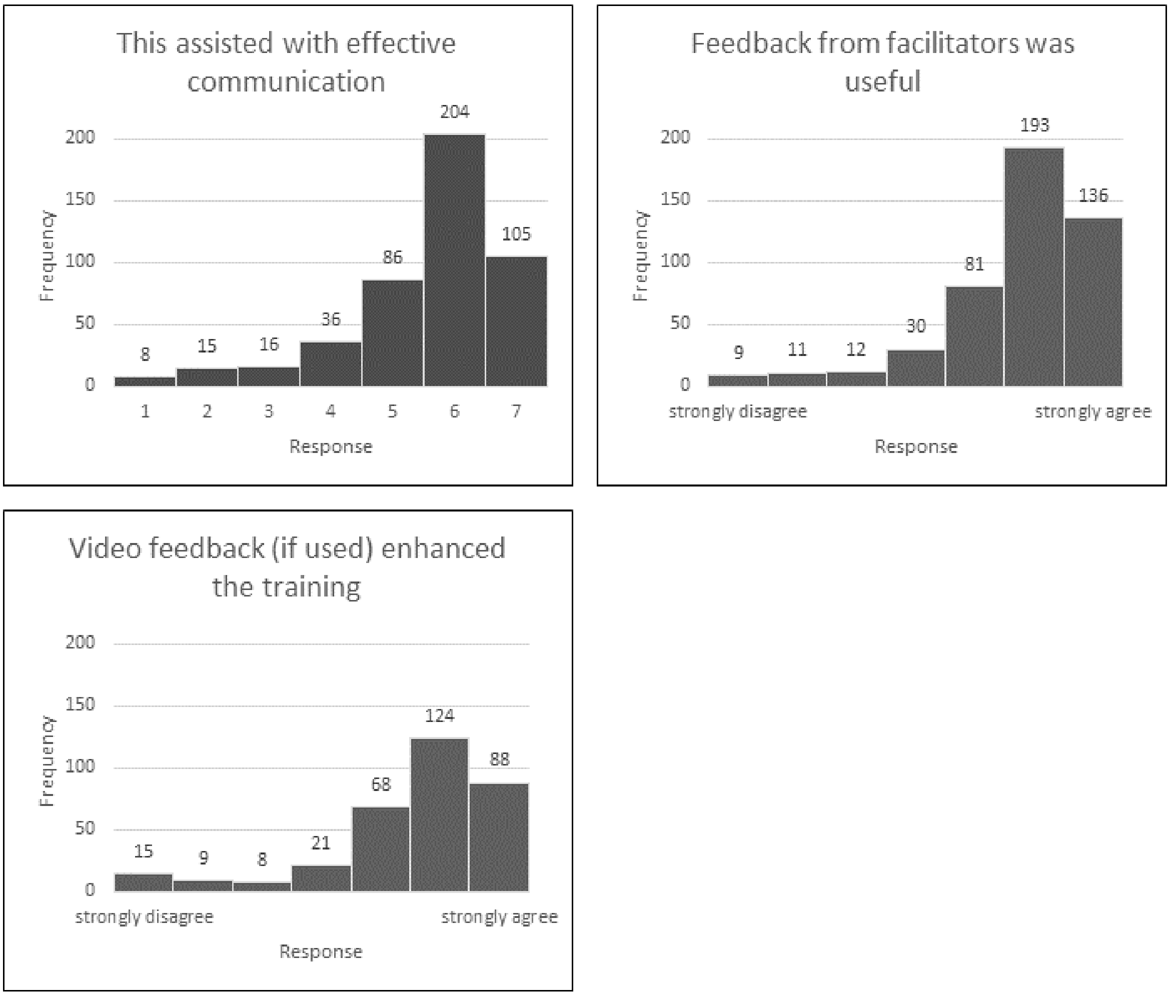


Figure 23-25 Response to simulated scenarios

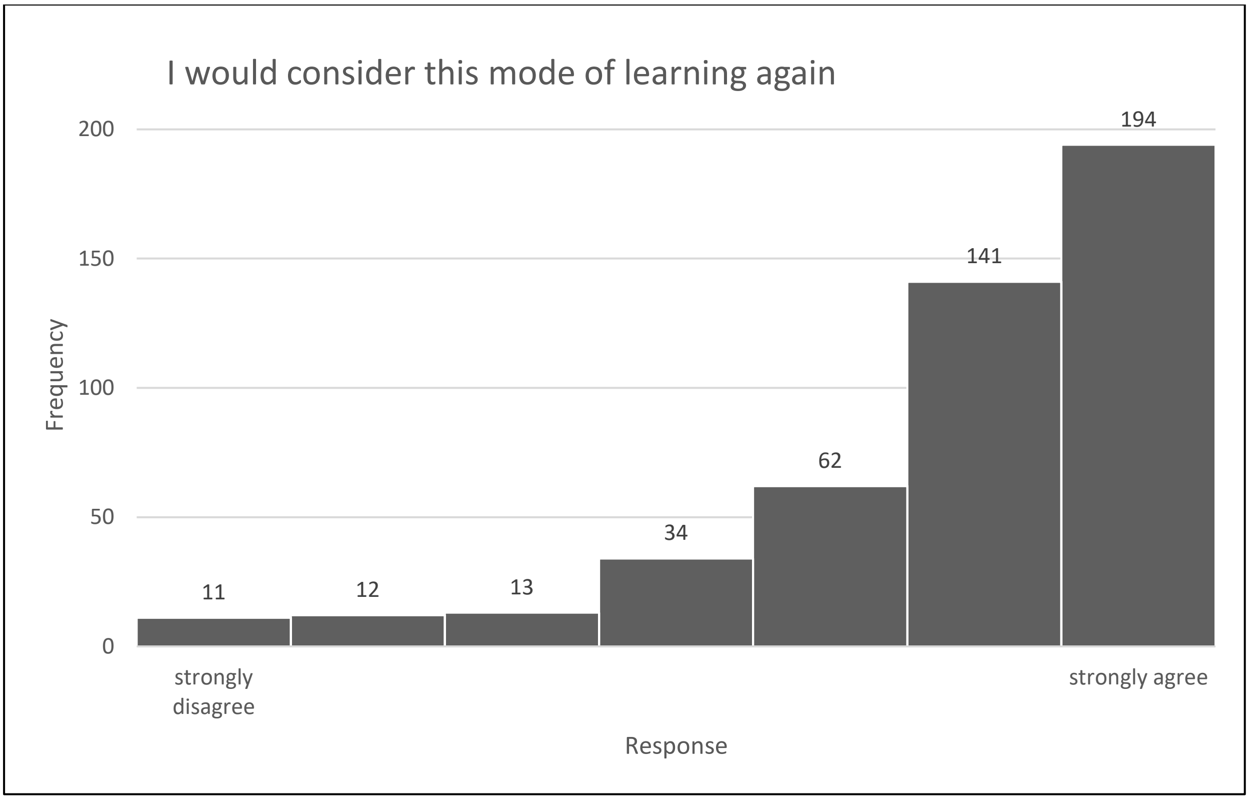


Figure 26 Willingness to consider simulated scenarios again

4.4.7 Overall perceptions of simulation

Participants were asked to consider their perception of simulation based learning as a technique, regardless of experience, ranking on a scale from 1 (strongly disagree) to 7 (strongly agree) (Figures 27-35).

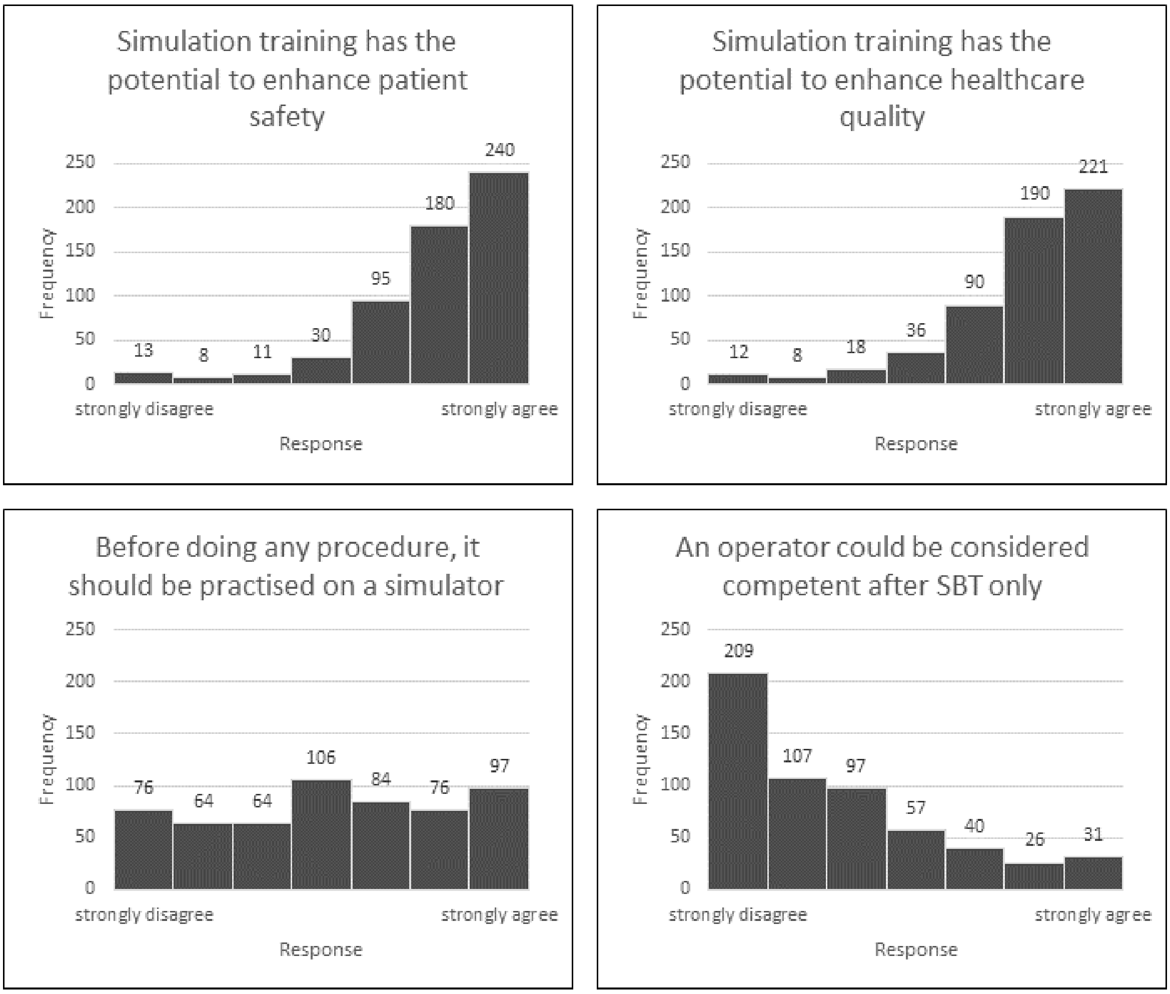


Figure 27-30 Overall perceptions of simulation

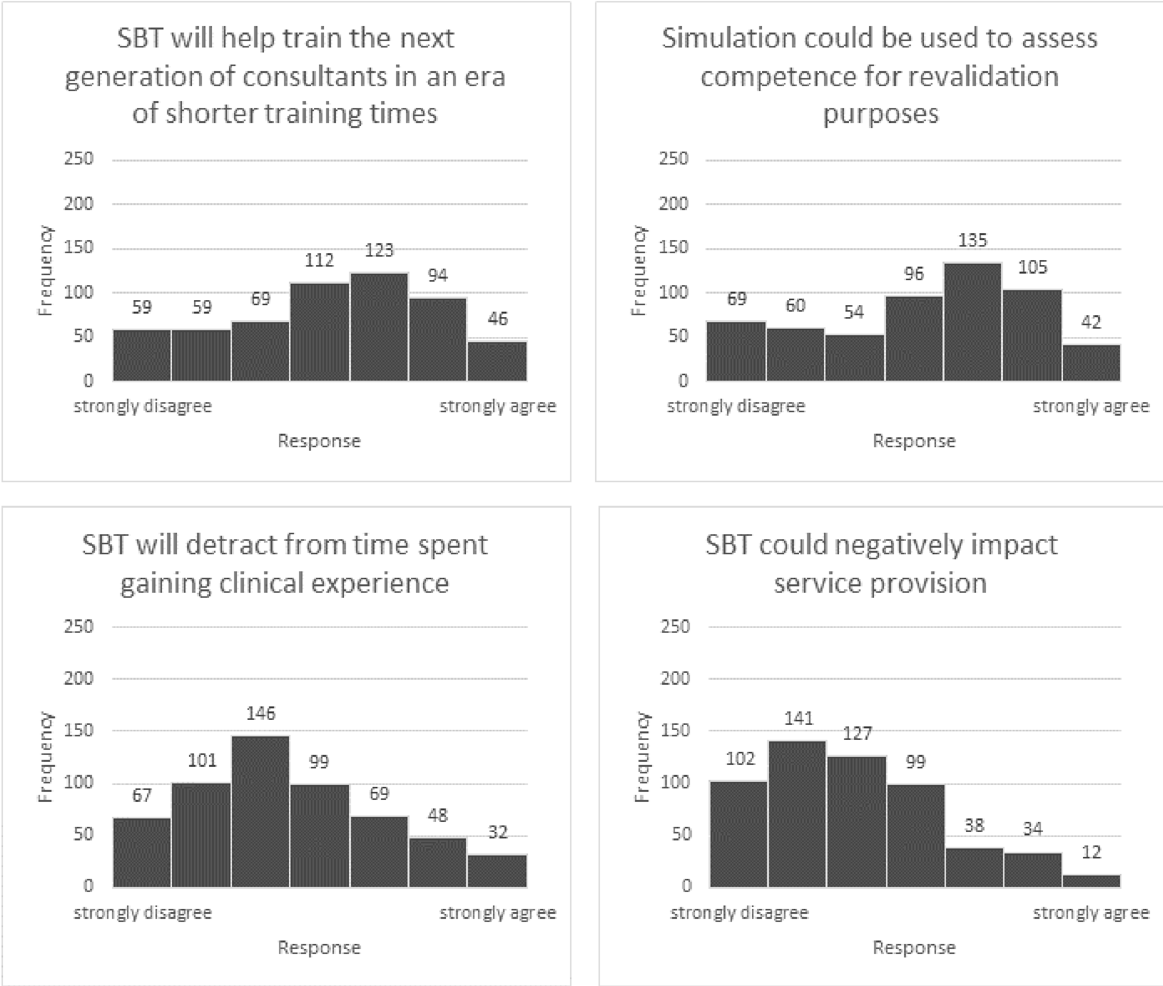


Figure 31-34 Overall perceptions of simulation

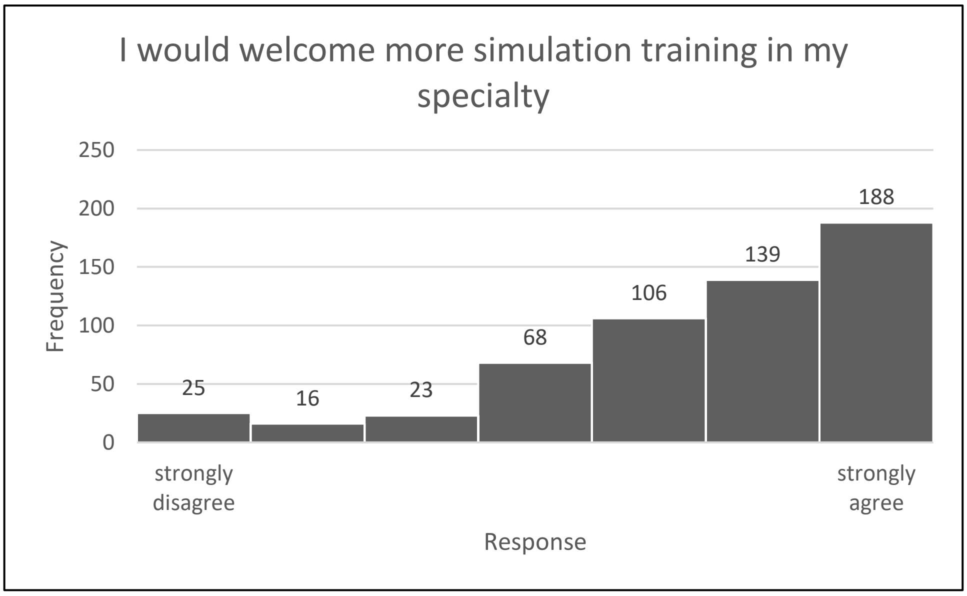


Figure 35 Willingness to consider more simulation training in future

There was a significant difference in the responses to these questions by specialty, although opinion did not appear to be significantly influenced by seniority, except for a trend demonstrating less agreement that an operator could be considered competent after only simulation training with increasing seniority, and less enthusiasm for further simulation training with increasing seniority (Figures 36-45).

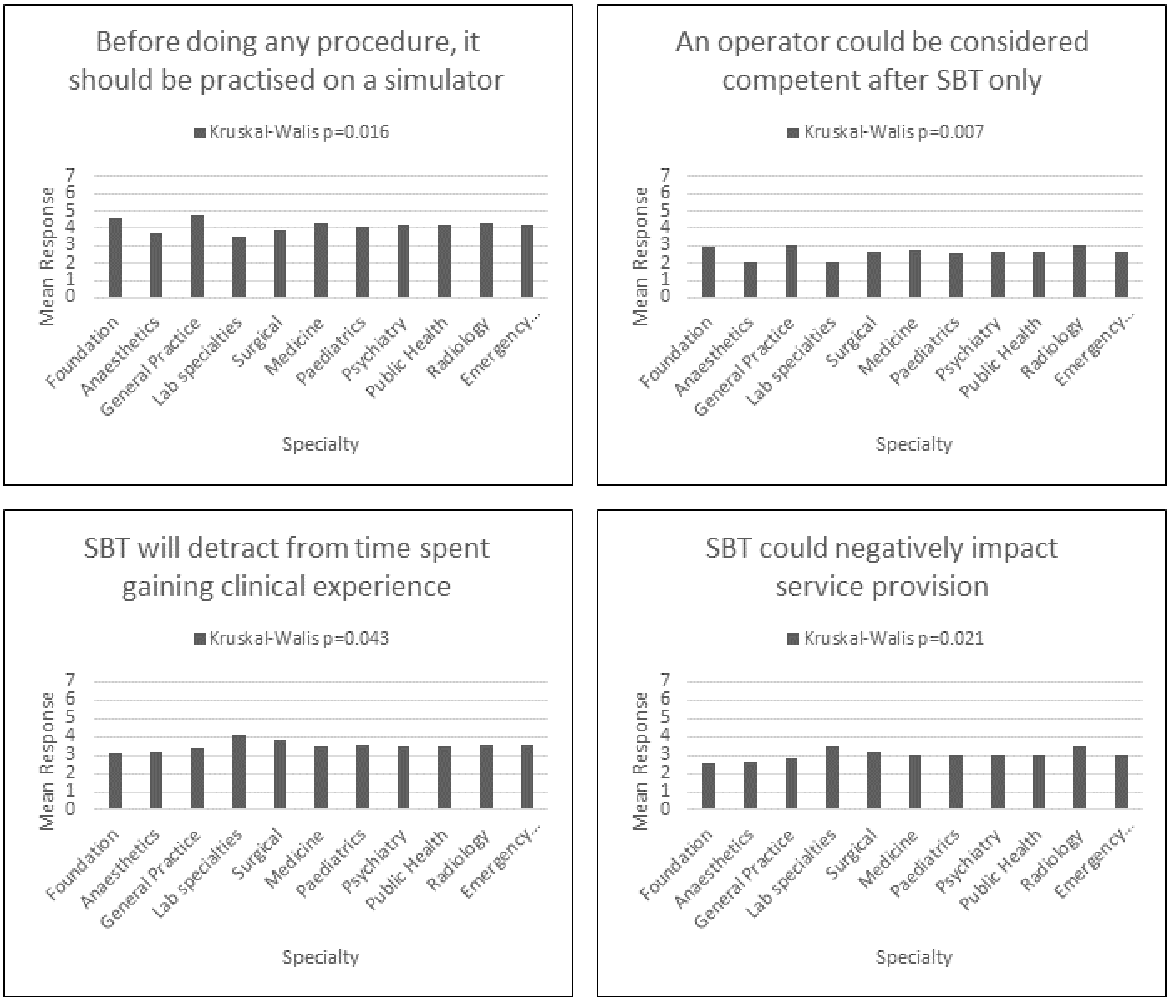


Figure 36-39 Perception of simulation by specialty

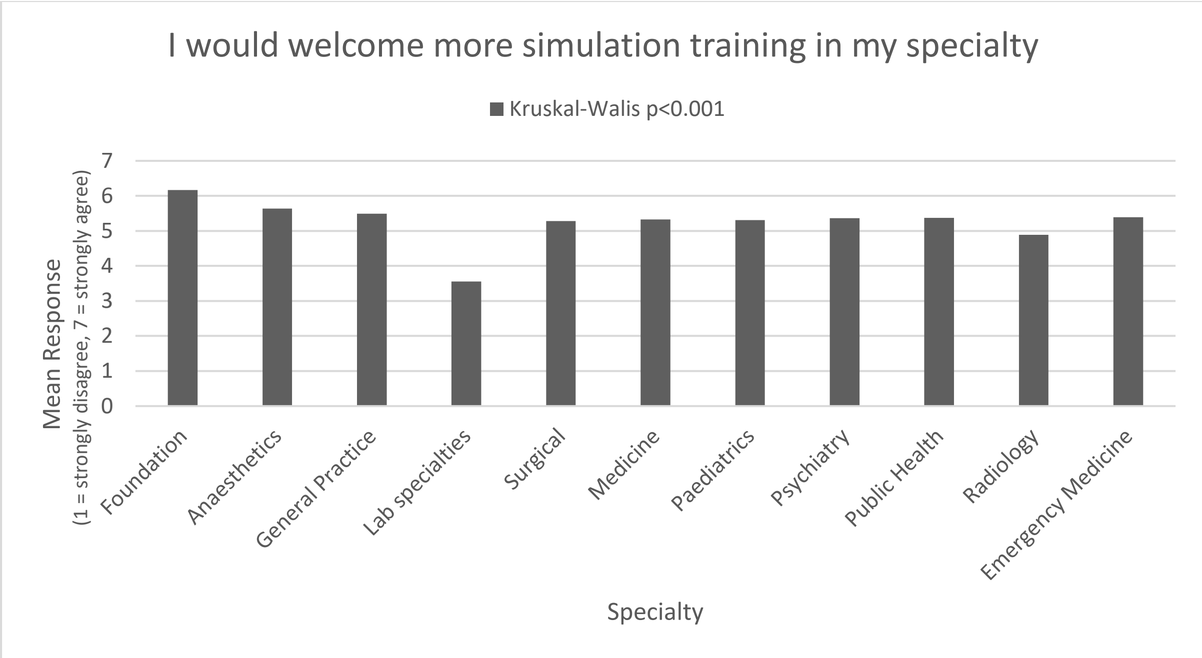


Figure 40 Willingness to consider more simulation by specialty

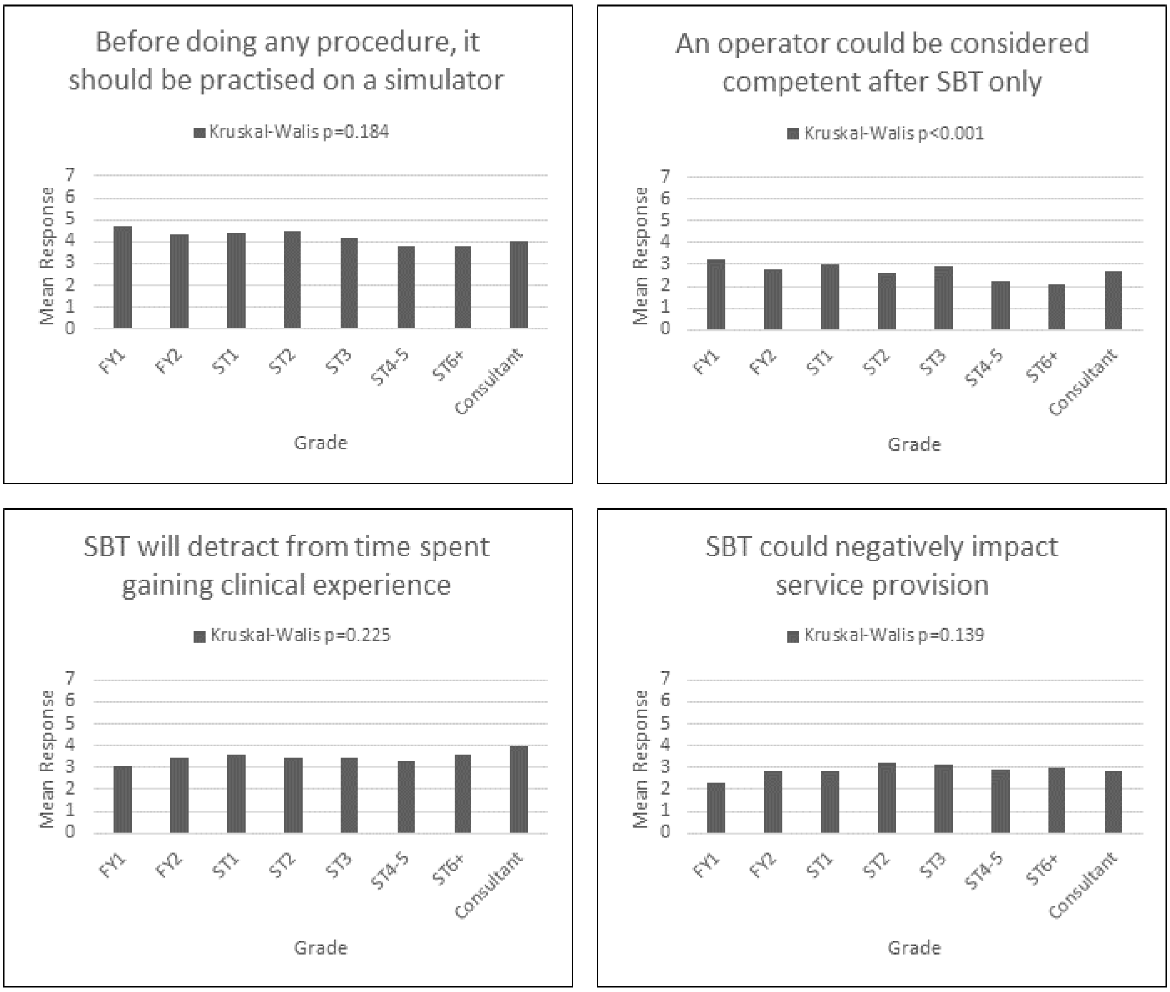


Figure 41-44 Perception of simulation by grade

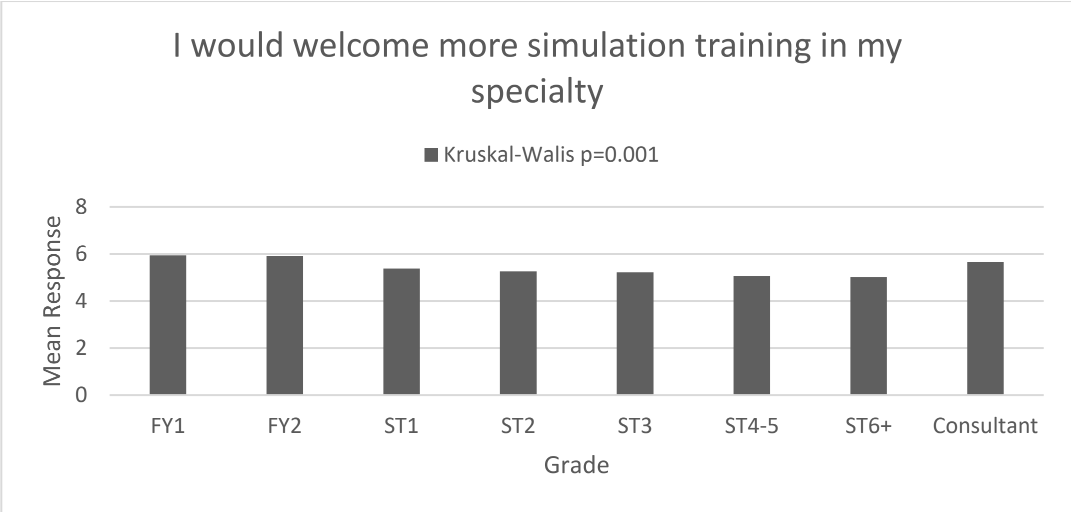


Figure 45 Willingness to consider more simulation by grade

4.4.8 Future intentions to engage with simulation

Respondents were then asked whether they had any plans to engage with simulation in the future (Figure 46).

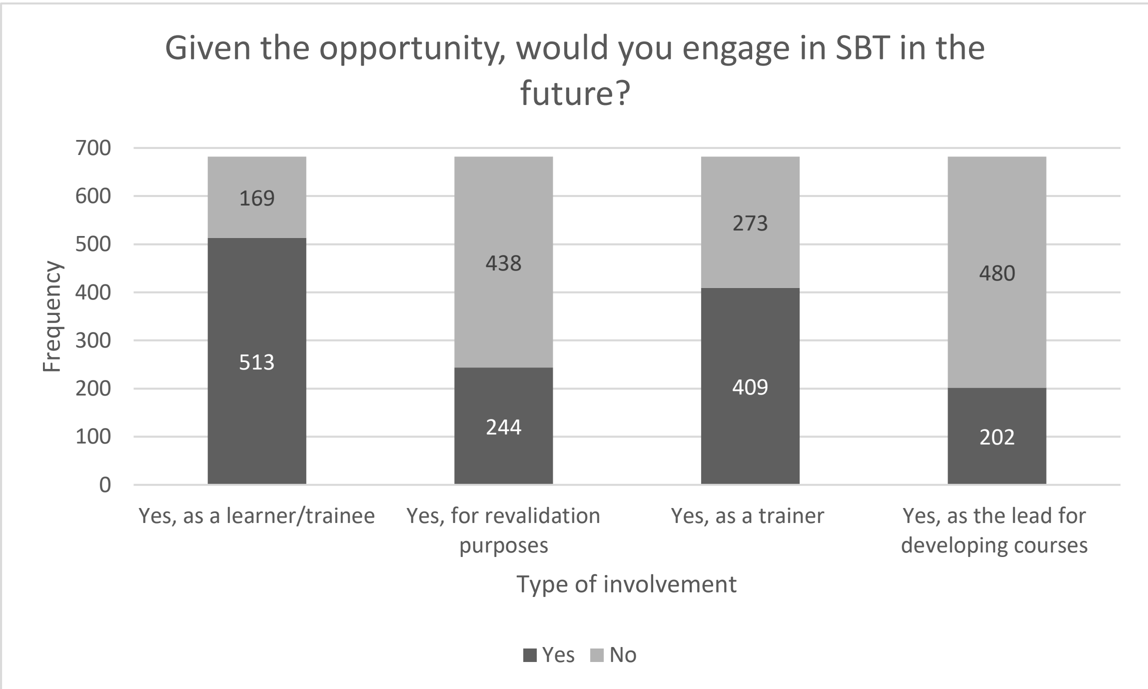


Figure 46 Intention to engage with simulation in future

4.4.9 Qualitative analysis

4.4.9.1 Word frequency analysis

A word frequency query was conducted on all of the free-text responses received, grouping similar words together (Table 19).

Word	Length	Count	Weighted Percentage (%)	Similar Words
training	8	100	3.75	train, trained, training
simulators	10	73	2.74	simulate, 'simulate', simulated, simulation, simulations, simulator, simulators
equivalent	10	69	2.59	equivalent
useful	6	49	1.84	used, useful, using
real	4	32	1.20	real, 'real
clinical	8	28	1.05	clinical
patients	8	28	1.05	patient, 'patient', patients
learning	8	27	1.01	learn, learning
think	5	26	0.97	think
time	4	25	0.94	time, times
experiences	11	24	0.90	experience, experiences
procedures	10	22	0.82	procedural, procedure, procedures
years	5	20	0.75	year, years
medical	7	19	0.71	medical, medication, medics
scenarios	9	19	0.71	scenario, scenarios
like	4	17	0.64	like, likely

skills	6	17	0.64	skill, skills
practice	8	16	0.60	practical, practice, practiced
emergency	9	15	0.56	emergancy, emergencies, emergency
work	4	15	0.56	work, working, works
final	5	14	0.52	final
needs	5	13	0.49	need, neede, needed, needs
help	4	12	0.45	help, helped, helpful, helps
based	5	11	0.41	base, based
develop	7	11	0.41	develop, developing, development, developments
good	4	11	0.41	good
much	4	11	0.41	much
particularly	12	11	0.41	particular, particularly
really	6	11	0.41	really
replace	7	11	0.41	replace, replacement, replaces
feel	4	10	0.37	feel, feeling
life	4	10	0.37	life, life'
trainees	8	10	0.37	trainee, trainees
however	7	9	0.34	however
spent	5	9	0.34	spent
substitute	10	9	0.34	substitute
team	4	9	0.34	team, teams
factors	7	9	0.34	factor, factors, factors'

competence	10	8	0.30	competence, competency, competent
course	6	8	0.30	course, courses
currently	9	8	0.30	current, currently
limited	7	8	0.30	limit, limitations, limited
session	7	8	0.30	session, sessions
teaching	8	8	0.30	teach, teaching
things	6	8	0.30	thing, things
'human	6	8	0.30	human, 'human
adjunct	7	8	0.30	adjunct
available	9	8	0.30	available
environment	11	8	0.30	environment
first	5	8	0.30	first

Table 19 Word frequencies in responses

4.4.9.2 Thematic analysis

A full thematic analysis was then conducted of comments. Responses were coded into six major themes, with a number of sub themes within each.

Major themes

1. Curriculum integration
2. Issues limiting the utility of SBT as it is currently offered
3. Positive aspects of SBT for medical training
4. Negative aspects of SBT for medical training
5. Potential for future development
6. Miscellaneous comments

Each of these aspects will be discussed in more detail below, with examples.

1. Curriculum integration
    a. The most prevalent sub theme within this group was reference to simulation being a useful adjunct to clinical experience, but not a replacement. This includes reference to using simulation as a method to supplement gaps in clinical experience during training. Examples of this are;
        i. *"Brilliant as an adjunct to real patient learning and ward experience"*
        ii. *"SBT is never going to replace real clinical experience but can be a useful adjunct."*
        iii. *"but multiple 'real life' attempts necessary to consolidate skills"*
        iv. *"However, I don't believe it should be used as the sole training tool"*
        v. *"I do not feel that SBT can be used to replace clinical training, but as an adjunct to it"*

vi. *"The main positives are dealing with emergencies that would soon be expected out of me as i progress in training that I don't necessarily have exposure to at present"*

vii. *"especially when we don't always have the opportunity to do them in real life) and clinical emergency scenarios as part of my training."*

viii. *"As technology advances, I would urge more investment into this area as I understand it to be the only type of education available currently that resembles clinical reality. One can never entirely replicate a sick patient on the ward but this comes close to enabling the clinician to learn skills that they can translate into real clinical work"*

ix. *"Vital at increasing confidence in a procedure or at managing teams. But should not replace clinical experience on real people (nothing can replace this)"*

x. *"*It *also is useful to provide as evidence on portfolios, where clinical exposure may not be possible at the time."*

xi. *"*We *have to be careful; simulation is an adjunct to clinical training not a replacement for it"*

b. The amount and access to simulation as part of training curricula, and its integration with other learning methods was another theme identified in comments

i. *"access to simulators is not well publicised. they are inconvenient (distant site, long winded training and access problems) to use and are not fully integrated into current training."*

ii. *"*Not *really had any access to SBT - in my trust its only really made available to junior doctors, medical students and nurses... not registrars and above as far as I can work out."*

iii. *"It is quite resource intensive (particularly where manikins and mock emergencies are involved), so can be quite difficult to get space on a course and can be prohibitively expensive"*

iv. *"I think SBT is grossly underutilized in undergraduate training in* (removed)*"*

v. *"Simulator training for registrars and for teams (i.e. F1 through to consultant) would be really helpful to develop skills, identify knowledge gaps and also more relevant to day-to-day working."*

vi. *"Greater access to this kind of training increases confidence and communication skills whilst avoiding the distraction of issues with time pressures/interruptions whilst on wards. Unsupervised opportunities to practice skills at any tome would also be invaluable"*

vii. *"Trainees spending time on simulators is surely more productive than writing TTOs etc. and if used effectively should increase productivity."*

viii. *"*Additionally *I believe this shortens the learning curve, especially when a procedure is practiced repeatedly in a short period if time"*

ix. *"Simulation training for surgeons should not be optional, it should be mandatory. I do not want my loved ones to be practice cases for trainees who are not competent. Surely it is safer to develop a degree of skill on simulation and then progress into real world operating? Additionally, I believe this shortens the learning curve, especially when a procedure is practiced repeatedly in a short period of time. … Again it should be mandatory in a modern surgical training program. Ideally the facilities could be better, modern computer games including online gaming are far slicker & more realistic than any surgical simulator I have been able to use."* – (ST3 or equivalent in surgery)

x. *"Needs to be aimed at the right level- with similar level fellow candidates to be useful."*

xi. *"*Currently *for many trainees they may only get one session per year - I think that this kind of stand-alone session has much less value."*

xii. *"*Wish *it was used more"*

xiii. *"Would welcome additional SBT opportunities (though can be difficult to attend if not local)"*

xiv. *"My final thought would be that I won't get my hopes up that we'll get more training like this, there just doesn't appear to be the funding, and it seems more and more that junior doctor training is being sacrificed for the sake of day-to-day patient care"*

xv. *"Well established simulator courses for F1/F2 and CMT/ACCS trainees. Little available for medical registrars."*

xvi. *"However I think to really learn from this modality, learners to be exposed to it on multiple occasions over their training."*

xvii. *"This will only work if it is one part of a structured training programme with learning objectives clearly stated."*

xviii. *"Trainers should decide what they want to teach and what is the best way to teach it. They may decide simulation can help."*

c. A number of respondents identified the utility of simulation in reinforcing behaviours in emergency scenarios and algorithm driven situations such as cardiac arrest drills;

i. *"It's particularly useful for training in algorithm based emergency management (e.g. difficult airway algorithm) so that when the practitioner encounters this for real they have done the drill many times before."*

ii. *"While working in clinical medicine I found simulation training useful for new skills and emergencies, but no substitute for adequate clinical experience."*

iii. *"I found it particularly useful in ALS and other emergency simulated sessions. I think these kind of scenarios are needed and in a way should be part of revalidation exercises as it ensures everyone keeps their knowledge up-to-date."*

2. Issues limiting the utility of SBT as it is currently offered

   a. Inconsistency in the way that simulation is delivered, including the quality of facilitation

      i. "*At my local hospital* (removed) *simulation was very specialty-dependent - the* (removed) *department run an outstanding weekly course which was just brilliant, other areas do nothing."*

      ii. *"When delivered well, in a carefully thought out scenario, with appropriate realism and equipment, in the right environment and properly debriefed. Done well, you feel immersed in a "real" situation, and the cues you pick up in real life are there, and your brain can end up believing you're doing it all for real. Badly done, it's irritating, tiresome, ineffective and has a negative impact on everyone involved. There's too much of the latter around at the moment."*

      iii. *"Simulation will be largely operator dependent Arguably it is easier to develop for acute life threatening scenarios and would not be applicable to many specialities"*

      iv. *"This has not been my experience of simulation. It has been piecemeal and generic, for example a one off session on how to manage an acutely unwell patient. You cannot practice managing every possible peri-arrest situation, even if SimMan can replicate all of them."*

v. *"Excellent if led well, a waste of time unfortunately in reality in my experience"*

vi. *"*My *final thought would be that I won't get my hopes up that we'll get more training like this, there just doesn't appear to be the funding, and it seems more and more that junior doctor training is being sacrificed for the sake of day-to-day patient care."*

b. The engagement of learners with simulation was felt to be a crucial factor in acceptance becoming more widespread, and the utility that it would bring.

  i. *"The key I think lies in people engaging correctly with it. If you can get people to treat it like a real scenario then it becomes useful but I think people are prone to dismiss it off hand, especially if they think 'human factors' aren't important. These typically are people who think more time should be spent on 'real medicine/surgery' and have little appreciation for the value of skills beyond technique/specific knowledge, and how poor their 'soft' skills actually are."*

  ii. *"is crucial, as is learner acceptance and engagement"*

  iii. *"Like any teaching process the effectiveness of simulation depends much on the enthusiasm of those training but also those learning. I have had really enthusiastic trainers who make everything enjoyable and memorable. A despondent student can bring the class down. Often, individuals may shy away from volunteering at the risk of looking incompetent and this is an important fact as these individuals are likely to benefit more. This can however, be overcome by developing rotas to ensure everyone has an attempt."*

c. Poor fidelity of the simulators at replicating real life clinical scenarios and procedures

i. *"but is still not good enough for complex technical training like ultrasound scanning"*
ii. *"I feel simulation scenarios where you are the only person available and have to do everything is very unrealistic and not always helpful"*
iii. *"I strongly feel that the training required to become competent in a particular task should be identical to, or mirror as closely as possible the actions involved in that particular task. As the technology stands at present I think that looking at real slides and virtual slides are too different for the latter to be used as a method of training for the former. I worry that simulation based training, or virtual slides, are being more and more widely used in histopathology to get around problems like distributing glass slides, without much thought being given to the quality of experience and training being offered to the person using those virtual slides."*
iv. *"*WRT *histopathology, the technology that is required for enabling simulation based training (virtual slides) to approximate the experience of seeing a real glass slide is still not readily available. Internet connection speeds are too slow and the graphics capabilities of most computers are still mostly not good enough to manipulate and instantaneously present in high definition, without pixilation, very large image files."*
v. *"Often it is a very unrealistic scenario - the pacing of it is unlike real life, and often the staff are deliberately withholding information/you can't get additional help to an extent that is just realistic. There are limitations with the realism of the dummies. Often I find that the prospect of being filmed is often worse than experiencing the same scenario in a real emergency!"*

d. Facilitation quality being inadequate

i. *"The facilitation by 2 consultants was terrible - doing scenarios was useful - but insight into how different personalities/grades interact in a team was fairly woeful. Is there any training out there - preferably by psychologists to train the trainers?"*

ii. *"and partly because the facilitators were pretty poor. So, like most training, there is probably a lot of variability."*

iii. *"*Good *feedback is crucial, as is learner acceptance and engagement"*

e. A lack of evidence for the use of simulation

i. *"it should not be thought of as the answer to all problems or rolled out without creating an evidence base."*

ii. *"Simulation seems to have massively increased over the past few years, but I am not aware of any clear evidence it has made a difference to patient safety or outcome"*

3. Positive aspects of SBT for medical training

a. One of the key themes raised as a positive aspect to SBT was the ability to practise in a safe and protected environment with no risk of patient harm, and the replicability was recognised.

i. *"It provides a safe environment for someone to reflect on their performance so that when they encounter the real thing they are better prepared."*

ii. *"We need better facilities and models, but I believe this is a fast developing area and one which will be increasingly useful in an era of 'risk free' training"*

iii. *"*I *enjoy simulation training. It is in a safe but realistic environment and provides a valuable learning experience."*

iv. *"*Greater *access to this kind of training increases confidence and communication skills whilst avoiding the distraction of issues with time pressures/interruptions whilst on wards."*

v. *“Simulation training does however enable a safe environment to practice a skill and ultimately this should then improve patient safety”*
vi. *“making mistakes when it won't harm but can be learnt from.”*
vii. *“Crucially, you can make mistakes without any adverse effects to patients. It isn't the real thing, but it’s very close, especially when the vital signs are being manipulated and people are asking you what you want to do next - I found the simulations where you as an FY1 need to make an assessment of a critically ill patient and handover to someone senior over the phone and convince them to come and see your patient when they are reluctant, to be particularly useful and a secure way of learning.”*
viii. *“Without jeopardising a patient’s life”*
ix. *“learn from mistakes and others”*
x. *“in terms of it takes away the consequences for your actions which may not be the correct ones at the time-however this is all part of the learning curve as a junior doctor”*
xi. *“As technology advances, I would urge more investment into this area as I understand it to be the only type of education available currently that resembles clinical reality. One can never entirely replicate a sick patient on the ward but this comes close to enabling the clinician to learn skills that they can translate into real clinical work.”*
xii. *“Simulation training is a very useful way to demonstrate to colleagues important skills required in a particular scenario and the potential consequences of poor execution.”*
xiii.

b. There were multiple comments regarding the utility of simulation in specific specialty applications

i. *“the paediatric department run an outstanding weekly course which was just brilliant,”*
ii. *“extremely useful in anaesthesia.”*
iii. *“Good for specific skill - suturing jig etc.”*
iv. *“In Foundation and Core Medical Training, I found simulator based training very helpful for first goes at central line insertion, arterial line insertion etc. Although not exactly like the "real" feeling you get when carrying out the procedure on a patient, it helps you feel more slick and confident of each step when you are performing the procedure on a patient”*
v. *“pivotal for Obstetrics and Gynaecology training”*
vi. *“Has a role in initial learning of procedures”*
vii. *“no use for operative simulators”*
viii. *“new skills like chest drain insertion”*
ix. *“While working in clinical medicine I found simulation training useful for new skills and emergencies, but no substitute for adequate clinical experience”*
x. *“prepare someone before undertaking the procedure on a patient”*
xi. *“It's value for teaching emergency scenarios is probably greater than that for teaching complex diagnostics of the sort needed in geriatrics.”*
xii. *“think it is useful at SHO/junior registrar level or when doing a procedure for the first time but for more experienced surgeons is of fairly limited use” –* (ST6 or above trainee)
xiii. *“In regard to more complex procedures including surgical operations, it would be more appropriate to simulate prior to performing the procedure on the patient.”*
xiv. *“I believe the role for simulation based training may be limited in histopathology”*

xv. *"Medicine is not like this. I can see that simulation would be useful in a limited number of situations in medicine, such as learning a specific procedure or improving awareness of defined human factors etc."*

xvi. *"feel sim is very important in anaesthetics and emergency specialties"*

xvii. *"I am not sure if sim has a place in cellular pathology... at least I can't think of any right now!"*

xviii. *"Simulation will be largely operator dependent Arguably it is easier to develop for acute life threatening scenarios and would not be applicable to many specialities"*

xix. *"The less practical specialties lend themselves well to simulator training."*

c. It is recognised that as well as technical skill development, human factors training, including team working and communication is also an area which SBT lends itself to.

i. *"think that simulation training is potentially extremely valuable for training specific scenarios and also exploring human factors."*

ii. *"I have found simulation most useful when concerning human and medical factors together"*

iii. *"feel simulation can be useful but in recreating the team environment.*

iv. *"Good for scenario based training and communication/ team work eg ALS/ATLS"*

v. *"They help you understand how easy it is to become focussed on one aspect of the patient's situation and how that must be avoided. If you do it a few times, you learn to take a step back."*

vi. *"Not enough focus on human factors in current training."*

vii. *"Excellent to highlight communication factors and try things for first time"*

viii. *"Much more work needs to be done in human factors training, particularly where multiple specialities are involved, and particularly in medical specialities"*

ix. *"Superior learning tool - particularly supportive of teamwork & communication processes"*

d. Finally, an increase in confidence prior to performing procedures in clinical situations was described by multiple respondents;

i. *"Excellent for building confidence"*

ii. *"that has helped build my confidence and decrease my stress as well. With new procedure, doing it in simulation first again has increased my confidence in being able to attempt it on actual patients."*

iii. *"With new procedure, doing it in simulation first again has increased my confidence in being able to attempt it on actual patients."*

iv. *"Greater access to this kind of training increases confidence and communication skills whilst avoiding the distraction of issues with time pressures/interruptions whilst on wards. Unsupervised opportunities to practice skills at any time would also be invaluable"*

v. *"It's particularly useful for training in algorithm based emergency management (e.g. difficult airway algorithm) so that when the practitioner encounters this for real they have done the drill many times before."*

vi. *"SBT can help establish correct technique and familiarity with equipment used for procedures, which should help when doing the procedure for the first time on an actual patient."*

vii. *"This is one of the most effective learning tools I have used."*

viii. *"SBT is an important tool for developing confidence in managing complex emergency medical situations"*

ix. *"Vital at increasing confidence in a procedure or at managing teams. But should not replace clinical experience on real people (nothing can replace this)"*

x. *"In Foundation and Core Medical Training, I found simulator based training very helpful for first goes at central line insertion, arterial line insertion etc. Although not exactly like the "real" feeling you get when carrying out the procedure on a patient, it helps you feel more slick and confident of each step when you are performing the procedure on a patient"*

xi. *"Done well, you feel immersed in a "real" situation, and the cues you pick up in real life are there, and your brain can end up believing you're doing it all for real."*

xii. *"allows you to be hands on,"*

xiii. *"They help you understand the things you are never taught from lectures or books (that sometimes, you have to know where things are around the room and that although you may think you are giving good instructions, in the heat of the moment, you need to learn to be clear)."*

4. Negative aspects of SBT for medical training

   a. One of the main points raised was the fidelity of simulators. Whilst this is something that is likely to improve with iteration of design, some are unconvinced that they will ever be able to replicate real life patient contact and hence are not useful. Allied to this is the concern that time spent in simulation will detract from clinical experience.

      i. "*If a trainee has first-hand operative experience of a particular procedure, subsequent simulation of the same procedure has very limited benefit."*

      ii. *"Bits of plastic do not represent how patients look and feel when they are sick - this needs to be taught in real life rather than fabricated scenarios."*

iii. *"SBT is never going to replace real clinical experience but can be a useful adjunct."*

iv. *"Never a replacement for clinical experience, so time spent in real clinical situations should not be too limited by extra simulation training."*

v. *"I don't think we should be using SBT as a replacement for real patient experience"*

vi. *"Increasing demands for service provision alongside EWTD is strongly detrimental to training and clinical experience. SBT does not remedy this and is no substitute for performing the procedures in vivo (there is a limit to how realistic SBT can be). Time spent in SBT is time not spent, for example, in theatre."*

vii. *"Body textures differ, tissue colours differ and emotional states (amongst operator and 'patient') differ. It is a substitute that should never have been invented. The amount of money spent on it can be spent more effectively on travelling to countries where medical services are limited. The developing world will benefit and experience gained by the learner would be unparalleled."*

viii. *"Plastics for example- you really need time training on real patients as there is no substitute for the handling of real, live skin"*

ix. *"A lack of time to train due to shortened number of years and EWTD should not be compensated by simulation training - these issues should be addressed directly"*

x. *"Nothing replaces real life, on-the-job training coupled with proper tutoring."*

xi. *"It is absolutely no substitute for actual operative experience in theatre"*

xii. *"Watching experienced doctors become frozen like rabbits in headlights because you have removed them the actual working environment and all the* *cues that go with it, while trying to reproduce actual clinical signs on a plastic doll, convinced me that much of simulation training is an utter waste of money brains and time."*

xiii. "time *spent on simulation MAY detract from opportunities for real experience in theatre. Only theatre time will give surgeons the skills they need, and SBT will not replace the time lost due to EWTD restrictions."*

xiv. *"SBT is detracting from clinical experience"*

5. Potential for future development
    a. The theme of revalidation was raised on a number of occasions by respondents;
        i. *"However, I don't believe it should be used as the sole training tool, nor do I believe it can accurately 'test' someone up for revalidation especially if they have not used the simulator before. This would better be measured through directly observed practice."*
        ii. *"I think these kind of scenarios are needed and in a way should be part of revalidation exercises as it ensures everyone keeps their knowledge up-to-date"*
        iii. *"Consultants should be regularly assessed using sim to ensure they are up to date with protocols and emergency management of patients"*
        iv. *"I found it particularly useful in ALS and other emergency simulated sessions. I think these kind of scenarios are needed and in a way should be part of revalidation exercises as it ensures everyone keeps their knowledge up-to-date."*
        v. "SBT *is essential in our medico-legal environment to give trainees the opportunity to "act up" to a role which they haven't previously occupied. I think "see one, do one, teach one" is going to become "see one, simulate two, do three, revalidate!"*

vi. *"Simulation training enables an objective measure of performance but this is not a measure of competence. Competence needs to be assessed over time and competence varies over time. Failure to perform a procedure can lead to loss of competency in that procedure. It would therefore not be suitable to use simulation as a measure of competence for revalidation etc."*

vii. *"but should not be used for revalidation as presently there are no robust mechanisms to ensure a sufficiently reliable, valid and re-producible assessments"*

viii. *"without the participation of sufficient numbers of highly trained individuals with sufficient insight into the procedure being assessed. who guards the guardians??"*

ix. *"Simulation for training is ok but simulated exam is the most non sense"*

b. One respondent felt that SBT should be used primarily only as a remedial tool for those practitioners identified as being in difficulty in their clinical workplaces.

   i. *"however, that should for those employee or trainees who are assessed being incompetent or required further training."*

c. The potential for improvement in simulator fidelity; and improvements in how it is deployed was described

   i. *"As technology advances, I would urge more investment into this area as I understand it to be the only type of education available currently that resembles clinical reality. One can never entirely replicate a sick patient on the ward but this comes close to enabling the clinician to learn skills that they can translate into real clinical work"*

   ii. *"I think that technological improvements and developments will make SBT more useful in the future."*

iii. *"Ideally the facilities could be better, modern computer games including online gaming are far slicker & more realistic than any surgical simulator I have been able to use."*

d. Finally, there were some comments regarding the projection for increasing use of SBT in medical training

   i. *"I would suggest that SBT will become a more and more prominent feature of medical training and practice as the years pass."*

   ii. *"Simulation training has a lot of potential,"*

   iii. *"I really think this is the future of medical education and needs to be incorporated at an earlier stage at medical school (not just from 3rd year). I would love to get involved in future."*

   iv. *"however a 1-day session per year is not nearly enough for lasting benefit"*

   v. *"would like to have more simulation training in human factor in patient safety"*

   vi. *"Wish it was used more"*

   vii. *"It think it should be used more in undergraduate and postgraduate training"*

   viii. *"SBT provides an avenue for practise and development for clinicians at all stages in their careers and can very closely resemble real life work"*

6. Miscellaneous comments

   a. Four comments referenced specifically the nature of this survey.

      i. *"Too many questions"*

      ii. *"good luck with your study"*

      iii. *"Bad questionnaire, it feels like you are looking for specific answers for your future publication"*

iv. *"I think this survey is helpful in answering some interesting questions, however, I think providing an open answer box is more suitable for the question in section"*

b. One respondent remained unsure about the nature of what is referred to as SBT.

   i. *"I don't really know what SBT is: whether it is the same as role play and using mannequins to practice clinical skills (which I am familiar with), or whether it is something else completely. SBT seems to be the new 'buzz-phrase' and is used often, but it's not clear to me whether this is a new name for an old concept or something entirely new?"*

c. Specific exemplars of good practice in delivering SBT were described. To preserve confidentiality, they have not been reproduced here.

d. Finally, this comment was not felt to fit with any of the existing coding structure, but has been presented alone as an exemplar of a detailed and considered reflection on the place that simulation occupies in medical training.

   i. *"Too often comparisons are drawn between the aircraft industry and healthcare. They are not the same. Pilots work in a highly controlled environment which lends itself to simulation. Medicine is not like this. I can see that simulation would be useful in a limited number of situations in medicine, such as learning a specific procedure or improving awareness of defined human factors etc. This will only work if it is one part of a structured training programme with learning objectives clearly stated. This has not been my experience of simulation. It has been piecemeal and generic, for example a one off session on how to manage an acutely unwell patient. You cannot practice managing every possible peri-arrest situation, even if SimMan can replicate all of them. I mention SimMan because he sums up what is wrong with simulation. He draws inevitable comparisons to an* *aircraft simulator. Knowing about the safety culture in the aircraft industry, trainers got very excited about this, and rushed out to get patient simulators with a view to copying the airlines. This was the wrong way to go about things. Simulation cannot be used in the same way by healthcare staff as it can by pilots. A simulated patient that can accurately reproduce physiology is pointless, because there are too many possible clinical scenarios to practice. Trainers should decide what they want to teach and what is the best way to teach it. They may decide simulation can help. To quote The Simpsons, "You know, a town with money's a little like the mule with a spinning wheel. No one knows how he got it, and danged if he knows how to use it!"”*

4.5 Discussion

4.5.1 Summary of results.

A total of 656 valid responses were received. From the four major regions which responses were collected from, approximately 3.81% of those invited answered. Responses were collected from all training grades and all major medical specialties. A majority of respondents had undergone simulation training in simulation scenarios, and life support, with fewer than half having procedural training or experience of simulated ward environments. There appeared to be a peak in exposure at ST2 level, with a rapid decrease by seniority, although this was not true for procedural training. The majority of respondents were unsure of the availability of simulators in their current training region, and few were able to access them. Participation in the facilitation of teaching using simulation was low (5.6-18%), and correlated weakly with experience of simulation as a learner. Respondents generally did not express an opinion on whether procedure simulators accurately replicated the real procedure, although despite this did accept the utility in the development of new skills and maintenance of existing skills. What was not experienced was exposure to realistic procedural complications.

Facilitator feedback in procedural learning was strongly felt to be useful, and simulator generated feedback was also useful although less so. The majority of respondents would consider simulation based learning for procedural skills in future.

For non-procedural skill simulation, there was agreement that the representation of real clinical practice was accurate, and that this was useful to increase human factor awareness, improve team working, leadership and communication. Again, facilitator feedback was perceived as useful, as was the use of video feedback. The majority of respondents would consider participating in this form of learning again, and considered SBME as having the potential to enhance patient safety and healthcare quality.

There was a spread of responses when considering whether procedures should be practised on a simulator in advance of real life, and strong disagreement that an operator could gain competence exclusively using simulation.

There was little agreement on whether simulation had an important role in consultant training during shortened training times, and a weakly positive response to the use of simulation for revalidation. It was not felt to detract from clinical experience or service provision. There was a strong agreement that respondents would welcome more simulation as part of their training. A majority of respondents would engage in simulation as learners (75.2%) and as teachers (60%) in the future, but fewer would for revalidation (35.8%) or as lead educators (29.6%).

The predominant themes were of curriculum integration, the perceived strengths and weaknesses of SBME, including delivery and inconsistency issues as well as technical and fidelity limitations of the technique as currently offered, albeit with potential for development.

4.5.2 Response rates

Response rates to the survey were disappointing, but did reach the numbers required to be a representative sample of the population being surveyed. In one meta-analysis, the mean response rate to online surveys was 39.6% (SD 19.6%) of the target population, although this was not exclusively based on surveys delivered to physicians (221). Studies have demonstrated that the offer of an incentive for survey completion significantly increases response rate, and that higher incentives result in greater completion rates (222). Furthermore, survey length and completion reminders also play a part in the response rate(223,224), and there is some evidence to suggest that response rates to surveys are declining overall (225,226).

At the request of the ethics committee, a single invitation only was sent to potential participants. A reminder may have increased response rates. No offer of incentive was provided, which is widely thought to be unethical and expensive. It was therefore unfeasible within the constraints of the study to offer an incentive to all participants. The offer of entry into a prize draw on completion has been associated with modest improvements in response rates at best, and requires additional complexity in terms of ensuring fairness and data collection from respondents in order to administer (227,228).

One postgraduate dean declined to distribute the survey to trainees, citing the volume of such requests received by the deanery for distribution to trainees, and no response was received from 14 deans, after both an initial and a follow up request. Since the publication of the majority of the studies above, advances and accessibility of web-based technology has dramatically increased, which may be having the opposite of the desired effect by flooding people with requests for survey completion.

4.5.3 Representation

Respondents from all training and non-consultant grades and specialties were obtained, although there may be over-representation of the medical and surgical specialties. No data is available on the numbers of trainees per specialty in the regions either from the GMC or the Royal Colleges and Deaneries, however good representation by grade is seen.

The results demonstrate a varying penetration into training of simulation by modality. The majority will have undergone simulated scenarios and life support courses using SBME methods as a teaching strategy, however there is far less penetration of procedural skill training, and uptake of unsupervised skills training is low. The relatively low proportion of respondents who reported undergoing life support simulation training was somewhat surprising as it is a requirement that all trainees attend a life support course. This may have been a reflection of the phrasing and explanation of the question; respondents may not have registered the well-established life support courses as using simulation methodology, or may have assumed the question was phrased to enquire about their current role rather than cumulative experience. There is also a much lower rate of experience of simulated ward experience. This appears to be grade dependent, with 92% of FY1 doctors having undergone simulation scenarios (possibly at undergraduate level), but only 72.5% at ST6+ level. A similar pattern is seen for experience of simulated ward environments. Conversely, experience of simulated procedural training appears to increase with seniority, from 14.8% at FY1 level to 44.2% at ST6+. Exposure to the different types of courses available appears to peak at ST2 level. This is an interesting finding, and likely reflects the increased focus on simulation in recent years. Many of the current generation of ST2 doctors are likely to have graduated in around 2011, around the time of the beginning of the expansion of simulation heralded by the chief medical officer. A single department study in 2005 demonstrated that the most junior trainees had had a significantly greater experience of simulation than more senior staff, both in terms of the number who had undergone simulation training, and the number of exposures(229). Unless there is a drop off in what is offered, it is anticipated that as those juniors continue to progress upwards in their careers, and those following experience the same level of simulation, these numbers will increase.

4.5.4 Simulator availability

Awareness of the availability of simulation equipment was variable. The ASPiH national simulation scoping project revealed that the majority of regions have access to a simulation centre, with 87 in the UK. In this study, 77% of hospitals had a manikin simulator, although nursing staff were found to be the biggest users of these. Advanced procedural trainers (including virtual reality) were present in 31% of hospitals, and were the least used resources (127). A similar survey of simulation providers by the Association of American Medical Colleges (AAMC) demonstrated that for postgraduate trainees, internal medicine, surgery, paediatrics, emergency medicine and anaesthetics were the biggest users of simulation (230). In the results from the present study, low numbers of trainees reported having the opportunity to access the simulators which are available. For procedural skill simulators, 41.1% were unsure whether the opportunity for free practice was available, 24.6% did not think it was, and only 6.7% did report the opportunity to access these resources. This was somewhat improved for the simulators during formal skills courses, with 18% of trainees reporting availability to them. This is borne out by the 22.9% of respondents who reported having had experience of supervised procedural training previously, with a correlation with increasing seniority, which has been demonstrated in another study which found increasing exposure to simulation with increasing seniority, although a mismatch between what trainees wanted and what their supervisors perceived they needed (231). The AAMC study demonstrated a drop-off in simulation use with increasing seniority, albeit with much greater initial levels of participation from baseline, and for senior physicians, 43/64 hospitals reported delivering simulation activity. It is also interesting to note the fact that 59% of simulation facilities were located in central locations but that high levels of participation were maintained (230).

4.5.5 Access to simulation

There was a positive response to the question of whether respondents would welcome more simulation training in their specialty, with 76.6% responding positively to this and 75.2% reporting that they would engage with simulation in their future training. The analysis of the qualitative data raised the theme of access to simulators as a problem. These results do suggest that there is an access problem to simulators. Possible reasons for this which were raised by respondents include time and resource constraints on the trainees themselves; simulation activity frequently occurring as part of oversubscribed and expensive formal taught courses and the pressures of clinical work, and this has been suggested by previous studies as being a common barrier to greater use of the technique (229,232). There were also reasons related to the provision and location of simulators, and awareness of their availability. It may be that when housed in centrally located simulation centres, they are less visible and trainees and their trainers are less likely to utilise them on an opportunistic basis. The provision of faculty able to deliver simulation is a recurrent problem; by its nature, delivering simulation is a resource intensive exercise with pressure on facilitator numbers. This is highlighted in the ASPiH study, with a recommendation that lead clinicians for simulation are identified in each area(127). In the present study, the majority respondents had no experience of facilitation using SBME. There was a weak correlation between personal experience of this method of learning and going on to deliver it. Sixty percent of respondents however did express plans to become involved in delivering teaching using SBME in the future, with 29.6% as the lead for developing courses. Acquisition of the equipment is not sufficient to deliver SBME to all of those who wish it. Poor facilitation was highlighted in the qualitative data. There were a number of comments which referenced variable quality facilitation and in particular the leadership of courses as an important factor in the educational value derived from the experience, which has also been previously demonstrated(233,234). A stressful or intimidating environment was cited in a previous study as being a deterrent to participation as a learner(235). This presents a problem; if skilled faculty numbers are lacking, there will be impetus to make it as easy as possible for those demonstrating an interest to engage as teachers, without compromising the learning experience for learners. Initiatives such as Train the Trainers courses and the use of co-facilitation between experienced and novice faculty as well as more detailed fellowship programmes and postgraduate courses specific to SBME delivery have started to open up(236,237). Additionally, projects such as the Health Education England Technology Enhanced Learning Hub, and the ASPiH national simulation standards project may help to offer some standardisation and minimum quality assurances to learners for what is offered. A similar situation is seen in the USA, where the Society for Simulation in Healthcare offer accreditation for educators and organisations delivering SBME. The number of respondents who expressed an interest in getting involved in teaching using simulation in the future is an encouraging finding, although there is of course no guarantee that this will translate into action. Far fewer would contemplate leading on the development of courses although 202 is higher than expected. At present, the provision to capture and encourage interested trainees to engage and develop their facilitation skills is patchy and opportunistic, although some models of good practice are seen with the Resuscitation Council UK Advanced Life Support course faculty replenishment scheme being an example of a standardised and structured method of attracting new teachers. As new generations of trainees progress through training with simulation components embedded, there will be greater opportunities to recruit future generations of simulation educators.

4.5.6 Procedural skills training

Those who had had procedural skills training were asked about their experiences. There was a trend towards agreement that the simulation represented the real-life procedure accurately, although one of the major themes to arise from the qualitative data was the unrealistic nature of the simulators experienced. It may be that only those who have had negative experiences in the past were motivated to comment on this issue. What is interesting however is that the fidelity of the experience does not appear to have limited the utility of the technique. There was stronger consensus of the utility of simulation in learning a new procedural skill, and maintaining skills in procedures already familiar. There was also the question of whether learners were exposed to realistic procedural complications. One of the key strengths proposed for simulation is the lack of potential patient harm that can occur. There is evidence that simulation can accelerate the early part of the procedure learning curve, and that inexperienced operators are those most likely to experience complications. Both causing the complication, and acquiring the skills required to respond appropriately would therefore seem to be an important role for simulation to play which we may not be achieving. The fact that this survey was responded to by trainees may however be a biasing factor in this interpretation; by definition experienced operators will be best placed to define the realism of complications. There was good agreement that feedback from trainers was considered useful, but no overall agreement on feedback delivered automatically by the simulators themselves. There is evidence that unsupervised practice in simulation may not be a useful exercise in itself, and that debrief is required as an integral component(88). Whilst automatically generated metrics such as procedure time may be considered a form of automated debrief to stimulate reflection in the learner, these results would suggest that this is no substitute for personalised feedback and facilitated debrief (74,238). Assessment has been demonstrated to drive learning, and the presence of a trainer is a potential stimulant to the trainee in this regard independently of the educational method being used. Overall, there was reasonably strong agreement that trainees would consider this mode of procedural learning in the future. This is supported by previous studies in surgical trainees, and recommendations that simulation should be integrated into curricula for those training in practical specialties(239–242).

4.5.7 Simulated scenarios

In respect of scenario simulation, there was a greater agreement that the simulation reflected the reality of clinical practice than for procedures. As described above however, these results must be interpreted with some caution as the demographics of those who had undergone scenario simulation differ from those who had had procedure simulation training. There was a strong agreement that the simulation led to an increased awareness of human factors, and that this helped with developing effective team working skills, leadership and communication. This has also been demonstrated in observed behaviours in those undergoing simulation training(243–246). These are all areas where there is some evidence to support the use of simulation. As with procedural skill simulation, there was a strong agreement that feedback from facilitators was useful, and that also where used video feedback was a useful component of debriefing(74). There is no clear evidence that video assisted debriefing is a useful adjunct in simulation, and in some scenarios, it may actually be detrimental. No further questions were asked on this occasion regarding the circumstances in which the video debriefing was used, and whether it was used indiscriminately or selectively as this was not the primary focus of the study however this does add some support to those who choose to employ video recording and playback as a component of their debriefing that it is well received and perceived useful by learners(59,109,247).

4.5.8 General attitudes to simulation

The final series of questions were aimed at exploring perceptions on the utility of SBME in the context of training. There was a strong agreement that SBME in training has the potential to improve patient safety and healthcare quality. Whilst there are a number of studies limited to specific scenarios which do demonstrate improvements in patient safety following simulation training interventions, it is interesting to note the seemingly widespread perception amongst trainees that there is a real role for SBME to play in safety and quality improvement. In the qualitative analysis, there were a few comments related to a lack of evidence of benefit. There may be bias in the results in so far as those who volunteered to respond to a survey on the topic of simulation are likely those aware of it, and perhaps more likely to hold strong opinions on the topic (either positive or negative). Interestingly, a survey of neurosurgical programme directors also supported increased use of simulation in training, with the perception that patient outcomes could be improved by this(248). Despite the safety and quality potential however, there was a wide spread of response on the subject of whether procedures should be first practiced in simulation before being performed on patients. The issues of access to simulation which arose as themes in the qualitative data may be important here; if it were mandated that all procedures should be practised for the first time on a simulator (as was advocated by the chief medical officer in 2009(9)) then adequate and convenient access to this training will be required alongside, as described by Zausig et al(249). In a study published in 2006, a division was seen between the opinions of junior and senior surgical residents on this point, with 75% of juniors but only 13% of seniors in agreement that skills should be first practised in simulation. In that study, uptake of the technique was significantly higher amongst the junior residents(250). The concept of using simulation as an adjunct to learning in clinical settings was a major theme in the responses, which is aligned with the strong agreement that simulation training alone could not lead to competence. When considered in isolation, simulation is a technique to prepare professionals for clinical practice, and considering any one component of the training in isolation is unlikely to be helpful, and the responses in the present study on the question of whether an operator could attain competence in a procedure through simulation alone were empathetically against this. This suggests that the place for simulation should be integrated into comprehensive curricula(251). There is some evidence however to suggest that it may have a role in replacing some aspects such as taught lectures, or even some of the time spent in clinical care (252,253).

4.5.9 Training the next generation of consultants and general practitioners

There was a wide spread of opinion on whether simulation would be useful in training the next generation of consultant level practitioners, and as a tool to evaluate competency for revalidation. This is a topic which requires further exploration, as there are elements of assessment and the robustness of the measurements we make in simulation which have not been explored here, although alluded to in a few comments and other work(90,103,254–256). There may be a number of reasons for this, but some suggested by respondents include the abstraction of simulations from real life, which may be a representation of the level of fidelity which we can achieve currently, or the willingness to suspend disbelief amongst those undergoing simulation. Any form of summative assessment will modify the behaviour of the learner, and abstraction to an unfamiliar environment or working practices may amplify this (257). This is consistent with a previous study of anaesthetists, who were in favour of the use of simulation for training, but not for use in reaccreditation(258). It is interesting to note however that in the AAMC survey, overall 61% of hospitals reported using simulation as an assessment tool, albeit only 18% in validation or certification. Whether the consultant training cannot be envisaged as a result of perceived logistical inadequacies in the delivery of simulation, or a more fundamental issue of the level at which we are able to train being too basic using current techniques for consultant level practice is another area which requires further exploration, but again the AAMC study reports that it is in widespread use in the USA(230).

On the subject of whether time spent in simulation would detract from gaining clinical experience, there was a trend towards disagreement with this sentiment, and similarly that it could negatively impact upon service provision requirements. The European Working Time Directive has now been in place for a number of years, and whilst there were previously concerns about time for training and patient care as a results of this, the cohort responding may now have adjusted to the new working practices(12,259,260). Many of those leaving comments described a paucity in provision, or difficulty in arranging time away to attend simulation events. Some described the experiences they had had as a much more useful exercise than routine clinical tasks, reflecting the ability of the scenario designer to distil key learning objectives into scenarios and deliver a more predictable experience. This is especially important when considering uncommonly encountered situations and infrequently performed procedures, as has also been described elsewhere in the literature(261). There was a strongly positive response welcoming more simulation training from the majority of respondents, and this would place the onus on educators and employers to manage the availability of simulation and working schedules to ensure adequate access to this type of training without jeopardising patient care. One small study in 2007 found similar barriers to access to simulation as have been demonstrated in the present study, and that simply making simulators accessible for voluntary participation did not lead to a high uptake, with the recommendation that if it is to be effective, participation should be mandatory(172).

4.5.10 Themes from the survey

The key themes to emerge in the qualitative data which were not directly related to earlier questions with those of simulation being most useful as an adjunct to help increase confidence, particularly in situations and procedures where opportunities for real-life practice are rare. This is in keeping with multiple other studies on the utility of simulation(262,263). A safe and supportive environment in which to practice and gain feedback on performance seems to be key here. The variability of what is offered both in terms of provision, who it is aimed at and offered to and the quality of simulation was a key theme. There were also many who felt that simulation was limited by the fidelity offered by current technologies, but there was a degree of optimism regarding the potential for this to improve in the future. In a small 2001 study, only 30% of learners described the simulation manikin used as offering a realistic experience, and 38% of educators agreed. Whilst the present study is not directly comparable, 351/473 (74%) respondents descried their experience as an accurate representation of real clinical practice, which may suggest that fidelity has improved over this period(264). Duran et al (265) in a survey of 326 surgical trainees found that 86% believed in the educational value of simulation, although this was focussed primarily on the acquisition of technical skills for a specific group. They have concluded that integration into the formal training curriculum is required in order to fully realise the potential benefits that it has to offer.

4.5.11 Final conclusions

These results demonstrated that a majority of trainees have previously had the opportunity to participate in simulation during their careers, and that there was considerable variation regionally as well as across specialties and grades in the provision and access. Those in the more junior stages of their career have had more opportunity to engage, which may be a reflection of the increasing use of the technique. Those that have engaged with SBME largely would be interested in this form of education again, although the quality of facilitation is an important theme. Few have themselves engaged as facilitators, although the majority would consider this. There is a perception that SBME has the potential to enhance healthcare quality and patient safety, but that it should be considered an adjunct to clinical training rather than a replacement. These findings were consistent across grades and specialties.

Equity of access and integration with the curriculum were key areas which are important to trainees, and if opportunities are limited by resource or time, it is imperative that what is delivered is relevant and well facilitated. This should be co-ordinated to ensure that the maximum benefit is achieved from the facilities which are available.

5 Discussion and conclusions

5.1 Summary of results

Three studies have been conducted, examining different aspects of SBME, and its context within contemporary postgraduate medical training.

Use of a single session teaching course in temporary transvenous pacemaker implantation resulted in a significant increase in confidence amongst novice operators with regards to this skill. There was some decay in this confidence over time, but values remained above baseline at 140 days after attendance. Practical assessment demonstrated that successful wire placement was achieved in only 60% of cases before the course, but in 100% of cases afterwards although both total procedure and radiation times for the procedure increased considerably in the post course evaluation.

Use of an entirely online simulation programme when compared to a more traditional tutorial based approach to ECG interpretation demonstrated no significant difference in the effectiveness of either approach in teaching the skill of ECG interpretation. Both methods of teaching were well received by the recipients, and contributed to a self-reported increase in confidence in ECG interpretation.

A survey of 656 postgraduate medical trainees in the UK demonstrated that a majority had undergone SBME in some form, but that many were unaware of what facilities were available to them in their current training regions. Participation in teaching roles using SBME was low. SBME was generally perceived to be useful for both procedural skills training and for practising clinical scenarios, but this was not universal and several barriers were identified with regards to access and increased adoption, including curriculum integration and inconsistent experience.

If a single message is to be taken from these three studies, it is that SBME for medical trainees provides a potentially valuable adjunct to training curricula, but that there are barriers to wider deployment which need to be addressed.

5.2 The effectiveness of SBME as a tool for training healthcare professionals

In the first two studies presented, one demonstrated no significant difference between the technique and a more traditional and already well established model in improving knowledge, whilst the other demonstrated an increased in self-reported confidence but less clear objective measurements of increased technical ability. Returning to the Kirkpatrick hierarchy model of evaluation, we can conclude that there is a positive effect in terms of learner reaction, and that there does appear to be a positive effect on learning, but that we cannot evaluate the effect on behaviour or outcomes based on these data. Numerous other studies have examined these aspects, and many are able to demonstrate the potential for SBME to effect a change in behaviour such as improved operative performance or compliance with protocols. This has been demonstrated both using the surrogate of performance in simulation, and in real world clinical practice such as expert-observed procedural competence and adherence to protocol in emergency care. These studies have been conducted across a number of fields including catheter based and surgical procedures, resuscitation and emergency clinical scenarios. In addition, there is ample supporting evidence of the potential for improvement in knowledge as a result of SBME and many studies have demonstrated a positive reaction, with affinity for the technique and an improvement in confidence.

There are fewer studies which have demonstrated an improvement in clinical outcomes, i.e. at a patient rather than practitioner level. The evidence that they contribute in demonstrating improved outcomes for patients is persuasive but may not be generalizable to all areas of clinical practice given the methodologies used. Table 20 below summarises some of the landmark studies which have been conducted in simulation which have demonstrated explicit change in patient outcomes attributed directly to the use of simulation. There are potential confounding factors in a number of these studies, such as the Barsuk study using a different patient demographic between the control and intervention arms (medical vs surgical ICU patients), the Theilen study evaluating two concurrent interventions (the formation of an in hospital emergency response team and a simulation programme to accompany it simultaneously), and the cholecystectomy studies using expert-evaluated complications such as liver injury and burning non-target tissue which may not correlate with final clinical outcomes for these patients.

Lead Author	Year published	Study design	Area of focus	Control	Simulation intervention	Outcome	Significance	Reference
Barsuk	2009	Cohort control	Central venous catheter insertion	Lecture and conventional training	Mastery learning (approx. 4 hours)	Reduction in catheter related blood stream infection	P<0.001	(168)
Seymour	2002	RCT	Laparoscopic cholecystectomy	Conventional training	Mastery learning (approx. 1 hour)	Expert assessed procedural complications (including gallbladder injury, liver injury, burning nontarget tissue)	P<0.006	(266)
Draycott	2008	Pre/post training retrospective observational study	Shoulder dystocia in childbirth	Conventional training	Single, 30-minute practical session on a manikin as part of a one-day course	Reduction in incidence of neonatal injury and brachial plexus injury	Relative risk 0.25 for neonatal injury, 0.31 for brachial plexus injury	(267)
Stewart	1984	Non-randomised controlled trial	Prehospital intubation amongst paramedics	Didactic teaching plus simulation plus observed practice vs didactic teaching plus simulation	Some received manikin training plus animal laboratory training, others manikin only	Successful intubation and complications	No significant difference (r^2 = 0.143)	(268)

Ahlberg	2007	Case control study	Laparoscopic cholecystectomy	Simulation vs traditional training	Mastery learning across a series of proficiencies up to 56 hours in total	Expert assessed procedural complications (including gallbladder injury, liver injury, burning nontarget tissue)	P<0.04	(170)
Siassakos	2009	Retrospective cohort study	Umbilical cord prolapse	Conventional training	Single simulation scenario within a day long obstetric emergency course	Time from diagnosis to delivery	P<0.001	(269)
Theilen	2013	Retrospective cohort study	Recognition of the deteriorating child in hospital	Conventional training	All staff attending 4-10 simulations of acutely unwell children (and formation of an emergency response team)	Time to ICU admission, consultant review and length of stay, mortality	P<0.01 for all	(270)

Table 20 Studies demonstrating change in patient outcomes

To return to the comparison of the use of aircraft simulators for aviation safety, the obvious analogy is to evaluate the impact of simulation training using adverse incidents (e.g. air crashes or near misses) as the outcome marker. It is accepted that an increase in pilot skill and ability to respond to unforeseen circumstance is sufficient evidence to justify the incorporation of simulation into routine aircrew training, although there is no explicit outcome data available. What is less well accepted is whether an increase in individual or team healthcare professional skill will result in a reduction in adverse patient events. There are many potential confounding factors and other interacting variables in either scenario which serve to make such studies difficult to conduct and interpret. Air crashes are fortunately uncommon events which may arise as a result of a large number of triggers. Similarly, adverse events in patient care may be as a result of factors intrinsic to the patient and their disease, the contribution of a large number of staff involved in their care and the system in which they are treated. Biomedical trials typically recruit selected patients with a clearly defined problem and attempt to control rigorously for confounding factors in order to arrive at an estimate of the effect of a specific intervention and the probability of the significance of that effect. Whether this is feasible at a level of randomising patients to be treated by groups of healthcare staff trained in different ways, and whether it is ethical to do so if we are able to demonstrate an increase in the skill of those professionals is questionable. Evaluation of the outcome data from the introduction of the World Health Organisation surgical safety checklist required the analysis of surgical outcomes for 7688 patients in order to detect an absolute reduction in mortality of 0.7% and complications of 4%(271). Considering the cost and logistical challenges of implementing and running studies such as the ones presented in this thesis for far more modest numbers, such an undertaking would be considerable in its resource use.

From the survey conducted, several of those who responded who cited a lack of evidence for the effectiveness of SBME as reasons for either non-engagement or a lack of desire to do so in the future. Whether this is a result of these individuals appraising the literature for themselves and arriving at this conclusion is unclear, but it may be that large-scale trials demonstrating a significant improvement in patient outcome would be sufficient to alter the opinions of these respondents. What was not evaluated is whether the demonstration of increased professional competence would suffice. Undoubtedly, it is plausible to link a technique which has the potential to significantly improve the skill of procedural operators, or the performance of tasks by staff responding to emergency situations with improved outcomes but not explicit. Even the introduction of whole scale SBME for a group, with prospective collection of outcome data may be confounded by concurrent advances in medical technologies, system design and scientific knowledge.

5.3 How should we deliver SBME for postgraduate medical training?

SBME represents a technique to deliver education, which is expanding in scope and capability. Even if we accept that it does have utility in increasing the competence of professionals, this should not be accepted as a universal truth and used to justify its inclusion in all areas. Poorly run SBME is unlikely to achieve the intended aims, and a number of those who responded to the study described episodes where facilitation or the application of the simulation was inadequate and hence did not lead to an effective learning experience. As demonstrated in the ECG simulation study, other education techniques may be equally effective, or even superior to SBME, and whilst the capability of the technologies available is impressive, there will still be areas where the fidelity is inadequate at present.

One clear theme which arose from the survey is that SBME should be applied as integrated into training curricula. Indeed, this is one of the key recommendations from a comprehensive systematic review of the features of simulations which lead to effective learning(57). Whilst this should be one of the key factors considered from the outset of designing any educational programme, there is a sense that many of the interventions currently employed are driven more by the availability of equipment and staff skill. A visit to the exhibition area of any simulation conference will demonstrate the wide potential available, and the technical capabilities of the equipment but this may lead to unfocussed or patchy delivery not driven by learning needs. Regional variations in provision and accessibility have been raised as a concern in a report by the National Simulation Development Project, which is mirrored in the findings of the survey conducted for this work(127). These variations in what is available may be on a regional level, or a more localised scale including between nearby hospitals and even between departments and staff groups within the same institution. If we are to recommend the incorporation of SBME routinely into postgraduate medical training curricula, we must be able to provide this with equity. The SBME offered should be relevant to the curricula in which trainees are operating, and the curricula themselves should reflect this opportunity.

5.4 Augmentation or replacement of clinical opportunities and other educational activities

These studies have demonstrated that simulation is well received by learners, and that a majority will engage with the process, but that as it is presently offered, should not be considered as a valid replacement for clinical experience but rather as an augmentation. This may be particularly relevant for novices to acquire new skill during the early part of the learning curve when complication rates are at their highest, or for uncommonly encountered situations. Typically, SBME is considered to be a resource-intensive exercise in terms of faculty, equipment and cost. The ECG simulation exercise was an interesting exploration of whether in certain areas it could actually reduce the level of faculty time investment required although it is more likely that in reality it would be most useful as an augmentation rather than replacement. Additionally, the financial cost of deploying the final product may be considerable and potentially prohibitive if it does not result in savings from instructor time.

I have been involved in a number of projects concerning the deployment of SBME on a wide scale to trainees, including sitting on committees which aim to target these to areas of educational need.

One such project which has now been running successfully for four years is the provision of a two-day introductory simulation course in practical procedures to those commencing Cardiology training at ST3 level. This comprises mentored sessions with 1:1 facilitation for angiography, pacing, central venous and arterial access and pericardiocentesis. Others include a more basic practical procedures course for Foundation trainees, an emergency scenarios course for Core Medical Trainees and *in situ* simulation sessions in a number of clinical units. All of these share a number of features in common; they have been very well received by the trainees and have generated positive feedback but are time consuming to run, require complex logistical arrangements and large numbers of faculty.

5.5 Time for training

One of the most important challenges encountered in conducting this research, and indeed in running other simulation programmes has been the availability of trainee doctors. We frequently struggled to fill sessions, or faced attendees dropping out at the last minute as a result of working patterns, staff shortages or unforeseen clinical pressures. This is especially true of running *in situ* sessions in clinical environments which require staff and facility availability. There is concern that moderation of working hours has led to a reduction in overall training time and may lead to deficiencies in competence(45,272,273). Simulation, especially that which is associated with a high transfer effectiveness ratio would seem to be an ideal solution to this problem; concentrating experience and allowing the trainee to maximise the use of their clinical time as a result(274). The reality, however is that as a result of compressed working hours and the requirement to provide medical cover to services, trainees find it challenging to access such training opportunities(275,276). Given the reported variability in the quality of the experiences and the other pressures on trainees such as the completion of postgraduate exams and participation in audit and research, it is unsurprising that participation is not always afforded the highest priority by trainees. If simulation continues to be considered a desirable addition rather than delivered as a core component of training curricula, with appropriate assurances of quality attached then this is a situation which may not change.

5.6 Further work

Designing and conducting studies to evaluate the impact on patient outcomes for the use of simulation should be the aim of the global simulation research community. On a more modest scale, further exploration into the use of a mastery learning approach to the teaching of TPW implantation is planned, developing and validating a series of competencies to achieve for the procedure. An evaluation of the use of a blended learning approach to ECG interpretation skills is also planned, using the web-based simulation as a platform to deliver synchronous tutorial sessions as part of a more comprehensive curriculum.

5.7 Conclusion

There is a growing body of evidence that SBME has the potential, when appropriately applied and delivered, to increase the knowledge and both technical and non-technical skills of healthcare professionals. Whether this translates to an improvement in patient outcomes is less clear from the currently available evidence, and is a challenging phenomenon to study. If we accept that an increase in skill is acceptable evidence to recommend the adoption of simulation, further planning and curriculum integration will be required to deliver this most effectively, ensuring the quality of what is delivered and ability of trainees to access this when they need to. Inevitably, the technology behind the simulators will continue to improve, and techniques will advance in enhancing the fidelity which can be delivered but unless this is associated with more systematic integration into training, its adoption may be limited. The following quote, taken from one of the respondents to the survey is a useful summary of the present situation.

"This will only work if it is one part of a structured training programme with learning objectives clearly stated. This has not been my experience of simulation. It has been piecemeal and generic… To quote The Simpsons, "You know, a town with money's a little like the mule with a spinning wheel. No one knows how he got it, and danged if he knows how to use it!"

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Appendices

Appendix 2.1 – Ethics committee approval

The University Of Sheffield.

The Medical School.

29 April 2013

Dr Jivendra Gosai
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Dear Dr Gosai

PROJECT TITLE: 'Simulation Based Training in Temporary Pacemaker Insersion – SMBRER264

I am pleased to inform you that on 26 April 2013 the School's Ethics Reviewers **approved** the above-named project on ethics grounds, on the basis that you will adhere to and use the following documents that you submitted for ethics review:

i) Ethics application form [approved – 26 April 2013]
ii) Protocol [approved – 26 April 2013]
iii) Candidate Invitation Letter [approved – 26 April 2013]
iv) TPSim Pre Course [approved – 26 April 2013]
v) TPSim Post Course [approved – 26 April 2013]
vi) TPSim Candidate [approved – 26 April 2013]
vii) Consent Form [approved – 26 April 2013]

However the Lead Reviewer has asked that you correct the spelling of 'simulation' in the candidate information.

If during the course of the project you need to deviate from the above-approved documents please inform me. The written approval of the School's Ethics Review Panel will be required for significant deviations from or significant changes to the above-approved documents. If you decide to terminate the project prematurely please inform me.

Yours sincerely

Jean Lazenby
School Research Ethics Administrator

Enc

Appendix 2.2 – Pre course questionnaire

Centre Number:

Study Number:

CANDIDATE PRE COURSE QUESTIONNAIRE

Title of Project: Simulation of Temporary (Transvenous) Pacemaker Insertion

Name of Researcher: **Dr Jivendra Gosai**

Please spend 5 minutes answering the following questions

Have you ever inserted a pacing wire (as first operator)?

Yes No

If so, approximately how many have you performed (as first operator)?

1-4 5-9 10-14 15-20 >20

How long ago (in months) was the last time you performed this procedure?

<1 <6 <12 >12

If you have never performed this procedure, have you watched one being done?

Yes No

On a scale of 1-5 where 1=not at all confident and 5= very confident please rate the following

U/C = Unable to comment

	1	2	3	4	5	U/C
I would be able to insert a TPW unsupervised						
I would attempt this procedure in an emergency						
I could identify immediate complications						
I could deal with immediate complications						
Most current consultant physicians could perform this procedure						

If I were to call for help for/during a temporary pacing, I would ask

Consultant General Physician   Cardiology Registrar/Consultant   Other

Thank you

Appendix 2.3 – Post course questionnaire

Study: Simulation of Temporary (Transvenous) Pacemaker Insertion

Please spend 5 minutes answering the following questions

Did you find this training course useful?

Yes No

Did you find this course enjoyable?

Yes No

On a scale of 1-5 where 1=not at all and 5=extremely, how accurate do you feel this simulation was?

1 2 3 4 5 U/C

Would you recommend this course to a colleague?

Yes No

On a scale of 1-5 where 1=not at all confident and 5= very confident please rate the following

U/C = Unable to comment

	1	2	3	4	5	U/C
I would be able to insert a TPW unsupervised						
I would attempt this procedure in an emergency						
I could identify immediate complications						
I could deal with immediate complications						

Any comments?

Thank you

Appendix 2.4 – Follow up questionnaire

Study: Simulation of Temporary (Transvenous) Pacemaker Insertion

Please spend 5 minutes answering the following questions

Please enter your identifier

Since the course, have you inserted a pacing wire?

Yes, unsupervised Yes, as first operator supervised Yes, as second operator No

Have you seen one inserted since the course?

Yes, more than one Yes, one No

Have you had any patients where a TPW might have been indicated?

Yes, more than once Yes, once No

If Yes, how was the patient treated (please select all that apply)?

Chronotropic drugs (atropine, isoprenaline, dopamine, adrenaline etc.)

Transcutaneous pacing

TPW implanted locally

Transfer to another centre for TPW

Reversal agents (digibind, glucagon etc.)

Supportive therapy

Permanent pacemaker implant

No specific treatment

Other (please specify)

Please rate your confidence in the following related to how you feel about the skill NOW

U/C = Unable to comment

	1 Not at all confident	2	3	4	5 Very confident	U/C
I would be able to insert a TPW unsupervised						

I would attempt this procedure in an emergency						
I could identify immediate complications						
I could deal with immediate complications						

Are you on the A(I)M or G(I)M curriculum, or both?

A(I)M

G(I)M

Both

Neither

Do you expect to have TPW insertion signed off as a competence by CCT?

Yes, competent to perform the procedure unsupervised and deal with complications

Yes, able to perform the procedure with limited supervision/assistance

Yes, able to perform the procedure under direct supervision/assistance

No

Any further comments or remarks you would like to raise regarding?

This research

The course/training and simulator

Temporary pacing and your training

Anything else

Many thanks. For any other queries, please contact j.n.gosai@sheffield.ac.uk

Appendix 2.5 – Pacing experience questionnaire

Centre Number:

Study Number:

ONLINE QUESTIONNAIRE

Title of Project: Simulation of Temporary (Transvenous) Pacemaker Insertion

Name of Researcher: **Dr Jivendra Gosai**

Have you recently found yourself in the position where you would have considered the use of a temporary transvenous pacemaker?

Yes No

How long ago was this?

<24h <3 days <1 week <1 month >1 month

Was a pacing wire inserted?

Yes No

If so, by whom

Me Medical Consultant Cardiologist (Cons or SpR) Other

Was the indication

Bradycardia Tachyarrhythmia Prophylactic Other

Was transcutaneous pacing used?

Yes No

Were drugs (atropine, isoprenaline, glucagon etc.) used to attempt to treat bradycardia?

If a wire was inserted, were there any complications?

Yes (please specify overleaf) No

Was the patient transferred?

Yes (in same hospital) Yes (inter-hospital) No

Thank You

Appendix 2.6 – Comments on the course

Post Course

Very useful course. It will be useful having a pacing box during the course. Also to include a small booklet, mainly with regards to the indications/complications and the desirable number that needed for setting the pacing.

Dr. **** was very patient with us. This course has helped me gain confidence. Good interactive teaching session. Approachable, good teaching skills.

Despite being a half day, it is the most useful simulation based educational day I've been to. The presentation was excellent; facilitator was a perfect teacher - great ability to transmit knowledge. Level appropriate for MI/GIM SpRs. The Angiomentor was highest fidelity and the demonstration of the technique was thorough. This course makes sense. PW is unfortunately a procedure that we DO NOT have opportunity to practice in the real world. Son on this occasion sim courses are useful. Great course. Enough time and support within the course to practise. Thanks

Useful have not done a TPW before. Would be more confident to do one with some supervision.

Very useful course. Feel more confident of doing temporary pacing at emergency situations

Excellent. Really helpful. Just one suggestion, would be better if had a pacing box just to see the complete instrumental connections.

Great course. Would recommend to new GIM SpRs/CT2s

A real pacing wire to look at would be good. Very good course and very appropriate.

Very useful course. Lot of chances to practice.

Excellent experience. Made temporary pacing much less daunting & excellent delivery of theoretical component.

Loved the course. It was excellent. The lecture was concise and very informative. Loved it.

Very useful. Good instructors - both of them

Hope this course will be very useful in real life

Very good course. Would benefit from access training as well.

More confident to gain experience with supervision. Aware of complications and who to call for help. Thank you

Could also attempt to use the TPW inserted to capture, identify the threshold and leave pacing

Follow up survey

Little chance to do it yourself if not cardiologist training.

In circumstances in clinical practice the ability to insert temporary pacing skill could be so vital for medical registrars. This course offers this great opportunity to equip oneself as a competent medical registrar

The course is excellent for those of us who work in a tertiary centre and have limited experience with inserting temporary pacemakers, most of us will be expected to then work in district general hospitals where expectations vary. Even if I am not confident to insert unsupervised, I am happy to have some experience of the procedure.

Excellent course. Opportunities to practice are rare (in hospital). I feel as well prepared as possible without multiple "real-life" procedures performed.

I found this course useful - it certainly gave more confidence in putting in a wire, however the infrequency with which they are required on call would concern me and probably mean they are best inserted by an on call cardiologist. Thankyou

Realistically this isn't something I see or come across often enough to gain competence at. However, the course was useful predominantly in refreshing indications for considering when a temporary pacing wire might be indicated and also troubleshooting problems when patients already have temporary pacing wires inserted (a much more common scenario).

I would also like to say that I had no idea previously about how I would insert a TPW, so even though I'd still be highly unlikely to give it a go, in an absolute emergency then I might be able to do it and give the patient a chance.

Appendix 3.1 - Ethics committee approval

The University Of Sheffield.

29/10/2014

Jivendra Gosai
Cardiovascular Science

Dear Jivendra

PROJECT TITLE: Evaluating the use of a novel ECG simulation software package
APPLICATION: Reference Number 001793

On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 23/10/2014 the above-named project was **approved** on ethics grounds, on the basis that you will adhere to the following documentation that you submitted for ethics review:

- University research ethics application form 001793 (dated 22/10/2014).
- Participant information sheet 003160 (22/10/2014)
- Participant consent form 003156 (22/10/2014)

If during the course of the project you need to deviate significantly from the above-approved documentation please inform me since written approval will be required.

Yours sincerely

Jean Lazenby
Ethics Administrator
Medical School

Appendix 3.2 – Test sheet and questionnaire

Post course questionnaire

1) After attending this session, how confident do you feel in ECG interpretation?

1	2	3	4	5
not at all		confident		very confident

Please circle the number which best applies to you

2) Do you feel the session you attended was a useful way of teaching ECG interpretation?

1	2	3	4	5
not at all		confident		very confident

Please circle the number which best applies to you

3) Do you feel the session improved your ECG interpretation skills?

1	2	3	4	5
not at all		confident		very confident

Please circle the number which best applies to you

Question 1:

Atrial Fibrillation ☐

Atrial flutter ☐

Sinus rhythm ☐

Atrial tachycardia ☐

None of the above ☐

Question 2:

Idioventricular rhythm ☐

Anterior ST elevation ☐

Left bundle branch block ☐

Digoxin toxicity ☐

Right bundle branch block ☐

Question 3:

Left ventricular hypertrophy ☐

Digoxin effect ☐

Inferior ST elevation ☐

'High take off' ☐

Lateral ST elevation ☐

Question 4:

Mobitz Type 2 3:1 AV block ☐

Mobitz Type 2 2:1 AV block ☐

Complete heart block ☐

Sinus bradycardia ☐

Mobitz Type 1 'Wenckebach' AV block ☐

Question 5:

Atrial Fibrillation with fast ventricular rate ☐

Ventricular tachycardia ☐

AV nodal re-entry tachycardia ☐

Atrial tachycardia ☐

Atrial flutter ☐

Question 6:

Ventricular tachycardia ☐

Ventricular fibrillation ☐

Agonal rhythm ☐

Sinus tachycardia ☐

AV nodal re-entry tachycardia ☐

Question 7:

Hypokalaemia ☐

Hyperkalaemia ☐

Digoxin effect ☐

Brugada Syndrome ☐

Hypertrophic Cardiomyopathy ☐

Question 8:

Normal sinus rhythm ☐

Lateral ischaemia ☐

Right ventricular hypertrophy ☐

Left ventricular hypertrophy ☐

'High take off' ☐

Question 9:

Ventricular fibrillation ☐

Normal sinus rhythm ☐

Ventricular tachycardia ☐

Atrial flutter ☐

Agonal rhythm ☐

Question 10:

Normal sinus rhythm ☐

Mobitz type 1 "Wenckebach' AV block ☐

Complete heart block ☐

Sinus pauses ☐

Sinus bradycardia

Appendix 3.3 – All comments received

Simulator Group

Comments

More 12 lead examples of pathology would be better

Comparing pathological ECG traces to normal would have been helpful

Liked heart visualisation and questions at end. More info on management of conditions would be helpful.

Really liked axis and NSR explanation. Would have liked same level of explanation throughout e.g. why does ST elevation appear on ECG as it does…

Software v useful & interactive w friendly and helpful instructions

Good visualisation of axis. Image sometimes hard to make out when looking through heart tissue to see relevant part.

Mnemonics useful. If software showed cardiac muscle contraction simultaneously with electrical activation, I think it would be easier to follow.

Very useful to see depolarisation spread across heart. May have been helped by combination of simulation and verbal teaching

LVH and RVH sections could have been improved as extremely brief.

Really helped with understanding cardiac axis. Some things more easily clarified by asking questions, so would be useful to have at least someone around to ask about the ECGs.

Good explanation of principals and reasons behind the ECG patterns. Good to go through normal at beginning. More examples of other ECG patterns e.g. WPW. RAD and LAD not shown on ECG examples.

Good software. Didn't manage to get through much of the software in time given, so test may be more representative of knowledge I came in with.

Interactive. Maybe a bit more guidance at certain points like what is Vp on ECG in one bit. Directions on heart confusing.

Good having a 12 lead ECG available for each condition. I found progress bar misleading.

Good explanations of different pathologies with good background of normal rhythm. Good ECG pictures. Axis very difficult to understand- maybe needed dumbing down more to start with. System quite slow and constant activation of heart while trying to read can be off-putting.

Arrhythmias well explained/ Visual modelling allows you to see the pathologies easily. It's dull. No opportunity to ask questions when stuck. Does not accommodate auditory learners. Teacher better than laptop every time. You can't build a rapport with a computer program. Best used as revision tool. Did not understand tutorial on pacing.

Good mix of interactive 3D imaging, ECG reports and explanations. Some might find reading through blocks of text difficult, perhaps incorporating a few ideas to explain pathologies?

You could go through at your own pace. Needed more time. Poor score in test not reflective of how good software is!

Labelled ECG good. Needed bigger screen.

Able to learn at own pace. Able to better visualise relationship between heart and ECG. Explains things clearly.

Visualisation of individualised lead pictures made me understand the ECG interpretation much easier. Everything makes sense! I struggle with whole picture therefore individual leads helped me understand what I was looking for.

Graphic display of heart in multiple views and planes. Live 12 lead ECG. More time needed for slow workers.

Computer programme is very good. Needed more time to complete and get my head round each teaching point.

Easier for me to work through at my own pace and with the simulator emphasising teaching points. There were a few typos. I would prefer a delay in beginning the simulation so I can read a little before watching. Although I know I can pause in myself.

Clinical correlates were good. Many times you are taught an ECG abnormality but not why. Takes a while to read info. Then look at electrical activity then 12 lead ECG etc. Takes time to go through.

Concise, simple, uses stereotypical ECGS instead of patient ones- they can be more complex. Needed more time, possibly with integration of teaching and software.

Useful to have animation on what is happening in heart. Needed more time.

Software very good. Useful to see how electrical activity represented in different leads in real time. Didn't get through all tutorials in time.

Software is great. Needed more time.

Summaries at end of longer section would have improved it.

Useful interactive tool. I needed more time, but this wouldn't be a problem if the tool was used in normal teaching.

Good to use software and visualise heart next to ECG. Quieter room would have helped.

Good to get interval ranges. Could do at own pace. Simple language at basic level.

Useful tool for ECG learning. 3-month access good. Stepwise approach would have been useful addition. Needed more time as I'm a slow reader.

Interactive model. More time to complete. Include case histories.

The simulation was good and the explanations were simple but thorough. More time allocated to read through the information.

Good visual representations. Can go at own pace. Need more time to interact with heart and to visualise ECG. Need to make own notes as I use simulation.

Nice interactive session. Allowed to see in detail how leads work and can visualise conduction. Longer on the simulator - allow more time to read and absorb information. More guidelines on how to work the leads - took a while to find and load.

Explained it all well, able to go at own pace, ECG annotated. Axis could be better explained. Could let you practice examples at end.

Useful to compare ECGS, structure made easy to follow. Simulation confusing- didn't really use it.

Would be better to work with guidance. Some aspects I still didn't understand e.g. axis. Pull up ECG examples useful. Liked summary points in red.

Go at own pace

All major topics covered. Would be nice to ask questions.

Good visuals. Teaching ways of differentiating between similar ECGS e.g. ANNRT vs VT.

Explanation of axis and mnemonics.

Visualisation of the simulator

Missed having questions to answer as you would get in lecture. Slow. Not enough example ECGS.

Structured tutorial. Needs more of a clinical focus.

Pacing section in axis wasn't useful and I couldn't get it to work. Not enough time.

Quiz was helpful. Intro takes too long and takes a while to learn how to use all features. Slides very busy. Would benefit from voiceover explaining animated heart. Software assumes basic knowledge of ECG. Pacing wasn't clear. Not enough time.

Just reading not enough-needs audio. Some content was too complicated. Axis section very confusing. Too long. Management not covered.

Good systematic approach. Simulation not clear and a bit distracting. Would be good to have 12 lead ECG showing all the time. Clinical cases to link signs and symptoms would be good.

Animation sometimes confusing. Tutorial at beginning would be useful to go through systematic interpretation step by step.

3D imager is good. No step by step guide. Screen too busy. More background info needed at beginning. Wide range of level taught- some very simple, some too complex.

I am a visual learner so it was helpful to see the movement of conduction through heart from any angle alongside ECG. I found different coloured arrows helpful which pointed to what writing was talking about. There were occasional acronyms which I couldn't understand and couldn't find explanation.

Axis explanation and arrhythmia teaching good. Explanation of different leads and how that affects ECG + further explanation of 12 lead ECG would have been good.

Good categories of questions. Audio explanations may focus the user + phrasing in different ways may have helped me understand.

The simulation was brilliant- very helpful to visualise the heart and compare the ECG. Maybe needed more time. Could explain more why the leads show different patterns.

Tutorial program covered all major heart conditions that cause changes to the ECG and clearly pointed out what these changes were. Took time to get used to program. Contained a few silly spelling errors.

Good teaching on arrhythmias and what goes wrong. More on actual ECG and what arrhythmias do to ECG and process on how to interpret.

Changing the leads and cardiac axis really helpful, showing the full ECGS also helped. Felt very rushed and would have liked more time. Would be good to go through again.

Nice to be able to view ECGS with commentary.

Too slow. Liked ECG simulations

Being able to see ECG for every pathology

Well designed

Good 3D images. Needed more time.

Able to learn at own pace. Lacked questions during teaching.

Able to learn at own pace.

Would have preferred face to face teaching

Difficulty opening some of the ECGS (standalone app)

Good visual representations. Needed more time.

More time. Liked axis explanation.

Lecture Group

Comments

Find it useful when people demonstrate planes and leads on themselves- helps to visualise direction of electrical stimulus

Size of group good. Interactive and questions for us. Could have had handouts with examples…

Good explanation regarding types of abnormalities. Interactive questions. Needed more type. Teaching treatments would have been useful.

Pre reading material before tutorial would have been useful.

Very simply explained. More time needed.

Good detail. More examples needed.

Coul ask questions. Handout on ECGs?

It covered breadth of material well. Taught well with examples. Handout with exaples?

Everything was well explained at an appropriate level of detail.

Covered large amount of information. Maybe discuss how to present an ECG.

Oportunity to ask questions and clarify gaps in knowledge to improve understanding.

Covered imporant abnormalities. Easy to follow. Information on ECG leads could have been better.

Was able to ask questions. Improved understanding of common abnormalities.

Lots of arrhythmias covered. Very clear.

Large amount of content distracting. Would have preferred 2 sessions rather than 1 long one.

tepwise approach for ECGs.

The teaching and explanation of axis deviation was good. Larger ECG images would have made them project better and be easier to see.

Clear explanations with clear examples pitched at correct level.

Able to ask questions. Good Speed. Would have liked handout.

Small teaching group was great. Good to have gentle forum to ask questions that may seem silly on wards.

Good teaching. Appropriate pace. Wide coverage of ECG interpretation and open to questions.

Concise, clear slides. More interactive. Teaching on axis not clear

Explanation & recap of medical science bits such as anatomy & electrical conduction of the heart. Teaching regarding the axis interpretation.

Interactive & able to clarify questions well

Interactivity. Diagrams/examples. More explanation of basics

Labelled images helped

Pictures helped, systematic approach, could have been slower

Logical structure

Showing pictures.Good presentation. More pointing out differences in ECG.

Quiz useful for testing knowledge. Needs brief outline of what expected at F2 level.

Well structured. More examples. Needed a break.

More time

Good explanations. More questions to audience e.g. quiz on ECG strip before explanation.

Good use of examples. More group interaction. 'Unkown cases' to work through as group.

Small group environment good. Good pace. More examples of axis deviation.

Willing to answer questions. More information on underlying pathology.

Good range of topics covered. More time to go through each ECG.

Step by step guide. Needed longer.

Logical. Bit fast at end. Handouts helpful.

Lots of examples. Good speed. Maybe more Ecg examples of each condition.

Good pace/coverage and not too much info. Quiz as we were going through rather than end?

Step by step method and clear explanations. Maybe slower on last few slides.

Good to have a set routine for looking at ECGS in future. Slower pace to check people understood more complicated concepts.

Good examples. Smaller groups better.

Knowledge of teacher/good pace. Ask more questions.

All good

Survey

Appendix 4.1 – Ethics committee approval

The University Of Sheffield.

The Medical School.

15 August 2013

Dr Jivendra Gosai
Cardiovascular Science
Medical School
Beech Hill Road
Sheffield
S10 2RX

Medical School Office
Jean Lazenby
Research Ethics Administrator
Beech Hill Road
Sheffield S10 2RX

Telephone: +44 (0) 114 271 2287
Email: j.lazenby@sheffield.ac.uk

REF: SMBRER277

Dear Jivendra

Survey on UK clinicians' attitudes to simulation based training

I am pleased to inform you that on 15 August 2013 the School's Ethics Reviewers **approved** the above-named project on ethics grounds, on the basis that you will adhere to and use the following documents that you submitted for ethics review:

i) Ethics application form [approved – 15 August 2013]
ii) Survey Questions [approved – 15 August 2013]
iii) Invite Email [approved – 15 August 2013]

If during the course of the project you need to deviate from the above-approved documents please inform me. The written approval of the School's Ethics Review Panel will be required for significant deviations from or significant changes to the above-approved documents. If you decide to terminate the project prematurely please inform me.

Yours sincerely

Jean Lazenby
School Research Ethics Administrator

Appendix 4.2 - Survey questions

This is a copy of the questions for the survey, with information and consent question included. The consent question is mandatory to proceed, and any respondent not selecting an option will be prompted to do so.

The survey is available to view online at https://www.surveymonkey.com/s/CJ2JBJH

Survey of Attitudes to Simulation Based Training

Many thanks for completing this short survey to help gauge attitudes to simulation based training (SBT). This study has undergone ethical review by the University of Sheffield Medical School Research Ethics Committee. It should take less than 10 minutes to complete. There are 11 questions.

Simulation based training is not a new concept, but the scope of what can be achieved is increasing with technological advances. Many areas are now investing heavily in the provision of equipment and facilities. To date, there has been no large scale study published of the attitudes of doctors in the UK towards SBT. This study aims to establish that, and inform the debate.

Further information regarding this study can be obtained by contacting Dr Jivendra Gosai on mdp12jng@sheffield.ac.uk

1. This is a short survey on attitudes towards SBT in the United Kingdom. No personal identifiable information will be collected or held by the research team. If you consent to proceed, please tick the "Yes" box below.

   If you do not consent, please choose "No" or close your browser window and no data will be recorded. If at any time whilst completing the survey you wish not to proceed, please close your browser window. Please leave blank any question after this one which you do not wish to answer, or which does not apply to you.

   Space is available at the end of the survey for comments.

I have read the above, and agree to proceed	Yes	No (this will close the survey)

2. What Grade of doctor are you?

Consultant		ST2/CT2 or equivalent	
SpR or StR in final two years (ST6 or above equivalent)		ST1/CT1 or equivalent	
SpR or StR in mid training (ST4 or ST5 or below equivalent)		FY2	
ST3 or equivalent		FY1	
Other – Please specify			

3. In which region do you practise?

Scotland	West Midlands
East Midlands	East of England
North East England	London
North West England	South East
Yorkshire and Humber	South West
Wales	Northern Ireland

4. Please indicate your primary specialty (a further question will ask subspecialty if appropriate)

Medicine	Radiology	Public Health
Surgery	Lab based medicine	Paediatrics
Obstetrics and Gynaecology	Psychiatry	Ophthalmology
General Practice	Emergency Medicine	Other (please specify)
Surgery	Anaesthesia	Foundation programme

5. Please indicate your sub-specialty if appropriate

Medical Specialties	Surgical Specialties	Laboratory Medicine	Anaesthesia
Core medical training	Core surgical training	Chemical pathology	General anaesthetics
Acute medicine	Cardiothoracic surgery	Microbiology and virology	Pain
Allergy	General surgery	Histopathology	Intensive care medicine
Audiovestibular medicine	Vascular surgery	Immunology	Core anaesthetic training/ACCS
Cardiology	ENT		
Oncology	OMFS		
Clinical genetics	Plastic surgery		
Clinical neurophysiology	Trauma and orthopaedics		
Clinical pharmacology	Urology		
Sexual and reproductive health			
Dermatology			
Endocrinology and diabetes			
Gastroenterology			
Medicine for the elderly and stroke			
Haematology			
Infectious diseases			
Neurology			
Palliative medicine			
Rehabilitation medicine			
Renal medicine			
Respiratory medicine			
Rheumatology			

Sports and exercise medicine			

6. Have you undergone simulation based training in any of the following areas as a learner? (please select all that apply)

Simulated scenarios (emergencies, consultations etc.)	
Simulated ward environment	
Specific procedure training such as angiography, central line insertion (supervised directly by an experienced operator)	
Specific procedure training (unsupervised)	
ALS/ATLS/IMPACT style course	
Other – Please Specify	

7. Do you know whether simulators and facilities are available in your hospital/region, and if so, have you had the opportunity to access them? (please tick all that apply)

	I don't think this is available	I am not sure	This is available	I have the opportunity to access this
Procedure simulators for free/unscheduled practice				
Procedure simulators used as part of a formal skills course				
Manikin simulators				
Standardised patient				

8. Have you been involved in simulation training as a facilitator/tutor? (please tick all that apply)

	For undergraduates	For postgraduates
Yes, to facilitate Procedure Training		
Yes, to facilitate emergency scenario training		
Yes, as an instructor on an ALS or similar course		

9. If you have had simulation training FOR SPECIFIC PROCEDURAL SKILLS (central line insertion as an example), please rate in the following areas, where 1 = strongly disagree, 7 = strongly agree and U/C = unable to comment. If you have not, please proceed to the next question.

	1	2	3	4	5	6	7	U/C
It felt like an accurate representation of the real procedure								
It helped me to develop a new skill								
It helped me to maintain my skills in a procedure I already practise								
I was exposed to realistic complications								
Feedback from facilitators was useful								
Feedback generated by the machine (e.g. total time taken, other metrics) was useful								
I would consider this mode of procedural learning again								

10. If you have had simulation training FOR EMERGENCY SCENARIOS (human factors, crisis management, communication skills), please rate in the following areas, where 1 = strongly disagree, 7 = strongly agree and U/C = unable to comment. If you have not, please proceed to the next question.

	1	2	3	4	5	6	7	U/C
It felt like an accurate representation of real clinical practice								
I gained an increased awareness of human factors								
This assisted with effective team working								
This assisted with effective team leadership								
This assisted with effective communication								
Feedback from facilitators was useful								
Video feedback (if used) enhanced the training								
I would consider this mode of learning again								

11. Please could you indicate your attitudes towards simulation training (regardless of whether you have had experience or not). 1 = strongly disagree, 7 = strongly agree and U/C = unable to comment.

	1	2	3	4	5	6	7	U/C
Simulation training has the potential to enhance patient safety								
Simulation training has the potential to enhance healthcare quality								
Before doing any procedure, it should be practised on a simulator								
An operator could be considered competent having undergone SBT only								
SBT will help train the next generation of consultants in an era of shorter training times								
Simulation could be used to assess competence								

for revalidation purposes								
SBT will detract from time spent gaining clinical experience								
SBT could negatively impact service provision								
I would welcome more simulation training in my specialty								

12. Given the opportunity, would you engage in SBT in the future? (please tick all that apply)

Yes, as a learner/trainee	
Yes, for revalidation purposes	
Yes, as a trainer	
Yes, as the lead for developing courses	
Other (please specify)	

13. Please add any further comments or thoughts on the subject of SBT in medicine

14. Thank you for your time. For any further information, please email mdp12jng@sheffield.ac.uk

Appendix 4.3 Invitation Letter

The University Of Sheffield.

Dear Doctor

Survey on current attitudes and experience of simulation training in the UK

Simulation training is being increasingly used in postgraduate medical training across the UK and worldwide. To date, there is little evidence on the acceptability and opinions of this across the medical community outside of those who deliver simulation training and have attended simulation training.

You are invited to complete a short survey to determine attitudes towards simulation amongst clinicians in the UK. The intention is to gain as many responses as possible across all disciplines and grades of doctor. The results will be used to help inform the debate on this.

The survey should take no longer than 10 minutes to complete and no identifiable information will be saved. To complete this, please use the link https://www.surveymonkey.com/s/CJ2JBJH.

If you have any questions, please contact Dr Jivendra Gosai on mdp12jng@sheffield.ac.uk.

Many Thanks

Dr Jivendra Gosai

Dr Makani Purva

Dr Julian Gunn

SMBRER277 Approved 15.08.13