The University Of Sheffield.

The role of multimedia in cognitive surgical skill acquisition in open and laparoscopic colorectal surgery

By

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I have dedicated this MD thesis to my dear family, for all their unconditional love, encouragement and sacrifice. I feel blessed to have such a caring and loving family (both Indian and Mauritian!).

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SUMMARY/ ABSTRACT

Introduction:

Changing work patterns have led to reduction in training hours with potential to affect surgical skills training. Multimedia can be used to supplement cognitive surgical skills training outside the operating room. A systematic review of 21 studies on the role of multimedia in surgical training and assessment demonstrated that multimedia effectively facilitates acquisition of surgical skills and was associated with significant improvement in technical skills and cognitive skills. The aim of this project was to design and develop a multimedia educational tool in anterior resection surgery and evaluate the effectiveness of this tool in teaching and assessment of cognitive surgical skills.

Methods:

An online multimedia application was developed by filming multiple procedures; editing films into key procedural steps using cognitive task analysis; and integration onto a navigational interface platforms. All steps were supplemented with animation, text and voiceover.

A randomised control trial was conducted to evaluate the effectiveness of online multimedia in comparison to conventional teaching in cognitive surgical skills acquisition. All trainees were assessed before and after the study period.

Results:

Of 59 trainees recruited, 52 completed pre-test assessments. Data from 43 trainees was available for final analysis. Baseline pre-assessment scores were similar in both groups. Senior trainees achieved significantly higher pre-test mean scores compared to junior trainees ($p<0.01$). Post-test scores improved significantly in both groups and the mean change in scores in the multimedia group was higher (6.60, SD 5.10) compared to the control group (4.89, SD 3.66) was not statistically significant ($p=0.21$). In the multimedia group 67% strongly agreed the tool was a useful adjunctive educational resource. 67% and 88% of trainees felt their cognitive surgical skills improved.

Conclusions:

Multimedia is an effective self-directed learning resource for cognitive skill acquisition in colorectal surgery and is well accepted as a training tool outside the operating room.

CHAPTER 1 – INTRODUCTION

1.1 Setting the scene: current surgical training

Historically, post-graduate surgical training in the United Kingdom had previously been based on the apprenticeship model, a concept popularised by William Halsted over a century ago [1]. Surgical skills were then acquired in an informal manner where the surgical trainee learns to perform surgery under the supervision of a trained surgeon on a "see one, do one, teach one" basis [2].

More recently, work patterns in the UK have changed with increasing reliance on shift systems and a reduction in work and training hours as specified by the European Working Time Directive (EWTD). Likewise in the United States, new labour laws limit a resident to an 80-hour week [3]. Prior to the Calman report (a seminal event in the development of the modern surgical training programme in 1993) a surgical trainee may have expected to work over 30,000 hours prior to becoming a consultant surgeon [4]. With the combined impact of changing working practices and the recent Modernising Medical Careers (MMC) reforms training hours have now fallen to below 6000 hours [5]. The current model involves earlier specialisation and a programme of seamless training from graduate to consultant status, further reducing the period of generic training.

Surgical trainees are now increasingly removed from normal working hours in which the majority of traditional operative training and experience is gained [6]. This has led to an overall net reduction in trainees' clinical and operative experience. The reduction in operative experience means that operative competence can no longer be assured on the basis of experience alone [7]. In addition to this, increasing consultant accountability for patient safety and greater diversity of available techniques within each speciality, has led to a reduction in training opportunities [8]. The rapid growth of new surgical procedures has also reduced teaching time and resulted in an increasing need for effective alternatives to help trainees acquire surgical skills [9].

Surgical trainees are now in a position in which they are required to learn a growing number of techniques and technologies whilst having less hands-on experience [10]. Therefore, to maximise training opportunities, today's trainees need to attend operating sessions already primed with the necessary theoretical knowledge and relevant practical background.

1.2 Skills/ operative competency

Identification of the core proficiencies that collectively define operative or surgical competence (skills taxonomy) is important. Surgical competence encompasses a combination of technical skills, knowledge, decision making, leadership and communication skills [11]. Competence is generally defined as proficiency in all areas; technical and non-technical [12, 13].

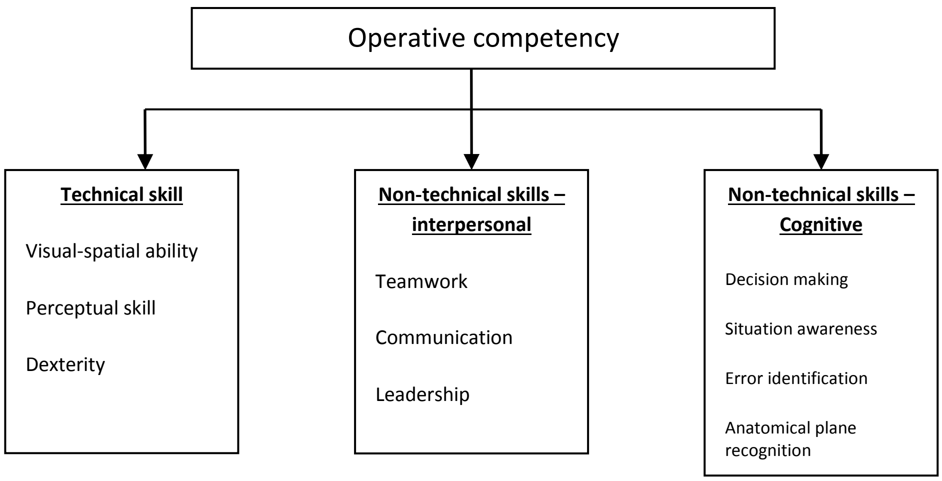


Figure 1.1 Operative competency: Technical and non-technical skills

Technical skills include visual-spatial ability, perceptual skill and dexterity. Non-technical skills can be divided into interpersonal and cognitive skills. Interpersonal skills include teamwork, communication, leadership, and team management and to a lesser extent planning and recognition. The important cognitive skills are clinical decision making, anatomical/factual knowledge, anatomical place recognition, situation awareness and error detection [14] (Figure 1.1). Other cognitive skills include anticipation and adaptation.

1.2.1 Technical skills

Visual-spatial ability is an innate attribute, which correlates with the ability to learn a new task [15]. Perception and perceptual skill are functions of both experience and judgement [16]. Psychomotor skills are a combination of dexterity and anatomical knowledge [15]. The use of skills workshops incorporating virtual reality systems and bench models are the most effective methods of developing technical skills outside the operating room [17].

1.2.2 Non-technical skills

Surgical decision making is a complex process that integrates critical thinking with factual knowledge and experience. It has been ranked as the most important trait required for a competent surgeon [16, 18]. Approximately 75% of important events in the operation are related to making decisions and only 25% to manual skill [18]. Overall, many consultant surgeons regard development of non-technical skills as even more essential than technical skills in surgical trainees [19].

High-hazard industries have recognised for a long while that technical expertise does not guarantee safe operations. They therefore introduced non-technical skills training, often called Crew Resource Management (CRM) designed to enhance performance [20]. A Parliamentary Report into Patient Safety in July 2009 stated that, "Lack of non-technical skills can have lethal consequences for patients [21]. However, the NHS lags unacceptably behind other safety-critical industries, such as aviation, in this respect skills training must be fully integrated into undergraduate and post-graduate education." Non-technical skills training in surgery is therefore one method of enhancing surgeons' performance in the operating room, in order to improve patient safety [22]. Analyses of adverse events in health care have revealed that many underlying causes originate from failings in non-technical aspects of performance rather than lack of technical expertise [23]. Such skills require very different acquisitional characteristics compared to motor skill and require consideration and training in their own right.

1.2.3 Surgical skill acquisition

Surgical skills traditionally are acquired through 3 consecutive stages: the cognitive, associative, and autonomous stages [24-26]. In the cognitive stage, the trainee learns surgical theory and concepts. During the associative stage, trainees practice surgical skills, and in the autonomous stage, surgical skills are able to be performed and practised without conscious thought [26, 27].

1.3 Practical skills training models

1.3.1 Technical skills

Although no educational technology can replace the craft apprenticeship required to teach and train a surgeon [28], the above mentioned changes have led to a rapid development of practical models to address reduction in time to attain the necessary operative skills [29]. Educational models used to augment general surgical skills training outside the operating room, however, tend to focus on technical performance.

The most notable new models used to teach surgical skills have been surgical simulation [30]. Thus far, the main focus of surgical simulation using animal models, mechanical bench stations and virtual reality systems [31] has been to train and objectively assess technical skills using tools such as the Objective Structured Assessment of Technical Skills (OSATS) [32]. This allows a safe environment in which the training is focussed on the needs of the “trainee” rather than the “patient” [33].

Although such platforms clearly demonstrate educational benefit for skills acquisition, they are cost intensive, time consuming, and bonded to schedules and locations [34, 35]. These limitations may potentially limit their widespread use in general surgical training programmes. Another criticism of these models is that they do not place emphasis on the role of non-technical skills as a vital component of an operation. Technical skills continue to be rigorously studied and make up the majority of the objective data in surgical training and assessment [36].

1.3.2 Non-technical skills

The only real focus on non-technical skills instruction has been the development of behavioural scoring systems, such as NOTSS: Non-Technical Skills for Surgeons and The Oxford Non-Technical Skills (NOTECHS) scale [14, 37]. These systems have concentrated on teamwork and communication skills for assessment and training based on observed skills in the intra-operative phase of surgery.

However, although consultant trainers and expert surgeons in the UK readily acknowledge the importance of non-technical skills [18] and in particular cognitive surgical skills; there has been a general lack of emphasis on the structured teaching and assessment of these important skills sets.

Traditional teaching methods to teach cognitive surgical skills include didactic lectures, textbooks and surgical manuals and attendance at educational forums (study days on surgical registrar training programmes/ scientific local and national conferences). Surgical education in the modern era is, however, enhanced with technological advances [38]. The use of these new technologies, however, have been a matter of ongoing debate [39, 40], as well as the need for the development of new ways to improve teaching standards [41]. Multimedia-based platforms has recently gained popularity as a training tool in a variety of health-related fields [42].

1.4 Multimedia technology

Multimedia is an under-used educational adjunct that may be used to augment cognitive surgical skills, outside the operating room environment. Definitions for the term 'multimedia' may vary. However, most experts agree that multimedia is media that uses a combination of different content forms, and can be defined as the integration of text, audio, images (still and moving), animation, video, and interactivity content forms. Mayer simply describes multimedia as "presentation of content that relies on both text and graphics [43].

Multimedia is already one of the most widely used training tools in military, high-tech industry and the business world [44]. The positive impact of multimedia learning has also been established in medical education [45]. Supplemental computer-based/ multimedia training has been a component of undergraduate training, particularly in US medical schools [46]. Yet use of multimedia in surgical training is still a relatively new concept, particularly in post-graduate training programmes.

The multimedia evidence base has also grown within surgical education and has been shown to be effective in disciplines including radiological education and surgical pathological conditions [47-49]. The use of multimedia technologies has also been evaluated in other patient health-related fields with positive results; particularly with regards to the patient pre-operative counselling and consenting process [42] and patient comprehension, whilst reducing peri-operative anxiety to improve in-patient hospital experience [42, 50].

Multimedia has shown to lead to increased efficiency [51] by decreasing the learning curve by 60% and increasing retention by 50% when compared to traditional didactic training [52]. Whilst providing an effective delivery for training, multimedia also has a number of advantages over conventional methods of teaching. Multimedia can create a safe structured learning environment that is trainee-centred and self-paced [53] and can provide support for all levels of training. Repeated practice in a learner-centred (self-directed approach) environment may augment operating room experience, and may help engender confidence in surgery, particularly in inexperienced trainees [54].

Additional potential advantages of multimedia include flexibility in time and location, facilitation of novel instructional methods and the potential to personalise instruction to individual needs [55]. This can be achieved by delivery of multimedia tools as stand-alone packages (CD-ROM/ DVD) or via the internet ("e-learning"). Additionally, increasing departmental budget constraints for courses may force trainees to "pick and choose" only mandatory courses. Travelling commitments in terms of time and cost may further deter trainees from attending such courses. Multimedia could potentially solve some of these issues. Multimedia would therefore appear to be a suitable medium for surgical skills training.

The influence of the internet in the last decade has been evident in many spheres of education, including medical and surgical education. The internet has rapidly changed the landscape for information and resources sharing among the surgical community and has revolutionised the access to surgical education [56, 57]. With the growth of online learning, the internet would now appear to be an ideal forum for dissemination of surgical education [56]. Multimedia learning tools, when accessible on the internet, have added advantages over simulation training, educational courses and study day programmes which require trainee attendance and therefore impose demands on scheduling conflicts due to busy clinical commitments [54]. The internet offers a tailored education for all levels of surgical expertise [57]. Nowadays, high speed internet streaming enables users to playback high-quality HD videos that enhance the clarity and dissemination of operative information.

Some educators view the widespread use of multimedia applications in medical and surgical education as inevitable [54]. There has been increasing backing from educators for implementation of innovative teaching methods that make use of multimedia [58]. There is also some evidence to suggest that surgical trainees in the UK are dissatisfied with traditional teaching methods [56] while there appears to be a growing interest with online multimedia augmented instruction [59].

Recognition of the principles of adult education (self-direction, experiential and reflective) is an important factor to consider during development of new training methods in surgical education [60]. This may explain why some trainees feel dissatisfaction with current traditional teaching methods. The combination of all these factors would suggest that trainees may potentially benefit from multimedia-based instructional tools for the purposes of surgical skills training.

1.5 Multimedia design – theories and principles

A number of key concepts relating to educational theory and multimedia design principles need to be carefully considered in the development of the multimedia educational tools. These concepts and principles are now discussed.

1.5.1 Constructivist teaching approach theory

Constructivism approaches knowledge as a large integrated body of information [61] and makes effective use of learners' prior knowledge and existing cognitive structures based on knowledge and experiences [62]. Learning is not a passive, but an active process of knowledge construction, whereby knowledge need not be transferred, but rather constructed by the learner [63]. Multimedia-based tools should align to the tenets of constructivist theory by actively engaging learners whilst stimulating an understanding of the information [64].

1.5.2 Cognitive load theory

The significance of the working memory in the learning process is that in order to reach long-term memory storage, information needs to be first processed by the working memory [65]. Learning is (according to Sweller [66]) an alteration in the long-term memory which in humans has practically unlimited capacity [65, 67]. That capacity is used to store knowledge in schematic forms, in which schemata represent “cognitive constructs that incorporate multiple elements of information into a single element with a specific function” [65, 68]. Following acquisition of a new schema (i.e. pictorial, spoken or written [69], it can be improved by practice and finally automated (e.g. reading text). If a schema is automated, the conscious effort needed to perform a related task will be decreased [65, 68]. Automation frees capacity in working memory for other functions [64].

Cognitive Load Theory [66, 70, 71] states that working memory is limited in its capacity to process incoming information. This creates important considerations for multimedia design [64]. The information retained and processed by the working memory is referred to as cognitive load [61, 71, 72]. Cognitive overload places excessive demands on the learner’s attention, undermining the learner’s capacity to process information effectively; thereby diminishing the learning experience [61].

According to Sweller, Van Merrienboer, and Paas [72], there are three types of cognitive load: intrinsic, extraneous, and germane [64] (Figure 1.2).

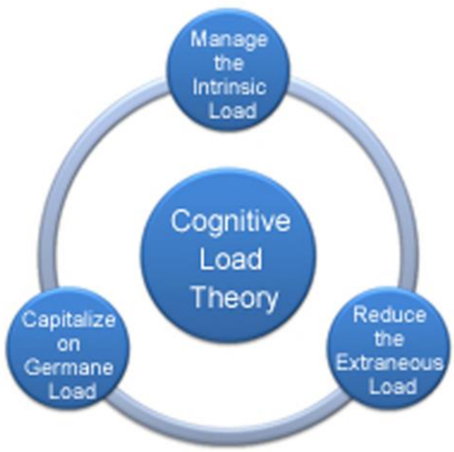


Figure 1.2 Instructional Strategy Based on Cognitive Load Theory: Vayuvegula V. Weblog. http://blog.commlabindia.com/elearning-design/instructional-strategy-cognitive-load (Accessed February 28 2015)

Intrinsic load: Intrinsic cognitive load is due to the intrinsic nature (difficulty) of information presented. Intrinsic cognitive load cannot be altered by multimedia design [73].

Extraneous load: Extraneous cognitive load is caused by the manner in which information is presented to learners. Extraneous load is under control of multimedia designers [74].

Germane load: Germane load enable learners to dedicate their cognitive mental resources to processing, construction and automation of schemas, helping to facilitate development of learner's knowledge base. This enables knowledge to be committed to long-term memory [72].

Creating the balance between these cognitive load types is critical to successful multimedia development. If a learning tool is able to increase germane load and decrease extraneous load, a learner's attention can be re-directed to key elements [66] (Figure 1.3) to focus on essential (goal-directed) information [61].

When designing multimedia educational tools, it is also important to take into account numerous factors that can affect cognitive load. These include

(1) The complexity of the educational material

(2) The rate of information presentation

(3) The capacity of the learners to be able to manage the rate of presentation

(4) The familiarity of the learner with the educational material [75].

It is important to account for these factors to reduce cognitive overload. In this way, the efficacy of the educational material can be potentially improved. This will again enable trainees to focus on essential goal-relevant information.

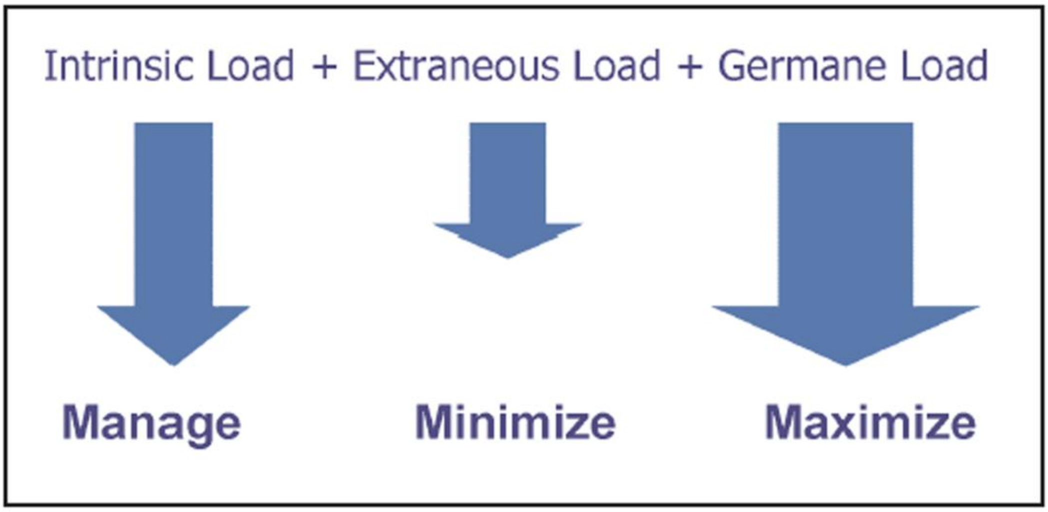


Figure 1.3 Efficiency in e-Learning: Proven Instructional Methods for Faster, Better, Online Learning http://www.learningsolutionsmag.com/articles/245/efficiency-in-e-learning-proven-instructional-methods-for-faster-better-online-learning (Accessed on February 20 2015)

Following this assumption, Sweller and Mayer proposed several design techniques based on Cognitive Load Theory [69, 72]. These principles/effects were identified as:

Worked example effect - This effect states that providing learners/ trainees with worked-out examples of problems to study can be just as or even more effective in building schemas and performance transfer than having trainees work out similar problems on their own [64].

Split attention effect - Educational material requiring both textual and graphical sources should integrate the text into the graphics in a way that clearly demonstrates the relationship between the textual and graphical components [64].

Redundancy effect - This effect occurs when information that can be fully understood in isolation (as either auditory or visual information), is presented to both channels as essentially the same. Integrating redundant information in both working memories can lead to an increase in cognitive load [64].

Modality effect - This effect asserts that effective working memory capacity can be increased by using auditory and visual working memory together rather than using one alone [64].

1.5.3 Cognitive theory of multimedia learning

Cognitive theory of multimedia learning, derived from cognitive load theory, provides an account of how people learn from words and pictures [66, 69, 72, 76]. Cognitive Theory of Multimedia Learning [69, 77, 78] states that multimedia narration and graphical images produce verbal and visual mental representations, which integrate with prior knowledge to construct new knowledge [64] (Figure 1.4).

Cognitive theory of multimedia learning suggests that there are two distinct channels in the human information processing system. One system processes information presented in visual or pictorial format; the other system processes information in an auditory or verbal format. This is known as the dual-channel theory of multimedia learning [76, 79, 80]. Each channel has a "limited capacity" to process incoming information [61, 67, 80].

The cognitive processes of learning progresses through distinctive pathways: from sensory memory (once information is presented as pictures or sounds) through to working memory (where information is compartmentalised into separate "representations" such as sounds or images) before information is collected, integrated and processed, finally being retained as long-term memory [43, 79, 81].

Cognitive Theory of Multimedia Learning is based on several assumptions [69, 82]:

- Dual-channel assumption: The verbal and visual channels in our working memory are separated and can be used for processing information simultaneously thus enhancing process of learning [83].

- Limited capacity assumption: these channels have limited capacity [67] and limited time to hold information. Too much information leads to cognitive overload [79].
- Active-processing assumption: Learning is an active process of collecting, organizing and integrating new information [69, 83].

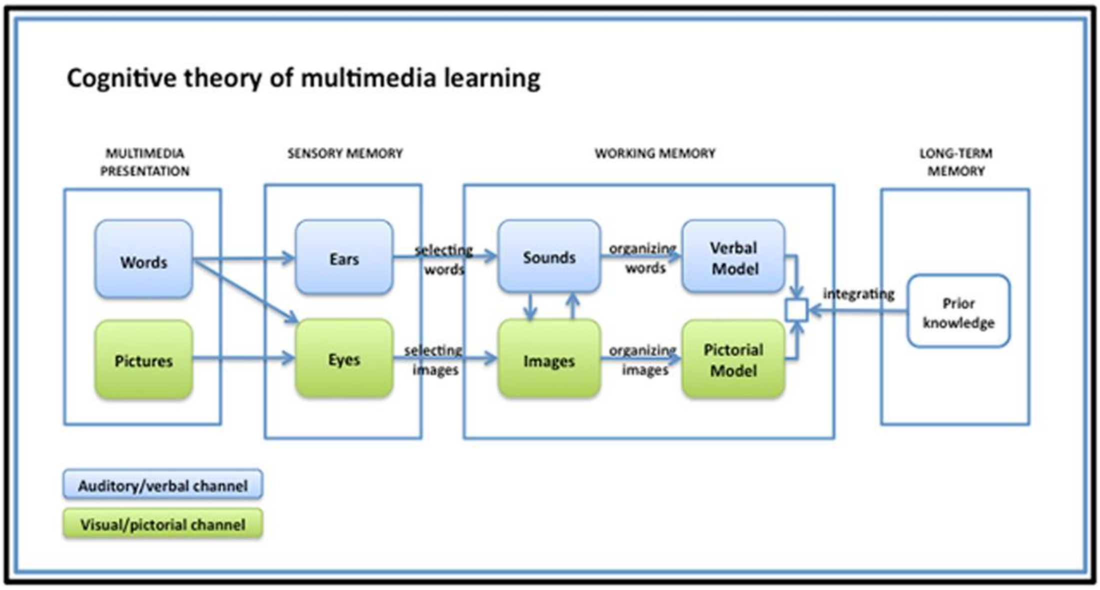


Figure 1.4 Learning theories: Cognitive theory of multimedia learning http://teorije-ucenja.zesoi.fer.hr/doku.php?id=learning_theories:cognitive_theory_of_multimedia_learning (Accessed on February 5 2015)

1.5.4 Adult learning principles

Adherence to adult learning principles in multimedia design plays an important role in successful implementation. Adult learning theory has been described in five principles [84, 85]:

- Adults are independent and self-directing
- Adults bring a range of knowledge base to the learning experience
- Adults value learning that integrates everyday life
- Adults are interested in problem-centred approaches
- Adults are motivated by their interests more than by external pressure

The principles of adult learning should be incorporated into multimedia design and structure.

1.5.5 Multimedia design principles

The design of surgical multimedia tools is critical to conveying accurately all the essential operative information in an efficient, concise and ordered manner [86]. Multimedia education presents various challenges to the designer and the learner. For designers the aim is to create a product that minimises the demands on cognitive load so that the learners can assimilate the new material, while simultaneously learning to interact with the multimedia educational tool [86]. The principles for designing effective multimedia are based on cognitive theory of multimedia learning [66] as described above. A number of experts in the field of multimedia education have published key principles to create effective multimedia resources.

Mayer extensively studied the principles of cognitive theory of multimedia and calls for instruction with multimedia that are based on empirical evidence [43]. Some concepts are similar to Cognitive Load Theory principles proposed by Sweller. Mayer set out key concepts in multimedia design [43, 69, 76] which are displayed in the table 1.1 below:

Eliminate external distracters	
Coherence principle	Exclude extraneous words, pictures and sounds
Signalling principle	Highlight essential material
Redundancy principle	Do not add on-screen text to narrated animation
Spatial contiguity	Place printed words next to corresponding graphs
Temporal contiguity	Place corresponding narration and animation at the same time
Encourage learners to establish "mental frames" for the material	
Segmenting principle	Present animation in learner-paced segments
Modality principle	Present words as narration instead of printed text
Pre-training principle	Prepare/ read ahead of time
Facilitate integration of new material with prior established knowledge	
Multimedia principle	Present words and pictures rather than words alone
Personalisation principle	Employ conversational style instead of formal dry style to present words

Table 1.1: Key concepts in multimedia design. Adapted from Mayer R.E.[87]

Grunwald [61] also identified a number of practical guidelines for production of cognitive efficient multimedia learning tools relating to interface design and navigation.

Interface design: The very first thing the end user sees of your multimedia presentation is the interface design or "viewing screen". Good interface design can maximize the advantages of multimedia while minimizing the disadvantages. The interface is the "visible personality" of the multimedia tool. A successful learning tool requires both effective educational strategy and a cognitively efficient interface design to capitalise on the advantages of presenting information in multiple modalities [61]. Good interface design needs to provide the environment necessary to assist the learner in independent study that is productive for the learner [88] by presenting information in a logical manner and focussing on the learner's attention on key elements.

The interface needs to be approachable and easy-to-use to so that learner feels comfortable using it and is easily able to understand his/her way around it [89]. The interface must also remain constant to ensure extraneous load is reduced. The number of on-screen interface elements should be minimal at any given time to simplify the environment; again this reduces extraneous load [89]. Designers must also eliminate redundant information.

Navigation: Navigation refers to user's ability to control a multimedia tool, and skip or "navigate" between sections. A well-designed learning tool should minimise complexity and maximise freedom [88]. However there must be a balance in learner control; high navigational control may increase extraneous load and disorientate the user [90]. It is also important to consider that the active learner possesses two components: physical and mental [91]. Well-designed multimedia should use physical interaction, such as mouse-orientated navigation to foster mental interest by the learner [61].

1.5.6 Colorectal Surgery

Colorectal Surgery is a sub-specialty within General surgery. Colorectal surgery refers to a wide range of operations relating to the colon, rectum, pelvic floor and anus caused by diseases including inflammatory bowel disease (Crohn's disease and ulcerative colitis), colorectal cancer and diverticular disease. The sub-specialist interest of the research investigator (US) is colorectal surgery.

One of the key or index procedures performed in colorectal surgery is Anterior resection. This procedure is discussed in detail in the Methods section (3.1.2), covering the reasons for why this particular procedure has been selected for the study. This is the reason for choosing a colorectal procedure for this study; Anterior resection procedure forms the educational medium of the online multimedia educational tools.

1.6 Hypothesis

The use of ‘online multimedia educational tools’ is equivalent to conventional teaching methods in the acquisition of cognitive surgical skills and is an acceptable educational resource.

1.7 Study aims

The aims of this study were:

1. Determine the role of multimedia in surgical skills training and assessment by means of a systematic review of the literature
2. Design and develop multimedia educational tool in an index colorectal surgery procedure: Open and Laparoscopic Anterior Resection
3. Determine the effectiveness of the multimedia educational tool in teaching and assessment of cognitive skills by means of a randomised control study; and to evaluate its acceptability amongst post-graduate general surgical trainees

CHAPTER 2 – SYSTEMATIC REVIEW

2.1 Introduction

Prior to conducting a study on the effectiveness of multimedia educational tools in teaching and assessment of cognitive surgical skills, it is important to perform a systematic review of the available literature to establish the current evidence base on the role of multimedia in surgical skills teaching, training and assessment. There are currently no systematic reviews in the literature focussing on the role of multimedia in surgical training and assessment.

2.2 Aim of systematic review

The aim of this systematic review was to determine the extent to which the 'role of multimedia in surgical training and assessment' has been researched and to summarise the findings of published research.

2.3 Methods

2.3.1 Search and study selection

A detailed electronic search was carried out on the following databases: PubMed/ MEDLINE (1992 to November 2014), SCOPUS (1992 to November 2014) and EMBASE (1992 to November 2014). The last electronic search was conducted on 30 November 2014. The following search terms were used: ***(****Multimedia OR "computer learning" OR "internet learning") AND (surgery OR procedure) AND (teaching OR assessment OR* *education OR skills)*. One reviewer (US) performed the database search. The full text of relevant articles were then retrieved and reviewed. Duplicates were removed.

2.3.2 Inclusion and exclusion criteria

All original articles in the English language literature that evaluated the role of multimedia in the teaching, training or assessment of surgical procedures or surgical skills involving medical students, post-graduate surgical trainees (i.e. registrars, fellows, and residents) and practising surgeons were included. All articles deemed clearly or probably relevant were examined in full text. Studies had to include the use of multimedia in surgical or skills/ interventional procedures for inclusion in the data analysis. All study types were considered eligible. Articles focussing primarily on 'virtual reality training', 'simulation' or teaching non-procedural aspects of surgery (such as clinical anatomy, surgical pathology, clinical examination, interpretation of diagnostic tests); articles relating to dental surgery or orthodontics; and articles relating to patient education, governance, consent, ethics, service provision or epidemiology were excluded. Articles evaluating participants of non-surgical backgrounds (i.e. physicians or general practitioners, non-medical professionals) were excluded. Non-English Language articles, articles published only in abstract form, articles not representing empirical research, reviews, opinion papers, commentaries single case reports and commentaries were also excluded. If it was not possible to extract the relevant and necessary data from the published results, the study was excluded from the analysis.

2.3.3 Data extraction and analysis

One reviewer (US) independently reviewed all titles and available abstracts in the PubMed database and included articles meeting with the eligibility criteria. Full text articles were then retrieved via online access or in print from the British library in London.

A standard data extraction form was produced to ensure the systematic retrieval of relevant and necessary information/ results from the included studies. The following information was extracted: Year, Country, Discipline, Subject/ skill assessed, Study type, Control & type, Population & Number, Multimedia description, Delivery method, Instructional Methods used, Study format, Method(s) of Assessment, Timing of assessment, Summary of main results/ outcomes, Critical Appraisal, Risk of bias and Follow-up.

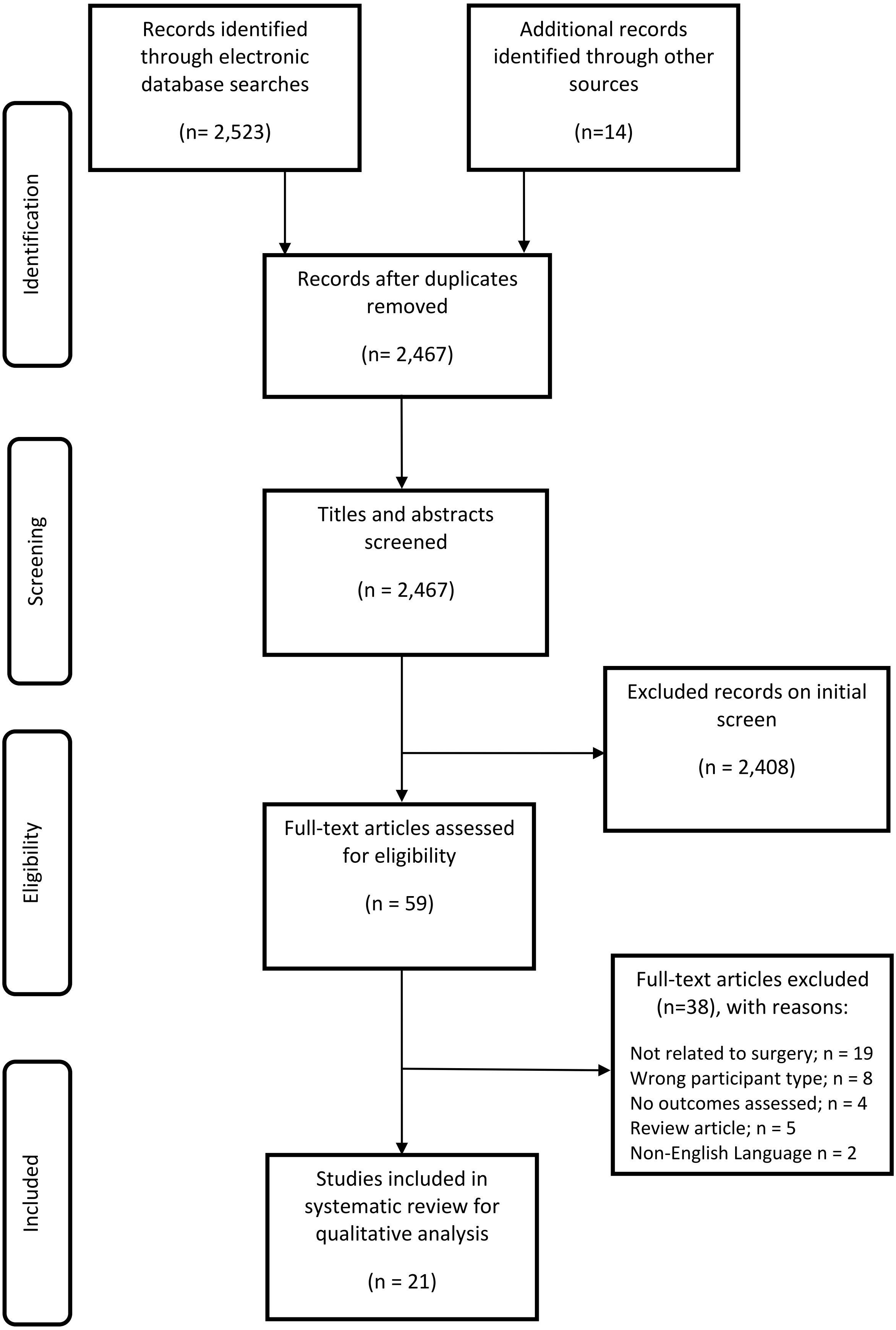
All data were initially collected by one reviewer (US). A second reviewer separately reviewed and extracted all data independently. Any disagreement over data extraction from the full text articles was discussed between the two reviewers and a consensus reached. Data were tabulated using Microsoft Excel. As a result of the significant variation in the outcomes and the heterogeneity of study methods, no data synthesis or meta-analysis could be performed. Therefore, the presentation of data is largely descriptive.

Study quality was assessed according to the methods stated in the Cochrane reviewers' handbook on a number of parameters. These include: quality of the study methodology reporting, randomization methods and allocation concealment, blinding of trainers and outcomes assessors, and sample sizes [92]. This systematic review was carried out in accordance to the PRISMA statement [93] to help transparent and complete reporting of this study.

2.4 Results

Figure 2.1 is a flowchart demonstrating the process of study identification, screening and assessment of eligibility and inclusion of articles in this study in the preferred reporting items for systematic reviews [93]. Table 2.1 shows the main characteristics of the 21 included studies and Table 2.2 shows the main outcome data of the included studies. The countries where the multimedia platforms were developed are shown in Figure 2.2. All included studies were published between 1999 and 2014 (Figure 2.3). The majority of the included studies (17/21; 81%) recruited a single participant group (i.e. residents only) and were single centre studies (76%). Just over half of the studies (11/21) enabled self-directed learning using multimedia platforms. However only 3 of these studies (27%) allowed for learning in unstructured settings in participant's own time/place, thereby adhering to adult learning principles

Figure 2.1 Flowchart showing selection of articles for review according to PRISMA guidelines



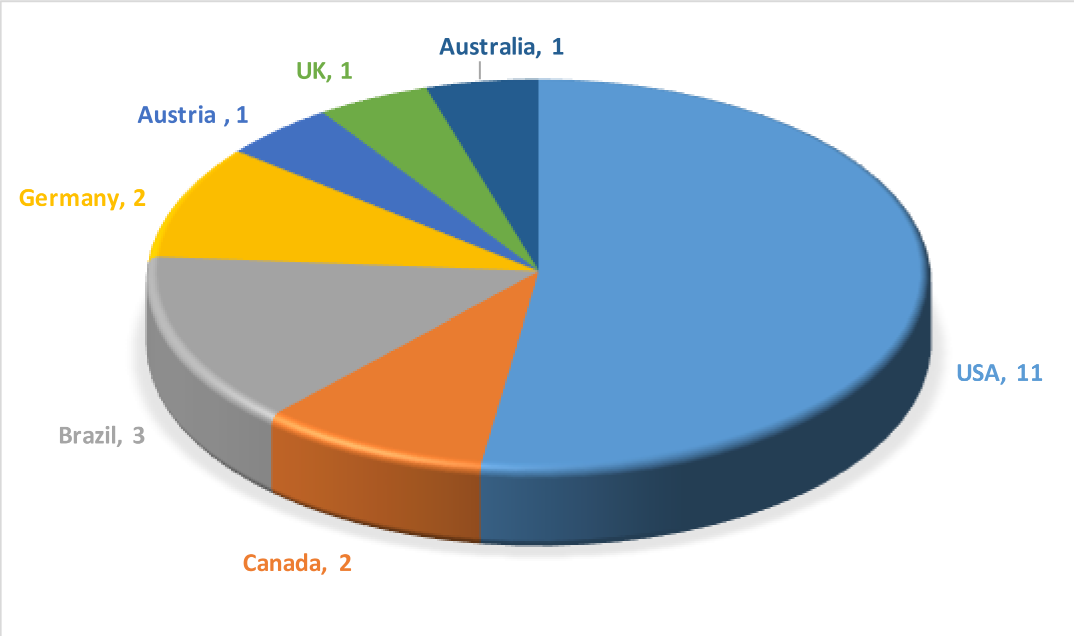


Figure 2.2 Geographic distribution of articles included in the study

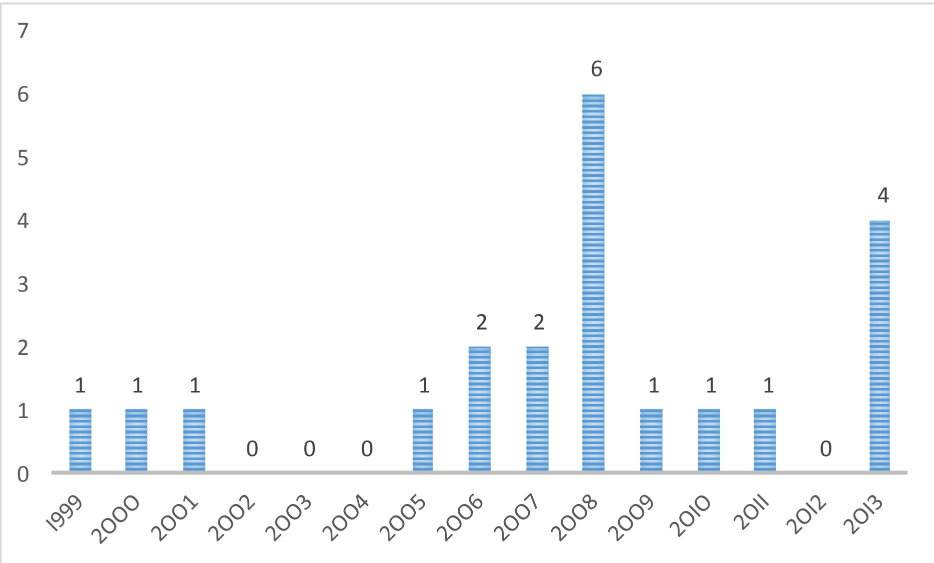


Figure 2.3 Number of published studies per year (1999-2013)

2.4.1 Multimedia and subject domains

A variety of multimedia technology was used across the studies. There were 12 (57%) multimedia platforms (including 2 bespoke CEVL (Computer Enhanced Visual Learning) curriculum platforms) designed to run off hospital/ skills laboratory computer workstations, 3 CD-ROMs, 2 DVDs, 3 internet-based programs and 1 mobile-device module (Figure 2.4).

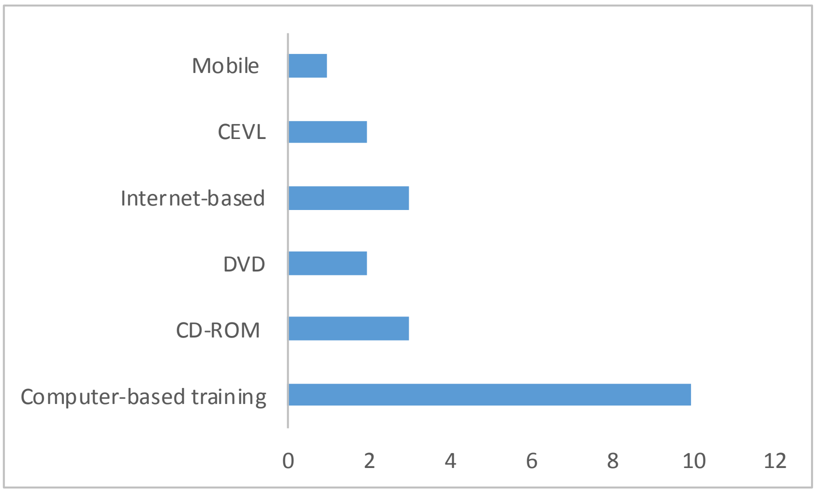


Figure 2.4 Delivery methods for multimedia platforms

Skills-based platforms were designed to teach and assess specific basic surgical skills, while procedural-based platforms were used to teach and assess surgical operations or procedures related to aspects of surgery. Overall, multimedia was developed in 7 (33%) skills-based and 14 (67%) operative/ procedural-related themes. Nine multimedia platforms were developed in the following surgical disciplines: general surgery (3), plastic surgery (2), and 1 in each of orthopaedics, ophthalmology, cardiac and urology. Another seven studies focussed on basic surgical skills and five other studies on specific procedural related aspects of surgery. The operations included laparoscopic cholecystectomy, aortic valve replacement, paediatric orchidopexy, cataract surgery for glaucoma, laparoscopic general surgery (i.e. groin hernia repair), flexor tendon repair, rhomboid skin flap, closed reduction and pinning supracondylar fracture. The specific procedural related aspects of surgery included were paediatric intraosseous insertion, paediatric emergency procedures, bronchoscopy and chest drain insertion.

2.4.2 Study designs

There were 14 randomized controlled trials (RCTs) and 7 non-randomized controlled trials (non-RCTs). There were 5 (out of 14) RCTs evaluating skills-based platforms and 9 RCTs evaluating procedural-based platforms. Two (out of 7) non-RCTs evaluated skills-based programs; 5 non-RCTs evaluated procedural-based platforms. In the RCTs, 8 (57%) of 14 had a pre/post test study design; 6 (43%) had a post-test only study design. In the non-RCTs, 4/7 had a pre/post test study design and 3 had a post-test only study design.

In 4/14 (29%) RCTs more than one control group was used. Overall, 20 control groups were used in the RCTs and they included traditional didactic expert instruction/ lectures (7), print media (3), media-comparative (4), practice training (3) and non-intervention (3). Concurrent control groups were used in 4 non-RCTs and included traditional live instruction (2), group with previous experience with intervention (1) (CEVL) [60] and no intervention (1).

In 19 studies (90%), one skill was assessed. In the other two studies [51, 94], which were RCTs, both technical and cognitive skills were assessed. Technical skills were assessed in 6 of 7 skills-based programs and 4 of 14 procedural-based programs, while cognitive skills were assessed in 2 of 7 skills-based platforms and 11 of 14 procedural-based platforms. Technical skills were assessed in 7 RCTs and 3 non-RCTs; cognitive skills were assessed in 9 RCTs and 4 non-RCTs.

2.4.3 Risk of bias

The 'Cochrane collaboration for assessing risk of bias' [95] was used to assess risk of bias for each RCT (Appendix 1). The risk category for the included RCT studies were: High risk (6, 43%), Low risk (4, 28.5%), Unclear (4, 28.5%). Non-RCTs were not assessed for risk of bias or quality.

2.4.4 Assessment methods

Table 2 provides a summary of instructional (teaching) methods, study format, methods and timing of assessment, main results, critical appraisal, and follow up. Various methods of assessment were used across the studies. The various technical skills assessment tools included: OSATS (3), structured checklists (2), self-assessment questionnaire (1), Global rating scale (2), ICSAD (1) and the CEVL score (1). Only 5 (24%) of these assessment tools has been previously validated. The various cognitive skills assessment tools included multiple choice questions (9), self-assessment (1), 'talk aloud' assessment (1), written checklist (1) and written test (1). None of these assessment tools have been previously validated.

2.4.5 Outcome measures

2.4.5.1 Technical skill

In the comparative controlled studies, multimedia demonstrated significantly improvement in technical skills performance in 4 studies (2 skill-based, 2 procedural-based studies) [35, 51, 94, 96]. In one non-controlled study, multimedia demonstrated significant improvement after intervention [97]. In one study, the control group showed significantly improved performance [46]. There was no difference in performance in three other studies (2 skills-based, 1 procedural) [54, 58, 60]. There was one study assessing technical skill performance with no comparative group; this study showed a significant improvement in baseline scores following the use of multimedia [98].

In three studies, retention tests were performed between 1-4 weeks following post-test assessments. In two studies, multimedia platforms demonstrated significant post-retention scores/ performance compared to controls [51, 96]. The third study did not demonstrate any differences in post-retention scores between groups [97].

2.4.5.2 Cognitive skill

Multimedia demonstrated significantly improved cognitive skill scores in 7 studies (6 RCTs) compared to controls (all procedural-based) [59, 94, 97, 99-102]. Significant improvement in scores for the control group was only demonstrated in one study [51]. No differences in scores were demonstrated in three studies (1 skills-based, 2 procedural-based) [103-105]. Two studies assessed cognitive skill with no comparative group [44, 106]. Improvement in self-assessed knowledge level [44] and significant differences in post-test scores between senior and junior trainees [106] were demonstrated in these studies. No retention tests were performed for cognitive skills.

2.4.5.3 Evaluation of multimedia for satisfaction/ acceptability

Evaluation of the multimedia platforms was assessed in 9 studies [46, 59, 60, 94, 99-101, 103, 104] (43%) using survey questionnaires. Results are summarised Table 2.2 and Appendix 2. Overall, evaluation in the 9 studies demonstrated positive results for multimedia platforms. No studies demonstrated poor evaluation of the platforms.

First author, year	Specialty/ discipline	Skill or procedure	Skills assessed	Study design	Participants	Method of delivery/ Multimedia description	Study number
Summers, 1999	Basic surgical skills	Knot tying and suturing techniques	Technical & cognitive	RCT, single centre	Medical students	Computer based training (CBT)	58 (didactic group-17; videotape group-20; CBT group-21)
Rosser, 2000	Laparoscopic skills	Knowledge of laparoscopic skills	Cognitive	Non-RCT, multi-centre	Residents and surgeons	CD-ROM presented from data projector <u>Description:</u> "The Art of Laparoscopic Suturing"	201
Ramshaw, 2001	General surgery	Laparoscopic general surgical procedures	Cognitive	Non RCT, single centre	Residents	CD-ROM	41
Prinz, 2005	Ophthalmology	Cataract/ glaucoma surgery	Cognitive	RCT Post-test only, single centre	Medical students	DVD <u>Description:</u> Ophthalmic Operation Vienna	172 (3D group-90; control group-82)

Friedl, 2006	Cardiac surgery	Aortic Valve Replacement	Cognitive	RCT, single centre	Medical Students	Delivery: Internet-based module Aortic Valve Replacement Multimedia Module	126 (Multimedia group-69; Print medium–57)
Xeroulis, 2006	Basic surgical skills	Suturing and knot-typing	Technical	RCT, single centre	Medical students	Computer-based video instruction (CBVI)	60 CBVI group-15, concurrent feedback group-15; Summary feedback group-15; control group-15)
Jowett, 2007	Basic surgical skills	One handed knot-typing	Technical	RCT, single centre	Medical students	Delivery: Computer-based video training (CBVT): run on laptop	30 (cease practice group-20; additional practice group-10)
Lee, 2007	Paediatrics (specific procedure)	Paediatric intraosseous (IO) insertion	Cognitive	RCT, single centre	Medical students	Instructional DVD for IO insertion	36 (DVD group-18; teaching session group-18)

Luker, 2008	Plastic surgery	Flexor tendon repair	Cognitive	Non-RCT Pre-post test; single centre	Residents	Delivery: Multimedia instructional video	9
Nousiainen, 2008	Basic surgical skills	Suture/ knot-tying technique	Technical	RCT; single centre	Medical students	Computer-based video instruction (CBVI)	24 (CBVI only-8; CBVI with self-directed study-8; CBVI and expert instruction-8)
Perfeito, 2008	Thoracic (specific procedure)	Pleural drainage technique	Cognitive	RCT; single centre	Medical students	CD-ROM: on departmental computer	35 (CD-ROM group-18; traditional class group-17)
Jensen, 2008	Basic surgical skills	Skin closure and bowel anastomosis	Technical	Non RCT; single centre	Residents	Computer based program in Skills Lab	45
Rogers, 2008	Basic surgical skills	Two-handed square knot	Technical	RCT; single centre	Medical students and interns	CAL (Computer assisted learning)	82 (CAL-40; Lecture and Feedback seminar group-42)
Ricks, 2008	Paediatric (specific procedure)	Paediatric emergency procedures	Cognitive	RCT; single centre	Medical students	CAL (Computer assisted learning) Hospital Info Services	23 (CAL group-13; control-10)

Sarker, 2009	General surgery	Laparoscopic Cholecystectomy	Cognitive	Non-RCT; multi centre	Trainee surgeons	Delivery: Computer-based program Description: LapSkill	20
McQuiston, 2010	Urology	Paediatric orchidopexy	Technical	Non-RCT; multi centre	Residents	Delivery: Website Description: Computer enhanced visual learning (CEVL)	57 (study group-36; control group-21)
Sterse Mata, 2011	Thoracic (specific procedure)	Bronchoscopy	Cognitive	RCT, single centre	Interns and residents	Delivery: Website (in computer lab) Description: EBronchoscopy	16 (Web-based group-8; control group-8)
De Sena, 2013	Plastic surgery	Rhomboid skin flap	Technical & Cognitive	RCT, single centre	Medical students	Multimedia CAL (computer assisted learning)	50 (CAL group-25; control group-25)
Davis, 2013	Thoracic: (specific procedure)	Chest drain insertion	Technical	Non RCT	Residents, US Army FST members and novices	Mobile learning module	128

Pape-Koehler, 2013	General surgery	Laparoscopic Cholecystectomy	Technical	2 x2 factorial RCT; multi centre	Medical students and fellows	Multimedia-based interactive platform (www.webope.de): Webop chapter: Laparoscopic Cholecystectomy on Pelvi-Trainer Internet-based on personal computer (PC)	70 (Multimedia-based training-18; practical training-17; combination training using with multimedia –based + practical training-18; No training -17)
Hearty, 2013	Orthopaedic surgery	Closed reduction and pinning of paediatric supracondylar fractures	Technical	Crossover RCT; multi centre	Residents	Computer enhanced visual learning (CEVL) module	28 (CEVL-14; control group-14)

Table 2.1 Overview of the main characteristics for the included studies

Author	Instructional Methods	Study format	Method(s) of Assessment	Timing of assessment	Summary of main results	Critical Appraisal	Risk of bias (RCTs only)	Longitudinal assessment
Summers et al	3 groups: Traditional didactic skills instruction Videotape: expert instructor led Multimedia computer based training (CBT) program: expert instructor present	Instruction (all participants): 60 mins Skill station: Performed on pig feet 90 mins (knot-typing) + 120 mins (suturing) for all groups	Written 50 item MCQ Structured checklist and specific objectives/anchored rating form Performance quotient score = derived from multiple observations	Baseline pre-instruction MCQ and skills assessment Immediate post-group intervention MCQ and skills assessment	Videotape and CBT groups demonstrated significantly higher enhancement of technical skills Following intervention, didactic group achieved significantly better scores in MCQ compared to other groups At 1 month follow-up: performance only improvement in CBT group	Learning effect – pre-instruction Expert instructors present for CBT group – bias Non-validated assessments Evaluators not experts Not blinded for pre and post group assessments	High	1 month
Rosser et al	Two methods: 3 groups underwent CD-ROM tutorial (US surgeons; Greek surgeons; US residents) 1 group underwent stand-up tutorial (US trained surgeons)	2-day course in classroom setting Length of tutorials not stated.	51-item multiple choice test: germane to the educational material.	Pre and post instruction (day 1)	Mean increase in scores between pre-post test was significant ($p<0.001$) and similar magnitude for each group	Non-RCT Selection bias Heterogeneous group Minimal description of multimedia tool Non validated assessment tool CR-ROM learning not self-directed	N/A	None

Ramshaw et al	Self-directed learning using multimedia programs (same for all participants)	Self-directed learning over 3 month period. Only available viewing in resident conference room	Self-assessment evaluation survey using 10-point scale of knowledge and comfort level	Post-study period (within 3 months)	Subjective knowledge level increased from 6.0 to 8.7 and comfort level increased from 5.3 to 8.1	Non RCT Selection bias Small sample size Non validated assessment tool	N/A	None
Prinz et al	Multimedia DVD for groups 2 Groups: Surgeons "view" of procedure 3D animated group: surgeons "view" and animated sequence	Based during 8-week block. Presentation viewed in lecture during classes. Presentations each 10 minutes	19 multiple choice questions Evaluation survey (four level ordinal scale) for both	Immediately post presentation	3D group outperformed control in both topographical and theoretical understanding (p 0<0.001) Interactive multimedia tools evaluated as important /valuable supplement to conventional teaching	No baseline score (pre-test); both groups may not be comparable Non validated assessment tool	Low	None
Friedl et al	Self-directed multimedia learning group Self-directed Print Medium group: 62 page structured booklet	1 day in Multimedia laboratory to study material (both groups): unlimited time Following day: operating room (OR)	20 item multiple choice questions Assessment of initial motivation (QCM) and confidence in use of computers (CUC) 28 tasks/ open questions to assess procedural understanding in OR Validated questionnaire: HILVE to evaluate teaching	MCQ Pre and post tool (immediately)	Multimedia group slightly more motivated than print group in the QCM test There were no significant differences in the multiple-choice pre-test and post-test responses Multimedia group needed significantly less study time compared to print group Performance in the operating room was significantly improved in the multimedia group when compared with the print group	Non validated MCQ assessment tool Immediate assessment ?preparation prior to course Target group medical students, not residents/ surgical trainees	High	None

Xeroulis et al	4 groups: Self-study with computer-based video instruction (CBVI) Expert feedback during practice trials (concurrent feedback) Expert feedback after practice trials (summary feedback) No intervention (control)	Participants viewed an instructional video then pre-tested on interrupted knots with 3 square throws All participants: 19 trials of practice (1 hour), in assigned training condition	Expert assessment Global Rating Scale (GRS): tissue handling, efficient hand movements, instrument use, flow, and overall performance Each component marked on 5-point scale Hand motion efficiency: Imperial College Surgical Assessment Device (ICSAD)	19th practice used immediate post-test 1 month	The CBVI, concurrent feedback and summary feedback methods were equally effective initially for instruction of this basic technical skill and displayed better performance compared to control At retention only CBVI and summary feedback groups retained superior suturing and knot-tying performance versus control	Method of randomisation stated or allocation concealment Groups numbers or characteristics stated Simple task: multiple practice attempts prior to post-test	High	1 Month
Jowett et al	CBVT module on double 1-handed knot tying (all participants) 2 experimental groups: Cease practice Additional practice Practice blocks on identical three quarter inch dowel model for both groups.	Performed in skills laboratory Practice period (intervals of 6 and 3 minutes) to self-assessed proficiency Additional practice group (4 extra 3 minute practice blocks)	15 item general self-efficacy scale Self-assessment questionnaire on test performance: 4-item global rating scale (to cease or additional practice) Pre, post and retention test of video captured material using objective rating scale	Immediately	Performance improvements in all groups ($p<0.05$) No differences in 2 groups.	Small sample size ?Target population – effect size ?subjective assessments of self-assessed proficiency – bias Single surgical skill assessed	High	1 week post-retention

Lee et al	2 groups Interventional group: DVD-based teaching medium Control Group: Traditional, four-step, face-to-face expert teaching Paediatric training mannequin	2 weeks prior to study, all candidates given theory notes on procedure Intervention group: 10 min DVD session, then 10min practice session with mannequin	Standardized checklist of critical steps for successful task completion (out of 10) Modified Likert score on teaching experience	Checklist completed at time of task completion	The interventional group significantly higher mean score compared to control teaching group No difference in the candidates' perception on satisfaction, anxiety and confidence level about teaching experience.	Small sample size Short exposure study time Non-validated assessments No baseline assessment to compare groups Learning bias from pre-training	Unclear	None
Luker et al	Intervention: Multimedia instruction video – self-directed Traditional learning (control group)	Skills lab setting: Performance of repair in 3 sessions Traditional learning session after 1st repair Instruction using multimedia after 2nd repair	Talk aloud protocol assessment tool: understanding of procedure and decision making points	Immediately following each repair	All residents showed improvement in knowledge and decision making after traditional learning All residents showed significant increase in knowledge and decision making after multimedia	Non-randomised Small sample size Residents of varying surgical experience Non validated assessment tool Learning effect bias after 2 sessions	N/A	None

Nousiainen et al	3 groups: Group 1: View six-phase version of video. Group 2: Self-directed interactive video learning during practice events Group 3: video and expert instruction (after 9th suture attempt)	All participants: 7-minute training session: an expert-narrated, instructional video on instrument knot-tying Practice duration: 18 trials 30-40 mins	Computer based assessment: Imperial College Surgical Assessment Device (ICSAD) Performance based assessment: videotaped performance assessed using a global rating scale by two blinded experts	Pre-test immediately after training session. Post-test immediately after practice session Retention test: 4 weeks	All three groups demonstrated significant improvements on both measures between the pre- and post-tests as well as between pre-tests and retention-tests ($P < .01$), no significant differences were detected among the three groups	Small sample size Subjective bias on plateau of performance Multiple practice sessions Learning bias/ practice effect with retention test Single basic technical skill?	Low	4 week retention test on suturing
Perfeito et al	2 groups: Group 1:Self-directed learning with multimedia program Group 2: Traditional Theoretical class	Group 1: 90 minutes self-directed learning in computer room Group 2: 90 min theoretical class	Objective theoretical test: 36 MCQs and 7 descriptive questions 2 subjective written assessments (for Group 1)	Post-test immediately following intervention Subjective assessments: immediately after program and more detailed again	No difference in MCQs, but there was a significant difference in descriptive results for Group 1 compared to Group 2 Subjective evaluation very positive	Small sample size ?no description on random assignment Non-validated assessment tool No baseline test to compare groups	Unclear	None

Jensen et al	Laboratory based instruction session Narrated digital video on skin excision/ closure & hand-sewn bowel anastomosis Porcine abdominal skin and harvested porcine small bowel	Multimedia-based cognitive pre-training Self-directed practice: 2 hours Faculty supervised practice: 2 hours Self-directed practice 2 hour practice session in skills lab 65-minute objective assessment	Digital video recording for task performance: modified OSATS score	3 objective assessments: pre-training on 1st attempt and post-training performed on last assessment Study survey assessment	Significant differences were seen between pre- and post-test for 5 of 6 objective measures Significant improvements were seen in both time to completion and OSATS global ratings score for both procedures	Small sample size Selection bias ?bias of faculty supervision or pre-training for benefits – multimedia pre-training not compared to practice, just as adjunct Immediate outcomes	N/A	None
Rogers et al	2 Groups: Computer-assisted learning (CAL): 12 step multimedia program – self directed LFS Session (CAL with a lecture and feedback seminar) Knot tying board and sutures	1 hour with CAL or LFS session End of session: all participants instructed to 2-handed knot	Rating scale (out of 24) to assess quality of knot typing: videotaped rater evaluation	Not specified (videotaped assessment)	CAL group had significantly lower quality of performance compared to LFS group No difference in proportion of participants able to tie a square knot or average time to perform task	Trainees received feedback whilst practising skill Non- validated rating scale assessment	Unclear	None

Ricks et al	2 groups: CAL group: self-directed web-based computerised tutorials on paediatric emergency procedures Control group: non-interventional	CAL group review all tutorials: 45 mins. Reviewed in hospital training center. Followed by assessment. Control group: assessment test followed by tutorials	20-item multiple choice examination	Immediately post tutorials (for CAL group)	Intervention groups had significantly higher average examination score	Small sample size No baseline test Participants notified about required procedural knowledge 2 weeks prior to study	High	None
Sarker et al	Self-directed, self-appraisal learning decision making tool Laparoscopic Cholecystectomy (LapSkill)	Investigator present: unlimited time review to LapSkill programme on PC and complete module questions	15 questions on LapSkill per module: 3 Modules on: didactic knowledge of operation, surgical technique, decision making ability	Immediately after completing programme	No difference in knowledge-based module Experts scored significantly in completion of task and surgical technique modules	Non-randomised Small sample size No baseline test No time limitation for test	N/A	None
McQuiston et al	CEVL paediatric inguinal orchiopexy curriculum (website): comprises 11 component steps Study group (No experience of CEVL curriculum) Control (staff accustomed to CEVL curriculum	Participants study curriculum before performing surgery (self-directed; no time limit Post-surgery: residents and attending mutually archive performance assessment	CEVL skills scores (derived from sum of ratings of each step/skill for max score 55 (11steps/skills at 5 points each) x case difficulty CEVL survey	Immediately after procedure or afterwards (no time specified)	No significant difference in percent who showed an improved learning score in study vs control. No difference in magnitude of average improvement Survey showed positive impact on learning operative progress, improved knowledge of procedure. Component portion specifically helpful	Small sample size Variable times to complete assessment Selection bias Both resident/ trainer involving rating skills scores Historical controls – no matched data	N/A	None

Sterse Mata et al	2 Groups: Traditional class: didactic live lecture Self-directed learning : Ebronchoscopy website	2 hour training session using website in computer lab or live lecture	20 multiple choice – written assessment	Immediately post intervention	No differences in test scores between the two groups Positive evaluation of Ebronchoscopy	Small sample size. Non-validated assessment tool	High	None
de Sena et al	2 groups CAL group multimedia software self-directed application Control group: Text-based print article	5 minutes of study exposure both groups Followed by 5 minute on performance rhomboid flap (training bench model) Control group then exposed to multimedia software for 5 minutes and reattempted rhomboid flap	Five multiple-choice (MCQ) test OSATS protocol	Pre and post MCQ test immediately before and after intervention OSATs assessment at time of practical	The computer-assisted learning (CAL) group had superior performance as confirmed by checklist scores, overall global assessment and post-test results All participants ranked multimedia method as the best study tool.	Short exposure study time	Low	None

Davis et al	2 groups/ methods: Intervention group: self-directed mobile-learning module (on Apple iTouch) Control group: No instruction	No duration for intervention group stated Participants placed a chest tube on Trauma-Man task simulator	14-item check list of chest drain insertion used to assess performance	Immediately after instruction or no instruction	Comparing the novice video group with the novice control group, the video group was more likely to correctly perform a finger sweep and clamp the distal end of the chest tube Comparing the expert video group with the expert control group, the video group was more likely to correctly perform finger sweeps, the incision, and clamping the distal chest tube	Non-expert, non-blinded evaluators Non-validated assessment tool	N/A	None
C. Pape-Köhler et al	4 groups/ methods: Multimedia-based training Internet platform (www.webope.de) Combination training using with multimedia –based + practical training Practical training No training (control)	Day 1: Baseline pre-test and 2-h training period (all groups) Day 2: Follow-up post-test The tests consisted of laparoscopic cholecystectomy in the Pelvi-Trainer	OSATS protocol	Video recorded Pre-test Day 1, Post-test Day 2 (24hr after)	The OSATS results were highest in the multimedia-based training group Multimedia-based training reached a significantly higher OSATS score compared to participants without multimedia-based training	Selection bias in inviting participants – only those completing questionnaire Small group size	High	None

Hearty et al	2 groups: Test group: Residents using textbook + completed e-learning module Control: Residents who used same textbook only E-learning module: Computer Enhanced Visual Learning platform (CEVL) on closed reduction and percutaneous pinning of supracondylar humeral fracture	One week to review textbook, then randomised into groups ?duration of module not stated given All participants followed in an procedure then complete satisfaction survey	60 question test on theory/methods of the case Satisfaction survey on CEVL module	Post-test ?immediately Test group: access to CEVL then complete test. Control group: complete test (then access to CEVL)	Test group scored significantly higher on the test compared to control group. All participants agreed the CEVL module was a useful adjunct to traditional teaching methods and majority (22/27) agreed module reduced anxiety in the operating room	Lack of control or time on preparation for case ?results influenced by prep work as opposed to module No baseline knowledge pre-test Coin flip randomisation No comment on assessors ?blinded No validated assessment tools Small sample size	Unclear	None

Table 2.2 Summary of outcome data from the included studies

2.5 Discussion

The evidence base for surgical educational interventions, though more limited compared to clinical interventions, is expanding as demand for evidence and outcomes research increases [107-109]. This systematic review focuses on the impact of multimedia educational platforms for teaching and assessment of surgical skills.

Despite heterogeneity of the included studies in terms of design, domain, methodology and outcomes, the following main findings emerged:

1. The majority of multimedia platforms in this review were developed for operative procedures. Of these, the majority (of operative-based platforms) taught and assessed cognitive skills; skills-based platforms tended to assess on technical skills.

2. In all comparative studies improvements were demonstrated in cognitive and technical skills for both multimedia and conventional teaching. In all non-comparative studies, improvements in both skills sets were also observed.

3. Multimedia and conventional teaching methods were equally effective in six studies (including four RCT studies); cognitive and technical skills were assessed in three studies each. All groups demonstrated improvement in skill performance. Only two studies (10%) found that multimedia had a significantly inferior performance compared to conventional teaching [46, 51]. No study found multimedia to have significantly poorer performance compared to no intervention.

4. Studies evaluating user satisfaction demonstrated a strong acceptance to support use of multimedia in surgical education.

The steady increase in published multimedia-based studies over the last six years, demonstrates a growing enthusiasm amongst surgical educators and developers. Although initially developed due to budget constraints and declining faculty numbers in undergraduate training of anatomy and basic skills [51, 54], the experience gained enabled the extension of multimedia technology to surgical training and construction of interactive procedural-based platforms.

Most studies recruited medical students to participate, as this would probably be easier than enrolling post-graduate trainees who have clinical commitments. This may account for the smaller group sizes in studies enrolling surgical trainees. However, medical students are a heterogeneous group compared to surgical trainees (due to selection bias and experience). This may have had an effect on the observed differences within studies [110]. The relative paucity of European studies compared to the US may be explained by allocation of funding for educational platforms, with more studies focussed on use of virtual reality simulation [92].

Multimedia platforms were developed for different types of procedures, demonstrating applicability in a wide range of disciplines. Multimedia-based surgical procedures, regardless of speciality, appear to be effective. The results of this systematic review demonstrate that both multimedia platforms and traditional teaching methods have a positive effect on surgical skills training. The reasons and potential mechanisms for this effect are discussed in detail in Chapter 5.

One major factor, not discussed in detail in any of the studies, relates to multimedia design and structure. Multimedia interventions designed and developed in the studies may range widely, from simple interface designs to highly sophisticated platforms [111]. Well-designed and constructed multimedia can enhance motivation, learning and transfer of knowledge and skills [43]. Designing multimedia involves considerable effort and is critical to conveying accurately all the necessary information [112].

User evaluation is a constructive and valuable assessment method to determine the educational success of multimedia [51]. However, over half the studies did not assess this important aspect. There are multiple factors that may influence user satisfaction including interactivity and ease of use. High levels of satisfaction suggest multimedia platforms are being carefully designed by the combination of technology experts and surgical educators [113]. However future studies need to address the developmental process in more detail, including use of software. Future developers and surgical educators need to consider multimedia design principles to ensure future educational success and acceptability.

Mode of dissemination of multimedia is an important factor. Whilst many of the early platforms were computer-based (57%) within skills laboratories or hospital work-stations bonded to location (and schedule), the latest platforms are more freely accessible, predominantly over the internet. Some of the disadvantages of e-learning include poor instructional design, cost to access website (e.g. WebSurg) [57] due to website maintenance), social isolation, and technical problems [114, 115].

Overall, the studies reviewed include a diverse range of training procedures and multimedia types. Also, the studies described different learning objectives, teaching methods, intensity of interventions and a wide range of learners, evaluation methods, and measured outcomes. Although heterogeneity of data complicates synthesis of the evidence [116], the consistency of positive findings reported amongst the studies do point to generalizability, relative feasibility and effectiveness of different multimedia approaches [116].

A third of studies in this review were non-RCTs. This may be explained by lack of resources to perform such studies [116]. To conduct a randomized study, researchers must have support from an institution(s)/ deaneries for recruitment of trainees and potentially funding resources [117, 118]. The reporting of methodological detail was often not comprehensive; this applied to the method and implementation of randomization (described fully in only 5 (36%) studies). Allocation concealment was only mentioned in 4 studies and blinding of assessors in 8 studies. Sample size and power calculation was only discussed in 5/14 randomised studies and sample sizes were, in general, small.

With rapid development and adoption of virtual reality simulators that have shown to be effective tools for teaching technical skills [119, 120], multimedia, although effective in basic technical skills acquisition [51, 58], is unlikely to play a significant role in teaching and assessment of this skill set. VR simulation, previously accessible only on expensive courses and in a small number of clinical skills laboratories, have started to be implemented into surgical training programmes [121] and will remain an important component of surgical training outside the operating room. The role of multimedia in surgical education would appear more suited to acquisition of cognitive aspects of non-technical skills. This is reflected in the greater number of studies focussing on cognitive skills assessment using procedural platforms.

Further studies are now required to address whether multimedia platforms can actually improve surgical skills performance. Studies could initially focus on assessment of intra-operative performance with procedural simulation models or live laparoscopic animal models before introduction into clinical practice.

For multimedia to be integrated into surgical curricula, it must be shown to be effective in unstructured, self-directed practice settings [54]. This requires educators to adhere to adult learning principles in both multimedia development and study design. Clear guidance on multimedia educational study designs may help in development of future studies.

2.5.1 Limitations

This review has a number of limitations. The study is limited by the availability of good quality studies. As discussed before, the heterogeneous nature of the evidence base precluded quantitative synthesis of the findings [122]. The studies identified were small in number, and the risk of bias was high in 6 out of 14 randomised studies (43%). Only four RCTs had samples of more than 15 study participants per group. Many studies only involved a single institution. These limitations hinder their ability to achieve statistical power and generalizability. Therefore, the strength of conclusions relating to validity of findings is limited [92]. Although evidence tables were used for demonstrating qualitative results, further quality of evidence grading such as GRADE [123] could have been used.

All studies focussed on lower levels of clinical competence [124] and the impact of the educational intervention on patient-centred outcomes is yet to be assessed. Therefore, it is yet to be determined whether positive results with multimedia-based training can be transferred in the clinical practice. In addition, the majority of the studies did not include long-term follow-up for retention of skills [98]. Recall ability may diminish over time unless the educational exposure is repeated [125].

In many studies, there was a lack of valid, reliable assessment tools [7] used to measure primary outcomes, particularly cognitive skills. None of the studies assessing cognitive skills used validated assessment tools. This lead to difficulties in assessing the results; as poor assessment methods may lead to improper interpretation [116]. Also, the use of identical pre-post/tests (57% of studies) may have contributed to improvement in scores simply by repetition, regardless of the intervention [126]. There is in general a lack of validated standardised surveys/questionnaires to evaluate user satisfaction [86] in these settings.

Other issues include lack of description of costs involved in the design and development of the multimedia platforms is not described. The issue of cost is very important in order for the readers and potential future developers to judge whether the reported outcomes offer value for money and therefore represent practical educational measures. The developmental process of the multimedia platforms were generally poorly discussed in each study and needs to be addressed in future studies in more detail.

2.5.2 Conclusions

Surgical education in the current era is enhanced with development of innovative educational tools. The results of this review suggest that multimedia is able to facilitate acquisition of surgical skills in an effective manner, but this may be more suited to cognitive skill acquisition using procedural-based platforms. Multimedia platforms appear to be valuable and well accepted educational tools to augment surgical skills training outside the operating room. The ultimate effectiveness of any educational intervention is to demonstrate an objective improvement in clinical or surgical performance and patient-related outcomes. This question remains largely unanswered and needs to be addressed in the future.

CHAPTER 3 – METHODS

The methods chapter is divided into two main sections:

- Development of Multimedia Educational Tools
- Randomised Control Study

3.1 Development of Multimedia Educational tools

3.1.1 DigiMed

DigiMed (http://www.digi-medical.co.uk) is a UK-based professional multimedia company (Leatherhead, Surrey) specialising in medical video-photography. DigiMed services include surgical filming, specifically full in-theatre live operating, and creative editing. DigiMed also has experience in development and implementation of interactive media tools for commercial and educational purposes, having produced a wide range of medical videography products in the medical and surgical industry.

DigiMed were recruited to provide the technological expertise required to develop and produce the multimedia educational tools. Members of the team involved in development and production were David Brown (Producer), Alex Martin-Verdinos (Filming and Creative Director), Chris Ribbens (Design Director) and Russell Crowe (Technical support). DigiMed professional services were funded by the Ethicon EndoSurgery educational grant.

3.1.2 Anterior Resection: Index Procedure

Anatomy of the colon and rectum

The entire colon is approximately 5 feet (150 cm) in length, and is divided into five major segments. The rectum commences at the rectosigmoid junction (end of the sigmoid colon) and is the last anatomic segment before the anus. The rectum is approximately 12cm long. The rectum ends at the level of the anorectal ring. The rectum is followed by the anal canal, before the gastrointestinal tract terminates at the anal verge.

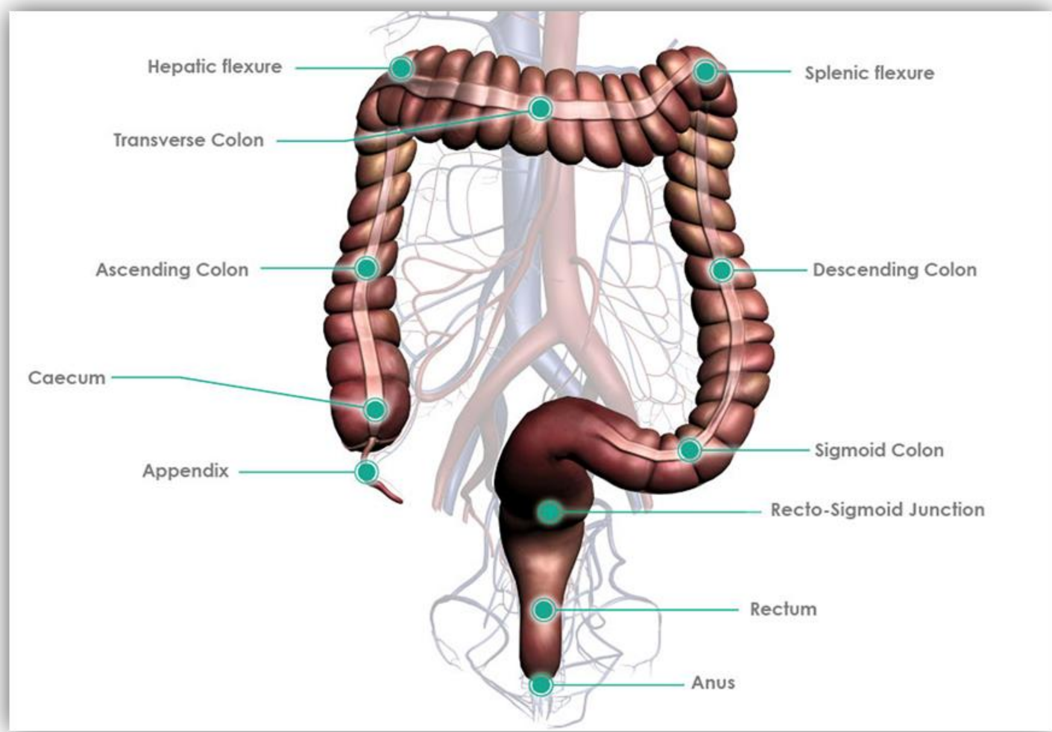


Figure 3.1 Anatomy of the colon and rectum.

Common Colorectal Procedures: tumour specific. DigiMed 2012 (App)

Anterior resection (of the rectum) is an operation that involves removing part or the whole of the rectum (Figure 3.1 and 3.2) before restoration of bowel continuity or anastomosis.

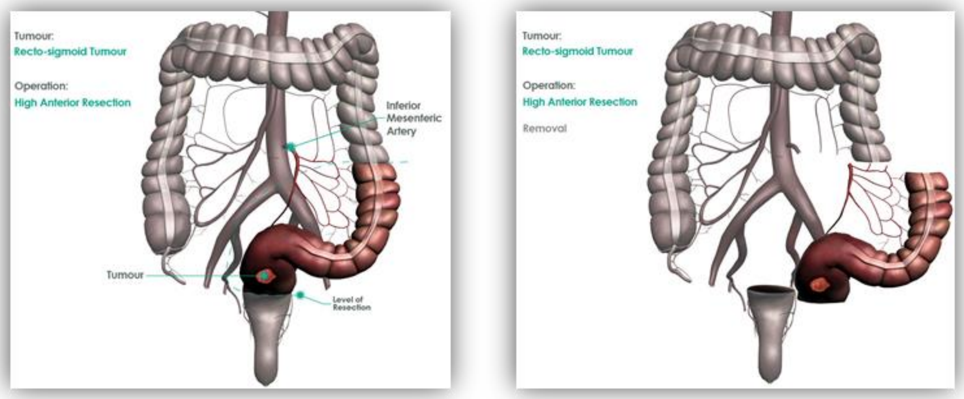


Figure 3.2 High Anterior Resection: Recto-sigmoid tumour and resection margins

Common Colorectal Procedures: tumour specific. DigiMed 2012 (App)

The anastomosis step involves joining the two ends of healthy bowel together, namely the proximal left colon (descending or sigmoid colon) to the upper/ mid or distal rectum or anus (Figure 3.3). This step can be achieved with use of sutures, or more commonly with stapling devices.

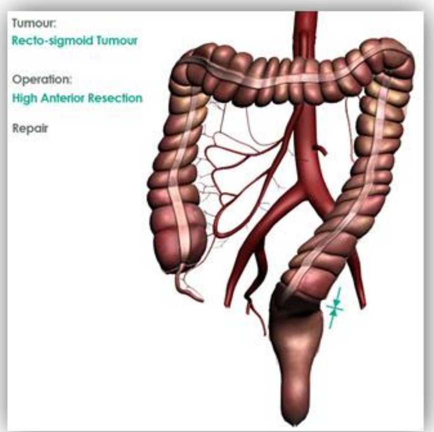


Figure 3.3 Anastomosis between left colon and upper rectum

Common Colorectal Procedures: tumour specific. DigiMed 2012 (App)

Anterior resection surgery is performed via two approaches (open and minimally invasive laparoscopic or 'key hole'). The open approach is a performed via a long incision in the midline of the abdomen and the laparoscopic approach involves a number of small incisions.

This operation is performed for various pathological conditions such as distal sigmoid and rectal cancer, diverticular disease and Crohn's disease and occasionally for gynaecological conditions. Anterior resection (of the rectum) is therefore a common operation performed in colorectal surgery in the UK. For example data from the National Bowel Cancer Audit Annual Report 2013, between April 2011 to end of March 2012, showed that out of 4,615 patients diagnosed with rectal cancer, 3,029 patients (66%) underwent an Anterior resection [127].

Anterior resection (of the rectum) has been assigned as an index procedure by the Intercollegiate Surgical Curriculum Project (ISCP) [128]. The ISCP is a competency-based curriculum requiring trainees to demonstrate competency and progression of surgical skills using structured, formative work-placed based assessments (where specific procedural skills are assessed using a Procedure-Based Assessment (PBA) form).

Trainees need to acquire both open and laparoscopic surgical skills in anterior resection surgery. Depending on complexity, trainees will be expected to perform this surgery in part under supervision at a junior level (ST3-ST6). Senior trainees (ST7-8), with a subspecialty interest in colorectal surgery, will be expected to perform all the steps of this operation competently by the end of their training (ST8). In addition senior colorectal trainees need to have performed a minimum of 30 Anterior Resection procedures for Certificate of Completion of Training (CCT) in General Surgery [129], with at least three procedures required at ISCP Level 4 (able to performed unsupervised and able to deal with complications) [128].

For the above reasons, anterior resection surgery was considered a suitable procedure for development of multimedia educational tools. Multimedia educational tools have therefore been developed in open and laparoscopic anterior resection surgery for the purposes of teaching and assessment of cognitive surgical skills.

3.1.3 Intra-operative open and laparoscopic video capture/ filming

This was the first phase in multimedia development. Open and laparoscopic intra-operative filming was performed at the Royal London Hospital, Whitechapel, London (Barts and the London NHS Trust) and The Princess Grace Hospital, Marylebone, London (HCA Healthcare) from October 2009 to December 2010. Additional laparoscopic intra-operative footage was obtained at Prince Charles Hospital (Cwm Taf UHB, Merthyr Tydfil, Wales). Informed consent for filming was obtained for all patients for the purposes of teaching, publication and research on standard NHS or private sector consent forms.

3.1.3.1 Open surgery filming

For open surgery, thirty-one procedures performed for both benign and malignant disease and comprising a spectrum of technical difficulty, were filmed by the research fellow (US) using a Sony standard definition 'DCR-SR47' camcorder. The research fellow scrubbed for all cases and the camcorder was covered in a sterile drape at all times. This facilitated close-up video capture of the key anatomical structures and procedural steps. Following each procedure, the unedited media was transferred onto a hard-drive, labelled and stored as digital video files (AVCHD).

3.1.3.2 Laparoscopic surgery filming

For laparoscopic surgery, thirty-five procedures were filmed. All laparoscopic intra-operative video footage was recorded directly from the theatre High Definition (HD) stacking system onto an Apple Mac Book Pro® (17-inch, 2.4 GHz quad-core Intel Core i7) laptop via a video capturing device (Blackmagic design). The Blackmagic Design USB and component H.264 video recorder is connected to the laptop via the USB connection (pre-installed with Blackmagic software). S-video cables are connected to HD stacking system video recording unit to replay the video imagery directly to the Apple Mac Book Pro® laptop. Each procedure was directly in QuickTime File Format on the internal hard-drive.

3.1.3.3 Exterior filming

DigiMed filmed a number of open and laparoscopic anterior resection procedures exteriorly to enable a global overview of patient positioning, set-up and arrangement of equipment within the operating room. Exterior filming also captured various angled "bird's eye" views of particular procedural steps.

No identifiable patient information was included during any filming. This was confirmed again during the video editing process. Following completion of open and laparoscopic filming, the video files were transferred to a portable drive (Western Digital WD® 500GB drive) and then copied and stored onto secure internal high-speed Hitachi SATA 2 terabyte (TB) 7200rpm hard drives at the DigiMed office ready for video editing.

3.1.4 Cognitive task analysis

Open and Laparoscopic Anterior Resection are complex operations that require a number of key steps to be executed for successful completion of the operation. A trainee may or may not be familiar with some or all the steps of the operation depending on prior knowledge and experience. To teach and train this operation, a structured format or framework needs to be constructed to enable all trainees to learn the required steps.

In order to appreciate how surgeons work and proceed through a particular surgical operation, it is essential to know how they structure information and make key decision making steps whilst performing the operation [130]. Traditionally, this has been based on the ability of experts to describe the operation by self-recall. However, when expert surgeons describe how they perform a complex operation, they may inadvertently overlook up to 70% of the critical information trainees need to learn [131]. This is because, as surgeons begin to develop expertise, their actions become automated. Automated actions and knowledge function outside of conscious awareness/ inspection [130]. It can therefore become difficult for expert surgeons to explain the individual operative steps required for completion of an operation [132, 133].

Cognitive task analysis (CTA) is a specific educational method that can be used to obtain performance expertise in which key decisions are related to both simple and complex actions [132, 133]. The collective purpose of CTA methods is to assist expert surgeons in the detailed description of operation, to enable extraction of the relevant information [130].

Applying cognitive task analysis to a surgical procedure allows deconstruction of the procedure into specific steps so that instruction can be directed to the key intra-operative decision making points [132]. The specific purpose of performing cognitive task analysis for open and laparoscopic anterior resection was to identify the critical operative steps and the key cognitive issues decision making that are important for teaching, training and assessment [106].

An expert panel consisting of a two colorectal surgeons (Professor Sina Dorudi and Mr Ayan Banerjee) participated in a cognitive task analysis for the open and laparoscopic anterior resection.

The cognitive task analysis involved a series of interviews conducted by the research fellow (US) with the two surgeons using a semi-structured interview similar to methods used and previously described [130]. All interviews were initially recorded on a dictaphone (onto a microcassette) and transcribed verbatim into word document before transfer into an appropriate table format.

The CTA series of interviews were performed in three phases with questions pertaining to:

- Steps (including decision steps accompanied by alternatives)
- Processes (who does what, when and where)
- Reasons (why do this, and not that)

The first phase of interviews was conducted outside the operating room in which all relevant information pertaining to each procedure was extracted. Open and laparoscopic anterior resections interviews were conducted separately. Open and laparoscopic anterior resection was deconstructed into a series of key constituent steps (Table 3.1). Open anterior resection was deconstructed into eight key steps. Laparoscopic anterior resection was deconstructed into nine key steps.

Open Anterior Resection Steps	Laparoscopic Anterior Resection Steps
Set-up	Set-up
Mobilisation of sigmoid and left descending colon	Port placement
Splenic Flexure Mobilisation	Medial-to-lateral Approach
Intersigmoid fossa dissection	Lateral Approach
Vascular pedicle division and further colonic mobilisation	Splenic Flexure Mobilisation
Rectal Mobilisation	Further colonic mobilisation steps
Rectal Transection	Rectal Mobilisation & Transection
Anastomosis	Specimen delivery
	Anastomosis

Table 3.1 The key steps identified by Cognitive Task Analysis (CTA) for open and laparoscopic anterior resection

Due to the complexity of the operations, each step is further sub-divided into a series of subtasks. For open anterior resection, the following additional information for each subtask was identified: Surgeon position, first assistant position, second assistant, patient position and instrumentation required. For the subtasks in laparoscopic anterior resection the following additional information was identified: operating team positions, patient position, ports and instruments used (in each port).

For each subtask for both open and laparoscopic operations, details were documented of specific actions and interactions performed by the operating team. Strategies relating to cognitive skills, specifically exploring decision making processes were noted. Discussions pertaining to each operation took up to three hours each.

The second series of interview sessions took place in the operating room during live procedures. This allowed the research fellow to directly observe the surgical team interacting and performing the operation, whilst making dynamic 'real-time' intra-operative decision making steps. This also gave the opportunity to discuss with surgeons each step/ subtasks in detail in terms of difficulty, anatomy and pathology. This was enhanced by observation of numerous cases providing opportunities for the fellow to implicitly understand each step and subtasks. This also enabled reinforcement of the decision making processes. All the operative information was again recorded on a Dictaphone before transcription verbatim comprehensively into word documents, detailing each step (and the subtasks comprising each step) specific actions and interactions, and describing the decision making points.

The third phase of interviews were conducted to resolve any conflicting points. Following this, the final tables were reviewed and approved by the two colorectal surgeons. Tables 3.2 and 3.3 show the steps, subtask and decision making points.

Step	**Subtask**	**Decision making points**
Set-up	Set-up and access	Length of incision
1. Mobilisation of sigmoid and left descending colon	**a.** Assessment of pathology	Is safe access to the left paracolic gutter possible? Y – Proceed to 1b N – Proceed to 1g
	b. Division of congenital peritoneal attachments	
	c. Develop plane between sigmoid/ left descending mesocolon and retroperitoneum	
	d. Continue to develop plane to identify Left gonadal vessels	
	e. Continue dissection to identify Left ureter	
	f. Cranial dissection to mobilise descending colon mesentery off Gerota's fascia	Is Adequate length of colon been achieved? YES – proceed to Step 2 NO – proceed to Step 3
	g. Medial-to-lateral Approach: Medial peritoneal incision	
	h. Develop plane between mescolon and retroperitoneum	
	i. Vascular pedicle division	
	j. Medial planar dissection	
	k. Gain access to Left paracolic gutter. Divide lateral attachments	

2. Splenic Flexure Mobilisation	**a.** Approach to Splenic Flexure	Lateral – proceed to 2b Supracolic – proceed to 2g
	b. Continue cranial dissection mobilising descending Left colonic mesentery off Gerota's fascia	
	c. Enter Lesser sac	
	d. Continue dissecting Greater Omentum off distal transverse colon	
	e. Supra-colic and lateral dissection planes meet to take flexure down	
	f. Complete splenic flexure mobilisation to the midline	(Proceed to Step 3)
	g. Enter lesser sac	
	h. Continue dissecting Greater Omentum off distal transverse colon	
	i. Supra-colic and lateral dissection planes meet to take flexure down	
3. Inter sigmoid fossa dissection	**a.** Divide attachments between distal sigmoid mesocolon and floor of LIF	
	b. Hypogastric nerve identification	(Proceed to Step 4)
4. Vascular pedicle division and Further Colonic Mobilisation	**a.** Pass fingers into plane developed in intersigmoid fossa	
	b. Reflect colon laterally and divide peritoneum adjacent to pedicle	
	c. Divide anterior peritoneal leaf overlying pedicle	
	d. IMA/IMV individually divided	
	e. Assessment of pulsatile bleeding: if inadequate resect	If poor, perform step 2 (if not already done)

	colon back to pulsatile flow	+/- 4h-4k to mobilise colon and re-assess flow If still inadequate: staple colon and proceed to step 5, 6 and 7i (colostomy formation)
	f. Division of proximal colon	Perform 7b and 7c if necessary Return to perform 4g
	g. Assessment of colonic length. Is further length required?	NO – proceed to step 5 YES – Has splenic flexure been mobilised? (if not go to step 2) and return to 4h If splenic flexure has been mobilised and further length still required, perform 4h-4k (re-assess after each subtask)
	h. Further omental dissection off transverse colon	
	i. Division of anterior leaf of transverse mesocolon off posterior stomach wall	
	j. Divide axial mesenteric vessels	
	k. Double ligation IMV	(Proceed to step 5)
5. Rectal Mobilisation	**a.** Divide right pelvic peritoneum	
	b. Right-sided postero-lateral mobilisation	
	c. Divide left pelvic peritoneum	
	d. Left-sided postero-lateral mobilisation	
	e. High or Low Anterior resection	High Anterior

	required (pathology dependent)	Resection – proceed to 5f Low Anterior Resection – proceed to 5g (Female) then 5i-5j proceed to 5h (Male) then 5i-5j
	f. High AR: Ensure circumferential mobilisation below transection and divide mesorectum Proceed to Step 6 (Rectal transection)	
	g. Female LAR (Anterior dissection)	
	h. Male LAR (Anterior dissection)	
	i. Divide lateral ligaments	
	j. Complete dissection to pelvic floor	(Proceed to step 6)
6. Rectal Transection	**a.** Ensure circumferential mesorectal division to demonstrate muscle tube	
	b. Stapled transection of the rectum	
7. Anastomosis	**a.** Is there adequate colonic length for anastomosis? Proceed to 7i if anastomosis precluded	YES – proceed to 7b NO – Mobilise splenic flexure (Step 2) if not already done If further length still required, perform subtasks 4h-4k (re-assess after each subtask)
	b. Select size of circular stapler Apply purse-string/ insert anvil	
	c. Secure purse-string to base of anvil	
	d. Clear excess mesenteric tissue	

	Bury any small diverticulae	
	e. Introduce circular stapler transanally	
	f. Advance trocar to through transacted rectum	
	g. Attach anvil to trocar Ensure correct orientation of bowel	
	h. Perform air test	If positive: repair anastomosis +/- re-fashion Consider diverting stoma Consider drain insertion
	i. Colostomy formation	Consider drain insertion
	j. Right colonic transposition technique	Use in situations when use of left colon not possible for anastomosis Consider drain insertion

Table 3.2. Cognitive task analysis: Open Anterior Resection

Step	Subtask	Decision making points
Set-up		Optimal placement of theatre equipment
Port placement	Umbilical port insertion	
	Are RIF adhesions present?	YES – insert x2 LIF 5mm ports and divide adhesions NO – insert RLQ port
	10-12mm RLQ port insertion	
	R lateral 5mm port insertion	
	Optional ports	i.e. Epigastric port required for splenic flexure mobilisation?
	Confirm diagnosis	
	Technically feasible to proceed?	YES - proceed to Medial-to-lateral Approach/ Splenic Flexure mobilisation NO – Consider immediate or planned conversion
Medial-to-lateral Approach	Identify right peritoneal leaf overlying base of sigmoid mesocolon and vascular pedicle	YES – Proceed to medial peritoneal incision NO – Divide congenital sigmoid attachments. Once attachments are divided, proceed to medial peritoneal incision
	Divide congenital sigmoid attachments	Proceed to medial peritoneal incision
	Medial peritoneal incision	
	Develop plane between retroperitoneum and hypogastrics	
	Left ureter identification?	YES – Proceed to take down ureter/ gonadals off sigmoid mesocolon NO – Perform lateral approach to identify ureter. Once ureter identified

		proceed to create medial peritoneal window
	Perform lateral approach to identify ureter	
	Taken down ureter/ gonadals off sigmoid mesocolon	
	Create medial peritoneal window	
	Pedicle Transection	Divide IMA/IMV together or individually
	Elevate transacted end of pedicle	
	Medial planar dissection	
	Divide lateral peritoneal attachments	
	Is there adequate length of mobilised left colon?	YES – Proceed to rectal mobilisation NO – Mobilise splenic flexure If further length still required, perform further colon mobilisation steps (e.g. divide axial vessels)
Lateral Approach	Divide lateral attachments as far as safe access allows	
	Create medial peritoneal window	
	Pedicle transection	
	Is there adequate length of mobilised left colon?	YES – Proceed to medial-to-lateral approach to divide IMA/IMV. If medial approach already done, proceed to rectal mobilisation. NO – Mobilise splenic flexure (if not already done) If further length still required, perform further colon mobilisation steps (e.g. divide axial vessels)
Splenic Flexure Mobilisation	Reflect Greater Omentum	
	Enter Lesser sac	

	Mobilise transverse mesocolon off posterior stomach wall	
	Continue dissection along transverse colon towards spleen	
	Continue mobilisation dividing attachments to laterally to flexure	
	Complete mobilisation to the midline	
	Is further length required?	YES – Divide axial vessels If further length required, perform further colonic mobilisation steps NO – Proceed to Rectal Mobilisation. If already done HAR/LAR? Nb. Consider Medial-to-lateral approach to mobilise splenic flexure (commencing with high ligation IMV)
Further colonic mobilisation steps	Divide axial mesenteric vessels close to origin Is further length still required?	YES – Perform Splenic Flexure mobilisation (if not already done) If SF mobilised, Perform further colonic mobilisation steps (re-assess length after each step) NO – Proceed to rectal mobilisation. If done HAR/LAR?
	Division of axial mesenteric vessels	Re-assess colonic length
	Further omental dissection off transverse colon	Re-assess colonic length

	Continue adhesiolysis between posterior stomach wall and transverse mesocolon	Re-assess colonic length
	Divide L colic artery	Re-assess colonic length
	Double ligation IMV	Proceed to pelvic dissection If already performed HAR/LAR?
Rectal Mobilisation	Take down R/L hypogastric nerve trunks off upper mesorectum	
	Divide L pelvic peritoneum	
	Divide R pelvic peritoneum	
	Postero-lateral mobilisation	
	High Anterior Resection or Low Anterior Resection?	Pathology dependent
High Anterior Resection (HAR)	Circumferentially mobilise below transection level	
	Mesorectal division	
	Introduce endoscopic stapler	
Low Anterior Resection (LAR)	Intracorporeal rectal transection	Proceed to specimen extraction/ LLQ incision
	Continue posterior mobilisation	
	Divide R/L pelvic peritoneum to reflection	
	Division of anterior peritoneal reflection	
Male LAR	Continue postero-lateral mobilisation in TME plane	Male or Female?
	Anterior dissection posterior to seminal vesicles	
	Continue TME planar dissection postero-laterally	
	Division of anterior mesorectum	
Female LAR	Division of lateral ligaments	
	Create muscle tube at pelvic floor	Proceed to specimen delivery
	Anterior dissection posterior	

	to vaginal vault	
	Continue TME planar dissection postero-laterally	
	Division of anterior mesorectum	
	Division of lateral ligaments	
	Create muscle tube at pelvic floor	
	Introduce endoscopic stapler	
	Intracorporeal rectal transection	Proceed to specimen delivery
Specimen delivery	LLQ incision	
	Insert wound retractor and exteriorise transected bowel	
	Division of colonic mesentery	
	Confirm pulsatile arterial bleeding	YES – proceed to divide colon In patients with co-morbidity, consider LIF colostomy formation NO – Resect colon back to pulsatile bleeding If poor supply is still poor, perform mobilisation steps and re-assess bleeding or consider colostomy formation. If all mobilisation steps have been performed and colonic blood supply remains inadequate, staple colon and perform LIF colostomy
	Divide colon	
	Apply purse string/ insert anvil	
	Replace colon into abdominal cavity and close fascia or twist wound retractor	
	Is further colonic length	YES – Perform colonic

	required?	mobilisation steps (axial vessel division/ SF mobilisation/ further steps) NO – Proceed to Anastomosis
Anastomosis	Introduce circular stapler transanally	
	Advance trocar through transected rectum	
	Introduce anvil holder and attach to trocar	
	Close stapler until snug tight	
	Fire stapler	
	Inspect anastomosis & Perform air test	If positive, repair/ refashion anastomosis +/- diverting stoma For LAR perform a diverting stoma Consider drain insertion
	Port and Wound closure	If diverting stoma, perform RIF trephine and fashion loop stoma

Table 3.3. Cognitive task analysis. Laparoscopic Anterior Resection

The comprehensive CTA tables for open and laparoscopic anterior resection detailing relevant operative information, including possible errors or pitfalls are shown in appendices 2 and 3. The CTA tables would also outline the voiceover and guide creation of particular animation sequences.

It is important to note that there is no set pathway to completing an anterior resection, open or laparoscopic, and therefore decisions need to be made dynamically – some steps may need to be revisited. This is reflected in both CTAs.

The cognitive task analysis for open and laparoscopic anterior resection forms the educational framework and design for each multimedia tool. Importantly the CTA tables provided further information – i.e. how many videos clips were needed (based on the number of subtasks per step) - that guided multimedia structure and design.

3.1.5 Multimedia content

3.1.5.1 Multimedia development timeline

Between October 2010 and January 2011 a series of meetings were held with the DigiMed team to discuss the design and development of the multimedia tools. All aspects were extensively discussed including projected costs of each tool and a timeframe for development. The design of the multimedia tools followed a chronological order. Design, development and production of the open multimedia tool took place from January 2011 to March 2011. The design, development and production of the laparoscopic multimedia tool took place from March 2011 to July 2011.

3.1.5.2 Software development

Adobe® Flash® Professional CS5 (10.1) was the commercially available multimedia authoring program used for development of both educational tools. Authoring programs can be defined as software that allows its user to create multimedia applications (Wikipedia). An authoring program has pre-programmed features for the development of interactive multimedia. The multimedia tools are based on construction of the interface map. As described, the interface map is the viewing screen or “the stage” for interaction with and navigation between the “elements”. The elements have designated functions within the map (i.e. video clip location for a particular subtask) located in specific zones.

The authoring programming software writes, and assists with writing “code” that enables building of the elements to create the graphical interactive interface maps. The procedural steps and subtasks derived from the cognitive task analysis form the basis of the open and laparoscopic interface map design.

The construction of the interface maps, and key functions of the interface map required for navigation are now briefly described. Though the layout of the open and laparoscopic anterior resection interface maps differ (discussed later in this section), construction of each interface map follows the same principles and structure based on three ‘layers’:

Layer 1:

The inertia layer allows interactivity with the interface map (i.e. mouse-orientated). Users are able to zoom in and out and move the map from left to right. This function is in-built within the programme. A specific area within the map can be designated for this particular function, enabling other areas to be fixed in a constant position.

Layer 2:

The multimedia assets or elements are then built onto the map. These elements can either be toolbars, panels, icons or arrows that have a designated function. All elements (e.g. icon) are created in image design programmes. Adobe® Photoshop® CS5 or Adobe® Illustrator® CS5 software have been used for this purpose for multimedia development.

The assets form the framework of the multimedia tool. All assets designated the same function have a consistent format to give users a clear understanding of the map. For instance all video icons are the same size and allocated in an orderly fashion at a specific location on the map.

Layer 3:

Once the elements have been built into the map, the final layer is the video and information boxes. For instance video clips are placed in the corresponding icon on the map and text information is placed in panels relating to the individual video clip. The icon needs to be opened before the clip is played back

Two essential multimedia functions are now explained. These functions allow users to form a clear mental picture of the map.

Rollover function:

Particular elements are used for graphical purposes to allow interactive, visual communication.

The rollover option works by cursor movement over an element to ‘highlight’ that specific element (i.e. icons or arrows) on the interface map. The rollover option is a method of providing clarity and user interactivity. This is designed by writing a command to the element that will initiate a ‘movie’ function (although this is <u>not</u> video content).

The ‘movie’ functions by assigning a “key frame” to the element. This is a value marker that enables a ‘movie’ to be initiated on the screen over a pre-determined time period so that the element can either be permanently highlighted or remain until another the cursor is moved to rollover another element. ‘Movies’ may simply result in elements being highlighted. However in some instances a pathway of command can be set up to enable a piece of text appearing at another location on the map.

The rollover function is prominently used in the open tool. This allows text information to be “hidden” from the interface screen unless the user accesses a particular element or subtask icon. This reduces redundant information on the interface screen.

Pathway of commands

To enable the user to fully interact and navigate the map, a series of commands need to be programmed to integrate the elements. Adobe® Flash® Professional CS5 (10.1) enables developers, by writing an action script, to command to an element to activate another command and thereby constructing a “chain” of commands i.e. instruct an element when activated, by either rollover or clicking, to perform a command. Using the example from above, this command will activate text information to be highlighted when a particular element is rolled over. Alternatively a network of commands can be constructed to open a video playback clip when an element is clicked.

Assigning a command to elements can set-up any network of commands that will enable users to navigate from one area of the map to another. All these commands are built into the interface map.

3.1.5.3 Open Anterior Resection interface map: design specifics

An easy-to-use navigational interface map, allowing unrestricted interaction, was constructed to enable users to follow the steps to perform the procedure sequentially or navigate directly to areas of particular interest.

Three specific areas or zones were designed on the interface to display the content, media and text (Figure 3.4). This allows consistency in the presentation of information presentation.

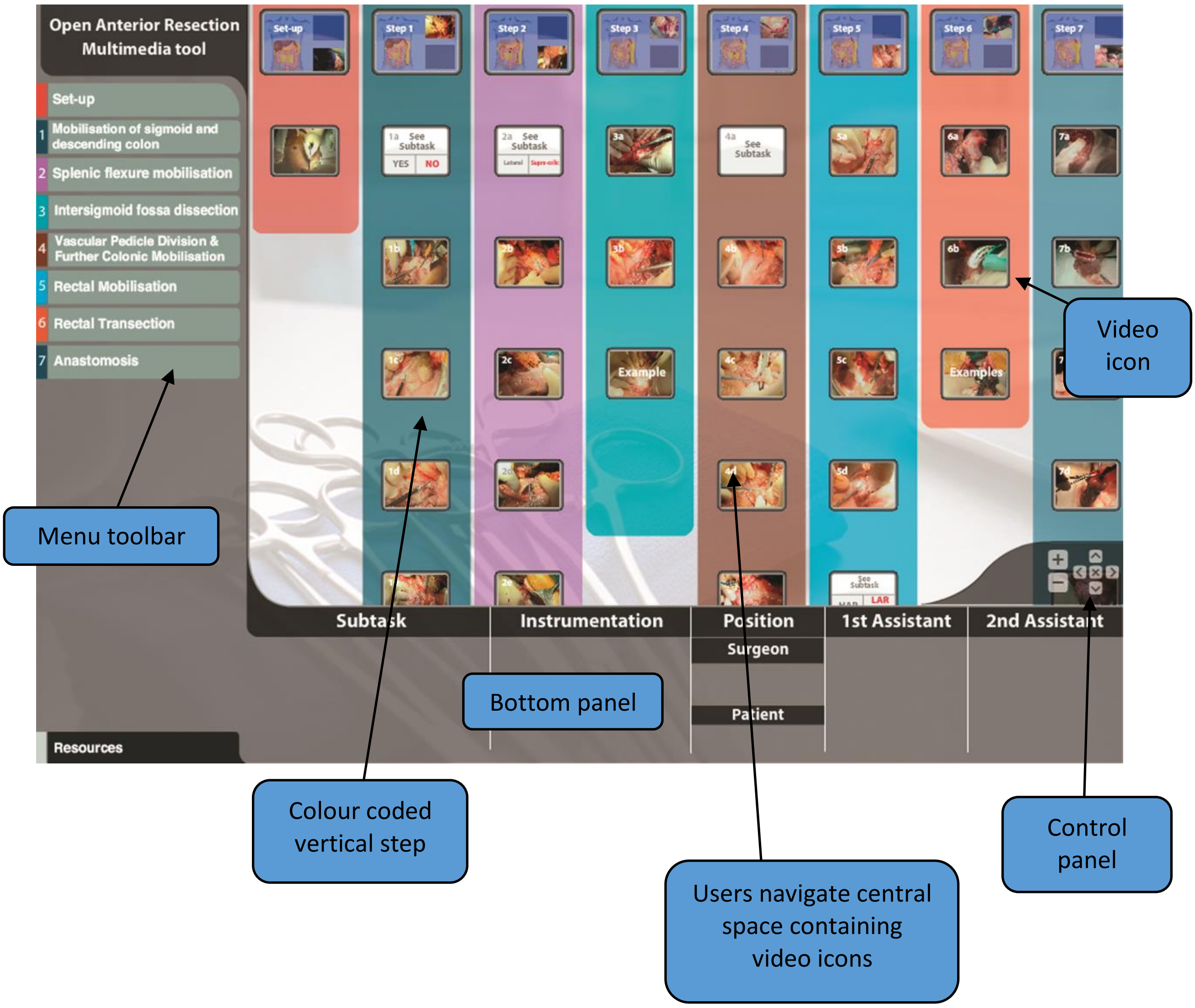


Figure 3.4 Open Anterior Resection interface map demonstrating the key design features in three specific zones: menu toolbar, central space for video icons and bottom panel for subtask, instrumentation, team and operating position

1. A menu toolbar was created on the left-hand side delineating the eight key steps; clicking on each step will open the subtasks required to complete the step.

2. A bottom panel was created to display subtask information, instrumentation, team (Surgeon and first/second assistant) and patient position.

3. A large central space on the map was created for icons and video content. Individual icons formed part of a colour-coded vertical pathway for the step (subtasks) (see Figure 3.4).

The key features of the open tool are:

1. Simple interface map layout with steps aligned vertically with subtask icons occupying the interface space

2. Interface map following a vertical pathway created from the beginning of the operation (i.e. Set-up to Anastomosis).

3. Ability to navigate directly to particular step or subtask icon at any time

4. Constant menu toolbar and bottom information panel

5. Text information only displayed when icons are “rolled-over”

3.1.5.4 Laparoscopic Anterior Resection interface map: design specifics

The Laparoscopic tool uses the same multimedia principles as the open tool but varies in design. Building on the experiences of the open multimedia tool design and development, the research team and DigiMed decided to alter the layout of the laparoscopic tool to further engage the user and facilitate improved interactivity. The laparoscopic interface map differs from the open map in that the users need to make decisions to complete the operation. The interface map and navigational features were designed to be simple and required low mental effort. The steps/ subtasks derived from the laparoscopic cognitive task analysis form the basis of the interface map design.

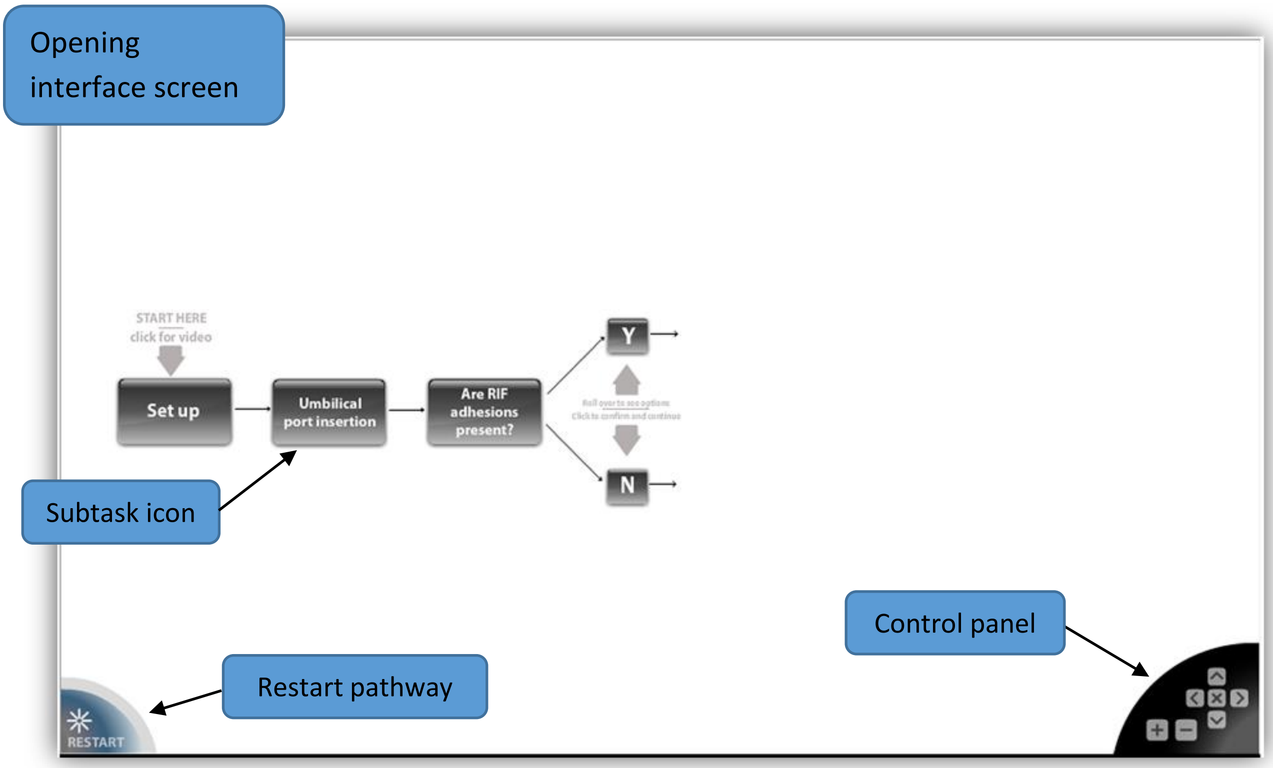


Figure 3.5 Laparoscopic Anterior Resection interface map – opening interface "viewing" screen. This map is arranged in a left-to-right linear pathway

The key features of the laparoscopic tool are:

1. Simple interface map layout with subtask icons occupying the interface space.

2. Interface map follows a linear left-to-right pathway created from the beginning of the operation (i.e. Set-up) (Figure 3.5) and to the end (i.e. Port and Wound Closure). It is important to note that, although the CTA deconstructed the operation into nine steps, the actual steps are not shown in a toolbar (such as displayed on the open tool). However the subtask icons follow fixed sequential linear pathway and various steps are colour-coded.

3. All potential pathways (i.e. all the potential combination of steps to complete the operation) have been integrated onto the interface map. The user therefore is required to interact with the interface by making decisions at key points. Users are presented with Y/N optional boxes and can choose either option. Choosing a particular option will activate a chain of command opening a sequence of subtasks. To proceed, the next decision making Y/N optional box must be clicked to activate another set of subtasks (Figure 3.6). Only the relevant subtasks in a particular pathway will then be activated and displayed. Only the chosen pathway is displayed at any given time (Figure 3.6). All other subtasks in another pathway are not therefore visible until an alternative option is selected. In this way, the user is able in focus on a particular pathway in a cognitively efficient manner. Users are also able to review the pathway chosen at any time by dragging the cursor on the map.

4. When users choose to view a video clip for a given subtask, all subtask information are displayed simultaneously when the video box is opened.

5. All mobilisation steps are colour-coded (e.g. splenic flexure mobilisation in blue). This provides consistency in information presentation.

6. Although users are unable to directly activate a particular sequence of subtasks (e.g. anastomosis) from the start, the interface has been designed for users to become quickly orientated with the map and therefore quickly 'jump' to these sections once they have familiarised themselves with the interface map layout.

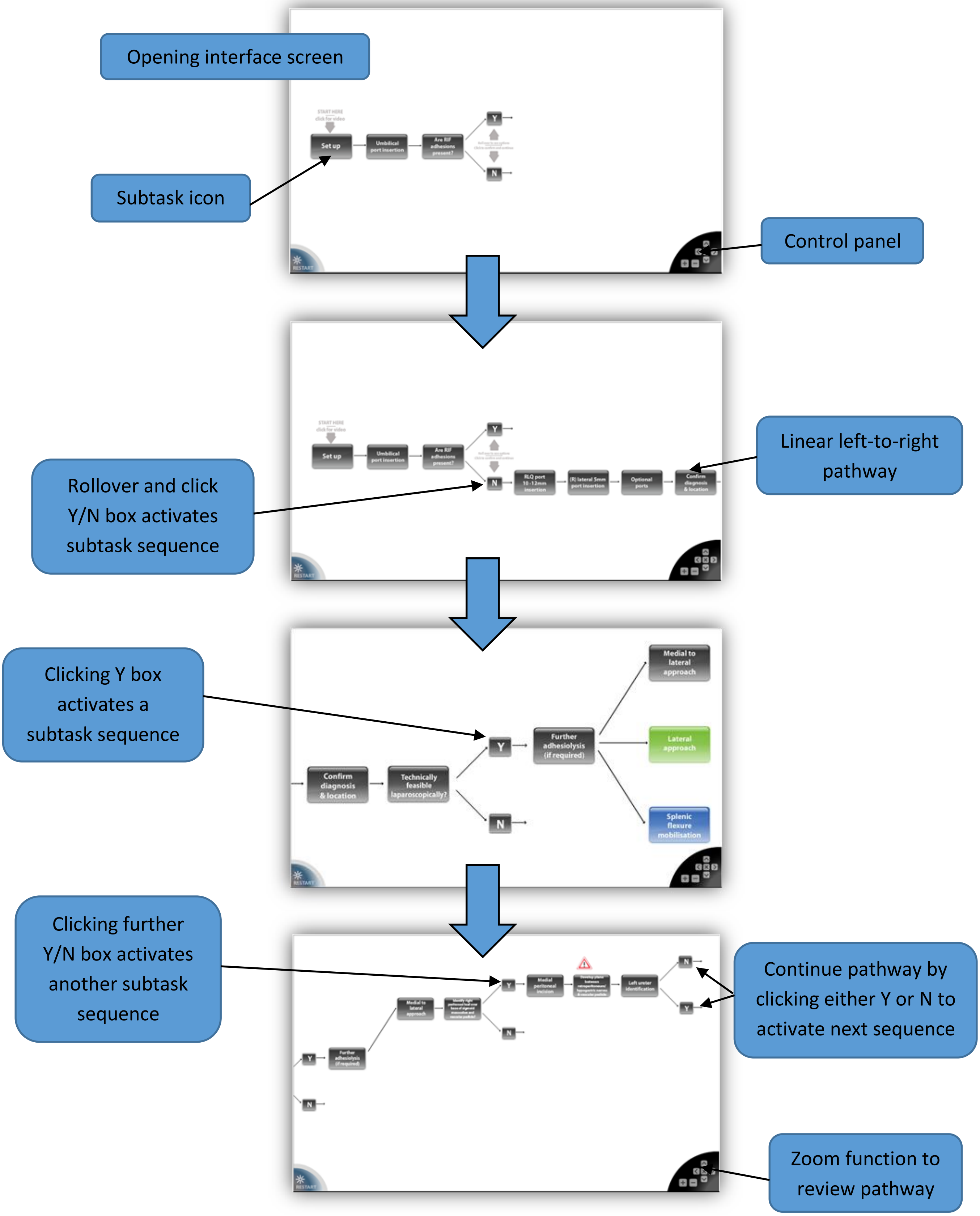


Figure 3.6 Interaction with laparoscopic interface map to open a particular subtask video clip

There are a number of key differences between the open and laparoscopic interface maps shown in Table 3.4:

	OPEN	**LAPAROSCOPIC**
Screen design	Three zonal areas: Menu toolbar, bottom panel, and video icon area	Larger interface : icon displayed
Navigation	Video icon/ content area	Entire interface
Interface information presentation	All information presented on interface. Menu toolbar and bottom panel remain constant Each step pathway coloured	Only the subtask icons displayed for pathway user has chosen Specific icons coloured
Step/ subtask pathway	Vertical	Linear (Left-to-right)
Decision making points/ steps	All pathways remain on screen Information also displayed on bottom panel; users need to navigate to these subtask and return (if out of sequence on the map) i.e. from subtask 5i to 4f	*Only* the pathway chosen displayed on screen Unable to 'jump' out of sequence Decision making step chosen at particular stages (same as a live procedure)
Review pathway option?	No	Yes
Subtask information display	Rollover/ clicking icon on interface displays information on bottom panel on interface screen	Subtask information only displayed once video icon is clicked opened and video sequence played back
Playback sequential video clips	Control panel enables users to open next subtask video icon directly	Users need to close video clip and click on the next subtask video icon to playback

Table 3.4. Differences in design and layout of the open and laparoscopic tools

3.1.6 Media content

Following development of the interface maps, testing to ensure correct function of all maps and agreement by both the developers and research teams; the production and integration of media content onto interface maps was done. Media content integration onto both multimedia maps was identical and therefore will be described in one section. The following sequence involved:

- Editing of video content
- Production of animation sequences
- Voiceover
- Annotation of edited video clips
- Text information for each subtask
- Instrument glossary
- Final review
- Production of 'How-to-use' videos

The content addresses key aspects of the open and laparoscopic procedures including:

- Relevant factual and anatomical knowledge
- Dissection in the correct anatomical planes
- Key decision making points required to complete the steps (each subtask)
- Technical aspects and knowledge of instrumentation, stapling devices and various energy sources
- Team and patient positioning
- Use of assistance

The educational content provided is of relevance to all (ST3-8) levels of general surgical trainees.

3.1.6.1 Editing of video content

All media content was edited on an Apple iMac desktop (2.8GHz dual core processor 18GB RAM) at the DigiMed office. All editing steps of media content were guided by the research fellow (US). Each video clip was individually edited with the creative film editor (Alex Martin-Verdinos), guided by the research fellow (US). Production of each video clip took place in the following sequence:

1. Selection of the subtask requiring editing of video clip footage.

2. Amalgamation of footage stored on the internal hard-drives from the various examples for the subtask (i.e. open: subtask 1b: Division of congenital peritoneal attachments). The various examples have been carefully selected to demonstrate common anatomical and pathological variations. Additional further video footage demonstrating the same subtask in differing cases was also edited into the "examples" subtask.

3. Using Final Cut Pro (an editing suite application software package) relevant video was extracted (non-destructively) from the hard-drive and any redundant video material excluded; original content was not disrupted. Final cut Pro saves all the information for a particular clip over a timeline. Footage can be placed anywhere along the timeline.

4. Each clip was edited into succinct clips lasting between 30 seconds and 2.30 minutes.

5. The video remains in an uncompressed format. Once the clip was completed, it was rendered into a file on the hard-drive. Following completion of all video editing clips, relevant animation sequences were produced.

3.1.6.2 Production of animation sequences

Individual video subtasks were identified in which it was felt that learning could be enhanced (or anatomy explained in more detail). Animation sequences were constructed and incorporated for these video subtasks. The following animation sequences were produced using Adobe® After Effects® CS5.5 software:

1. Upon selecting any given open step there is an overview video that introduces the important anatomical and technical aspects by means of animation (produced by N Kullar).
2. Set-up subtask (laparoscopic tool)
3. Lesser sac anatomy (used in both tools)
4. Intra-luminal circular stapler firing sequence to create anastomosis (used in both tools)
5. Inferior mesenteric artery blood supply (used in both tools)
6. Inferior mesenteric vein blood supply (used in both tools)
7. Double ligation of inferior mesenteric vein (used in both tools)
8. Marginal artery blood supply (used in both tools)
9. Blood supply of the rectum (used in both tools)
10. Anatomy of the rectum (used in both tools)

For sequences (5-10) a 3D body was purchased from 3D Studio Max animation (by DigiMed). Anatomical images were taken and extracted as a tiff file into Adobe® After Effects®. Arrows were then created to annotate the anatomical structures. All files were imported into Final Cut Pro and assimilated into the relevant animation sequences and video clips.

Subsequently, all the video files were batch exported onto low resolution cross compatible MPEG-4 files (size: 20-50mpg) onto a portable drive. All the videos were then reviewed by the research team to ensure relevant and correct educational content. The videos were also assessed for clarity and whether further examples were required. In instances when video clips were deemed to be too long, further editing was performed.

3.1.6.3 Voiceover

A voiceover script was written by the research fellow (US) on a Word document for each individual video clip/ file. The voiceovers were each reviewed and edited with the research team before recording. Voiceover was recorded in a bespoke sound booth (at DigiMed office) by the research fellow (US). Whilst each clip was played back in the booth, voiceover was recorded via microphone directly onto the Final Cut Pro 'timeline'. For each video clip, the recorded audio needed to be synchronised with the video material. This involved time spent by the research fellow with the film editor (A V-M).

Concise voiceover was included for each video clip in keeping with multimedia design principles, covering key aspects on how to perform the subtask, anatomy, use of assistance and instrumentation. Once all the voiceover had been recorded, all clips were reviewed and, if necessary, re-recorded with the editing team to ensure each voiceover was correct.

3.1.6.4 Annotation

Annotations were used to highlight key anatomical structures and to facilitate anatomical plane recognition. Each video clip was reviewed and annotated. A series of colour-coded arrows and dotted lines were created in Adobe® After Effects®; colour related to dissection plane (blue) or anatomical structure (white) thereby providing the user with consistency in information presentation. The arrows were created, imported into Final Cut Pro and incorporated into the 'timeline' and video clip; annotations complemented and appeared on the screen to synchronise with the relevant voiceover.

3.1.6.5 Text information

For each subtask derived from the cognitive task analysis for open anterior resection (table 3.2), text information is provided on subtask (key points), instrumentation, surgeon and patient position and use of surgical assistance (1^{st} and 2^{nd} assistant).

For each subtask derived from the cognitive task analysis for laparoscopic anterior resection (table 3.3), text information is provided on subtask (key points), instrumentation/ ports and operating team (including use of assistance) and patient position.

The text information included salient points, and was similar to the voiceover, but was not identical. Text information was uploaded and integrated onto the interface maps once the video content had been uploaded.

3.1.6.6 Instrument glossary

A comprehensive glossary of all the instruments used in open and laparoscopic anterior resection surgery was also created. Photographs were taken in theatre using a Sony (Cybershot DSC-W200) digital camera of all the required instruments and files were copied onto the internal hard-drives. Ethicon EndoSurgery also provided high quality digital files of all the stapling instruments. Adobe® Photoshop was used to crop images.

The images were exported as .jpg files for review before integration onto a space constructed below the interface map. The images were divided into the following sections:

Open instrument glossary:	**Laparoscopic instrument glossary:**
• Retractors • Tissue forceps • Artery forceps • Bowel clamps • Stapling instruments • Energy devices • Other	• Port insertion • Endoscopic hand instruments • Bowel division and purse-string application • Stapling instruments • Energy devices • Port and Wound closure

3.1.6.7 Final media content overview

All edited clips, including the voiceover, were exported in low resolution cross compatible MPEG-4 files (size 20-50mpg) for final review by research team to ensure clarity and correct factual content. Any final adjustments were discussed and a number of video clips were re-edited and voiceovers re-recorded.

3.1.6.8 Trans-coding files and uploading onto the interface maps

Once all clips had been reviewed, the video files were trans-coded into Flash (flv.) files to be compatible with Adobe® Flash®. Each video file was labelled and exported as (flv.) files. The (flv.) files were imported and stored on the Adobe® Flash® programme and uploaded into the allocated video content spaces on the interface map. Following this, the text information for each subtask was transferred onto the appropriate space on the interface map. All files were published as stand-alone Flash (flv.) files. All (flv.) files were reviewed on the interface maps to ensure correct placement with the corresponding subtask icon.

The multimedia tools were then tested extensively to ensure all functions were working properly and also to ensure that all the pathways had been assimilated and functioning in the appropriate fashion.

3.1.7 How-to-use introductory videos

Clear and concise "How-to-Use" animated videos were then created for user demonstration of each tool (see DVDs or visit the colorectal training website). The videos covered examples of how to navigate the map and use of the available functions. Both videos were integrated onto the map and played automatically each time the tools were loaded. A skip button was created below the videos to direct users straight to the interface map.

3.1.7.1 How to use the multimedia tool?

A short explanation of how to use both multimedia tools, integrated with all media content, is given below. The section below explains how to use the tool multimedia tool, followed by a sequence of images demonstrating the tool (an example is shown from a pathway in each case).

3.1.7.2 Use of Open Anterior Resection Multimedia Educational Tool

To start interacting with the tool, users need to click on a particular step in the menu toolbar. This opens the list of subtasks (Figure 3.7). By rolling over each subtask, users are able see the text information displayed on the bottom panel.

Clicking on a subtask commands the subtask to zoom directly to the corresponding video icon on the map. An overview video introduces each step by summarising the key aspects to complete the step. Users then need to click on the video icon to start video playback; playback can be paused at any time and there is a function to increase or decrease the volume setting.

To follow a step sequentially, the user can follow all the subtasks by using the control panel in the right-hand bottom corner. Option buttons direct the user to the next subtask (or next step if at the final subtask) or return to the main interface map. In this way users have full control of the map creating a self-directed approach to the learning experience.

An additional resources section was built at the bottom of the menu toolbar. Videos clips including footage or animations of anatomical structures (e.g. lesser sac, marginal artery) and instruments were edited into separate sections in the resources section to provide quick reference.

The subtask information box, on the bottom panel, displays the key information and further decision making points whilst the video is being played back. The control panel in the right hand corner provide zoom function and also allow the map to be moved around.

The short ‘How-to-use’ video automatically plays each time the tool is loaded. The video provides users a quick demonstration on the tool and the how to navigate the map using the key functions. A skip button was placed below the video to direct users straight to the map.

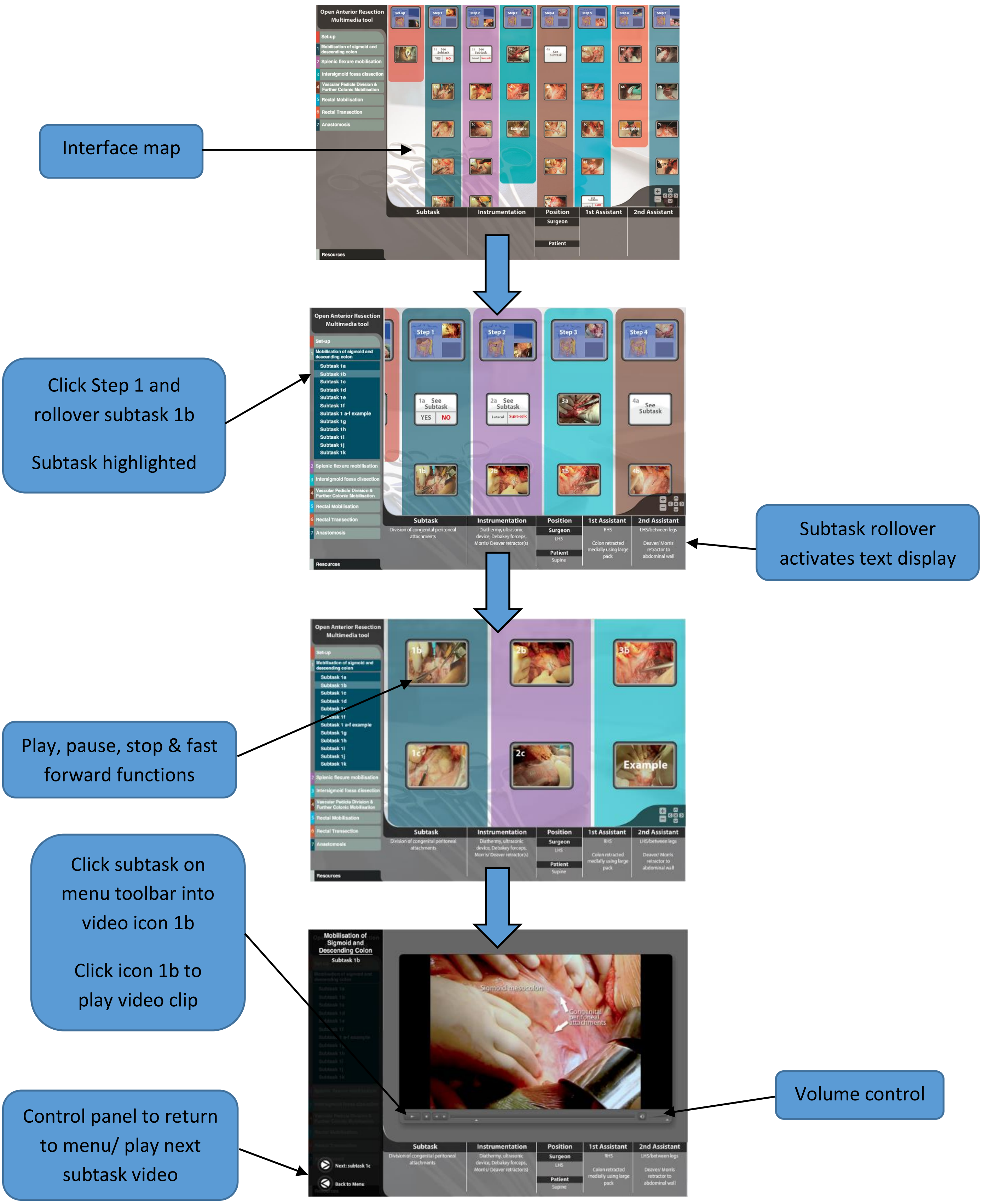


Figure 3.7 Interaction sequences with interface map to open a particular video clip

3.1.7.3 Use of Laparoscopic Multimedia Educational Tool

This tool is designed to cover all possible pathways (or combination of steps) to complete the laparoscopic procedure. Users interact with the tool by starting at the beginning of the procedure (i.e. Set-up subtask) and following subtasks sequentially in a linear left-to-right fashion to end with the ‘Port and Wound Closure’ subtask. To navigate the map, users need to rollover the optional Y/ N boxes (Figure 3.8). These boxes are designated at key decision making steps during the procedure.

Users can either choose to click and view each video icon or rollover/ click the Y/N boxes to create a pathway. Y or N boxes must be clicked to activate further subtask boxes until the next decision making stage (i.e. another Y/N box). For example the first Y/N box is after the ‘RIF adhesions present’ icon. This activates another sequence of subtasks until the next Y/N box is encountered, after the ‘Technically feasible laparoscopically’ box. Users can then choose three standard approaches to progress. All mobilisations steps are colour-coded. Users should continue along the pathway chosen until the next Y/N box is encountered. Using the control panel in the right hand corner allows users to review the pathway chosen at any time. Holding down the left mouse button also allows users to drag backwards on the ‘timeline’ or pathway.

To use an alternative pathway, users should return to the preceding Y/N boxes. Once a new pathway is chosen the previous subtasks displayed are erased from the screen. Therefore only one pathway is displayed at any given time. Users can also start a completely new pathway by clicking “restart”; users are then returned to the set-up box.

To open a video clip, users must click on the icon. This will activate the clip to be played back. The display below the video provides subtask key points, instrumentation used (ports required) and operating team/ patient position. The map does not allow users to view particular subtasks in the pathway directly. User will need to navigate the map by choosing the various Y/N options to locate the subtask. However, once users are accustomed to the tool, navigating the interface in this manner is straightforward.

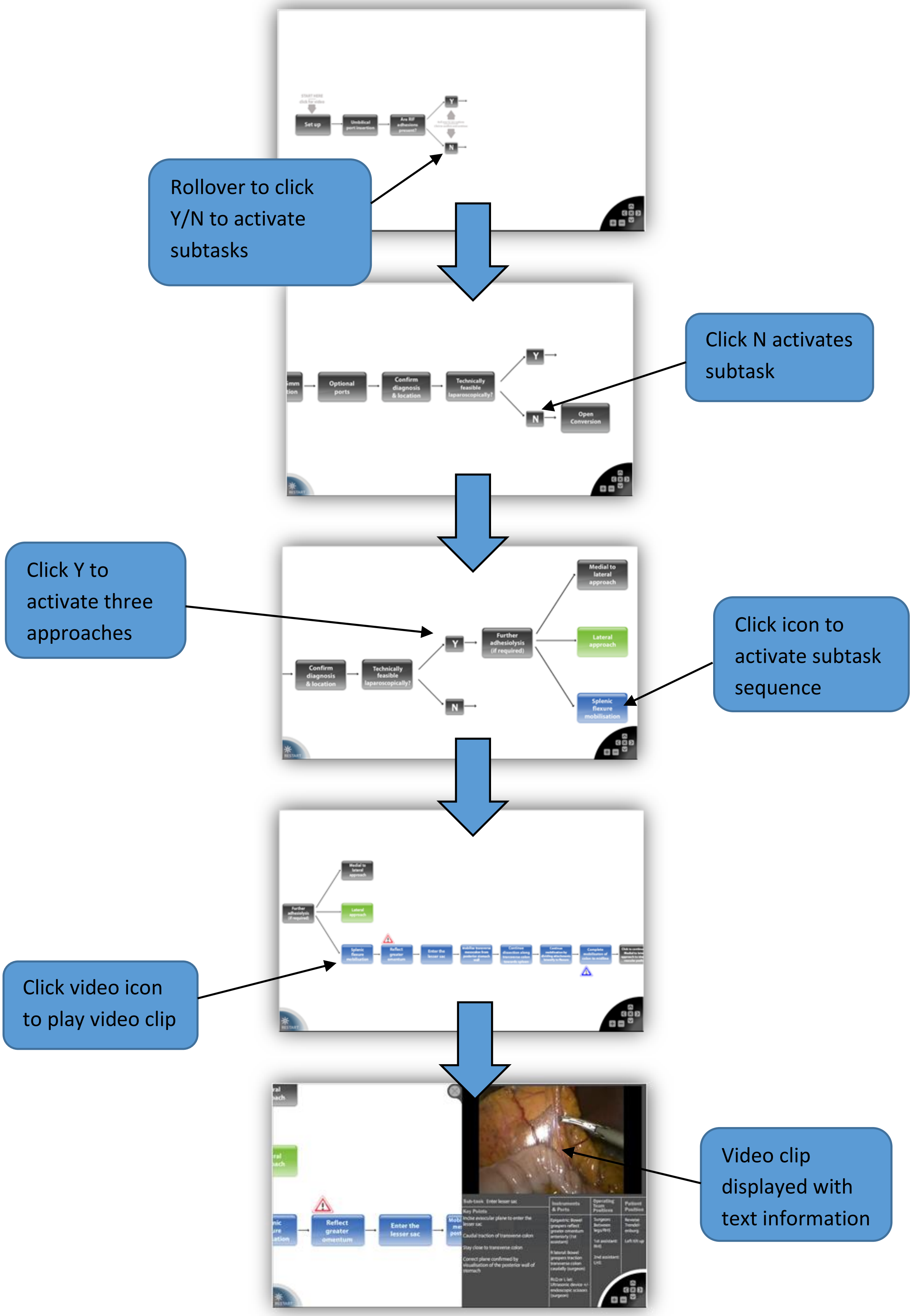


Figure 3.8 Interaction with laparoscopic interface map to open a particular subtask video clip

3.1.8 Colorectal Training Website

The delivery modality to disseminate the educational tools was via the internet. A domain was purchased able to store up to 20 gigabytes of space. The website was named: http://www.colorectaltraining.co.uk. All media stored on the Adobe® Flash® programme was then transferred and stored on the web server; the open and laparoscopic tools were housed on separate HyperText Markup Language (HTML) pages on the website.

The Educational Tools were designed to run via the web on any PC or Macintosh computer/ Android tablets/ iOS-based tablet (iPad) or smartphones (e.g. iPhone) using Internet Explorer, Safari or Mozilla Firefox web browsers [126]. The multimedia team had previously made informal enquires from users in hospital and private setting on computer specifications. It was therefore assumed that potential trainees all possessed computers that met the following minimum specifications to run the multimedia tools: 1GHz desktop/laptop, Windows XP/ vista/ Mac OS operating system including Adobe® Flash® plug-in version 7 or more recent, 1GB RAM and modern processor/ graphics card (both purchased after 2008).

The colorectal training website is made up of 1.24GB of data (475 items including videos, digital images, Flash animation, and script). There were a total of 69 video clips in the open tool (total data: 679MB) and 67 video clips in the laparoscopic tool (total data: 473.5MB).

The size of the video imagery in the open and laparoscopic tools was 600 x 337 pixels and 448 x 252 pixels respectively. The video characteristics (codec ONVP2, resolution up to 600 x 337 pixels, transmitted at an average rate of 300-600 kps) were deemed sufficient to allow quick start and reliable playback of videos without streaming problems. The size of the images in the instrument glossary below the interface maps were 250mm x 215mm. In the laparoscopic map there is also a bottom panel toolbar that functions as a pop-up screen when clicked to open the instrument glossary on the interface screen.

The two “How-to-Use” demonstration videos were loaded onto YouTube, a video-sharing website, on a private channel not accessible to the public. The embedded videos would play directly on the web link when activated.

The website was extensively tested on a variety of computers and internet service providers to ensure smooth running, in particular streaming of videos.

3.1.9 Adherence to multimedia design principles

The multimedia design principles highlighted in (Table 1.1) [87] are briefly discussed and how each principle has been considered and applied to the Open and Laparoscopic Anterior resection multimedia tools.

Coherence principle

Coherence principle states that extraneous pictures, sounds and words should be excluded [43, 75, 81]. In both tools, essential text was displayed in the information panels. To exclude use of extraneous words, text has been summarised (in abbreviated format) in all instances to ensure only key text information is displayed. No background music or extra sounds were used in either tool. Synchronised voiceover is directly related to each video clip (subtask video) and the narration highlights the key points required to complete each subtask. Extraneous pictures have been excluded to display only the key corresponding pictures for each video icon on the open interface map. Opening the video icon will display one picture or video display at any one time. On the laparoscopic interface map, no pictures are displayed on the interface map. Additionally all open and laparoscopic subtasks containing video footage has been succinctly edited, excluding extraneous material to adhere to the coherence principle.

Signalling principle

Signalling principle provides ‘cues’ on how to select and organise material and also refers to highlighting essential information [79, 81, 134]. Only essential graphics have been included to direct users to relevant information. Arrows guide users through subtasks, particularly in situations when presented with optional boxes (decision making). Pathways are also programmed to follow in a consistent manner i.e. the linear left-to-right pathway in the laparoscopic tool or vertical pathway in open tool.

Redundancy principle

The voiceover has been synchronised with video footage and the text information displayed provides a summary of the subtask, instrumentation and team position. The text acts as a reference for the user and intentionally avoids using "identical streams" of printed and spoken words, thereby adhering to the redundancy principle [76].

Spatial contiguity principle

Spatial contiguity states printed words should be placed near corresponding parts of graphics to reduce need for visual scanning [43, 69]. In the context of video and animation playback, anatomical structures have been highlighted by placing arrows and/ or text directly on or adjacent to the structures. Visual scanning is also reduced by placing all subtask information in close proximity to the video screen (discussed above). The rollover option on the open interface map highlights information in the bottom information panel only when the cursor is placed on a particular subtask. Fixed placement of the menu toolbar and information panel (in the open tool) also ensure that users know how and where to access text information in a consistent and deliberate manner. The laparoscopic interface map displays only the subtask icons in the chosen pathway; each icon is titled with text corresponding to the subtask, again minimising visual scanning. Once the icon is opened, the subtask video and text information displayed is contained on a single screen.

Temporal contiguity principle

Synchronising voiceover (narration) for all video or animation sequences conforms to the temporal contiguity principle which states that corresponding animation and narration are presented simultaneously rather than successively [75, 79].

Segmenting principle

Segmenting principle states that information should be presented in “bite-size” learner-controlled segments rather than as a continuous unit [43, 81]. Creating multimedia tools based on cognitive task analysis is particularly effective at segmenting information.

Modality principle

The modality principle instructs presentation of words as narration rather than as on-screen text due to the visual channel being overloaded. Therefore text information should be presented to the auditory channel, freeing the visual channel for complementary content [43, 81, 134].

The modality principle was not strictly adhered to. For both tools, all educational material (annotation, animation, video, text, and voiceover) required for each subtask is presented on the same screen. This enables users to focus on the subtask without needing to search for additional information elsewhere on the interface map. This was a situation in which it was difficult to combine interface map construction and design principles. After detailed consideration, it was felt that interface map construction and functionality would have been compromised if, for instance, links were created to minimise screen text. There is also evidence that some learners prefer reading text to hearing it [135] and this is potentially thought to result in better retention of knowledge [91].

Pre-training principle

Pre-training principle requires users to be pre-trained in advance [43, 75, 134] to become accustomed to the characteristics of the multimedia tools. Due to the educational study design, users in this study were not instructed on the characteristics or behaviour of the multimedia tool. However introductory videos were included to provide a broad overview of key multimedia functions and navigation of each interface map.

Multimedia principle

This principle states that words (text) and pictures are presented as opposed to words alone [76, 79]. All video icon subtask "picture" information on the open interface is related to text on the information panels. In both tools, text is presented with corresponding video in all instances (subtask information panels below video space) once the video icon has been opened (discussed above).

Personalisation principle

This principle states that a conversational style should be used to present words instead of "formal dry" style [43, 134]. During voiceover recording, attempts were made to impart an informal, conversational style to the voiceover for both tools; however due to succinct editing of each video narration was always kept concise and to the point.

Overall the majority of Mayer's principles on multimedia design have been incorporated into the development of both educational tools, despite design variations between each tool.

The effects identified by Sweller [66, 72, 136] with regards to design techniques are now discussed briefly:

Worked example effect

By introducing various decision making steps at key stages (i.e. is sufficient colonic length available?) in both tools and following the pathway to solve particular problems (i.e. further colonic mobilisation steps), the multimedia tools adhere to the worked example effect.

Split attention effect

Text was integrated on designated spaces below videos or within the toolbars (open tool), to complement the graphical components. All other graphical components, such as subtask "elements" or "icons" were clearly labelled with text.

Redundancy effect

As described in the “redundancy principle”, efforts were made not to repeat words or terms in the voiceover and text. In this way redundant information was avoided. However the text information would often give a quick summary to the visual and auditory information provided in the videos.

Modality effect

This effect adheres to the dual channel assumption of cognitive theory of multimedia learning. Therefore media is presented with both words and pictures. However efforts were made not to “overload” this memory bank. Videos were all succinct in timing and annotation/ animation was only utilised to complement and enhance media.

3.1.10 Validation of the multimedia tools

It is important to establish the acceptability of these educational tools amongst expert trainers prior to the randomised study. 80 Consultant colorectal surgeons and educational experts were contacted to review the multimedia. The surgeons and experts contacted were all known to the research team and were each emailed a Smart survey hyperlink in July 2011. They were sent a separate email in early August 2011 then asked to complete an online multimedia evaluation survey compiling 36 questions at the following link: http://www.smartsurvey.co.uk/s.asp?i=42361kxjkf . The design of the evaluation form is discussed in more detail in section (3.2.6.5). This evaluation survey, although similar to the survey sent to trainees on completion of the study, was adapted specifically for expert surgeons. Questions focussed on media integration, learning features and training tool appraisal. All questions were based on the Likert rating scale (Strongly Agree – Strongly Disagree). There was also the option to provide free-text comments after some statements. Specific questions were also asked on educational content: Did you identify areas which were factual incorrect? Are there specific areas that were unclear and need clarification?

The results of this evaluation are discussed in the results section and form an important component of the multimedia evaluation section. Based on this evaluation, changes to educational content were made before the randomised study commenced. The validation process also provided further opportunity to test the website for video streaming. Some minor technical issues were fixed before the study commenced.

3.2 Randomised Control Study

3.2.1 Ethics

Ethical approval for the study was obtained from the Sheffield University Research Ethics Committee (UREC) on 3 May 2011. Informed consent was obtained online from all study participants. The study was registered with ClinicalTrials.gov; ID: NCT01866436.

3.2.2 Study design

3.2.2.1 Study design discussions

A number of meetings were held with various external educational experts (Dr J Crossley, University of Sheffield and Professor J Beard, Northern General Hospital, Sheffield and Professor Roger Kneebone, Imperial College, London). Topics discussed included study design and control group types. After discussing the pros and cons of various study designs (post-test only or pre-post test) with the research team members, the study designed was formulated.

3.2.2.2 Randomised Study

A randomised controlled study was conducted on general surgical trainees comparing the effectiveness of multimedia and a control (study day) arm in cognitive surgical skill acquisition.

The methodology of the assessments included online timed (written) assessments to test cognitive surgical skills administered before and after the interventions/tests. The multimedia group also completed an online evaluation form.

3.2.3 Participants

General surgical speciality trainees (ST3-8), locum trainees (LAT) and middle grade general surgical research fellows (at ST3 level or above) regardless of sub-speciality interest were invited to participate. Core surgical trainees were excluded. Trainees were principally identified by approaching the training programme directors (TPDs) within each deanery. Following ethics approval, training programme directors (TPDs) within the London Deanery and Yorkshire and Humber Deanery were sent a covering letter detailing the purpose of the study. During July and August 2011, meetings were held with each of the four TPDs in the London training regions of the London Deanery to demonstrate the online educational tools and seek approval for trainee recruitment. In all instances, TPDs granted approval for trainee recruitment into the study. Approval was also obtained to recruit South Yorkshire & North Derbyshire trainees (Yorkshire and Humber Deanery), but it was not considered practical and necessary to recruit these trainees (as explained in the results section).

Trainees were all notified of the study details by email within which a hyperlink was inserted (http://www.colorectaltraining.co.uk). Permission was also obtained to place 'study invitation flyers' in Doctors' communal notice boards within teaching and peripheral hospitals in each training region. The London Deanery placed the 'study invitation flyer' onto their trainees' web forum 'Synapse'. Trainee members of the London Surgical Research Group (200 members) were also invited into the study via email. All trainees completed an online consent form to participate in the study.

3.2.4 Randomisation

Enrolled participants were randomly allocated into either the intervention (Multimedia) or control (Study Day) groups. A block randomisation was performed using computer generated random permuted blocks (prepared by Jean Russell, University of Sheffield statistician) within strata defined by age (34 or less, 34 or more), training experience (<ST5 level, ST5 level or more) and duration in colorectal firms at ST3 level or above (<12 months, 12 months or more); blocks were each of size 4. Participants had a 1:1 equal probability of being assigned to either group. The assessors were blinded to the study arm trainees are allocated to.

All study participants were allocated an individual unique study number (1-52). Data on age, ST level and experience in colorectal firms (at ST3 level or above) was extracted and passed to research member (Mr N Kullar). Each number was allocated to either the multimedia or study group based on the generated random sequence. The lead investigator who recruited the trainees was not aware of the random sequence, thereby ensuring allocation concealment. All trainees were then notified by email the group they have been allocated to.

3.2.5 Study setting

The study was conducted between 6th October 2011 and 23rd December 2011 (see summary of study timelines: Table 3.5). As per adult learning principles, the multimedia learning tools were disseminated (via the internet) in unstructured individual settings to allow users to engage in self-directed learning.

The setting for the study day location was in central London (HCA Boardroom, 30th Devonshire St, London) on 7th December 2011, to allow easy access for all participating trainees from the London Deanery.

Phase	Dates
Multimedia design and development	
Intra-operative filming	October 2009 – December 2010
Multimedia Tool Production	January 2010 – July 2011
Study ethics approval	3RD May 2011
Meeting with Deanery Programme Directors	Aug – September 2011
Randomised Study:	
Recruitment and Pre-Assessment phase	6th October – 23rd October
Randomisation process	24th October
Study period	8th November – 7th December
Post-assessment and evaluation phase	15th December – December 23rd

Table 3.5 Summary of study timeline

3.2.6 Interventions:

3.2.6.1 Recruitment and Pre-Assessment phase: October 6th– October 23rd

General surgical trainees invited to participate in the study were contacted by email in the 1st week of October to coincide with the annual change-over of ST trainees and allocation to a new hospital for the next six to twelve month placement. In a short introductory email, a study flyer attachment (see Appendix 7) and hyperlink (http://www.colorectaltraining.co.uk) were provided for trainees to access relevant study information (see Appendix 8: invitation webpage) on a Participation Information Sheet (see Appendix 9) and agree to participate on an online consent form (see Appendix 10). The purpose of this form was to explain all relevant study information. Following a short invitation statement, a series of questions covering the study were devised with a short summary explanation (only the questions are included in this section):

1. What is the background to this study?
2. What is Multimedia and what are Multimedia Educational Tools?
3. What is the study aim?
4. How do I participate and what will I do during the study?
5. Who is invited to participate in the study?
6. Who can I contact for further information regarding the study?
7. Will technical support be available?
8. Will my taking part in this study be kept confidential?
9. What will happen to the study results?
10. Who has ethically reviewed the project?

11. Who is supervising the study?

12. Who is funding the study?

After submission of the online consent form, trainees were directed to separate web pages on the secure web-based service (Smart survey software) containing the Trainee Proforma and Pre-Assessment Test. Completion of these forms were mandatory for participation in the study.

The Trainee Proforma was a demographic questionnaire on age, trainee level, colorectal experience and sub-speciality interest. Additionally, trainees' opinions were sought on effects of reduction in working hours on surgical skills training and current educational teaching methods using a 5-point psychometric (Likert) scale.

3.2.6.2 Assessment tool

The assessment tool (Appendix 12) was developed in the format of multiple choice questions and short answer questions. A large bank of two hundred questions (combination of multiple choice and single answer questions) was designed to comprehensively cover cognitive skills relevant to all the procedural steps in 'anterior resection' surgery. Question categories included:

- Anatomical knowledge/ anatomical plane recognition
- Factual knowledge
- Clinical/ intra-operative decision making

The question bank was developed by the research team. All drafted questions were discussed to ensure suitability for ST3-8 level trainees. Answers were also cross-checked for agreement amongst the research team. The assessment test question content was germane to the material/ information disseminated in the multimedia tools and study day. Although some questions relating to anatomical knowledge were drawn from anatomy textbooks and surgical encyclopaedia, this basic theory is covered in the multimedia tools. Guidelines on Intercollegiate Surgical Curriculum Project (ISCP) for expected level of trainee knowledge were also reviewed.

A 30 minute timed assessment tool comprising 30 randomly selected questions was composed. The question types included 20 multiple choice and 10 short answer questions with a maximum score of 40. The online pre-assessment needed to be completed in one sitting. Trainees were able to change their answers during this time period before automatic submission at 30 minutes.

The deadline for submission for all forms was the 23rd of October 2011. Completed forms and assessments were stored securely on Smart Survey software. Trainees were not able to access the online multimedia tools during the recruitment and pre-assessment period. The purpose of the on-line pre-assessment test score was to establish the baseline level knowledge of all participants, prior to randomisation.

3.2.6.3 Study period: 8th November - 7th December

The participants in the multimedia group were each emailed an individual login and password to access the multimedia tools on the colorectal training website http://www.colorectaltraining.co.uk. The login details were requested each time the website was accessed. Trainees were allowed unrestricted access to the educational tools for self-directed learning from 8^{th} November – 7^{th} December. After this date, trainees were denied further access. Email reminders were sent every six days during the study period with regards to the time left for access.

The study day involved a series of detailed interactive lectures covering all the steps of open and laparoscopic anterior resection surgery (table 3.6) (see Appendix 11 for Study Day flyer). Lecture time was equally divided to cover the open and laparoscopic procedures. All trainees completed 'Study Day' evaluation forms at the end of the day. Lectures for operative surgical techniques are thought to be best delivered in an interactive format (personal communication Prof PN Haray). The content for the Study Day was identical to the multimedia and was delivered in the following format:

- Lectures presented using Microsoft PowerPoint via an overhead projector
- All lectures were delivered by same speaker (Professor Sina Dorudi) with facilitation of discussion with another expert surgeon (Professor P N Haray)
- Each lecture was categorised into clearly defined sections:
    - Learning objectives
    - Overview of the step outlining the subtasks
    - Video clip to demonstrate each subtask
    - Key decision making points for each step

	Open Anterior Resection		Laparoscopic Anterior Resection
1000	Set-up/ mobilisation of the sigmoid and left descending colon	**1330**	Set-up & Port Placements
1025	Intersigmoid fossa dissection	**1340**	Medial-to-lateral Approach
1030	Splenic Flexure Mobilisation	**1400**	Lateral Approach
1050	Vascular/ bowel division	**1410**	Splenic Flexure Mobilisation
1105	Further mobilisation steps	**1430**	Further mobilisation steps
1115	Coffee	**1445**	Coffee
1130	Rectal mobilisation	**1500**	Rectal mobilisation (upper)
1205	Rectal transection & Anastomosis	**1515**	Rectal mobilisation (lower)
1230	Lunch	**1535**	Bowel division, rectal transection & anastomosis
		1555	Closing remarks/ Evaluation Form

Table 3.6 Open and Laparoscopic Anterior Resection Study day timetable of lecture

3.2.6.4 Post-Assessment Period: December 15th – December 23rd

After a period of one week, all study participants were emailed a hyperlink to complete the online post-assessment 30 minute timed test. The pre-assessment and post-assessment questions were both identical but the order of questions was different. Participants in the multimedia group were emailed a separate hyperlink to complete an online Evaluation form (Appendix 14).

3.2.6.5 Development of the Evaluation Form

The evaluation form was designed in the format of a questionnaire survey. The survey was designed from previously developed surgical multimedia evaluation tools [86, 137] and revised according to recent guidelines on surgical educational multimedia [86]. Validity of the form has been established from adaption of the published evaluation tools [86].

The evaluation was designed to cover three key sections:

- Interface design aspects
- Learning process/ features
- Training tool appraisal

The form comprises 38 clearly worded statements or questions assessing on of the above sections. Responses were based on a 5-point psychometric Likert Scale. Following revisions made from discussions with surgical educators, the evaluation form was approved by the ethics committee and disseminated online using a secure web-based service (Smart Survey) to facilitate ease of data collection.

The total study duration was three months and seventeen days. The duration between the two assessments was seven weeks.

3.2.6.6 Evaluation of assessments

After both tests were completed, hardcopies of the assessments were printed out, labelled with the same number used for participant randomisation (by researcher NK) and distributed to the assessors for evaluation. Assessors were blinded to the participants' group allocation and whether the test was pre-assessment or post-assessment. Each assessment was marked independently by the assessors and results tabulated in an Excel database and exported to SPSS for statistical analysis. Once analysed, results were emailed back to the trainees.

3.2.7 Outcomes

The primary outcome was improvement in assessment scores following implementation of the training modality (Intervention: Multimedia and control: Study day).

Secondary outcomes include the association between change in scores and level of training and acceptability of multimedia as a learning resource.

3.2.8 Sample size

Sample size was calculated using preliminary data from a pilot study of 50 (ST3-ST8) surgical trainees taking part in an anterior resection study day in January 2009 [138]. The study day was delivered by a colorectal surgeon (Professor Sina Dorudi) and covered all the steps of the procedure. Trainees were asked to complete a pre-study day written assessment, followed by a post-study day assessment immediately after the lectures had been completed. The mean (SD) pre- and post-assessments scores were 12.4 (4.56) and 26.8 (3.99) respectively.

The sample size was calculated with the assumption that the baseline (pre-assessment) score for both arms is the same. The mean change (SD) in score in the control group is 14.4 (4.9) and an expected mean change (SD) in score of 24.4 (SD 4.9) in the intervention group is assumed. The sample size required to test the hypothesis with a type I error rate of 5% and power of 80% was calculated to be 10 (per group). If the response rate is 20% and assuming a drop off rate of 20%, a total of 125 trainees needed to be approached.

3.2.9 Statistical methods

The baseline pre-assessment test ensured comparability of knowledge base and cognitive skills between study groups and helped to assess construct validity of the assessment tool. Basic descriptive statistics included numbers and percentages for categorical data, mean and standard deviation for normally distributed continuous data. This randomised study was based on 'intention-to-treat' analysis, but 'per protocol' analysis was also performed. Differences in assessment scores between test and control groups were compared using the unpaired Students' t-test (for normally distributed data). To analyse post-scores versus pre-test scores within the same group, paired t-test (for normally distributed data) was used. Data was analysed using SPSS (statistical package for social sciences version 16.0, Chicago IL). Significance levels were set at $P<0.05$.

CHAPTER 4 - RESULTS

4.1 Open and laparoscopic anterior resection multimedia educational tools

Two interactive web-based multimedia educational tools were designed and developed for open and laparoscopic anterior resection surgery. The design and developmental process took place from January 2011 to July 2011 and formed a significant component of this project. This process was led by the research team's lead investigator (US) in direct collaboration with DigiMed.

A total of 136 video clips were edited, annotated and synchronised with voiceover; in some instances specific animation videos were separately constructed and imported into the video clip. Each video clip required a careful review of all unedited footage before editing into succinct clips; this involved a significant input from the researcher in collaboration with the multimedia film editor at the DigiMed office. Each video clip fully edited required between 2-4 hours work in the DigiMed office.

The interface platform development for both the open and laparoscopic tools was constructed by one production team member (Chris Ribbens) in collaboration with the research fellow. The multimedia platforms were developed using a structured evidence-based approach based on the use of Mayer's multimedia principles [43, 75, 134]. Design of the open and laparoscopic tools were different in layout and navigation, whilst adhering to these design principles. Experience gained from construction of the open interface platform enabled construction of a more sophisticated design for the laparoscopic platform. This led to a change in the layout and level of interactivity of the laparoscopic tool. The laparoscopic tool offers a more "dynamic" and interactive "journey" through the operation, enabling trainees to make decisions at various key stages.

Particular attention in both tools was directed towards the interface, screen design, navigation and interactivity whilst being sensitive to cognitive load [66, 71, 139] to maximise multimedia learning.

All educational material used in the animation sequences, text and voiceover was written by the lead investigator and reviewed by the supervisory team (SD and PNH) for factual clarity and understanding. The vast majority of the edited video sequences were voiced by the lead investigator; a few pelvic video sequences were voiced by a member of the supervisory team (SD). This involved many hours spent in the DigiMed production office to edit all video sequences, voice each sequence and input the relevant text onto the tools.

Dissemination of the multimedia tools, for the purposes of the randomised study, was via the internet on a dedicated website. This adheres to adult learning principles of self-directed learning, although the tools were produced on DVD if required by trainees during the randomised study. All media is available for viewing at http://www.colorectaltraining.co.uk. Both educational tools are also available on DVD (see attached). The multimedia tools were the intervention used in the randomised study and were evaluated by the participants in the Multimedia group.

4.2 Development cost of the multimedia tools

The three main components of costs were:

1. Filming: £5,000. The large proportion (£4,000) was spent on filming of open anterior resections.
2. Editing: £10,000. This includes both animation and video sequence editing with voiceovers and integration of educational material onto the interface platforms.
3. Development of the interface platforms: £10,000. Development of the open tool cost £4,000 and £6,000 for the laparoscopic tool.
4. Website maintenance: £1,000

4.3 Trainee recruitment and characteristics

A total of 358 trainees were contacted for this study; of these 61 responded (17%). Fifty-nine (97%) provided complete demographic data; two trainees failed to complete the proformas despite being sent email reminders. Fifty-nine participants were randomised into the Multimedia group (n=30) and Study Day Group (n=29). Seven participants did not complete the pre-assessment test and took no further part in the study (3 in Multimedia group and 4 in Study Day group). Of the 52 participants completing the pre-assessment test, 27 were in the Multimedia group and 25 in the Study Day group.

Following completion of pre-assessment tests, a further three trainees withdrew from the study (all control group), citing inability to attend the study day and work commitments. All trainees who withdrew following randomisation in the Study Day group (n=7) were given the option to participate in the Multimedia group; four Study Day group trainees (unable to attend the study day due to scheduling difficulties) requested a change in group allocation into the Multimedia group. No multimedia group trainees withdrew from the study or requested change in group allocation. Nine participants randomised to the Multimedia group were excluded from the final analysis for the following reasons: no further contact following randomisation (n=3); participants failed to complete the post-test assessment and evaluation form (n=6). The overall drop-out rate following randomisation was 27% (16 of 59).

As completion of the pre-assessment and post-assessment tests was a pre-requisite for inclusion, only data from 43 participants were included in the final analysis (21 in the Multimedia group and 22 in the Study Day (intention to treat analysis)); 25 in Multimedia group and 18 in the Study Day group (per protocol analysis)). All participants attending the study day completed the post-test assessments (Figure 4.1).

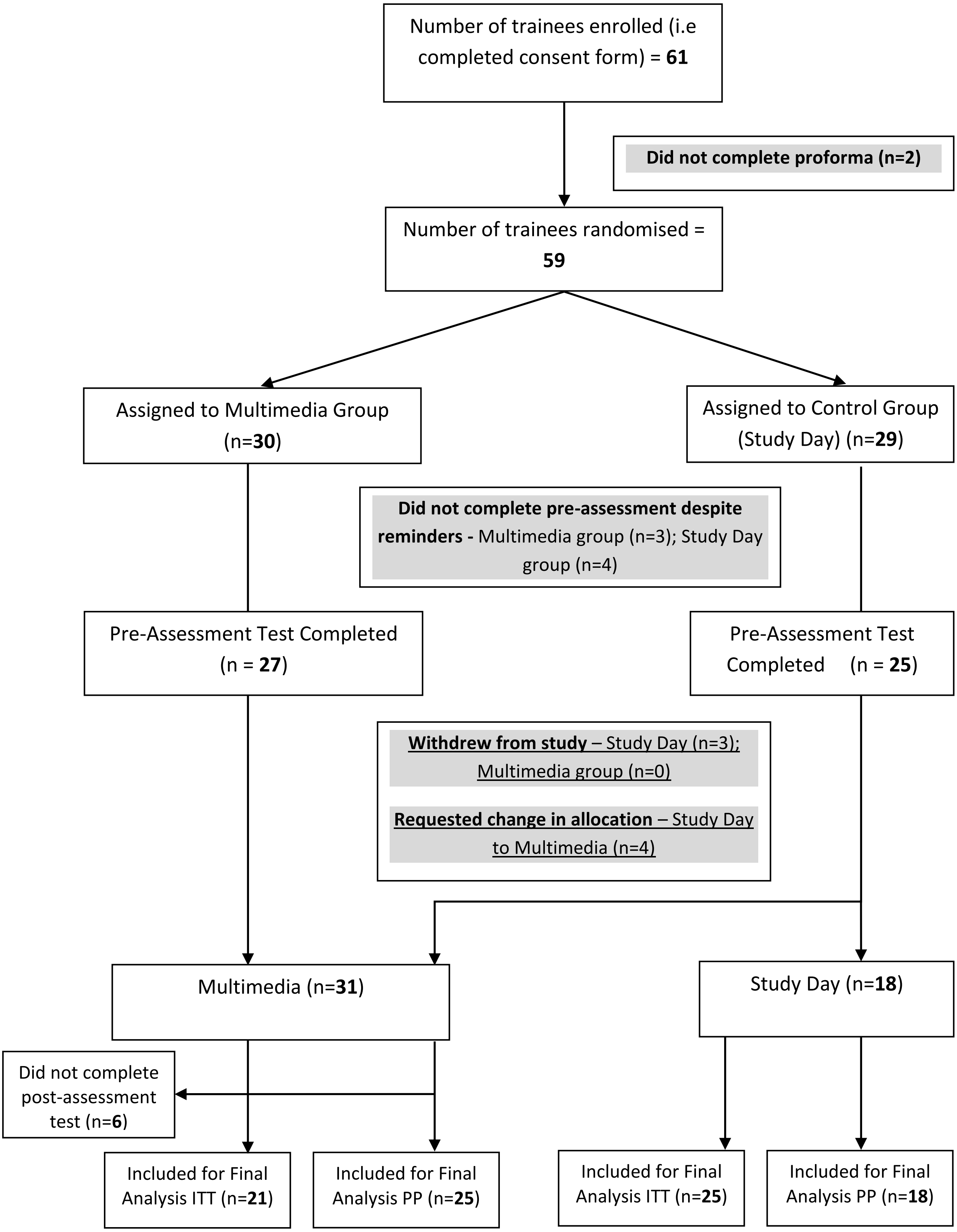


Figure 4.1 Flowchart depicting numbers included in enrollment, randomisation and final analysis

Three-quarters of trainees (75%) recruited into the study were in the intermediate category (ST3-5 Level) and were evenly distributed in each study group. Trainees in the senior category were predominantly from ST6/7 Level (20%) (Figure 4.2).

The majority of trainees had declared colorectal surgery as their current sub-speciality interest (58%), while (19%) were not sure (Figure 4.3).

There was a wide range of experience at ST level and above (0->36 months) and the overall experience in colorectal surgery was a median of 12 months. Over half the trainees (53%) had between 6-12 months experience in colorectal surgery. 56% trainees had over 12 months experience (Figure 4.4).

Figures 4.5 shows the numbers of supervised open and laparoscopic high and low anterior resections performed so far in their training. Similarly, figure 4.6 depicts the numbers of high and low supervised laparoscopic anterior resections performed by trainees.

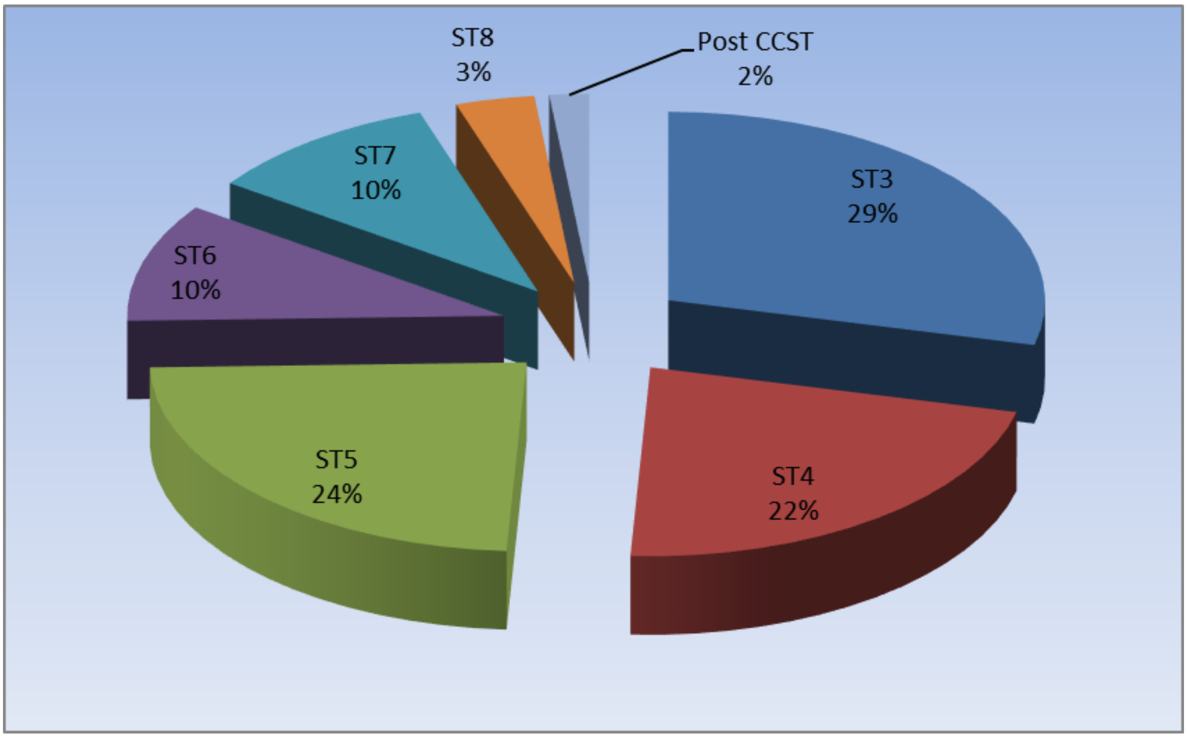


Figure 4.2 Trainee level distribution

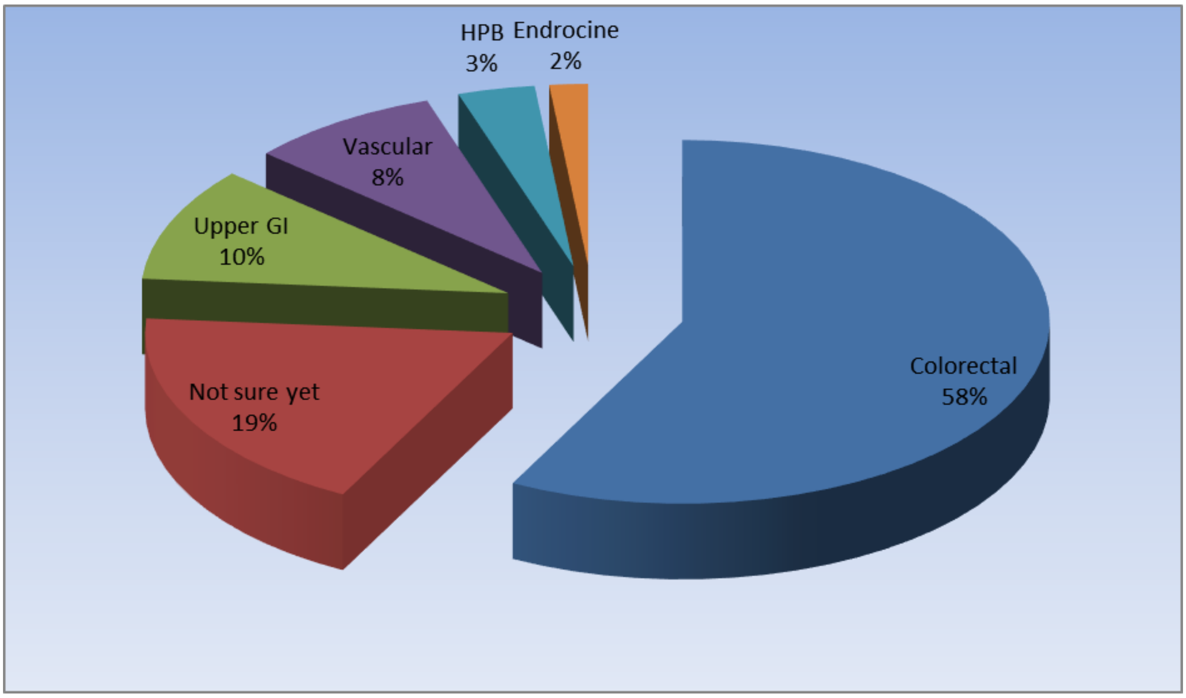


Figure 4.3 Sub-specialty trainee interest

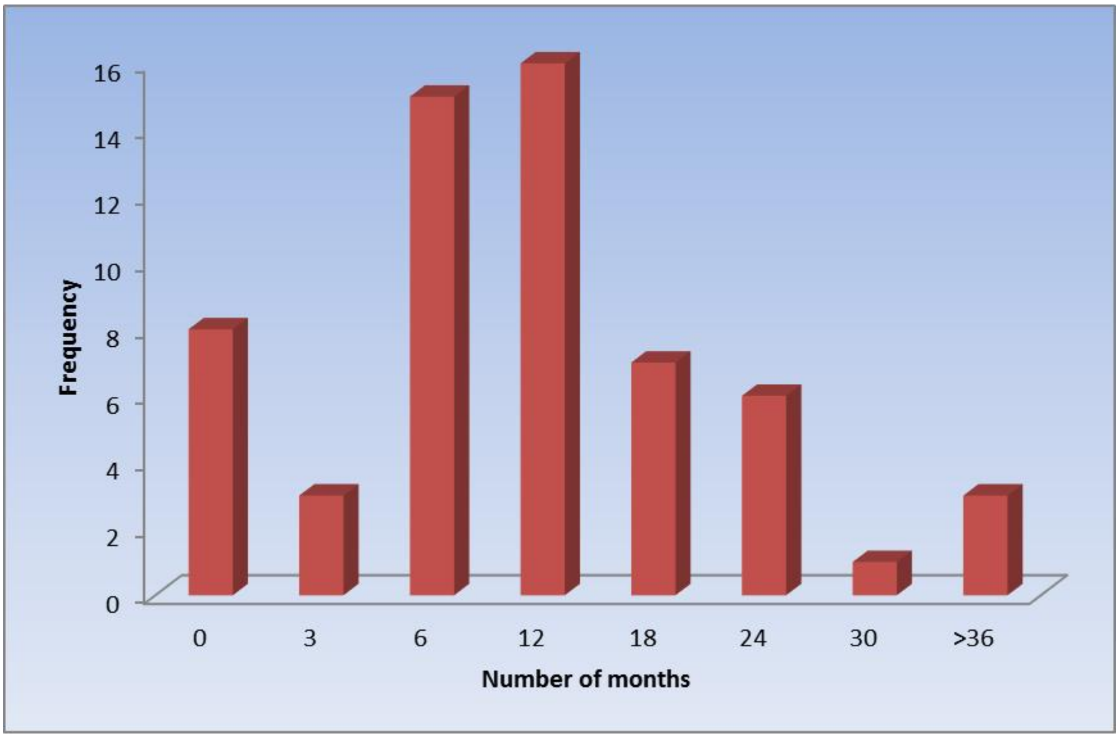


Figure 4.4 Colorectal experience at ST3 level or above

The trainees' demographics are summarised in Table 4.1. The table shows the groups in two categories as randomised and after post-randomisation exclusions (intention to treat (ITT) analysis and per protocol analysis (PP)).

In the 'as randomised' groups (prior to exclusions), the two groups (Multimedia group, n=30 and Study Day group n=29) were comparable with no significant differences between groups in terms of age (p=0.96, Students t-test), ST level (p=0.65, Mann-Whitney test), seniority of training (ST3-5 in one group versus ST6 and above in the other group) (p=0.71, Chi square with Yates correction), colorectal experience at ST3 level and above (Less than 12 months versus more than 12 months) (p=0.71, Chi square with Yates correction) and colorectal interest (p=0.68, Chi square with Yates correction). Comparisons made between the Multimedia (n=21) and Study Day (n=22) groups as per ITT analyses were similar to those obtained with the Multimedia (n=25) and Study Day (n=18) as per protocol analyses.

	All study participants	Multimedia Group	Control group	Multimedia group (ITT)	Control group (ITT)	Multimedia group (PP)	Control group (PP)
Number	59	30	29	21	22	25	18
Age: range (median)	33 (27-39)	32.5 (27-39)	33 (29-39)	33 (27-39)	32.5 (29-38)	35 (27-39)	31.5 (27-39)
Sex M:F	44:15	20:10	24:5	14:7	18:4	17:8	15:3
Trainee Level	*ST3* (17) *ST4* (13) *ST5* (14) *ST6* (6) *ST7* (6) *ST8* (2) *Post CCST* (1)	*ST3* (10) *ST4* (5) *ST5* (8) *ST6* (3) *ST7* (3) *ST8* (1)	*ST3* (7) *ST4* (8) *ST5* (6) *ST6* (3) *ST7* (3) *ST8* (1) *Post CCST* (1)	*ST3* (6) *ST4* (3) *ST5* (6) *ST6* (2) *ST7* (3) *ST8* (1)	*ST3* (7) *ST4* (5) *ST5* (3) *ST6* (3) *ST7* (2) *ST8* (1) *Post CCST* (1)	*ST3 (6)* *ST4 (3)* *ST5 (5)* *ST6 (4)* *ST7 (4)* *ST8 (1)* *Post CCST (1)*	*ST3* (7) *ST4* (5) *ST5* (3) *ST6* (1) *ST7* (1) *ST8* (1)
Sub-specialty interest	Colorectal (34) Not colorectal (25) Not sure yet (11) Upper GI (6) Vascular (5) HPB (2) Endocrine (1)	Colorectal (16) Not colorectal (14) Not sure yet (4) Upper GI (4) Vascular (3) HPB (2) Endocrine (1)	Colorectal (18) Not colorectal (11) Not sure yet (7) Upper GI (2) Vascular (2)	Colorectal (12) Not colorectal (9) Not sure yet (3) Upper GI (2) Vascular (2) HPB (2)	Colorectal (14) Not colorectal (8) Not sure yet (5) Upper GI (1) Vascular (2)	Colorectal (16) Not colorectal (9) Not sure yet (3) Upper GI (2) Vascular (2) HPB (2)	Colorectal (10) Not colorectal (8) Not sure yet (5) Upper GI (1) Vascular (2)
Colorectal experience *(ST3 level and above)* in months (range)	12 (0 - >36)	12 (0 - >36)	12 (0 - >36)	12 (0 - >36)	12 (0 - >36)	12 (0 - >36)	12 (0 - >36)

Table 4.1 Trainees' demographics summarised per group

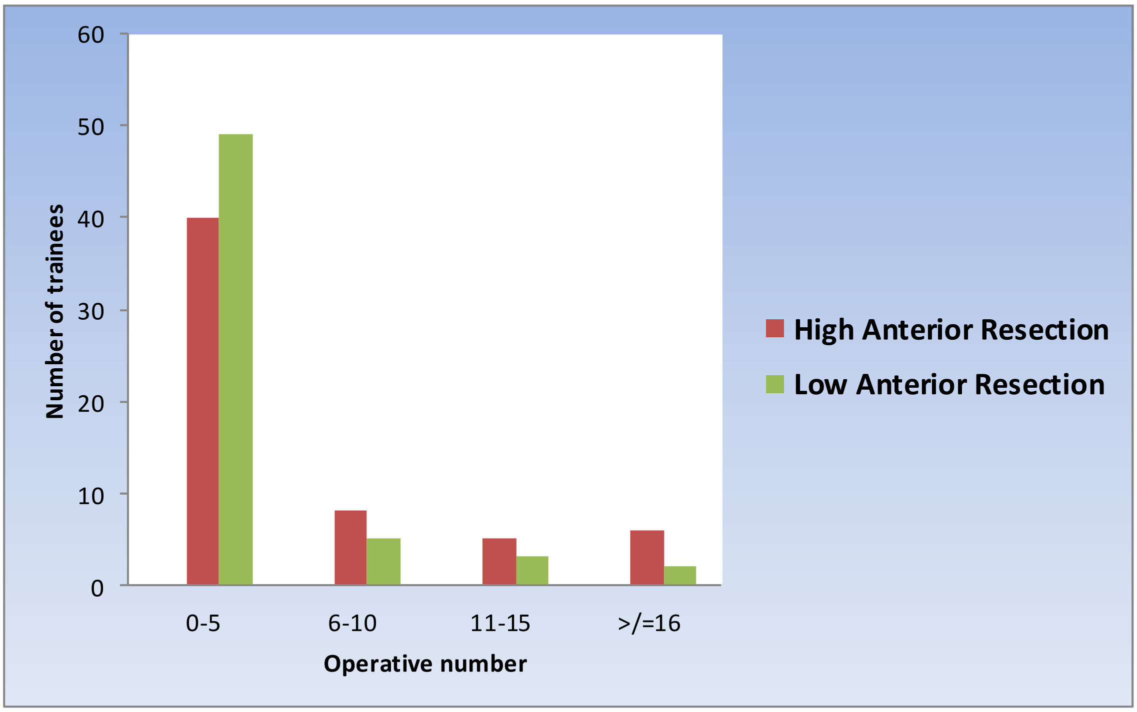


Figure 4.5 Trainee operative numbers for supervised open high and low anterior resection surgery

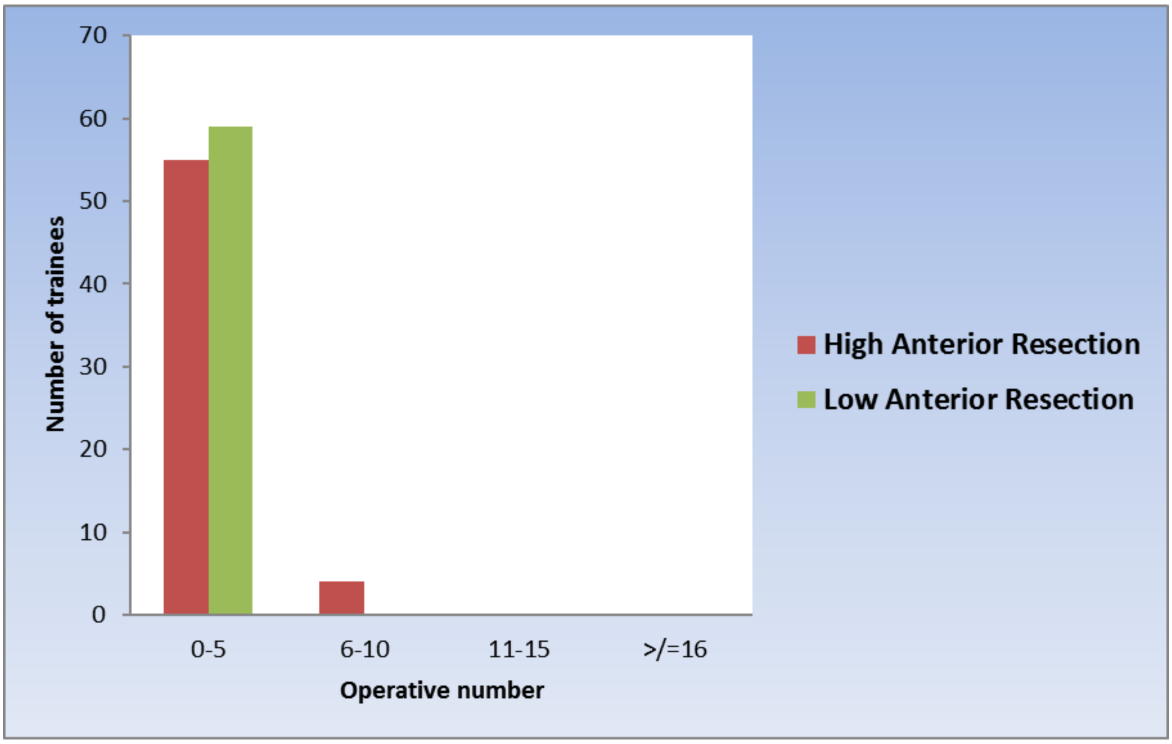


Figure 4.6 Trainee operative numbers for supervised high and low laparoscopic anterior resection surgery

4.4 Trainees' perceptions of working hours and educational tools

A significant proportion of trainees (88%) strongly agreed or agreed that the implementation of EWTD (European Working Time Directive) and changing work patterns was having a deleterious impact on their surgical skills training (Figure 4.7).

The majority had experience of video box trainers (76%) and virtual reality (VR) simulators (66%); a smaller proportion had experience of web-based tools (33%), human cadaveric (25%) and live animal (15%) models (Figure 4.8).

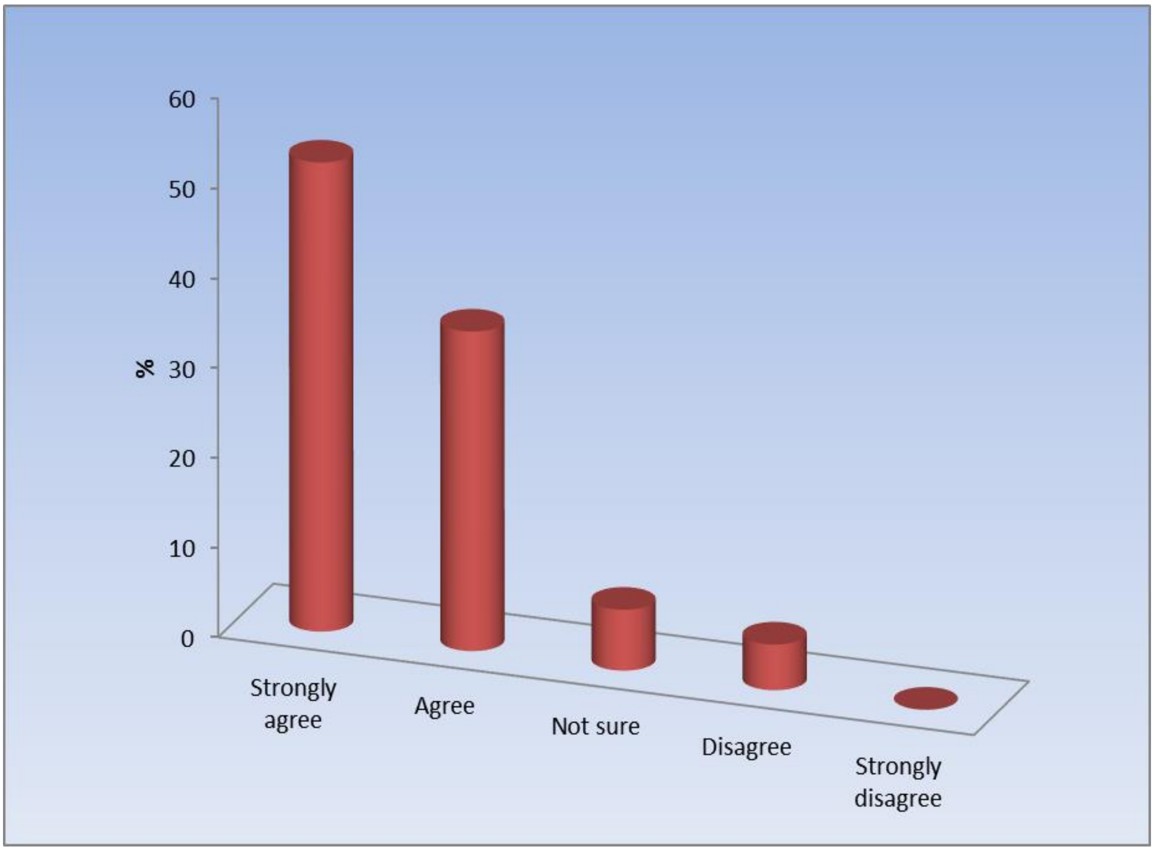


Figure 4.7 Trainees' response to the statement: "Implementation of EWTD (European Working Time Directive) and changing work patterns is having a deleterious impact on surgical skills training"

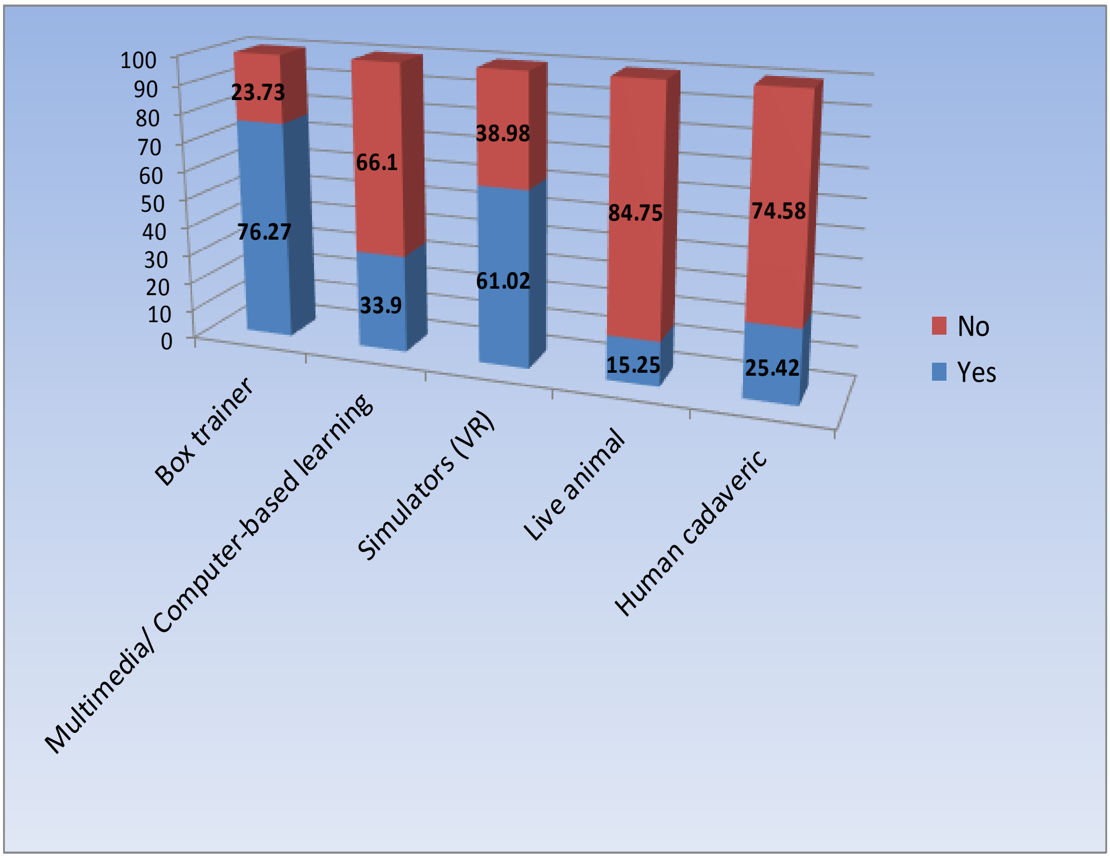


Figure 4.8 Trainee experience using augmented educational tool outside the operating room

Trainees with experience of these educational tools agreed that video box trainers (71%), VR simulators (49%), multimedia/computer-based learning (24%), human cadaveric (33.9%) and live animal (27%) models had improved their surgical skills (Figure 4.9).

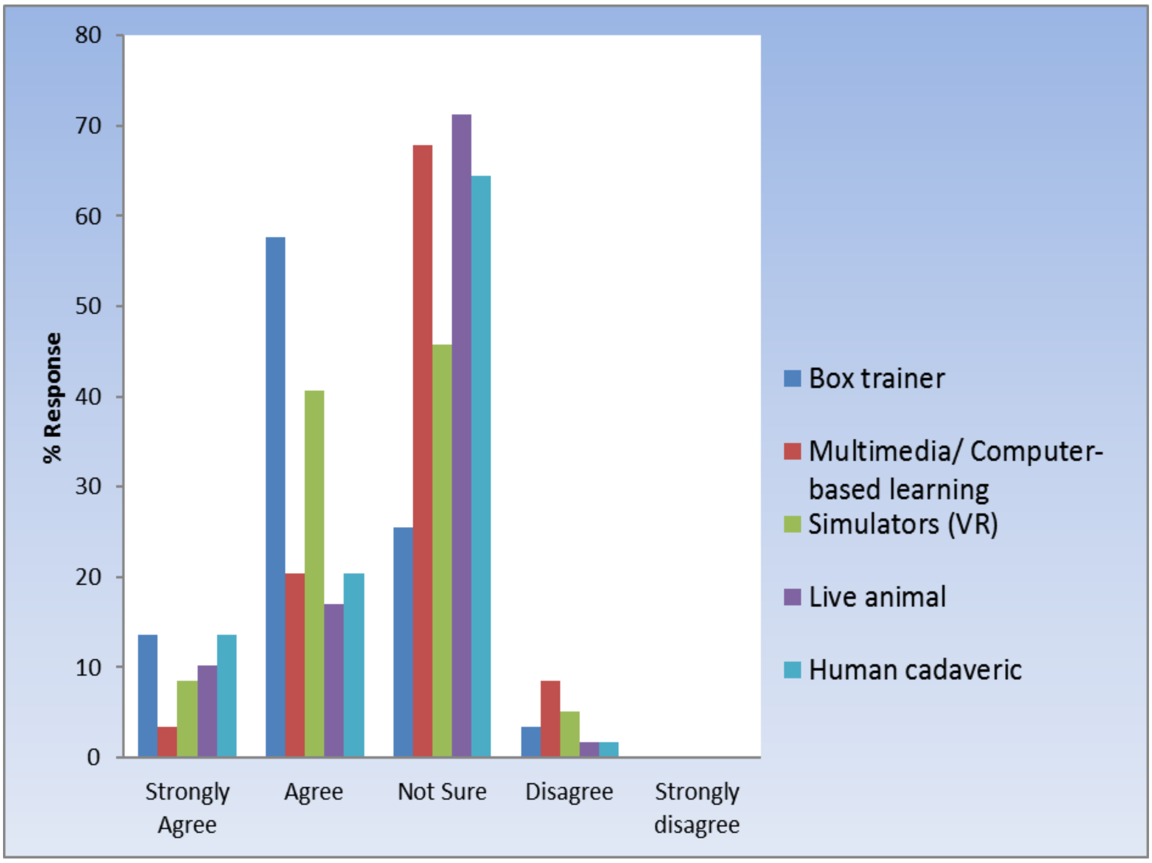


Figure 4.9 Trainees' response to statements on the usefulness of augmented educational tools for acquiring surgical skills

The majority of trainees occasionally browsed surgical educational websites (86.4%) (Figure 4.10). Of those accessing these websites, 57% did so either in the work-place (43%) or at home (14%) (Figure 4.11).

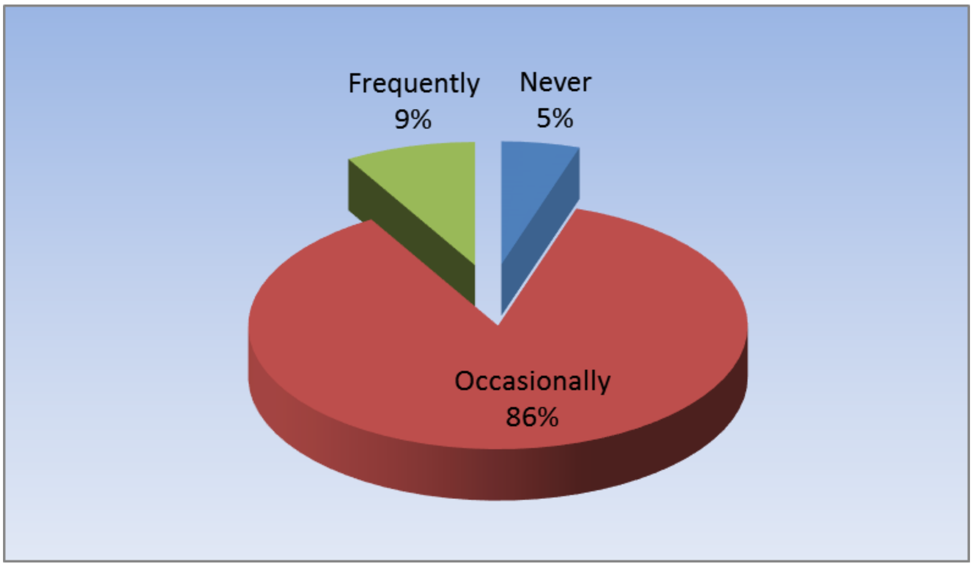


Figure 4.10 Frequency of browsing surgical websites

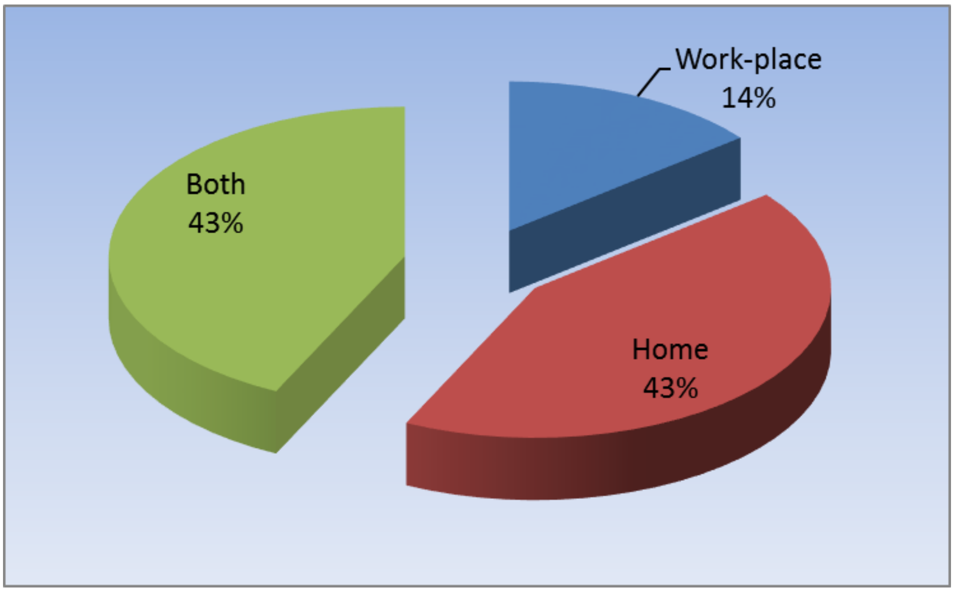


Figure 4.11 Predominant location that surgical websites are accessed from

4.5 Pre-Assessment Test results, validity of assessment and inter-rater reliability

The pre-assessment test scores for all participants were normally distributed (p=0.946; *One-Sample Kolmogorov-Smirnov test*). The mean pre-assessment test scores in the Multimedia group (19.67; SD 6.3) and Study Day group (20.6; SD 4.8) were similar (p=0.542).

The mean pre-assessment scores in Multimedia group (20.95; SD 5.84) and Study Day group (20.52; SD 4.93) as defined by 'intention to treat' were similar (p=0.795).
The mean pre-assessment scores in Multimedia group (21.92; SD 5.95) and Study Day group (19.08; SD 3.91) as defined by 'per protocol' analysis were similar as well (p=0.085).

Senior trainees (n=15) achieved significantly higher pre-assessment test scores compared to intermediate trainees (n=37) (mean+/-SD of 23.80+/-4.13 and 18.62+/-5.24 respectively; p<0.01). Trainees with greater colorectal experience (>12 months or more; n=31) had higher pre-assessment test scores than trainees with lesser colorectal experience (<12 months; n=21) (mean+/-SD of 21.76+/-5.81 and 17.69+/-3.84 respectively), but this was not statistically significant (p=0.07). Trainees expressing a subspecialist interest in colorectal surgery (n=31) had significantly higher pre-assessment test scores than the other 21 trainees who did not (mean+/-SD of 21.63+/-4.71 and 17.88+/-5.8 respectively; p=0.01). These results provide evidence in support of construct validity of the assessment tool.

Inter-rater agreement for pre-assessment scores (intraclass correlation (ICC) 0.99, (p=0.001)) and for post-assessment scores (intraclass correlation (ICC) 0.99, (p=0.001)) demonstrate that there was strong agreement between the two raters in the scoring of responses to the multiple choice and short answer questions.

4.6 Primary and secondary outcomes

Further results will be described for groups defined as per ‘intention to treat’ (ITT) and ‘per protocol’ (PP) analyses. ITT analysis is a pragmatic approach and may be seen to reflect real-life practice. PP analysis does however gives an indication of how results might occur if processes were followed and can also give a true effect of the interventional tools. However PP analysis does introduces bias. Due to trainees requesting/ offered a change in group allocation in the study, it was felt important to consider the two analyses to see if there were any differences.

4.6.1 Primary outcome measure

<u>Intention to treat analysis</u>

The mean pre-assessment and post-assessment scores were 20.95 (SD 5.84) and 27.55 (SD 6.36) respectively in the Multimedia and Study Day groups with a statistically significant difference ($p<0.01$) between the two. The mean change in score was 6.60 (SD 5.10). The mean pre-assessment and post-assessment scores were 20.52 (SD 4.93) and 25.41 (SD 5.05) respectively in Study Day group; the difference was statistically significant ($p<0.01$). The mean change in score was 4.89 (SD 3.66) (Table 4.2; Figure 4.12 shows the mean results of the assessment tests in the intention to treat analysis):

GROUP	Pre-Test mean (SD)	Post-Test mean (SD)	Mean change in scores (SD)	P value (Student T test)
Multimedia Group (n=22)	20.95 (5.84)	27.55 (6.36)	6.60 (SD 5.10)	<0.01
Study Day Group (n=21)	20.52 (4.93)	25.41 (5.05)	4.89 (SD 3.66)	<0.01

Table 4.2 Pre- and post-test assessment scores in the two groups of trainees

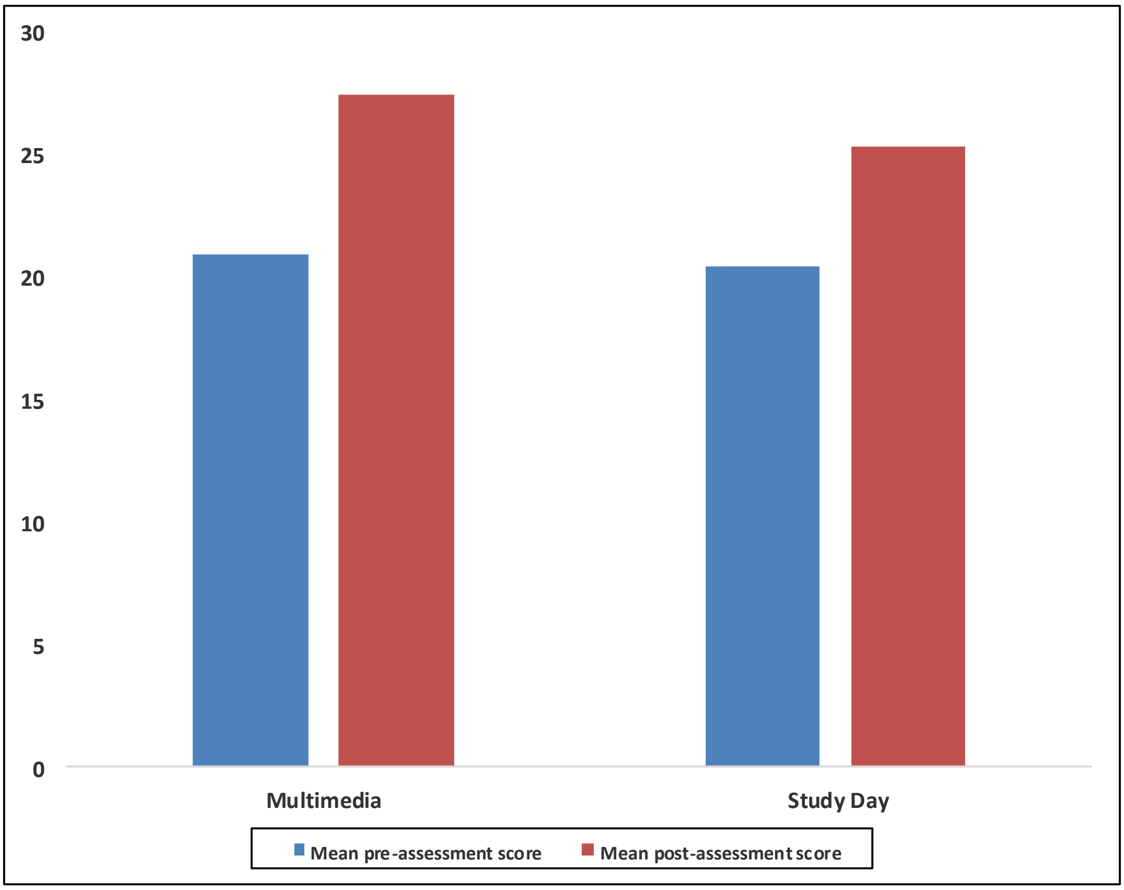


Figure 4.12 Mean results of the pre- and post assessment tests for two groups (intention to treat analysis)

Per protocol analysis

The post-assessment test scores were normally distributed ($p=0.97$; *One-Sample Kolmogorov-Smirnov test*). Table 4.3 presents descriptive statistics for each group on both Pre-Assessment and Post-Assessment Tests, and the results of the statistical data analyses (Students' t-test). Mean scores between pre-assessment and post-assessment scores were 21.92 (SD 5.95) and 27.94 (SD 6.03) in Multimedia ($p<0.0001$); the mean change in score 6.02 (SD 5.12). Mean scores between pre-assessment and post-assessment scores were 19.08 (SD 3.91) and 24.39 (SD 4.78) in SD ($p<0.0001$); the mean change in score 5.31 (SD 3.42). Within each group, the increase between the mean pre-test and post-test was significant (Table 4.3; Figure 4.13 below shows the mean results of the assessment tests in the per protocol analysis).

GROUP	Pre-Test Mean	Post-Test Mean	Mean change in scores (SD)	P value (Student T test)
Multimedia Group (n=25)	21.92 (5.95)	27.94 (6.03)	6.02 (SD 5.12)	<0.0001
Study Day Group (n=18)	19.08 (3.91)	24.39 (4.78)	5.31 (SD 3.42)	<0.0001

Table 4.3 Pre- and post-test assessment scores in the two groups of trainees

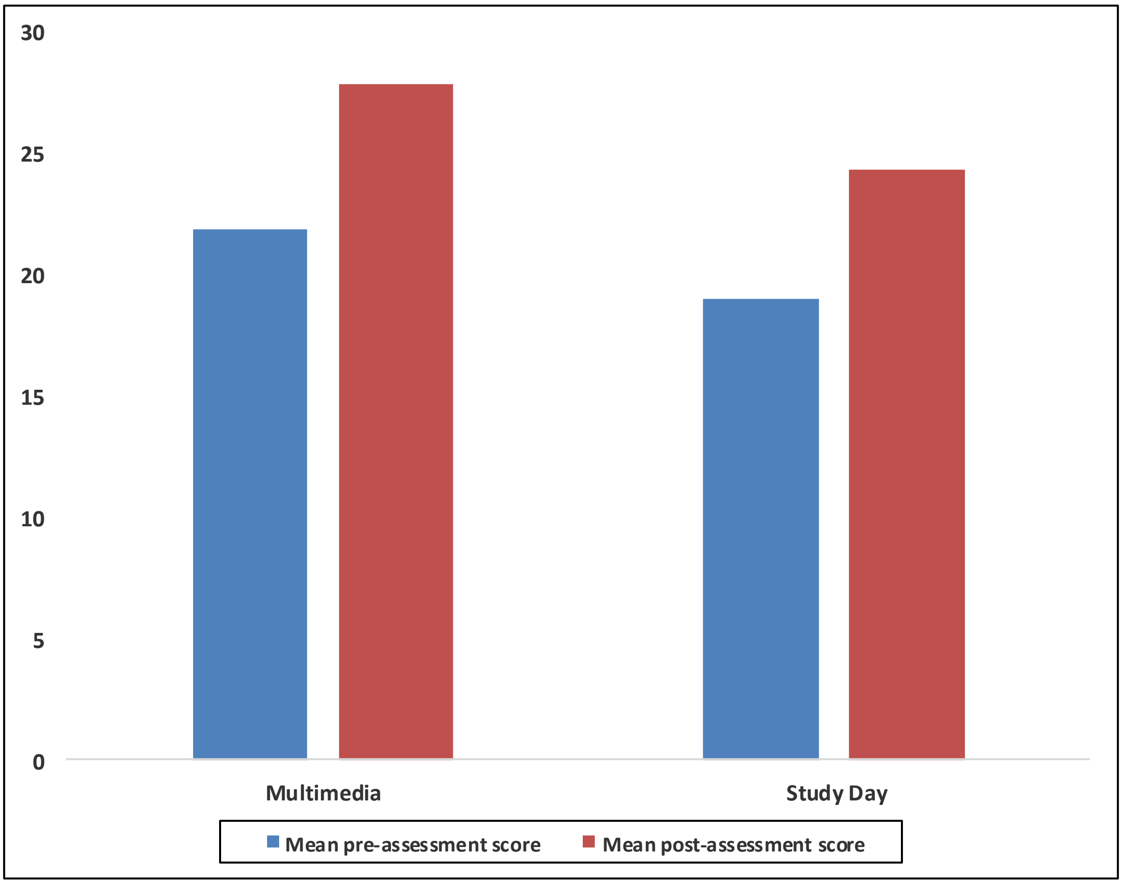


Figure 4.13 Mean results of the pre- and post assessment tests for two groups (per protocol)

Intention to treat analysis

The differences in scores between the mean results of the assessment tests for two groups (per protocol analysis) are illustrated by the whisker box-plots in Fig 4.14. The change in scores following the two interventions were similar and the difference between groups was not statistically significant (mean increase of 6.60 (SD 5.10) and 4.89 (3.66) in the Multimedia and Study Day groups respectively; p=0.21). Use of multimedia yielded comparable results to traditional teaching.

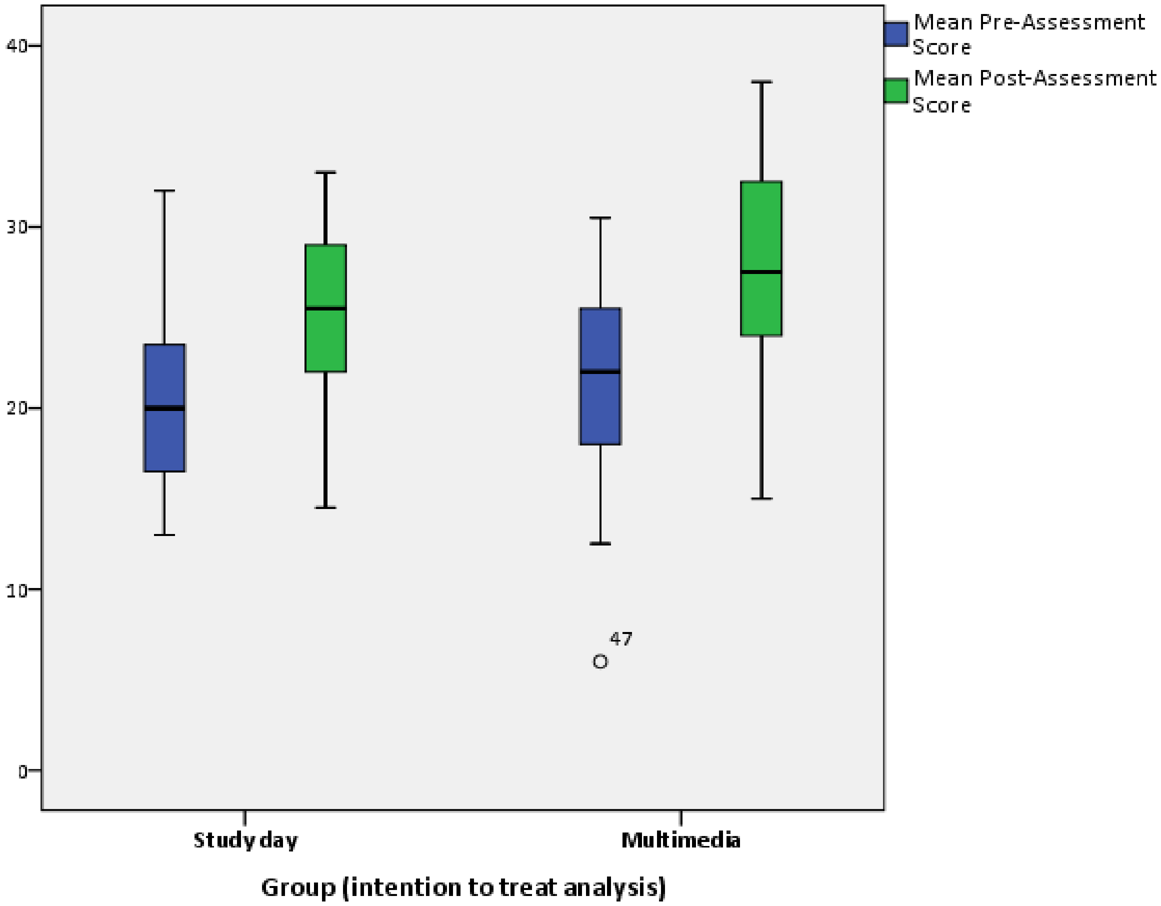


Figure 4.14 Whisker box-plot to illustrate the differences in scores between the pre- and post-assessment test scores for the two groups (intention to treat analysis). Range of scores represented by the vertical lines, horizontal thick black line denotes the median scores, and coloured boxes display the inter-quartile range. Outliers are displayed as small circles.

Per protocol analysis

The differences in scores between the mean results of the assessment tests for two groups (intention to treat analysis) are illustrated by the whisker box-plots in Fig 4.15.

Mean change in scores for Multimedia group 6.02 (SD 5.12) compared to the Study Day group 5.31 (3.42) was not significantly different (p=0.61).

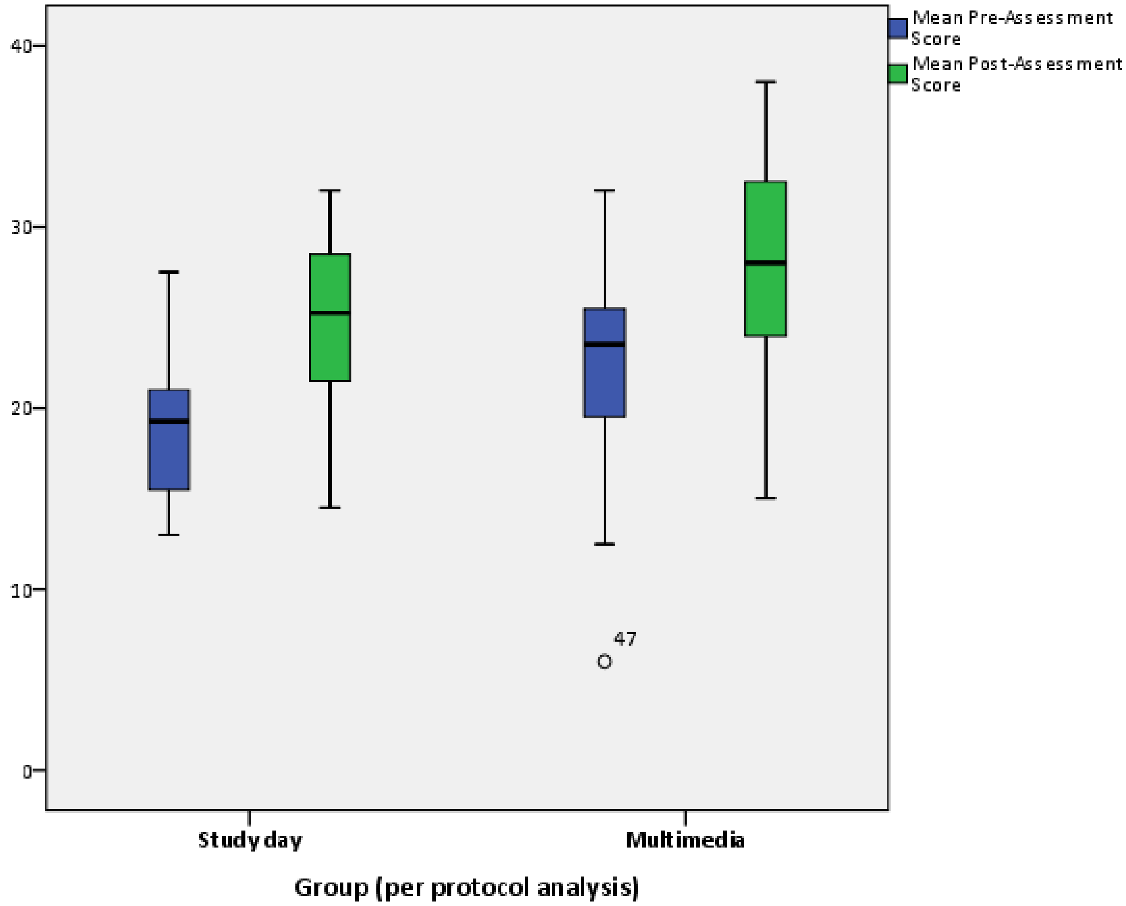


Figure 4.15 Whisker box-plot to illustrate the differences in scores between the pre- and post-assessment test scores for the two groups (per protocol analysis); range of scores represented by the vertical lines, horizontal thick black line denotes the median scores, and coloured boxes display the inter-quartile range. Outliers are displayed as small circles.

4.6.2 Secondary outcome measures

4.6.2.1 Correlation between baseline variables and change in assessment scores

The mean change in scores in the intermediate trainee group (n=30) was 6.83 (SD 4.47) compared to a mean of 3.15 (SD 3.33) in the senior trainee group (n=13) and this difference was significant (p=0.01).

Further analyses showed no association between the change in scores and the following variables:

1. Duration of colorectal experience: Trainees with less than 12 months experience (at ST3 level or above) (n=16) had a mean change in score of 6.25 (SD 4.4) and trainees with >/= 12 months (n=27) had a mean change in score of 5.41 (SD 4.54). This difference was not statistically significant (p=0.55).
2. Colorectal subspecialty interest: Trainees with colorectal interest (n=26) had a mean change in score of 5.33 (SD 3.98) and trainees with other sub-specialty interest (or no declared interest yet) (n=17) had a mean change in score of 6.32 (SD5.17). This difference was not statistically significant (p=0.48).

4.6.2.2 Evaluation of the Multimedia tools

4.6.2.2.1 Expert evaluation and validation of the tools prior to randomised control study

Twelve consultant colorectal surgeons and five educationalists completed the online questionnaire (21% response rate). Responses to statements and/or questions were recorded using a five-point Likert scale: from ‘strongly agree’ to ‘strongly disagree’.

Results from the three sections (design, learning process and multimedia training tool appraisal) are presented in the tables (4.4 – 4.8). Statements focussed on interface design features (tables 4.4 and 4.5), learning process features (tables 4.6) and multimedia training tool appraisal (tables 4.7 and 4.8).

Experts' responses were consistently positive regarding all features of the interface design for both the open and laparoscopic tools. Overall the open tool received slightly more strongly positive responses (table 4.4). All features of screen design received strongly positive responses. Importantly, all experts agreed that information was presented in an appropriate manner. All aspects of the learning process features of the multimedia tools received strong responses, although 30% were unsure whether the educational tools accommodated a wide range of learners' individual differences. Experts were also asked to appraise the multimedia tools as a training aid. Experts felt strongly that multimedia was more effective compared to surgical textbooks, and to a lesser extent educational courses/ study days for acquiring cognitive skills training. Experts felt strongly that the educational content was appropriate for ST3-8 trainees. With regards to the tools' ability to improve surgical skills, responses were strongly positive for factual/ anatomical knowledge (included anatomical plane recognition), and to a lesser extent for decision making.

Experts felt that multimedia was more appropriate for individual study (70%) (Figure 4.16) and that the primary use for the multimedia tools was prior to an operating list (80%) (Figure 4.17). Overall, the multimedia tools were well received with strong acceptance as a useful adjunctive educational tool for surgical trainees outside the operating room (Figure 4.18). Experts were also asked to comment on the educational content with regards to any areas identified that were factually incorrect or specific areas that were unclear or required further clarification. No areas were identified that were factually incorrect. A number of grammatical and spelling errors were noted; these were corrected and pre-checked before the study. Finally experts were asked to suggest any improvements in the tools prior to the study. A few experts had difficulty with regards to streaming of some video clips. This was addressed by disconnecting other devices from the network during video playback, and optimising the router for streaming. All issues were resolved satisfactorily before the study commenced.

4.6.2.2.2 Trainee evaluation

To evaluate the acceptability of the educational tools, all participants in the Multimedia group were asked to complete an online evaluation questionnaire. Twenty-five out of the thirty-one participants (response rate 81%) responded. Responses to statements and/or questions were recorded using a five-point Likert scale: from ‘strongly agree’ to ‘strongly disagree’.

Results from the three sections (on design, learning process and multimedia training tool appraisal) are presented in the tables (4.9 – 4.15). Trainees’ responses were consistently positive regarding all features of the interface design for both the open and laparoscopic tools. Overall the open tool received more strongly positive responses (table 4.9). All features of screen design received positive responses, though a small proportion felt that quality of the animation (8.4%) and appropriate use and size of text (4.4%) were not satisfactory (table 4.10). All trainees however agreed that the multimedia information was presented in an appropriate manner.

Trainees’ responses were also strongly positive for the learning features of the multimedia tools, in particular origin of motivation and goal orientation (table 4.11). Trainees were also asked to appraise the multimedia tools as a training aid. Regarding the advantages of multimedia over conventional lectures; continual access, flexibility in learning and ability to self-manage learning elicited strongly positive responses (table 4.12). Lack of feedback and interactivity (human contact) were cited as the main drawbacks of multimedia self-directed learning (table 4.13). Trainees felt that multimedia compared favourably to other standard educational methods for acquiring skills (table 4.14), the educational content was considered for ST3-8 level and that the tools had improved their cognitive surgical skills with regards to anatomical and factual knowledge/ anatomical plane recognition (table 4.15).

		Strongly agree (%)	Agree (%)	Not sure (%)	Disagree (%)	Strongly disagree (%)
The tool is easy to use	Open Surgery	45	55		0	0
	Laparoscopic Surgery	40	50	10	0	0
Mapping: the relationship between the choice you make (on-screen) and the educational tools response to your choice	Open Surgery	30	70	0	0	0
	Laparoscopic Surgery	30	60	10	0	0
Navigation: am able to move through to different areas of the tool easily	Open Surgery	30	60	10	0	0
	Laparoscopic Surgery	40	40	20	0	0
Media Integration: the different media integrate well on the tool	Open Surgery	60	40	0	0	0
	Laparoscopic Surgery	40	50	10	0	0
Overall functionality: this is a good educational tool to acquire cognitive surgical skills	Open Surgery	50	50	0	0	0
	Laparoscopic Surgery	60	30	10	0	0

Table 4.4 Expert opinions' on statements regarding interface design features of the educational tools

	Strongly agree (%)	Agree (%)	Not sure (%)	Disagree (%)	Strongly disagree (%)
Graphics: The overall quality of the graphics is good	60	40	0	0	0
Animation: The overall quality of the animation is good	50	50	0	0	0
Text: The size, format and font of the text is appropriate	70	30	0	0	0
Video: The general quality of the video imagery is good	70	30	0	0	0
Voiceover: The overall quality of the voiceover is good	60	40	0	0	0
Information presentation: The information has been presented in an appropriate manner	60	40	0	0	0

Table 4.5 Expert opinions' on statements regarding screen design features of the educational tools

	Strongly agree (%)	Agree (%)	Not sure (%)	Disagree (%)	Strongly disagree (%)
Goal orientation: The educational tools focus on cognitive skill acquisition	60	30	10	0	0
Experiential value: Experiential learning is the process of making meaning from direct experience. These educational tools provide relevant experience	30	60	10	0	0
Teacher role: The educational tools facilitate the teacher's role	60	30	10	0	0
Accommodation of individual differences: The educational tools accommodate a wide range of learners' individual differences	0	70	30	0	0
Origin of motivation: The educational tools are intrinsically motivating	20	70	10	0	0
Learner control: both tools allow unrestricted learner control over the material presented	30	70	0	0	0
User activity: the tools create an interactive learning experience	60	30	10	0	0
Learning demands: It is easy to deal with the different options available and to recognise and understand the options presented	60	40	0	0	0

Table 4.6 Experts' opinions on the statements regarding learning features of both educational tools

	Strongly agree (%)	Agree (%)	Not sure (%)	Disagree (%)	Strongly disagree (%)
Surgical textbooks	55.6	33.3	11.1	0	0
Educational Courses	11.1	44.4	44.4	0	0
Study Days	22.2	44.4	33.3	0	0

Table 4.7 Experts' opinions on whether multimedia was more effective than traditional teaching methods for acquiring cognitive surgical skills

	Strongly agree (%)	Agree (%)	Not sure (%)	Disagree (%)	Strongly disagree (%)
Level of educational content: The educational content is appropriate to ST3-8 level surgical trainees, in terms of scope and level of detail	55.6	33.3	11.1	0	0
Decision making skills	10	80	10	0	0
Factual and anatomical knowledge	50	50	0	0	0
Anatomical plane recognition	40	60	0	0	0

Table 4.8 Experts' opinions on level of educational content and whether multimedia could improve trainees' cognitive surgical skills

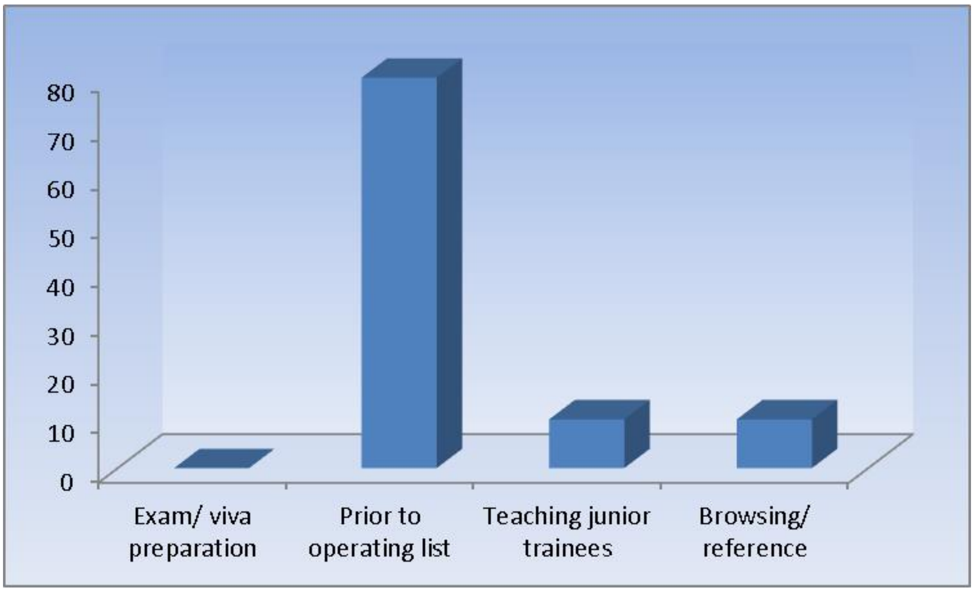


Figure 4.16. Expert opinions on primary use of the multimedia educational tools

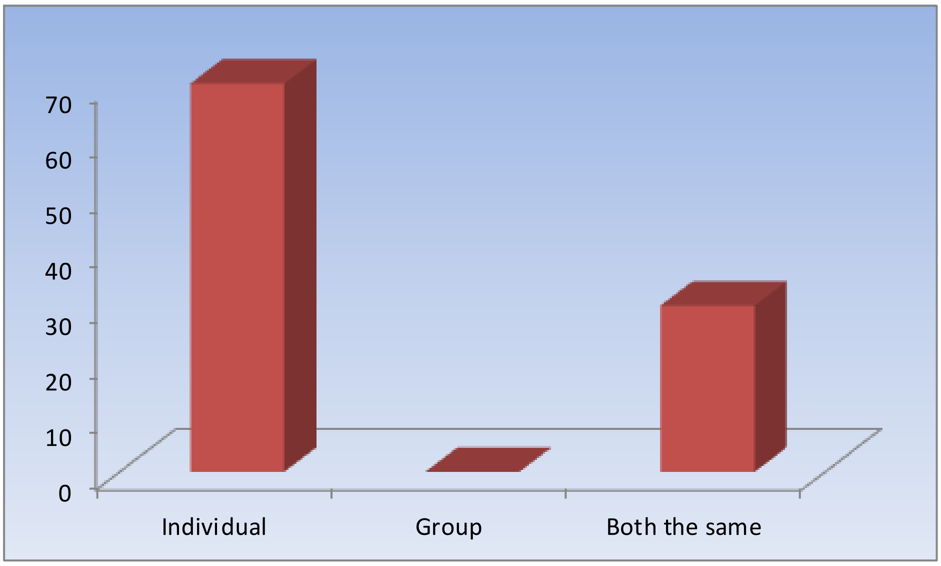


Figure 4.17. Expert opinions on whether the educational tools more appropriate for individual, group study or both the same

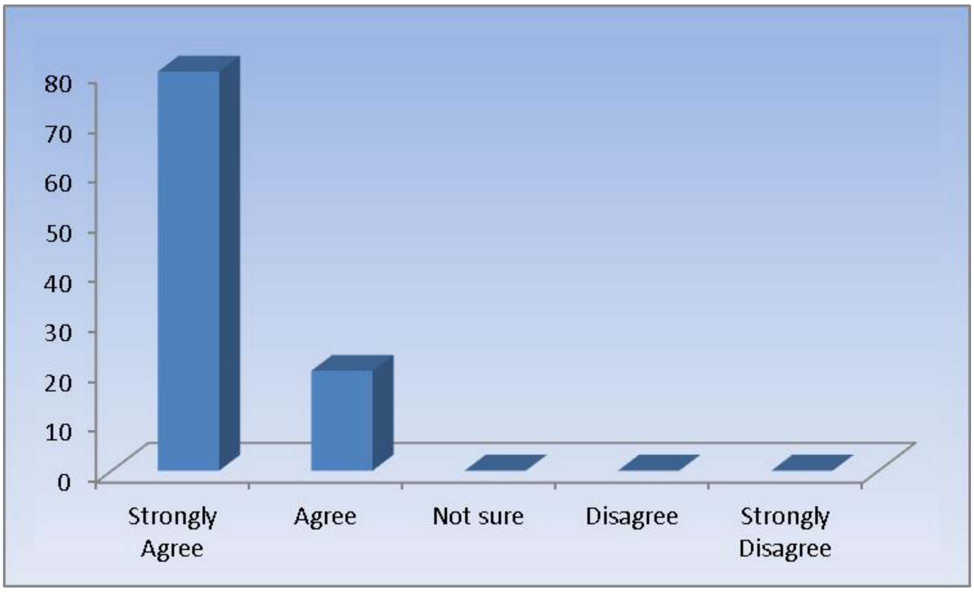


Figure 4.18. Expert opinions for the usefulness of multimedia as an educational tool outside the operating room.

		Strongly agree (%)	Agree (%)	Not sure (%)	Disagree (%)	Strongly disagree (%)
The tool is easy to use	Open Surgery	40	52	8	0	0
	Laparoscopic Surgery	28	60	60	4	0
Mapping: the relationship between the choice you make (on-screen) and the educational tools response to your choice	Open Surgery	39	52.2	4.4	4.4	0
	Laparoscopic Surgery	29.2	50	12.5	8.3	0
Navigation: am able to move through to different areas of the tool easily	Open Surgery	41.2	54.4	4.4	0	0
	Laparoscopic Surgery	29.2	50	8.3	12.5	0
Media Integration: the different media integrate well on the tool	Open Surgery	54.2	41.7	4.1	0	0
	Laparoscopic Surgery	37.5	50	8.3	4.2	0
Overall functionality: this is a good educational tool to acquire cognitive surgical skills	Open Surgery	45.8	50	4.2	0	0
	Laparoscopic Surgery	41.6	50	4.2	4.2	0

Table 4.9 Trainees' opinions on statements regarding interface design features of the educational tools

	Strongly agree (%)	Agree (%)	Not sure (%)	Disagree (%)	Strongly disagree (%)
Graphics: The overall quality of the graphics is good	62.5	33.3	4.2	0	0
Animation: The overall quality of the animation is good	58.3	33.3	0	8.4	0
Text: The size, format and font of the text is appropriate	39.1	52.1	4.4	4.4	0
Video: The general quality of the video imagery is good	54.2	45.8	0	0	0
Voiceover: The overall quality of the voiceover is good	50	45.8	4.2	0	0
Information presentation: The information has been presented in an appropriate manner	54.2	45.8	0	0	0

Table 4.10 Trainees' opinions on statements regarding screen design features of the educational tools

	Strongly agree (%)	Agree (%)	Not sure (%)	Disagree (%)	Strongly disagree (%)
Goal orientation: The educational tools focus on cognitive skill acquisition	33.3	62.5	4.2	0	0
Origin of motivation: the tools are intrinsically motivating	41.7	45.8	8.3	4.1	0
Accommodation of individual differences: The educational tools accommodate a wide range of learners' individual differences	8.3	58.4	33.3	0	0
Learner control: both tools allow unrestricted learner control over the material presented	33.3	45.8	16.7	4.2	0
User activity: the tools create an interactive learning experience	20.8	62.5	12.5	4.2	0
Learning demands: It is easy to deal with the different options available and to recognise and understand the options presented	39.1	56.5	0	4.4	0

Table 4.11 Trainees' opinions on the statements regarding learning features of both educational tools

	Strongly agree (%)	Agree (%)	Not sure (%)	Disagree (%)	Strongly disagree (%)
Continual access to educational material	54.2	37.5	8.3	0	0
Greater flexibility over time to learn	50	41.6	4.2	4.2	0
Independent self-management of learning (i.e. self-paced learning)	58.3	33.3	4.2	4.2	0
Lack of cost/travel time for study day	33.3	45.8	16.7	4.2	0

Table 4.12 Trainees' opinions on whether they agreed on the following advantages of online multimedia educational tools over traditional lectures

	Strongly agree (%)	Agree (%)	Not sure (%)	Disagree (%)	Strongly disagree (%)
Lack of feedback	0	58.4	33.3	8.3	0
Lack of interactivity (with lecturer)	17.4	56.6	13	13	0
Lack of motivation (due to absence of lecturer)	58.3	33.3	4.2	4.2	0

Table 4.13 Trainees' opinions on statements regarding disadvantages of the educational tools compared to traditional teaching methods

	Strongly agree (%)	Agree (%)	Not sure (%)	Disagree (%)	Strongly disagree (%)
Surgical textbooks	37.5	45.8	16.7	0	0
Lectures	33.3	33.3	29.2	4.2	0
Educational Courses	4.2	33.3	45.8	12.5	4.2

Table 4.14 Trainees' opinions on whether multimedia was more effective than traditional teaching methods for acquiring cognitive surgical skills

	Strongly agree (%)	Agree (%)	Not sure (%)	Disagree (%)	Strongly disagree (%)
Level of educational content: The educational content is appropriate to ST3-8 level surgical trainees, in terms of scope and level of detail	45.8	50	4.2	0	0
Decision making skills	12.5	54.2	8.3	16.7	8.3
Factual and anatomical knowledge	50	37.5	8.3	4.2	0
Anatomical plane recognition	33.3	41.7	16.7	8.3	0

Table 4.15 Trainees' opinions on level of educational content and whether multimedia has improved cognitive surgical skills

Trainees also indicated that the multimedia tools would be most useful prior to an operating list or in teaching and training junior colleagues (Figure 4.19).

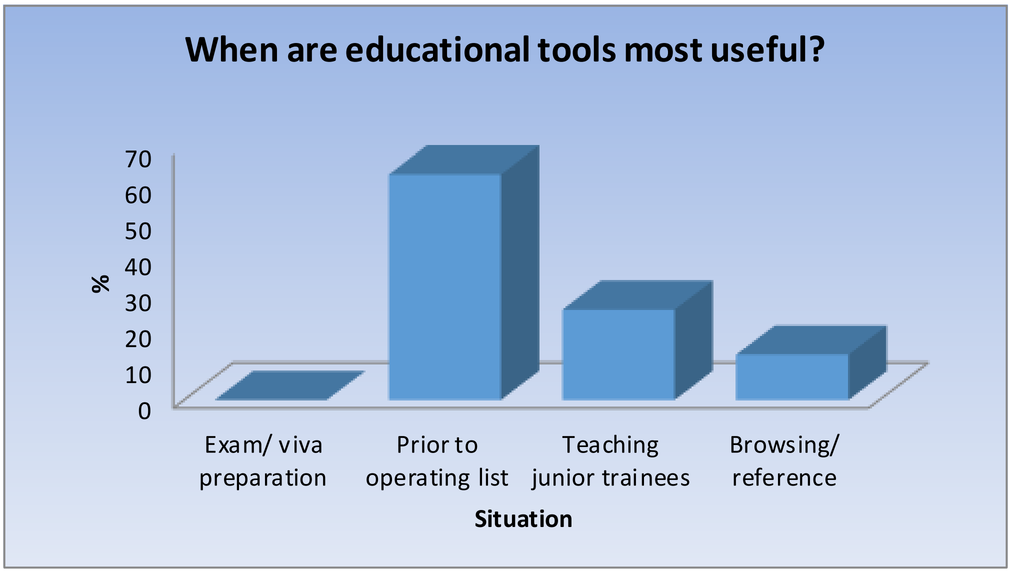


Figure 4.19 Responses regarding the situation in which the educational tool is most useful

Overall, the multimedia tools were considered to be a useful adjunctive tool in surgical skills training outside the operating room (Figure 4.20).

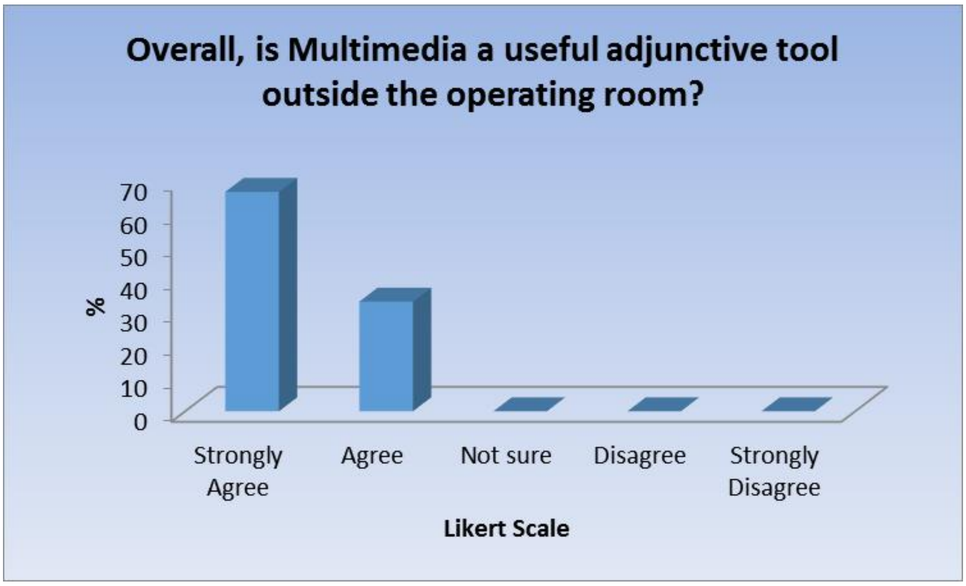


Figure 4.20 Trainees' opinions for the usefulness of multimedia as an educational tool outside the operating room

The results of the online trainee evaluation questionnaire demonstrate that the multimedia tools are well accepted as an augmented training aid outside the operating room.

4.7 Reasons for concluding the study

A total of 358 trainees were contacted for this study; of these 61 responded (17%). The drop-out rate (individuals who did not complete the study after consenting to participate) during this study was 27% (16/59).

The additional numbers of recruits required to test the hypothesis at a type I error of 5% and power of 80% was calculated (per group) to be 73. Using 17% response rate and a drop-out rate of 27% (as seen in this study), we calculated that a total of 1176 further trainees need to be approached (table 4.16).

Parameters	Pre-study estimate from pilot study	RCT results
Power	0.8	0.8
Type I error	0.05	0.05
Mean (SD) pre-assessment score in control arm	12.4 (4.56)	20.52 (4.93)
Mean (SD) post-assessment score in control arm	26.8 (3.99)	25.41(5.05)
Estimated sample size	20 (10 per group)	146 (73 per group)
Drop off rate	20%	27%
Estimated sample size given drop off rate	25	200
Response rate	20%	17%
Estimated sample size	125	1176

Table 4.16 Comparison between the sample size estimated from pilot study results and sample size shown to be required following completion of RCT

Table 4.17 shows current estimates of ST3-8 general surgical trainees nationally. The estimated sample size of 1176 exceeds the numbers of trainees nationally. This makes it unlikely that the estimated numbers of trainees required to participate in a further study can be recruited.

Deanery	Trainee numbers (ST3-ST8 Level)
East of England	58
London/KSS	302
East Midlands	88
Mersey	63
West Midlands	109
North Western	83
Northern	74
Oxford	55
Severn	44
South-West Peninsula	44
Yorkshire & Humber	171
Total	**1091**

Table 4.17 Royal College of Surgeons of England (Feb 2010) figures for numbers of general surgical trainees (ST3-8) in each deanery

On the basis of the above, it was not considered feasible to perform a study that would recruit adequate numbers even if all other deaneries in England were approached. The opinion of the research team in consultation with an expert statistician (Jean Russell, University of Sheffield) was to conclude the study.

CHAPTER 5 – DISCUSSION

This study involved two main sections: multimedia educational tool development and a randomised controlled study. Online multimedia educational tools for open and laparoscopic anterior resection surgery were designed and developed in collaboration with DigiMed. The online multimedia tools were then evaluated by an expert panel of surgeons and tested for their effectiveness in the acquisition of cognitive surgical skills by means of a randomised study. To our knowledge, this is the first operative multimedia tool developed and evaluated in open and laparoscopic colorectal surgery to facilitate cognitive surgical skill acquisition.

Both online multimedia tools were based on the educational framework derived from cognitive task analysis performed for each operation. This allowed a structured approach to construction of the interface maps. An evidence-based approach and adherence to the principles of multimedia design facilitated the creation of 'easy-to-use', interactive, navigational interface maps. During development, efforts were made to minimise "cognitive load" to enable dissemination of the educational media content in an effective and efficient manner.

Cognitive skills training relevant to surgical procedures is important and represents an integral component of surgical competency [140]. Establishment of cognitive skills will allow trainees to focus on technical skills when performing procedures [141]. Some suggest cognitive skills must be taught before psychomotor skills training [12]. However, there remains a dearth of studies relating to multimedia and surgical skills training. In the context of published literature, there are currently few multimedia platforms designed and evaluated for specific operative learning in cognitive skill training [59, 60, 101, 132, 142] for post-graduate surgical trainees. Furthermore, only one study incorporated use of cognitive task analysis in multimedia design to facilitate multimedia learning [132].

5.1 Summary of the main demographic study findings

The relatively low response to this study (17%) was disappointing, particularly as study commitments were not onerous. Clinical commitments, participation in other studies, lack of interest in the study due to other specialist interests, perceived lack of benefit from participation and lack of 'hands-on' or practical training are some of the reasons that may explain the low response rate. Given the complex level of anterior resection, core surgical trainees were excluded from the study.

It is difficult to comment on whether recruitment would have been proportionately higher in another Deanery. The fact that this study was conducted outside a main academic teaching hospital may have been a factor. Although the London Deanery precluded advertisement of educational studies on their website, efforts were made to advertise the study to all London trainees, through meetings and support provided by London Deanery regional general surgical training programme directors.

The educational purpose of the study focussing on cognitive skills acquisition appears to be more appealing to less experienced (intermediate) level trainees; the median study age of 33 would also indicates this. The low numbers of operative experience in anterior resection surgery (particularly laparoscopic) also reflect this. The smaller proportion of senior level trainees (15 %) enrolled in the study maybe accounted for by other academic commitments (e.g. FRCS exit examination revision/ courses or research work). One could speculate that a study of this nature is unlikely to be of perceived benefit for senior trainees.

As would be expected, the majority of trainees (57%) recruited expressed an interest in colorectal surgery. A study related to colorectal theme is likely to generate more interest amongst trainees with a committed sub-specialist interest in colorectal surgery. The remaining participants' interests were fairly evenly split amongst all surgical specialities (23%) and those who were currently undecided (20%). The general trend showed that the majority of senior level trainees recruited had a colorectal interest, whilst intermediate level trainees' interests were evenly split amongst specialties.

Trainees were predominantly male (75%) and this may reflect gender demographics amongst trainees in each deanery. Participation in an educational study is unlikely to be influenced by gender and therefore was not considered to be an important factor in this study. However evidence has demonstrated that females show more improvement after being taught with 3D animated multimedia programs compared to males [101].

The majority of participants (88%) strongly agreed/ agreed that reduction in training hours is having a negative impact on their training. This highlights a significant problem in the delivery of surgical training in current training programmes within the EWTD. Reduction in clinical and operative exposure, affecting the ability to acquire, practice and enhance surgical skills justifies the need to continue development of new educational tools to augment surgical skills training outside the operating room.

Regarding use of adjunctive educational tools, trainees had mainly experience of using video box trainers and virtual reality (VR) simulators. Only a small proportion had used multimedia or computer-based training tools (33%).

Trainees responded positively to the practical models (video box trainer, VR simulators) to improve surgical skills, although a large proportion (over 60%) remained unsure; this may be related to lack of exposure to the training tools. These particular tools tend to concentrate on technical skills acquisition. Only 24% believed Multimedia/ Computer-based learning tools improved their surgical skills, whilst 8% disagreed. Again a significant portion were unsure (68%) and this is likely to be due lack of multimedia/ computer programs related to surgical skill acquisition. Additionally, only few surgical websites existed (at the time of the study) that teach and train surgical skills or procedures WebSurg [57]. However, it has been shown that trainees with minimal experience of “e-learning”/ multimedia-based learning in surgical specialties have expressed an interest in accessing this type of adjunctive educational tool, and this access should be provided nationally rather than just locally, for all trainees [143].

5.2 Randomised study

This randomised study evaluated the effectiveness of multimedia learning in comparison to conventional "Study day" teaching for the acquisition of cognitive skills in operative colorectal surgery. This is the first multimedia tool evaluated in a randomised controlled setting in colorectal surgery.

The primary outcome measure was the change in assessment scores. Results were analysed in two ways: 'intention-to-treat' and 'per protocol'. Pre-assessment scores, post-assessment scores and mean change in scores in the two groups for the two types of analyses were similar. To reduce bias, randomisation was performed after the pre-test.

Post-test assessment scores demonstrated a significant improvement in acquisition of cognitive skills following both multimedia and conventional teaching.

For intention to treat analysis, the mean change in scores in the multimedia group was higher (6.60, SD 5.10) compared to the control group (4.89, SD 3.66). Although there seemed to be a greater improvement in scores in the Multimedia group compared to the control group this was not statistically significant (p=0.21).

For per protocol analysis, the mean change in scores for the multimedia group (6.02, SD 5.12) was higher compared to the Study Day group (5.31, SD 3.42); again this difference was not significant (p=0.61).

The findings of this study are consistent with other published studies [103-105]. However, there are other studies that have demonstrated superiority of multimedia compared to conventional teaching methods [94, 99, 100]. Only one study has demonstrated superiority of conventional teaching methods compared to multimedia [51]. It is difficult to make comparisons with the above mentioned studies (as alluded to in the systematic review (Chapter 2)) due to the heterogeneity in important factors such as study conditions, assessment tools and control groups. For instance, Summers [51] suggests skilled live instructors may provide additional information that may make a "lasting impression" to improve cognitive skills. Overall results do show that multimedia and conventional teaching methods are both valuable methods for improving cognitive skills acquisition. Results also suggest that multimedia is a good adjunct to traditional teaching methods; additional advantages of multimedia learning being availability “24-7” if disseminated online and flexibility in time and place for learning.

The results of this study demonstrate that multimedia, tested in individual self-directed settings, is effective in transferring and improving cognitive skills in operative colorectal surgery. This also means that online multimedia educational tools can be used with confidence to teach cognitive skills.

The potential mechanisms for why multimedia and study day (live instruction) improve cognitive skill acquisition are now explored. Why do multimedia platforms have a positive effect on skills training?

Multimedia educational tools should aim to accomplish something that a book or other instructional tool cannot, whilst improving upon these traditional instructional methods (i.e. using interactivity, doing something faster or more economically) [45]. The combination of various forms, while potentially offering unlimited interactivity, enhances multimedia over standard instruction because multi-sense learning is thought to be superior to traditional, non-interactive, didactic methods [51]. The use of interactive media stimulates the different visual and auditory receptors of the learner; which in turn improves the understanding and transfer of complex temporal and spatial events. It would seem logical that visual examples of expert surgical skill or procedural performance are likely to be more effective in developing surgical skills than reading text alone [84].

A person retains only about 10-15% by reading, 10-20% by listening, and 20-30% by what is seen. However, 40-50% of knowledge is retained by presentation of visual and auditory material in an ordered manner [61]. This is the basis of the cognitive theory of multimedia learning [43]. It would appear that visual examples of expert operative performance are likely to be more effective in developing surgical skills than merely reading text alone.

In operative surgery, well designed multimedia educational tools are an effective way to contextualise a surgical procedure to enable trainees to learn skills in a constructive manner [132]. Surgical procedures require high level of preparation and training. Rather than learning operation steps through text and images in textbook or manuals, multimedia can provide interactive, engaging visual information whilst simultaneously facilitating spatial orientation [38]. Similar to multimedia enhancement of the patient consent process, through audio-visual stimulatory cues compared with standard consent [42], surgical procedures can offer the same stimulus to learning surgical procedures.

Multimedia learning is also enhanced by the application of cognitive task analysis (CTA) [130]. The stepwise analytical approach [105] to enable teaching surgical skills, provides a method of integrating the automated skills and knowledge of experts into a form more easily understood by trainees [132]. CTA allows a structured approach to learning, by creating a logical sequence for grasping theory and decision making, thereby facilitating transfer of cognitive skills [132]. This allows trainees to enter the operating room having learnt the key procedural principles and essential decision making points.

Multimedia training not only teaches cognitive skills but also improves practical skills in a way that imparts important components of the operation such as sense of tissue, the handling of instruments [35]. Multimedia training has also be shown to improve simple motor skills [35, 144]. It is also postulated that multimedia learning can complement the cognitive phase of motor skills learning. Fitts & Posner [24] who proposed three stages of motor skills learning: the cognitive, associative, and autonomous stages. The cognitive stage involves gathering information and building a mental picture of the operation, prior to putting actions together (associative) and practicing (autonomous) [25].

Use of adult learning principles have shown to lower learning curves and increase retention rates when compared to conventional teaching methods [52]. Adult learning is enhanced by an approach that is self-directed, with a focus on the learner rather than the teacher [30]. The interactive, self-directed, self-paced learning environment of multimedia lends towards adult learning principles by allowing users to learn independently, without the constraints of time and place. Multimedia allows learners to personalise their learning according to their own schedules [54]. This setting is ideal for trainee surgeons with busy clinical schedules; trainees can choose to acquire the relevant skills before or during their rotations where development of skills can be practiced and enhanced [100].

The internet or “e-learning” is an advantageous delivery method for dissemination of multimedia content. It offers easily accessible information “24-7”, capacity to access other weblinks, and potentially regular updates [114, 145, 146]. With e-learning, trainees can access learning in their own preferred time and place [115, 147], adhering to adult learning principles. This is further enhanced with improved fast internet speed on portable devices (i.e. iPads and smartphones) increasing opportunities for surgical multimedia e-learning [148]. Another benefit is the ability to include assessment and feedback in e-learning [56, 115, 146].

Nonetheless, although multimedia has obvious educational benefits, trainees achieved gains in knowledge from the study day demonstrating that conventional teaching remains a valuable learning resource. Well-designed lectures remain an invaluable source of educational information. The presence of an expert and the addition of interactivity to the lecture format also facilitate the learning process, by providing increased opportunity for trainees to discuss various issues and delve into the expert’s thought processes [103] thereby enhancing the learning experience [132].

Secondary outcomes were the association between change in scores and level of training and acceptability of multimedia as an educational learning resource. Trainee level was the single most important variable factor in determining improvement in scores. Pre-assessment scores were significantly better for senior trainees compared to junior trainees, whilst post-test assessment scores were similar; suggesting that the interventions had the ability to bring trainees to a similar knowledge level, regardless of training level.

Although cognitive skills improved in all trainees, junior trainees appeared to gain the most from multimedia learning. Within the multimedia group, junior trainees showed significant improvement in scores compared to senior trainees. In the study day group the differences observed in the improvement in scores between junior and senior trainees were not significant. These findings point to the potential efficacy of multimedia to enable junior trainees to gain a greater increase in cognitive skills level compared to senior trainees. This finding is in keeping with previous work [105] and also suggests that knowledge gains are greater at an earlier stage of training. This could be because senior trainees may have presumed they have the knowledge base and thus are less attentive to the educational content, whilst junior trainees are paying closer attention and effort to content they do not know [149].

There was no association between change in scores for colorectal experience or colorectal interest. Pre-assessment scores were significantly higher for trainees expressing an interest in colorectal surgery compared to those that did not, but the change in scores was similar regardless of chosen sub-specialist interest.

Evaluation of the multimedia tools by the multimedia group demonstrated that the educational tools were well received and valued as an adjunctive self-directed learning resource for cognitive skills training outside the operating room environment (see multimedia development 5.3 for further discussion). This study has extended the findings of a number of studies [46, 59, 60, 94, 99-101, 103, 104] demonstrating a strong acceptance for multimedia.

5.3 Multimedia development

It is important that educators need to be aware that whilst multimedia has clear educational benefits, designing multimedia involves significant effort in creating the material [112]. The majority of published studies have only made brief reference to the design process, logistics and time involved to develop multimedia training tools.

Initial open and laparoscopic video capture to build up a large library of varied cases took over a year. Demonstration of different clinico-pathological situations (i.e. distal sigmoid tumour or low rectal tumour) for each step/ subtask was a crucial element to highlight the key intra-operative decision making points that need to be considered. Therefore it was important to allow a significant amount of time in order to build a comprehensive library of cases.

Additionally, the structure and design of both interface maps required a substantial amount of programming time; particularly for construction of the laparoscopic interface map. A number of versions were reviewed and revised to ensure the maps functioned in a consistent and cognitively efficient manner. Coordination with the various members of the multimedia team at various points during creation of the tools was critical to successful development.

In the context of other multimedia technology, the only current comparable resource is the WebSurg website [57]. The educational tools developed for this study are specifically aimed at surgical trainees and focus deliberately on one procedure. WebSurg is aimed at qualified consultant surgeons and covers a wide breath of surgical disciplines.

5.4 Multimedia Evaluation

Educational tools can be assessed by improvement in standardised testing or other variables such as user learner satisfaction/ acceptability of the material. User evaluation is a constructive and valuable assessment method to determine the educational success of multimedia [51]. In addition users' feedback is likely to improve the effectiveness of multimedia tools. Therefore an important component of this study was to evaluate the acceptability of the educational tools.

Expert evaluation: There was a low response rate (21%) to request for evaluation of the tool by surgeons and educational experts. Busy clinical or educational schedules are the most likely reason to account for the poor response rate.

Although the interface design for both tools were scored positively, the open tool scored higher with regards to all aspects compared to the laparoscopic tool, particularly with regards ease-of-use to navigation. This may have been related to the increased complexity and interactivity in the laparoscopic tool.

All statements related to learning process and features received positive responses; although 30% were unsure regarding ‘accommodation of learners' individual differences’. The reasons for this are unclear and warrant further clarification.

Experts’ responses suggest multimedia learning tools can be more effective compared to other traditional adjunctive educational platforms, in particular surgical textbooks. If multimedia tools are deemed to be more effective than study days/ courses, this can potentially have cost saving implications for trainees.

Experts felt the educational content was applicable for ST3-8 level trainees, and this was an important factor considered during development. Dividing the operation into steps and subtasks allows trainees to self-direct to relevant educational material. Whilst being able to improve trainees’ cognitive skills, experts felt the most appropriate time to utilise the tools was prior to operating lists.

Trainee evaluation: The high response rate (81%) of the multimedia group to the online evaluation tool suggests trainees were motivated by the technology.

The results highlight the success of the interface design following implementation of multimedia design principles. Although most aspects of interface design (ease of use, navigation, and mapping) were well accepted, users approved the open design more strongly (table 4.9). The consistent structure of the open interface design may be a factor. Screen design (focussing on animation, text, video, voiceover, and graphics) and the integration of all these types of media onto both tools were well accepted.

Users responded positively to learning process and features (table 4.10). The majority of responses indicated that both tools achieved goal orientation by focussing on cognitive skills acquisition. Multimedia allows trainees to take the initiative and responsibility for their own learning, but this requires self-motivation [54]. Users generally felt the tools created an interactive learning experience and were intrinsically motivating which is an important factor in self-directed learning and adult learning principles.

Multimedia allow users the opportunity to search or navigate to educational media of their choice; multimedia also has the added advantage of repetition of media. Users can become more engaged with the content as they have control over the pace and the sequence of the content [54]. The majority of trainees (79%) agreed positively that the tools gave unrestricted user control. A small proportion disagreed and a number of trainees were unsure, suggesting further development of the tools is required to optimise this aspect.

Accommodation of a range of learner differences enables different learners to organize the information in a manner that reflects their learning style. Results indicates the tools are applicable to all trainees and suggest that multimedia adapts well to individual differences due to the high degree of learner control and the ability to cater for varying learning styles [150]. This also points to balanced use of “scaffolding” [151] having been successfully implemented.

In both tools efforts were made to engage users to focus on media for learning and not to divert attention to unnecessary information; in this way learning demands on the user could be minimised. Increased interactivity may have accounted for user disorientation, particularly in the laparoscopic tool, resulting in some negative responses. However, in general, strongly positive responses to learning demands placed on the user suggest that ‘cognitive load has been minimised’ this points to adherence to multimedia design principles during multimedia construction.

Both tools compared favourably with current teaching methods suggesting multimedia has as a role in surgical education. Though the interface and learning features are important, multimedia’s capacity to also allow flexibility in learning and self-paced learning are additional positive factors. This adheres to adult learning principles and is an important factor in modern surgical training. Users agreed the lack of human interactivity is a drawback, suggesting they still value personal communication and feedback from expert instructors. Implementing self-assessment and feedback into the multimedia tool, similar to the CEVL modules [142], will improve the aspect of feedback.

Trainees, in general, felt that the multimedia had improved their cognitive surgical skills. This may reflect the higher scores achieved by the multimedia group in the assessment tests. While the majority felt that their factual/ anatomical knowledge and anatomical place recognition skills had been enhanced, a proportion of users (25%) disagreed/ strongly disagreed that multimedia had improved their decision making skills. The reasons for this are unclear; we can speculate that these trainees may feel that multimedia is more applicable for attainment of procedural knowledge and that development of decision making skills should take place in the intra-operative environment. These results warrant further investigation. Ultimately the ability for multimedia to improve surgical skills needs to evaluated in clinical situations (i.e. studies on intra-operative decision making), and not merely by subjective evaluation of skills improvement.

Although there are areas that require further development and improvement, the responses to the learning process and features, and training tool appraisal statements were all generally positive from both experts and trainees. Favourable responses should be treated with some caution, as they may represent the enthusiasm of a small, self-selected group of motivated trainees and sympathetic experts, the latter being a selected group known personally to the research team. This would have introduced a certain amount of inherent bias and needs to be taken into account.

Overall, multimedia is a well received and valued adjunctive educational tool by both experts and trainees. Evidence from the literature and trainee responses' suggests feedback is a crucial component in the evaluation of multimedia educational tools and needs to be integrated into the design.

5.5 Cost of multimedia tool development

The issue of cost is very important in order for the readers and potential future developers to judge whether the reported outcomes offer value and are therefore represent practical educational measures. The overall cost of the multimedia tool development was £26,000 (breakdown of costs: results section 4.2).

Of the three main components, video sequence editing was the most costly. This is due to the time spent on individual aspects (annotation, voiceover and sometimes animation) of the production of each fully edited video clip.

The increased level of programming and interactivity of the laparoscopic tool was expected to be significantly higher than the open tool. However the experience gained from production of the open tool was able to reduce the amount of time spent developing the laparoscopic tool, offsetting some of the cost. This still resulted in £2,000 gap in costing between the tools. Future development should take into account these issues before embarking of interface development.

Although initial cost of development and resources needed to complete a multimedia production are initially high, this is potentially offset by reduced costs of organising study days which is potentially cost effective to both trainees and deaneries. It should also be noted that maintenance of such a website is relatively low.

5.6 Study strengths

This study has a number of strengths and each are discussed in the sections below:

The study design used in this educational study was randomised controlled study. The randomised controlled study design provides strong evidence to determine the causal-effect relationship between multimedia and outcome measures. The pre/post test study design allows measurement of the potential effects of self-directed multimedia by analysing the differences in the pre- and post-test assessment scores. The use of a control group (in this case a conventional method of teaching) allows examination of the true effects of multimedia. Stratified randomisation reduced selection bias enabling equal distribution of the important co-founding variables, identified before the study (age, colorectal experience and training level (junior or senior)), into the two groups. Comparable baseline variables in the two groups demonstrate the integrity of the randomisation process. Although randomisation was not based on the pre-test score (normal distribution of the trainees' baseline knowledge was assumed), both the groups were comparable for pre-test scores. The assessors were blinded to participation group allocation.

Another strength of this study was the setting. The majority of studies using multimedia educational tools in surgical training have taken place in the work-place setting [44, 59, 101, 103-105]. The intention in this study was for multimedia tools to augment cognitive skills acquisition outside the operating room by self-directed learning. In accordance with adult learning principles, the multimedia group were therefore tested in 'individual' settings to best create a self-directed learning setting and therefore abolish any "dynamic group effects" [54]. This also enabled the trainee to take on the responsibility to initiate his/ her own learning. Providing unrestricted access to the educational tools also allowed trainees to facilitate learning according to their own schedules. Study participants were recruited from a number of institutions (hospitals), and so results are generalisable to a wider community of trainees. In addition, recruitment was not confined to trainees with a particular sub-specialty interest. Results are therefore generalisable to surgical trainees in general at ST3-8 level.

The structured assessment tool developed for the study must assess what it is purported to measure. Any method of skill assessment must be practical, feasible, valid and reliable to be used with confidence [140]. Validity manifest in several different forms and this study shows that the assessment tool developed demonstrates construct validity. This assessment tool has been previously tested and validated on a separate group of trainees (personal communication, Prof Dorudi). The assessment tool also demonstrates excellent inter-rater reliability.

5.7 Study limitations

This study has a number of limitations. The limitations are discussed below:

The research team members involved in the cognitive task analysis (CTA) did not have a background in psychology. Although structured CTA methods were followed, discussions did not take place with any cognitive psychologists. Only two surgeons were interviewed in the CTA process and this assumes common practice relating to performance of steps of the open and laparoscopic operation.

Although evidence-based research guided the multimedia design and structure, particularly with regards to interface map construction, experts in multimedia design were not involved.

Although previously validated [138], the assessment tool is not standardised for use in colorectal surgery or cognitive skill acquisition. There are no previous studies on similar assessment tools. The question bank developed was not exhaustive and questions were not stratified/ categorised into difficulty levels or particular facets of cognition (i.e. decision making questions). In this way we were unable to perform sub-group analyses on questions to assess if improvement could be observed in particular categories. In addition, the question bank was developed solely by the research team. The assessment tool developed is essentially an arbitrary knowledge scoring system and therefore tests only elements of cognition.

Although the online survey previously validated, there were a number of areas that should have been covered in more detail. These include experts and trainees opinions on the interface and interactivity differences between open and laparoscopic tools. Evaluation on the variations in multimedia format would have provided valuable constructive feedback on the optimal interface design and structure. Opinions on the cost of multimedia development could have been considered.

Future evaluation should focus on the learning process and demands in greater detail to ‘measure’ cognitive load and ensure that this had been minimised.

No evaluation survey was performed for the Study Day. This would have provided useful feedback on the format of the lectures and interaction with experts (alluded to from the multimedia evaluation).

The response to the recruitment strategy is low (17%) but is comparable to published response rates for similar studies [152] which range widely from 15%-77%. Busy clinical schedules and other academic work commitments are the most likely significant contributory factors to the relatively low response rate. Another factor may have been pre-existing attitudes with regards to the value of interactive multimedia within the setting of an educational study, or based on past learning experiences.

As previously discussed, this study was conducted independent of an academic institute. This study was therefore not Deanery-driven nor did it have RCS (Royal College of Surgeons) approval. The London Deanery, due to administrative constraints, did not allow posting of this study on their main deanery website. These factors affected coverage of the study may have hampered recruitment.

Recruitment from one national training deanery poses a threat to external validity in terms of applicability to all general surgical trainees nationally. There is however no explicit reason to assume that the trainees from this region have different demographics or ability compared to trainees elsewhere. The higher proportion of trainees with a sub-speciality interest in colorectal surgery participating in the study represents another threat to external validity.

Participants recruited into the study may have represented a group of self-selected, motivated trainees that may affect generalizability of results. Also these trainees may have been more technologically advanced compared to their peers.

The overall study drop-off rate of 27% was high. Despite efforts made to commence study at the beginning of October to coincide with the start of the academic year and change-over of trainees between hospitals to allow sufficient time to organise study leave (at least six weeks in advance of the study day is required), the drop-off rate for participants assigned to the study day was significant (11/29: 38%). Scheduling difficulties to attend the study day due to clinical commitments were given as the main reason for non-attendance. Other contributory factors include lack of participant “enthusiasm”, lack of remuneration for study day attendance (travelling costs) and the length of the study period.

With regards to the multimedia group, all participants were assumed to be technically proficient using multimedia technology. Previous studies have employed CUC questionnaires to establish confidence [59].

Recruitment could have been expanded to core trainees to increase the sample size. However the complexity of open and laparoscopic anterior resection surgery mean that core trainees are very unlikely to perform this type of surgery.

It could be argued that recruitment should have been limited to trainees with a subspecialist interest in colorectal surgery only because of the complex nature of anterior resection surgery. However, during general surgical training, all trainees have the opportunity to perform anterior resection in part, or completely under supervision. Choosing less complex operation, such as right hemicolectomy or generic segmental colectomy may have been more applicable to general surgical trainees, potentially improving recruitment numbers.

In terms of educational evaluation, it is important to recognise that this study focussed on the lower levels of clinical competence [124] e.g. knows / knows how, rather than shows how / does. ‘Knows’, as demonstrated by the test, does not necessarily equate with ‘does’. As such, the impact of the educational intervention on clinical or patient-centred outcomes was not assessed in this study. The primary outcome measure is this study is a surrogate measure. It can therefore be argued whether multimedia can actually improve cognitive surgical skill acquisition in the workplace.

Further studies are needed to assess multimedia in the clinical setting using clinical and patient-related outcomes. Retention of knowledge over longer periods of time should also be assessed through longitudinal studies.

The geographical spread of trainees precluded invigilated assessment tests. Invigilated assessment tests would have increased study commitments and may have resulted in poorer response rates; recall for invigilated post-test assessments and to determine long-term retention has previously resulted in poor attendance (personal communication, Prof Dorudi).

The online assessment tests were completed by trainees in individual setting. Although the tests timed and completion in one sitting was mandatory, no measures were used to prevent collusion or access to other educational resources (via the internet or text-books) during the assessments.

Another limitation was the lack of data to show participants' usage of the multimedia tools. A possible reason for no significant difference found between the two groups may have been related to low amount of multimedia usage. As per adult learning principles, trainees were not instructed to view the tools for a specified time. However the control group achieved similar scores and were exposed to all relevant information, albeit all information was disseminated in one day.

Google analytics could have been used to analyse trainee utilisation and assess if self-directed multimedia learning had an effect on assessment score.

No preventative measures were employed for "diffusion of treatment" [101]; although the online tools were only accessible with individual passwords, control group participants may have had access to the online resources through personal communication with multimedia group participants (i.e. working in the same hospital).

All multimedia group participants were asked not to share their passwords/ logins with any other trainee. Whether the participants conformed to this request or not cannot be proven.

During the study period, participants may have been attached to colorectal firms performing or assisting with anterior resection procedures or attended similar educational courses. The improvement in results may have been due to trainees' clinical exposure and not due to the intervention. It is not possible to account for these variables in an educational study of this nature.

Although pre-post test study design has a strong level of internal validity and allows inferences to be made on the effect of the intervention/ control by analysing differences between scores, the use of a pre-test may sensitise trainee in unanticipated ways and their score on the post-test may be due to the pre-test. Randomisation was performed after the pre-test assessment (which was not a variable in the randomisation process), but both randomised groups had similar scores.

The use of identical pre-post assessment tests also raises the possibility that trainees' scores would have improved to the same degree simply by repetition of the assessment test, regardless of whether they had been exposed to either multimedia or the study day [126]. The improvement in scores may therefore reflect recall bias and a "learning effect". A separate control group without a learning intervention could have used; this group would have completed the pre- and post-assessments only as part of their study commitments. The inter-assessment period was prolonged to mitigate the chances of recall bias and familiarity.

The improvement in scores in the multimedia group was much less than what was expected during *a priori* sample size calculations. Given that the change in score was higher in the multimedia group, it is possible that a much larger study may have shown a significant difference between the groups [153]. We do not think though that the results negate the perceived benefits of multimedia. The tool has been shown to be a good alternative to traditional, didactic teaching and has advantages in the long term.

Given that multimedia is at least as effective as the control, the other advantages of multimedia including flexibility of time and place for learning and therefore greater sense of autonomy with learning, continual access to educational material and accessibility justify its role in surgical training.

Cognitive skills training has traditionally been through educational forums (study days/ conferences) and didactic lectures. The use of comparison groups for multimedia based instruction is controversial and presents a dilemma for trialists in educational studies. In this study, structured lectures delivered by an expert surgeon, were used as the control; another expert surgeon facilitated interactive discussion.

The reason for choosing 'Study day' as the control is that teaching through standardised lecture formats remains the most common teaching method currently used on post-graduate surgical programmes.

The study day was carefully structured to account for confounding factors. Identical content was presented to the multimedia tools (no differences exist in knowledge or expertise between experts and multimedia content). Any discussion separate to the multimedia content (such as a particular clinical situation) was not examined in the post-test assessments. The same lecturer was used to control for style differences [76, 81]. Nonetheless, expert instruction may still lead to bias and is a therefore a threat to internal validity. For instance, enthusiasm of instructor or trainee interaction with the lecturer, excessive speed of presentation, cognitive overload may all be confounding factors.

Some authors do however argue that media-comparative research (comparing computer-based instruction to non-computer based instruction) is logically impossible because there is no true comparison group and therefore comparison is "futile" [59, 154]. This is because observed effects cannot be ascribed confidently to the intervention group [154].

However, other authors argue that innovative teaching tools need to be evaluated to determine their effectiveness by comparing them to some standard of training [60, 155]. In addition, the cost of programming and the time spent developing multimedia applications mean that it is important that controlled studies demonstrate the utility of multimedia for education [156], to ensure resources are well spent and demonstrate educational impact [61].

5.8 Future development of the multimedia educational tools

Further development of the open and laparoscopic tools would involve:-

- Capture of more video footage including examples of low male and female pelvic dissections
- Additional section on complications related to anterior resection surgery including interviews with surgeons to discuss how to manage complications intra- and post-operatively
- Tips and tricks sections
- Integration of questions for the purposes of online self-assessments and immediate feedback that users can easily understand to allow for focussed, efficient remediation [99].
- A digital library relating to anatomy, surgical approaches, pathology
- Collaboration with other colorectal surgeons to provide media content and developing additional pathways

Future multimedia studies could focus on assessment of intra-operative performance with anterior resection simulation models or live laparoscopic animal models.

For the assessment of intra-operative non-technical skill performance, the following study strategy could be employed:

- Development of procedural specific evaluation rating scale and validation
- Feasibility study: a pre/post intervention study design assessing non-technical skills (using the pre-validated rating scales) on trainee surgeons on a procedure before/after intervention.
- Implementation on a larger cohort of trainee surgeons

For the assessment of intra-operative technical skill performance, the following study strategy could be employed:

- Randomised study with two groups: Pre-conditioning online multimedia training versus no training
- Assessment of technical skill performance OSATS/ task checklist or a specific validated evaluation scale on anterior resection simulation or live animal models.

Another prospect for the future is incorporation as a preliminary module into a VR lap simulator [106]. Use of the Multimedia Educational Tools could be combined with a VR simulator and this would bring together training in technical skills, knowledge and decision making to assess task completion [106].

The CEVL (computer enhanced visual learning) method is a platform to teach technical skills (as discussed in systematic review – Chapter 2). CEVL is an Internet-based program training method for trainee surgeons to perform surgery using components (intraoperative video and images, text, and computer animations) and provide access to a personalised surgical feedback/remediation archive [142, 157]. The use of CEVL has been shown to provide a consistent learning experience and is reproducible across institutions [142, 158].

Incorporated into CEVL module, trainees would perform open or laparoscopic anterior resections whilst being evaluated intra-operatively by trained raters and provided feedback about surgical performance. Outcome measures include the validated CEVL score and operating time. The CEVL method has been successfully implemented in paediatric urological surgery [142] and most recently in obstetric surgery (caesarean section) [158].

Intra-operative decision making: The multimedia tools could potentially be utilised "in the classroom" for teaching and reappraisal of surgical trainee to develop and consolidate their ability intra-operative decisions and improve their factual knowledge [106].

5.9 Implications for the future

Multimedia educational tools could potentially be developed for other ISCP general surgical and colorectal index procedures. This would involve a much more extensive multimedia development. There would also be a number of implications in terms of funding and logistics, mainly because this type of project would require a number of surgical trainees to initially accrue the video footage. However the advantages would be development of procedures (e.g. appendicetomy and generic segmental colectomy) that could encompass both elective and emergency surgery, thus being generalisable and applicable to a larger cohort of general surgical trainees.

VR simulation has already been integrated into surgical skills assessment as part of the selection process for Higher Surgical Training (HST) selection in the Irish National Training Programme [159]. Multimedia educational tools could potentially be integrated into part of the surgical skills assessment, focussing on the cognitive aspects of common procedures.

Some e-Learning projects have been introduced into some surgical specialties such as plastic surgery: ((e-LPRAS: e-Learning for Plastic, Reconstructive and Aesthetic Surgery [143]) and e-Surgery developed by the Royal College of Surgeons of England in partnership with HEE e-Learning for Healthcare (for early year's training: http://www.e-lfh.org.uk/programmes/surgery/).

Multimedia educational tools, developed for index operations/ procedures, could be integrated into General Surgery higher surgical curriculum to augment self-directed learning, focussing on the cognitive aspects of the key operative steps of procedures. Being web-based, the tools would be readily available '24-7'; particularly with the growing use of portable devices. Such tools could also be used to provide formative assessment and feedback, enabling trainees to prepare for their operating sessions.

Under the ISCP assessment framework for work-placed methods, PBAs are designed predominantly to assess technical aspects of performance [160]. However with growing interest to implement NOTSS (Non-Technical Skills for Surgeons) component to the PBAs, with piloting of NOTSS (https://www.iscp.ac.uk/assessments/notssassessment.aspx) [128], multimedia education may have the potential for a more prominent role in formative assessment.

In a recent publication, Geoff Norman, argues that too much research in digital/simulation education is focussed on "whether or not it shows gains compared to some kind of placebo". He suggests that, "one of the few universal truths in education is that any format is more or less equivalent to one another."[161]

Norman highlights the importance of relevant research. Three areas of research had been identified in this area: description, justification and clarification. Justification asks, "Did it work?", and clarification asks "why or how did it work?" [161, 162]. Clarification research is likely to lead to "greater ultimate efficiencies". It is therefore vitally important to understand the key elements in matching a technology to a learning situation/ environment, and not to be engrossed with attempting to prove a technological platform works [161].

So another direction multimedia studies in surgical training need to pursue in the future is, in collaboration with cognitive psychologists and medical education experts, to design studies to assess how multimedia can actually improve facets on surgical performance, and try to answer 'why it works' [163]. In this way, developers and educators may be about find multimedia's true worth or niche within surgical education and training.

5.10 Conclusions

Surgical education in the current era is enhanced with development of educational tools. On-line multimedia is an effective self-directed learning tool for cognitive skill acquisition in operative colorectal surgery and provides supplementary training outside the operating room. Multimedia Educational Tools appear to be equally effective to conventional teaching for improvement of cognitive surgical skills. This study has extended the findings of a number of studies demonstrating a strong acceptance for multimedia.

Further studies are now needed to determine whether Multimedia Anterior Resection Educational Tools can be used effectively to improve surgical performance. We also recommend that multimedia educational tools should be further developed for all index procedures and considered for implementation into post-graduate surgical training programs.

APPENDIX

Appendix 1 Risk assessment bias using the Cochrane Collaboration tool for assessing risk of bias [95]

Author	Sequence generation	Allocation concealment	Blinding of participants/ personnel & outcome assessors	Incomplete outcome data	Selective outcome reporting	Other potential threats to validity	Overall risk of bias
Summers et al	Unclear	High	High	Low	Unclear	High	**High**
Prinz et al	Low	Low	Low	Low	Low	High	**Low**
Friedl et al	High	High	High	Low	Low	High	**High**
Xeroulis et al	Unclear	Unclear	Unclear	Low	Unclear	High	**High**
Jowett et al	Unclear	Unclear	High	Low	Unclear	High	**High**
Lee et al	Low	Low	High	Low	Unclear	High	**Unclear**
Nousiainen et al	Unclear	Unclear	Low	Low	Low	Low	**Low**
Perfeito et al	Unclear	Unclear	Unclear	Low	Low	High	**Unclear**
Rogers et al	Unclear	Unclear	Low	Low	Unclear	High	**Unclear**
Ricks et al	Unclear	Unclear	High	Low	Unclear	High	**High**
Sterse Mata et al	Unclear	Unclear	High	Low	Unclear	High	**High**
De Sena et al	Low	Low	Low	Low	Low	High	**Low**
Pape-Köhler et al	Low	Low	Low	Low	Low	Low	**Low**
Hearty et al	Low	Unclear	Unclear	Low	Unclear	High	**Unclear**

Appendix 2 Summary of outcomes and results for included studies

Author	*Primary Outcome assessed*	Outcome Result	*Secondary Outcome assessed*	Outcome Result	*Secondary Outcome assessed*	Outcome result
Summers et al	***Cognitive knowledge***	Post instruction MCQ Didactic group: mean score (63%) Videotape group: mean score (49%) CBT group: mean score (49%) Statistical difference between didactic and other two groups (P<0.01)	***Technical skills performance***	Measure using: Performance Quotient (PQ) = (Instrument handling + body position + accuracy + tightness + alignment) x Percent completion Higher PQ score indicates better performance No significant differences observed among 3 groups when their immediate post-treatment PQ scores analysed	***Knowledge and technical skill at follow-up***	After 1-month F/UP: average group not significantly different for any of the groups After 1-month F/UP: CBT group PQ score (427) significantly different (p<0.01) from didactic (396) and videotape (413)
Rosser et al	***Cognitive knowledge transfer***	**Tutorial (control)** Pre-test 24.4 SD 8.0 Post-test 39.7 SD 7.8 Statistically significant p=0.001 **CD-ROM** US surgeons Pre-test 25.3 SD 6.2 Post-test 37.5 SD 7.1 Statistically significant p=0.001 US residents Pre-test 21.8 SD 6.9 Post-test 37.6 SD 7.3 Statistically significant p=0.001 Greek surgeons Pre-test 11.6 SD 5.4 Post-test 26.5 SD 10.7 Statistically significant p=0.001 **Post-test comparison** Differences among groups in comparing change in mean score from pre-test to post-test were non-significant Difference between the mean post-test score of US-trained residents and surgeons instructed by CD-ROM tutorial vs US-trained surgeons stand-up tutorial were not significant				

Ramshaw et al	***Cognitive Knowledge level***	**Overall Knowledge level (ALL LEVELS) (marks out of 10)** pre-training 6.0 post- training 8.7 **Knowledge level - PGY1 (Post graduate year 1)** pre-training 4.0 post-training 7.8 **Knowledge level – PGY2** Pre-training 5.7 Post-training 8.3 **Knowledge level – PGY5** pre-training 8.6 post training 10	***Evaluation survey***	Value of teaching safe performance 8.8/10 (Likert scale, with 10 highest level) **Compared to standard educational methods:** Training tool 8.6/10 Text 4.7/10 Lecture 5.1/10 Video 6.0/10 Animal lab 7.3/10	***Comfort level in performing surgery***	Overall comfort level = For performing or assisting procedure before and after training tool /10 (Likert scale; 10 highest) **Overall comfort PGY2** Pre-training 4.7 Post-training 7.6 **Overall comfort PGY3** Pre-training 6.0 Post-training 8.8 **Overall comfort level PGY5** pre-training 8.0 post-training 9.6
Prinz et al	***Cognitive knowledge transfer***	MCQ test – testing topographical and theoretical understanding 3D group outperformed control in both (p0<0.001) Topographical: 75 3D vs 59 Control Theoretical: 72 3D vs 61 Control	***Evaluation of program***	**Evaluation in mean in 3D group (Fully agree 1 to 4 disagree)** Satisfaction 1.2 Useful learning aid 1.4 Intelligibility for cataract surgery 1.7 Intelligibility for glaucoma surgery 1.6 Improvement of spatial ability 1.4 **Evaluation in mean in control group (Fully agree 1 to 4 disagree**) Satisfaction 1.3 Useful learning aid 1.6 Intelligibility for cataract surgery 1.7 Intelligibility for glaucoma surgery 1.8 Improvement of spatial ability 1.7 Largest difference in rating between groups was: Improvement of spatial ability P= 0.01		
Friedl et al…	***Knowledge level – MCQ test***	Mean % of correct answers to pre-test MCQ 30.6%+/-12.4% (Multimedia group) and 27.9%+/-11.4% (print group). Mean % of correct answers post-test MCQ 76.7%+/-13.3% (Multimedia group) and 76.9%+/=11.1% (print group). Knowledge gain significantly higher in both groups	***Satisfaction survey/ HILVE***	Most users felt comfortable with intellectual level of course and dimension demand = 4.13 +/-1.21 (optimum score = 4, exactly right) Subject relevance rated equally in both groups: multimedia 5.09+/-1.61 vs 4.94+/-1.55 print group) Overall operability and design of the program judged positive (5.61+/-1.14 multimedia group vs 5.8+/-1.19 print group)	***Performance in operating room***	Performance was significantly improved in the multimedia group (82.9% +/-10%) of tasks/questions resolved correctly compared to the print group (64.7%+/-12%; p<0.0001).

				Course stimulated self-directed learning with both media and an intrinsic motivation. General appraisal was 6.10+/-0.51 in the multimedia group and 6.12+/-0.65 in print group.		
Xeroulis et al	***Assessment of technical skills***	<u>Global rating scores (expert assessment):</u> No significant differences between the groups pre-test. All groups improved suturing and knot-tying performance from pre- to post-test (p<0.001) Mean gains in GRS scores only significant for CBVI and summary feedback groups CBVI, concurrent, summary feedback groups each demonstrated superior performance compared to control. No significant differences between these groups. 1-month retention – CBVI and summary feedback retained superior performance compared to control Hand motion analysis	***Assessment of technical skills (Hand motion analysis)***	All participants showed improvement in the numbers of movements/ total time – from analysis of performance curves No significant differences in number of hand movements – all groups improved movement efficiency at a similar rate Superior performance peak observed for all experimental groups compared to control. No differences observed between other groups	***? retention test***	At 1-month retention: CVBI and summary feedback retained superior skill performance compared to control.
Jowett et al	***Assessment of technical skills (pre-test, post-test and retention test)***	**Performance variable between Pre-test and first post-tests** Statistical improvements in performance variable in both groups **Between pre-tests and retention tests** Statistical improvements in performance variable in both groups No difference between the group on all tests Trainees who completed additional practice did not significantly improve their performance between 1st and 2nd post tests Trainees reach a common performance plateau at the point of self-assessed proficiency				

Lee et al	***Knowledge of critical procedural steps***	Mean score control group 6.00 (SD 1.84) and interventional group 7.56 (SD 1.65) significantly different p<0.01	***Candidates' perception of experience***	Mean satisfaction score for both groups was 5.00. Median anxiety score for both groups 2.00 Median confidence score control was 5, and 4 in intervention group. No statistically significant difference between the groups.		
Luker et al	***Knowledge of decision making procedural steps (talk aloud protocol)***	Statistical improvement (p=0.01) in total knowledge and understanding of advantages and disadvantages of decision making points as a result of intervention of the teaching videotape Average increase for total knowledge was 34.0 and 19.4 for understanding and disadvantages				
Nousiainen et al	***Objective improvement of basic surgical skills in suturing and knot-tying***	**Expert-based assessment (global rating scale)** Significant main effect between pre-, post- and retention tests (P<0.01) Main effect between groups and interaction between tests and groups was not significant **Total number of movements** Significant main effect between pre-, post- and retention tests (P<0.01) Main effect between groups and interaction between tests and groups was not significant **Total time (secs) to complete task** Significant main effect between pre-, post- and retention tests (P<0.01) Main effect between groups and interaction between groups not significant				
Perfeito et al	***Knowledge transfer on assessment scores between groups***	Mann-Whitney test – group 1 (Computer program) versus 2 (Traditional class): the calculated Z score was 1.9 and calculated critical Z score was 1.96. No significant difference between the two groups	***Program evaluation***	How satisfied were you with the CD-ROM? 66.7% completely, 33.3% partially Can CD-ROM replace theoretical classes? 5.6% completely, 94.4% partially		

Jensen et al	***Time to completion of tests with OSATS***	Significant improvements were seen in both time to completion and OSATS global ratings score **Bowel anastomosis** OSATS score: Pre-test:19.1; Post-test:50.3 P=0.001 Time to complete: Pre-test:58.9 mins; Post-test:50.3 mins P=0.001 **Skin excision and closure:** Time to complete: Pre-test 25.6 mins post-test 18.1 mins P= 0.001				
Rogers et al	***Performance score***	Performance score: Three surgeon rating scale: identifying all actions necessary for an optimal performance. max 24 CAL: Performance score: 12.8 +/-4.14 (SD) LFS: Performance score: 17.4+/-3.53 (SD) Significant difference (P<.0001) lower score for CAL group compared to LFS group. Average time: CAL: 19.6+/-9.6 secs Average time: LFS: 17.4+/-6.8 secs No significant time difference for task completion	***Educational session preference***	73/82 (89%) preferred the LFS session Lack of feedback: most cited negative feature of the CAL model (44%) of total group		
Ricks et al	***Cognitive knowledge***	MCQ 20-item test CAL (n=13) Average score: 16.3 (SD, 2.68) Non-intervention (n=10) Average score: 10.9 (SD, 1.37) Average examination score significantly higher for CAL group compared to non-intervention group	***CAL evaluation***	On scale of 1 to 5, CAL: User-friendly: 3.9 (average) Improved knowledge: 3.7 (average) Learned something new: 4 (average)		
Sarkar et al	***Differences in knowledge transfer between senior vs junior surgeons***	**Total scores** Statistically difference between expert vs intermediate (p=0.01) **Operative surgical technique knowledge** Statistically significant difference – p=0.038 **Knowledge-based module** No statistical significant difference Mean time to complete test 29.12 +/- 8.55 mins				

McQuiston et al	***CEVL skills score***	CEVL Score = sum of the ratings (Likert Scale rating 1 (simple) to 5 (complex) subjectively assessed by attending surgeon) x case difficulty CEVL score improved in 13 study group (86%) and 14 control (78%) participants Incidence and magnitude of improved resident skill performance did not significantly differ between groups: 10.5 (study group) and 13.4 control group) arbitrary units No deterioration after using CEVL in either group	***CEVL Questionnaire***	CEVL improved attention to detail (45.4% strongly agreed), improved knowledge of procedure (72% agreed), positively impacted progress of operation (54.6% strongly agreed) Component portion was very useful Comfortable performing orchiopexy after using CEVL Repetition and practice of steps were useful in learning experience and increased comfort level		
Sterse Mata et al	***Cognitive knowledge transfer***	Group A (Ebronchoscopy): Mean score 14.63 SD 1.41 Group B: (lecture group): Mean Score 14.75 SD 1.45 Student's t-test showing no significant difference between the test results of the two groups	***Subjective analysis***	E-bronchoscopy: Strong points: "Moving back and forth over text a key element" (5 students) Weak points: "too much text" cited by 3 students Lecture group: Strong points: quality of the teacher invaluable (5 students Weak points: too much information given in little time , too many slides		
De Sena et al	***Cognitive knowledge transfer***	The mean post-test sum score of five items was 4.44+/-0.58 (CAL group) was significantly higher than the Text group (3.32 +/-0.99) p<0.001	***Technical skill assessment***	OSATS protocol: Checklist and Global Assessment Scale The mean raw score of all 10 checklist items was 4.09 for the printed text group vs. 7.72 for the CAL group (p<0.002) Mean sum score of nine items of gross overall global assessment, which was 22.68 vs. 29.49 (p = 0.017).	***Software evaluation***	100% elected software as the best method of teaching and would recommend to a friend 32 (64%) felt needed software to be able to perform procedure without help; 10 (20%) would only need print text
Davis et al	***Checklist to assess performance of drain insertion***	Novice video group performed intrapleural sweep and clamp distal end of tube (p<0.001) more compared to novice control group Expert video group more likely to correctly perform finger sweeps, incision and clamping distal chest tube compared to expert control group (not significant) Experts least frequently completed full finger sweeps and avoided the neurovascular bundle				

Pape-Köhler et al	***OSATS technical performance (task-specific checklist)***	Pre-test results for all the groups were comparable; no significant differences The OSATS results were highest in the multimedia-based training group (4.7 +/- 3.3) p<0.001, practical training (2.5 +/-4.3), combination group (4.6 +/-3.5), control group (0.8+/-2.9)	***Effect of multimedia-based training***	36 participants (multimedia-based training + combination training) had OSATS 4.6 compared to 34 participants (without multimedia-training; practical training and control groups) OSATS 1.7; p<0.001. Multimedia-based training had a significant effect on performance.	***Effect of practical training***	35 participants (practical training + combination) OSATS 3.6 vs 35 participants (multimedia-based training + control) OSATS 2.8; practical training did not have a significant effect on performance
Hearty et al	***Cognitive knowledge transfer (of Preparedness Testing)***	Mean test group score (90.9 +/- 6.8) compared to mean control group score (73.5+/-6.4) was significantly higher (p<0.001) Test group scored significantly higher for each PGY class	***Survey of user opinion of effectiveness of module***	100% strongly agreed/ agreed that module was a useful adjunct to traditional methods for case preparation, improved knowledge and a useful platform for other related procedures. Majority strongly agreed/ agreed module increased comfort in the operating room (OR) and reduced anxiety in OR		

Appendix 3. Comprehensive CTA for Open Anterior Resection

Step	Sub-tasks	Surgeon position	1st Assistant	2nd Assistant	Patient position	Instrumentation
Set-up	Position patient (modified Lloyd-Davies), antibiotic prophylaxis, urinary catheter, TEDS/ Flowtrons, Bair Hugger, Prep and drape (Ioban incise drape). Vertical midline incision.	L/RHS	Opposite to surgeon	Between legs	Modified Lloyd-Davies position Supine	Scalpel, diathermy, Littlewood forceps
1. Mobilisation of sigmoid and descending colon	a. Assessment of pathology Is safe access to the left paracolic gutter possible? YES – proceed to 1b NO – proceed to 1g	LHS	RHS	Between legs	Supine	
	b. Division of congenital peritoneal attachments	LHS	RHS: Colon retracted medially using large pack	LHS/between legs: Deaver/ Morris retractor retract abdominal wall	Supine	Diathermy, ultrasonic device DeBakey forceps, Morris/ Deaver retractor(s)
	c. Develop plane between sigmoid/ left descending mesocolon and retroperitoneum	LHS	RHS: Colon retracted medially using large pack	Between legs: Morris/ Deaver retractor	Supine	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)

	d. Continue to develop plane to identify L. gonadal vessels	LHS	RHS: Colon retracted medially using large pack	Between legs: Morris/ Deaver retractor	Neutral	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)
	e. Further medial dissection to identify of L. ureter	LHS	RHS: Colon retracted medially using large pack	Between legs Morris/ Deaver retractor	Supine	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)
	f. Continued cranial dissection of left descending colonic mesentery off Gerota 's fascia (as far as safe access allows) Adequate length of colon mobilised? NO: proceed to STEP 2 YES: proceed to STEP 3	LHS +/- Between legs	RHS: Colon retracted medially using large pack	Between legs: Morris retractor +/- Deva retractor	Supine +/- left tilt up	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)
	g. Medial to lateral approach: Vascular pedicle identified and create medial peritoneal window	RHS	LHS: Colon retracted laterally	Between legs: Morris/ Deaver retractor to retract abdominal	Supine	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s), Littlewoods
	h. Develop plane between mesocolon and retroperitoneum to identify hypogastric trunk, left ureter and gonadal vessels Take down ureter/ gonadal cranially and caudally off sigmoid mesocolon	RHS	LHS: Colon retracted laterally and elevate peritoneal window (Babcock or retractor)	Between legs: Morris/ Deaver retractor to abdominal wall and colon	Supine	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)

	i. Vascular pedicle division – artery (IMA) and vein (IMV) divided separately	RHS	LHS: Colon retracted laterally and elevate peritoneal window (Deaver retractor)	Between legs: Morris/ Deaver to Retract abdominal wall/ colon	Supine	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, artery forceps (Dunhill/Roberts), Vicryl suture (IMA transfixed), Morris/ Deaver retractor(s)
	j. Continue medial planar dissection	RHS	LHS: Colon retracted laterally and elevate peritoneal window (Deaver retractor)	Between legs: Morris/ Deaver retractor to abdominal wall and colon	Supine +/- left tilt up	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)
	k. Access to left paracolic gutter. Divide lateral attachments	RHS	LHS: Morris/ Deaver retractor	Between legs: Morris/ Deaver to retract abdominal wall	Supine +/- left tilt up	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)

2. Splenic Flexure mobilisation	Approach to Splenic Flexure Lateral – proceed to 2B Supracolic – proceed to 2G					
	b. Continue cranial dissection mobilising left colonic mesentery off Gerota's fascia towards the spleen and dividing further lateral attachments n.b. Height of splenic flexure is often variable.	Between legs/ RHS	RHS: Colon retracted medially Debakey forceps	LHS: Morris retractor (L. Hand) Deva retractor (R. Hand)	Supine +/- Head up, tilt to RHS	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)
	c. Enter the lesser sac. Correct plane confirmed by visualisation of posterior stomach wall Note: Avoid caudal retraction of greater omentum. This may tear omental attachments to spleen and cause capsular injuries	Between legs/ RHS	LHS: Deaver retractor Reflect Greater omentum anteriorly	LHS/ between legs: Morris retractor	Supine or reverse Trendelenburg +/- left tilt up	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)
	d. Continue dissecting greater omentum off distal transverse colon laterally towards the spleen	Between legs/ RHS	L/RHS: Morris/ Deaver retractor	LHS: Morris retractor	Supine or reverse Trendelenburg +/- left tilt up	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)
	e. Supra-colic and lateral dissection planes meet. Divide attachments to take flexure down	Between legs/ RHS	LHS: Morris/ Deaver retractor	LHS: Morris retractor	Supine or reverse Trendelenburg +/- left tilt up	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)

	f. Complete mobilisation of splenic flexure and colon to the midline. The superior extent of mobilisation is identified by inferior border of pancreas and medially by the inferior mesenteric vein (IMV)	LHS	RHS: Retract colon medially	LHS: Morris/ Deaver retractor	Supine or reverse Trendelenburg +/- left tilt up	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)
	g. Enter the lesser sac. Correct plane confirmed by visualisation of posterior stomach wall Note: Avoid caudal retraction of greater omentum. This may tear omental attachments to spleen and cause capsular injuries	Between legs/ RHS	LHS: Deaver retractor Reflect Greater omentum anteriorly	LHS/ between legs: Morris retractor	Supine or reverse Trendelenburg +/- left tilt up	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)
	h. Continue dissecting greater omentum off distal transverse colon laterally towards the spleen	Between legs/ RHS	L/RHS: Morris/ Deaver retractor	LHS: Morris retractor	Supine or reverse Trendelenburg +/- left tilt up	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)
	i. Divide attachments to take flexure down	Between legs/ RHS	LHS: Morris/ Deaver retractor	LHS: Morris retractor	Supine or reverse Trendelenburg +/- left tilt up	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)

3. Intersigmoid fossa dissection	a. Divide attachments between distal sigmoid mesocolon and floor of left iliac fossa	LHS	RHS: Retract sigmoid colon medially	LHS: Morris retractor	Supine	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Morris/ Deaver retractor(s)
	b. Hypogastric nerve trunk identification and develop plane for pelvic dissection	LHS	RHS: Retract colon medially/ Langenbeck	LHS: Morris retractor	Supine	Diathermy, ultrasonic device DeBakey forceps, dissecting scissors, Langenbeck retractor, Morris/ Deaver retractor(s)
4. Vascular Pedicle Division & Further Colonic mobilisation	Fingers (left hand) passed into plane developed in intersigmoid fossa	LHS	RHS	Between legs	Supine	
	b. Reflect left colon laterally and divide peritoneum adjacent to vascular pedicle	LHS	RHS	LHS/ Between legs	Supine	Diathermy, ultrasonic device
	c. Division of anterior peritoneal leaf overlying vascular pedicle	LHS	RHS	LHS/ between legs	Supine	Diathermy, dissecting scissors
	d. IMA/IMV skeletalised and divided proximal to origin of 1st sigmoid vessels	LHS	RHS	LHS/ between legs	Supine	Diathermy, ultrasonic device, Moynihan/ Roberts DeBakey forceps, dissecting scissors, vicryl suture

	e. Assess for pulsatile arterial bleeding. If inadequate, resect colon back to pulsatile bleeding. Consider performing step 2 (if not already done) and/or 4h-k to mobilise colon to re-assess blood flow. If blood flow still inadequate staple colon and proceed to steps 5, 6 (rectal mobilisation and transection) and 7i (LIF end stoma formation).	LHS	RHS	Between legs: Morris retractor	Supine	Diathermy, Debakey forceps, Dunhill/ Kelly forceps, Mayo scissors, vicryl ties, Morris retractor
	f. Division of proximal colon Perform subtask 7b & 7c now if necessary – then return to subtask 4g	LHS	RHS	Between legs	Supine	Linear cutter OR crushing bowel clamp and scalpel, Diathermy, Purse-string and anvil
	g. Assessment of colonic length. Is further length required? NO: proceed to Step 5 YES: Has splenic flexure been mobilised? If not go to (Step 2) If splenic flexure already mobilised and further length still required: perform subtasks 4h-4k					
	h. Further omental dissection off transverse colon	LHS	RHS	LHS/ Between legs	Supine	Diathermy, Debakey forceps
	i. Division of the anterior leaf of transverse mesocolon from posterior wall of stomach	LHS	RHS	LHS/ Between legs	Supine	Dissecting scissors

	j. Divide axial vessels n.b. Divide as far as possible from mesenteric vascular arcade to avoid interruption of marginal artery	LHS	RHS	LHS/ Between legs	Supine	Diathermy, dissecting scissors, artery forceps, vicryl ties
	k. Double ligation of inferior mesenteric vein (IMV) below the inferior pancreatic border, lateral to DJ flexure	LHS	RHS Retract small bowel medially to visualise DJ flexure	LHS Morris/ Deaver retractor	Supine +/- left tilt up	Diathermy, Dunhill/ Roberts forceps, dissecting scissors, vicryl tie/ suture, Morris/ Deaver retractor
5. Rectal mobilisation	a. Divide R pelvic peritoneum Reflect rectum towards patients left knee Identify ureter and hypogastric nerve Protect and displace ureter with long scissors before pelvic peritoneum division	LHS	RHS Deaver retractor	Between legs St. Mark's retractor	Trendelenburg	Long straight scissors, diathermy, Deaver and St. Mark's retractor
	b. Right-sided postero-lateral mobilisation (in mesorectal plane) Retract the rectum towards the patients left knee Retract rectum towards the pubis for posterior dissection	LHS	RHS: St. Mark's retractor	Between legs: St. Mark's retractor	Trendelenburg	Diathermy/ ultrasonic device, Deaver/ St. Mark's retractors

	c. Divide left pelvic peritoneum Retract rectum towards the patient's right knee Identify ureter and hypogastric nerve. Protect and displace ureter with long scissors before pelvic peritoneum division.	LHS	RHS: St. Mark's retractor	LHS/ between legs: St. Mark's retractor	Trendelenburg	Straight (Nelson) scissors, Diathermy, Deaver/ St. Mark's re
	d. Left-sided postero-lateral mobilisation (in mesorectal plane) Retract the rectum towards the patients right knee Retract rectum towards the pubis for posterior dissection	LHS	RHS: St. Mark's retractor	LHS/ between legs: St. Mark's retractor	Trendelenburg	Diathermy, ultrasonic device, St. Mark's retractors
	e. HIGH AR or LOW AR. High AR – proceed to 5f Low AR – Proceed to 5g for FEMALE, then 5i-j Proceed to 5h for MALE, then 5i-j					
	f. Ensure circumferential mobilisation below the transection level & divide the mesorectum Proceed to Step 6	LHS	RHS Deaver/ St. Mark's retractor	Between legs Deaver/ St. Mark's retractor	Trendelenburg	Diathermy, ultrasonic device, St. Mark's/ Deaver retractor, Moynihan forceps, vicryl suture/tie
	g. Female LAR: Anterior dissection with development of mesorectal plane between rectum and posterior wall of vagina	LHS	RHS St. Mark's retractor	Between legs St. Mark's retractor	Trendelenburg	Diathermy/ ultrasonic device, St. Mark's retractors

	h. MALE LAR: Anterior dissection with development of mesorectal plane between rectum and seminal vesicles	LHS	RHS St. Mark's retractor	Between legs St. Mark's retractor	Trendelenburg	Diathermy/ ultrasonic device, St. Mark's retractors
	i. Division of lateral ligaments	LHS	RHS St. Mark's retractor	Between legs St. Mark's retractor	Trendelenburg	Diathermy/ ultrasonic device, long straight Nelson scissors/ ligaclips, St. Mark's retractors
	j. Completion of dissection in total mesorectal excision plane (TME) to the pelvic floor and clear mesorectal tissue to demonstrate a muscle tube prior to transection	LHS	RHS St. Mark's retractor	Between legs St. Mark's retractor	Trendelenburg	Diathermy/ ultrasonic device, long straight scissors, St. Mark's retractors
6. Rectal transection	a. Ensure circumferential mesorectal division to demonstrate muscle tube prior to transection					
	b. Stapled transection of rectum	LHS	RHS Deaver retractor	Between legs St. Mark's retractor	Trendelenburg	Linear stapler, right-angled bowel clamp, scalpel OR Curved Cutter Stapler (Contour) St. Mark's retractors

7. Anastomosis	a. Is there adequate mobilised colonic length for anastomosis? YES: go to subtask 7b NO: If not already performed: mobilise splenic flexure (step 2) If further length is still required perform subtasks 4h-4k					
	b. Select size of circular stapler Detach anvil Purse string and insertion of anvil	LHS	RHS	Between legs: Babcocks forceps to bowel wall	Supine	2/0 prolene/ PDS Purse string applicator (optional) Anvil, Diathermy, DeBakey/ Babcock forceps Linear cutter to fashion colopouch
	c. Secure purse-string to base of anvil	LHS	RHS	LHS/ between legs	Supine	Artery clip, anvil
	d. Clear excess mesenteric tissue Bury any diverticulae	LHS	RHS	Between legs	Supine	Diathermy, dissecting scissors, Debakey forceps and artery forceps, vicryl 2/0
	e. Introduce circular stapler transanally and advance to stapled transection line under guidance Ensure device is in closed position when introducing	LHS	RHS St. Mark's retractor	Between legs Introducing stapler transanally	Trendelenburg	Circular stapler, St. Mark's retractors

	f. Advance trocar through transected rectum following guidance from the surgeon Ensure spike is fully open before anvil attached (demonstrate coloured band)	LHS	RHS St. Mark's retractor	Between legs Twist knob counter clockwise to advance trocar	Trendelenburg	Circular stapler, St. Mark's retractors
	g. Attach anvil to stapler Check correct orientation of bowel Close stapler snug tight (for appropriate tissue compression) Wait 15 seconds before firing stapler Withdraw stapler transanally Inspect anastomosis Check doughnuts	LHS	RHS St. Mark's retractor	Between legs Closes stapler (by twisting knob clockwise) snug tight and fire Remove stapler transanally (open stapler with two ½ turns before	Trendelenburg	Circular stapler, St. Mark's retractors
	h. Perform air test to assess integrity of anastomosis If air test positive, consider diverting stoma and/or re-fashioning anastomosis For LAR, insert Blake or Robinson drain(s), mass closure and fashion diverting stoma	LHS	RHS St. Mark's retractor(s)	Between legs Insert Foley catheter and insufflate air using 50ml syringe	Trendelenburg	Bladder syringe, Foley catheter For stoma: Scalpel, diathermy, Czerny retractors, (Nelson) straight scissors, Babcock forceps, vicryl rapide 2-0 /3-0 For mass closure: Loop PDS, clips or Monocryl for skin (wash wound prior to skin closure)

	i.	Colostomy formation (in situations when marginal artery assessment inadequate (subtask 4e) / pathology or patient co-morbidity preclude anastomosis) Trephine LIF Cruciate incision in anterior sheath Ensure aperture fits two fingers Exteriorise bowel Mass closure before fashioning stoma	LHS	RHS	Between legs	Supine	Scalpel, diathermy, Czerny retractors, long scissors (Nelsons), Babcock forceps, vicryl rapide 2-0 or 3-0 For mass closure: Loop PDS, clips or Monocryl for skin (wash wound prior to skin closure)
	j.	Right Colonic Transposition Technique In selected situations when pathology preclude use of the left colon for pelvic anastomosis	LHS	RHS	Between legs Circular stapler	Supine/ Trendelenburg	Diathermy, Debakey forceps, Dunhill forceps, purse-string suture and anvil, circular stapler For mass closure: Loop PDS, clips or Monocryl for skin (wash wound prior to skin closure)

Appendix 4 Comprehensive CTA for Laparoscopic Anterior Resection

Step	Sub-tasks	Key points	Operating team positions	Patient position	Instrumentation & Ports
Set-up		Correct theatre set-up is fundamental to successful completion of the operation Jupiter or equivalent electric operating table with patient placed on beanbag (with pneumatic compression device). Antibiotic prophylaxis/ TEDS/ Flowtrons Ensure equipment in optimal position	Surgeon: L/RHS 1st assistant: Opposite side to surgeon 2nd assistant: Between legs	Modified Lloyd-Davies	
Port placement	Umbilical 10-12mm port insertion	Open (Hasson) method shown 1cm subumbilical incision Dissect to linea alba Identify base of cicatrix Small incision at the base and use blunt forceps to enter peritoneal cavity Insert port and confirm entry Establish pneumoperitoneum	Surgeon: L/RHS 1st assistant: Opposite side to surgeon 2nd assistant: Between legs	Supine	Scalpel, Mcindoe Scissors, Littlewoods, Dunhill, Vicryl suture x2, 10-12mm bladeless port Camera with 30 degree angled lens
	Are RIF adhesions present?	YES – insert x2 LIF 5mm ports and divide adhesions No – insert RLQ port			

	x2 L ports Divide RIF adhesions	Small skin incision Transillumination will demonstrate vessels to avoid Insert L lat/ paraumbilical and LLQ ports perpendicular to ant abdo wall under direct vision in a screwing motion, like “squeezing an orange on a juicer” Divide adhesions to allow visualisation for R-sided port insertion	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** Between legs	Supine +/- right tilt up	L lateral: Ultrasonic device or scissors LLQ: Johan grasper Scalpel, 5mm bladeless ports, Johan grasper, Ultrasonic or standard (diathermy) scissors
	RLQ port 10-12mm insertion	Small incision 2-3cm medial and superior to ASIS Transillumination will epigastric and superficial vessels to avoid injury Insert port perpendicular to ant abdo wall under direct vision in a screwing motion, like “squeezing an orange on a juicer”	Surgeon: L/RHS 1st assistant: Opposite side to surgeon 2nd assistant: Between legs	Supine	Scalpel, 10-12mm bladeless port
	Lateral 5mm port insertion(s)	Small right paraumbilical incision Transillumination will demonstrate vessels to avoid Insert port perpendicular to ant abdo wall under direct vision in a screwing motion, like “squeezing an orange on a juicer” Repeat step on left side (if not already done)	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** Between legs	Supine +/- right tilt up	Scalpel, 5mm bladeless ports

	Optional ports	Small incision 1-2cm inferior to xiphisternum. (Variable) Positioned at level of transverse colon to left of falciform ligament Insert port perpendicular to ant abdo wall under direct vision in a screwing motion, like "squeezing an orange on a juicer"	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** Between legs	Reverse Trendelenburg	Scalpel, 10-12mm bladeless port
	Confirm diagnosis & location	Laparoscopic assessment of peritoneal cavity Place patient in Trendelenburg position to allow small bowel migration out of pelvis Consider if procedure is technically feasible laparoscopically or planned conversion? YES - proceed to Medial-to-lateral Approach/ Splenic Flexure mobilisation NO - convert to open procedure	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** Between legs	Trendelenburg and left tilt up	R lateral: Johan grasper RLQ: Johan grasper

Medial to Lateral Approach	Identify the right peritoneal leaf over base of sigmoid mesocolon?	Elevate rectosigmoid to ant abdo wall to tent-up mesocolon Identify origin of vascular pedicle and sacral promontory YES – Proceed to medial peritoneal incision NO – Divide congenital sigmoid attachments. Once attachments are divided, proceed to medial peritoneal incision	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Left tilt up	L lateral: Johan graspers elevating mesentery (2nd assistant) R lateral: Johan graspers providing further traction (surgeon) RLQ: Johan graspers directing rectosigmoid to 2nd assistant
	Divide congenital sigmoid attachments	Grasp sigmoid mesocolon medially to traction peritoneal attachments Dividing these attachments allow tenting of sigmoid mesocolon for identification of vascular pedicle	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Left tilt up	**L lateral:** Johan graspers counter-tracting peritoneal attachments (2nd assistant) **R lateral:** Johan graspers retracting the sigmoid medially (surgeon) **RLQ:** Ultrasonic device or standard scissors (diathermy) for dissection (surgeon)
	Medial peritoneal incision	Open peritoneum from above sacral promontory to origin pedicle (right side)	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Left tilt up	**L lateral:** Johan graspers elevating mesentery (2nd assistant) **R lateral:** Johan graspers providing further traction (surgeon) **RLQ:** Ultrasonic device or standard scissors (diathermy) for dissection (surgeon)

	Develop plane between the retroperitoneum/ hypogastric trunks & vascular pedicle	Combination of blunt and sharp dissection to develop plane Structures to identify: left ureter, gonadal, hypogastric nerve trunks Correct plane ABOVE these structures Ureter is normally medial to gonadals and crosses iliac vessels Ureter may be found adjacent to vascular pedicle If ureter cannot be identified, lateral approach Confirm structure is ureter by its characteristic peristaltic movement on agitation	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Left tilt up	**L lateral:** Johan graspers elevating sigmoid mesocolon (2nd assistant) **R lateral:** Johan graspers tenting sigmoid mesocolon and peritoneal window (surgeon) **RLQ:** Ultrasonic device or standard scissors (diathermy) for dissection (surgeon)
	Left ureter identification? YES – Proceed to taken down ureter/ gonadals off sigmoid mesocolon NO – Perform lateral approach to identify ureter. Once ureter identified proceed to create medial peritoneal window				

	YES Take down ureter cranially and caudally off sigmoid mesocolon	Combination of blunt and sharp dissection to take down ureter from surrounding areolar tissue Caudal dissection in correct plane will extend into "presacral space" (ABOVE hypogastric nerves) Cranially clean tissue around origin of vascular pedicle	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS at level of patient's shoulder	Trendelenburg Left tilt up	**L lateral:** Johan graspers elevating sigmoid mesocolon (2nd assistant) **R lateral:** Johan graspers elevating sigmoid mesocolon and pedicle (surgeon) **RLQ:** Ultrasonic or standard scissors (diathermy) for dissection (surgeon)
	NO Perform lateral approach to identify ureter	Perform if medial approach unable to identify ureter Grasp sigmoid mesocolon and retract medially, placing peritoneal attachments under tension Divide lower lateral peritoneal rectosigmoid attachments Identify ureter and gonadal Develop plane (medially) between mesocolon and retroperitoneum Continually re-positioning graspers during mobilisation is essential to provide tissue tension for division	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Left tilt up	**Optional Epigastric:** Johan graspers providing further medial retraction (1st assistant) **R lateral:** Johan graspers retract sigmoid/descending medially and towards RUQ **RLQ:** Ultrasonic or standard scissors (diathermy) for dissection (surgeon)

	Create Peritoneal window	Performed to allow stapling of vascular pedicle Incise peritoneum on left-hand side of vascular pedicle Develop aperture under the vascular pedicle *Be careful of small bowel entering operative field. Sweep to RUQ.	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Left tilt up	L lateral: Johan graspers elevating sigmoid mesocolon (2nd assistant) R lateral: Johan graspers elevating pedicle (surgeon) RLQ: Ultrasonic device or standard scissors (diathermy) for dissection (surgeon)
	Pedicle transection	Introduce Endo linear cutter through RLQ port Accommodate pedicle into stapler and lock only when pedicle fully contained and adjacent tissue NOT caught up IMA/IMV to be transected together here or taken separately Re-inspect ureter and gonadals Wait 15 seconds to allow for tissue compression before firing stapler After transection remove stapler and check for haemostasis. Place mastoid swab if required.	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Left tilt up	**L lateral:** Johan graspers elevating sigmoid mesocolon (2nd assistant) **R lateral:** Johan graspers elevating pedicle and retract to caudally (surgeon) **RLQ:** Endo Linear cutter or interlocking clips and ultrasonic device

	Elevate vascular pedicle	Use 2nd assistant to elevate transected end of pedicle This manoeuvre will identify the plane between the colon mesentery and retroperitoneum	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Left tilt up	**L lateral:** Johan graspers elevating transected end of vascular pedicle (2nd assistant) **R lateral:** Johan graspers elevating colon mesentery (surgeon) **RLQ:** Ultrasonic device or standard scissors (diathermy) for dissection (surgeon)
	Medial planar dissection	Develop the plane between the colon mesentery and the caudal extension of Gerota's fascia cranially. If dissect above ureter, may go underneath gonadal and too lateral over psoas. Combination of blunt and sharp dissection Taken down gonadal Maximise leverage of mesentery so constantly reposition graspers Develop plane towards splenic flexure and the lateral peritoneal attachments Divide mesentery close to midline	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Left tilt up	**L lateral:** Johan graspers elevating transected end of vascular pedicle (2nd assistant). Reposition along mesentery **R lateral:** Johan graspers elevating cut edge of colonic mesentery (surgeon) **RLQ:** Ultrasonic device or standard scissors (diathermy) for dissection (surgeon) Mastoid intermittently

	Divide lateral peritoneal attachments as far as safe access allows	Perform this step following medial planar dissection Once peritoneum incised space entered from medial planar dissection Continually re-positioning graspers during mobilisation is essential to provide tissue tension for division	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Left tilt up	**Optional Epigastric:** Johan graspers providing further medial retraction (1st assistant) **R lateral:** Johan graspers retract sigmoid/descending medially and towards RUQ **RLQ:** Ultrasonic or standard scissors (diathermy) for dissection (surgeon)
	Is there adequate length of mobilised left colon? YES – Proceed to rectal mobilisation NO – Mobilise splenic flexure If further length still required, perform further colon mobilisation steps (e.g. divide axial vessels)				

Lateral Approach	Divide lateral peritoneal attachments as far as safe access allows	Grasp sigmoid mesocolon and retract medially, placing peritoneal attachments under tension Divide lower lateral peritoneal rectosigmoid attachments Identify ureter and gonadal Develop plane (medially) between mesocolon and retroperitoneum Continually re-positioning graspers during mobilisation is essential to provide tissue tension for division	Surgeon: RHS 1st assistant: RHS 2nd assistant: LHS	Trendelenburg Left tilt up	Epigastric: Johan graspers providing further medial retraction (1st assistant) R lateral: Johan graspers retract sigmoid/descending medially and towards RUQ RLQ and/or L lateral: Ultrasonic device or standard scissors (diathermy) for dissection (surgeon)
	Create Peritoneal window	Performed to allow stapling of vascular pedicle Incise peritoneum on left-hand side of vascular pedicle Develop aperture under the vascular pedicle *Be careful of small bowel entering operative field. Sweep to RUQ.	Surgeon: RHS 1st assistant: RHS 2nd assistant: LHS	Trendelenburg Left tilt up	L lateral: Johan graspers elevating sigmoid mesocolon (2nd assistant) R lateral: Johan graspers elevating pedicle (surgeon) RLQ: Ultrasonic device or standard scissors (diathermy) for dissection (surgeon)

	Pedicle transection	Introduce Endo linear cutter through RLQ port Accommodate pedicle into stapler and lock only when pedicle fully contained and adjacent tissue NOT caught up IMA/IMV to be transected together here or taken separately Re-inspect ureter and gonadals Wait 15 seconds to allow for tissue compression before firing stapler After transection remove stapler and check for haemostasis. Place mastoid swab if required.	Surgeon: RHS 1st assistant: RHS 2nd assistant: LHS	Trendelenburg Left tilt up	L lateral: Johan graspers elevating sigmoid mesocolon (2nd assistant) R lateral: Johan graspers elevating pedicle and retract to caudally (surgeon) RLQ: Endo Linear cutter or interlocking clips and ultrasonic device

	Is there adequate length of mobilised left colon? YES – Proceed to medial-to-lateral approach to divide IMA/IMV. If medial approach already done, proceed to rectal mobilisation. NO – Mobilise splenic flexure (if not already done) If further length still required, perform further colon mobilisation steps (e.g. divide axial vessels)				

Splenic Flexure Mobilisation	Reflect Greater Omentum	Insert epigastric port (if not already done) Reflect greater omentum towards stomach Exposure the avascular plane between the greater omentum and the transverse colon	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Reverse Trendelenburg Left tilt up	**Epigastric:** Johan graspers reflect greater omentum anteriorly (1st assistant) **R lateral:** Johan graspers traction transverse colon caudally (surgeon)
	Enter Lesser sac	Incise avascular plane to enter the lesser sac at level of distal transverse colon Stay close to transverse colon If staying in the correct plane, the space opens up and posterior wall of stomach/ pancreas is visualised	**Surgeon:** RHS/ between legs **1st assistant:** RHS **2nd assistant:** LHS	Reverse Trendelenburg Left tilt up	**Epigastric:** Johan graspers reflect greater omentum anteriorly (1st assistant) **R lateral:** Johan graspers traction transverse colon caudally (surgeon) **RLQ:** Ultrasonic device or standard scissors (diathermy) for dissection (surgeon)
	Mobilise transverse mesocolon off posterior stomach wall	Divide the anterior leaf of the transverse mesocolon of the posterior wall of the stomach In some cases these adhesions are not present Use of scissors without diathermy will reduce injury to the stomach wall	**Surgeon:** RHS/ between legs **1st assistant:** RHS **2nd assistant:** LHS	Reverse Trendelenburg Left tilt up	**Epigastric:** Johan graspers reflect greater omentum anteriorly (1st assistant) **R lateral:** Johan graspers traction transverse colon caudally (surgeon) **RLQ:** Ultrasonic device or standard scissors (diathermy) for dissection (surgeon)

	Continue dissection along transverse colon towards spleen	Separate the greater omentum off the transverse colon Continue dissection until a point where "you can't turn the corner" Continually re-positioning graspers along omentum and transverse colon will provide traction to aid dissection	**Surgeon:** RHS/ between legs **1st assistant:** RHS **2nd assistant:** LHS	Reverse Trendelenburg Left tilt up	**Epigastric:** Johan graspers reflect greater omentum anteriorly (1st assistant) **R lateral:** Johan graspers traction transverse colon caudally (surgeon) **RLQ:** Ultrasonic device or standard scissors (diathermy) for dissection (surgeon)
	Continue mobilisation dividing attachments to laterally to flexure	Divide lateral attachments to connect with colon mobilised from "above" Some surgeons may perform this step initially in splenic flexure mobilisation Retract colon at the flexure caudally and medially Release attachments between colonic mesentery and Gerota's fascia Dissection through L lateral port may be easier	**Surgeon:** RHS/ between legs **1st assistant:** RHS **2nd assistant:** LHS	Reverse Trendelenburg Left tilt up	**Epigastric:** Johan graspers reflect greater omentum towards stomach (1st assistant) **R lateral:** Johan graspers traction colon at flexure medially & caudally (surgeon) **L lateral/ RLQ:** Ultrasonic device or standard scissors (diathermy) for dissection (surgeon)

	Complete mobilisation to the midline	Retract colon at the flexure caudally and medially Divide attachments between transverse mesocolon and pancreas Midline mobilisation complete when inferior border of pancreas visualised	**Surgeon:** RHS/ between legs **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Right tilt downwards	**Epigastric:** Johan graspers reflect greater omentum towards stomach (1st assistant) **R lateral:** Johan graspers traction colon at flexure medially & caudally (surgeon) **L lateral/ RLQ:** Ultrasonic device or standard scissors (diathermy) for dissection (surgeon)
		Is further length required? YES – Divide axial vessels If further length required, perform further colonic mobilisation steps NO – Proceed to Rectal Mobilisation. If already done HAR/LAR? Nb. Consider Medial-to-lateral approach to mobilise splenic flexure (commencing with high ligation IMV)			

Further colonic mobilisation steps	Divide axial mesenteric vessels close to origin	Divide axial mesenteric vessels close to origin Is further length still required? YES – Perform Splenic Flexure mobilisation (if not already done) If SF mobilised, Perform further colonic mobilisation steps (re-assess length after each step) NO – Proceed to rectal mobilisation. If done HAR/LAR?			
	Further omental dissection off transverse colon	Further dissection of omental attachments will increase the length of mobilised colon Reflect omentum over stomach and anteriorly. Dissect in the avascular plane staying close to colon Assess if sufficient length has been gained	**Surgeon:** RHS/ between legs **1st assistant:** RHS **2nd assistant:** LHS	Reverse trendelenburg	**Epigastric:** Johan grasper elevating omentum (1st/2nd assistant) **R Lateral or RLQ:** Johan grasper traction colon caudally **RLQ or L lateral:** Ultrasonic device or standard (diathermy) scissors
	Continue adhesiolysis between posterior stomach wall and transverse mesocolon	Divide attachments to posterior stomach wall will increase length of mobilised colon Assess if sufficient length has been gained	**Surgeon:** RHS/ between legs **1st assistant:** RHS **2nd assistant:** LHS	Reverse trendelenburg	**Epigastric:** Bowel grasper reflects stomach anteriorly **R Lateral:** Johan grasper traction mesocolon caudally **RLQ/ L lateral:** Scissors

	Divide L colic artery	View the middle colic vessels and origin left colic vessels Divide left colic artery close to origin Clean mesentery to expose vessel Apply ligaclips and divide Assess if sufficient length has been gained	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Left tilt up	**Epigastric:** Johan grasper retracting small bowel to RUQ **R Lateral:** Johan grasper pulling mesentery and vessel caudally **RLQ:** Ultrasonic device/ ligaclips
	Double ligation IMV	Identify IMV under inferior border of the pancreas. Clear small bowel from operative field Divide peritoneum adjacent to IMV Apply Ligaclips This step creates significant gain in colonic length	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Left tilt up	**Epigastric:** Johan retract small bowel to RUQ **R Lateral:** Johan grasper pulling mesentery and vessel caudally **RLQ:** Johan grasper/ Ligaclips/ ultrasonic device
	Division of axial mesenteric vessels	Vessel division provides increase in colonic length Variable anatomy Important to take vessel (e.g. ascending branch of left colic) medially close to posterior abdominal wall Dividing mesenteric vessels closer to bowel wall may disrupt mesenteric vascular arcade and compromise marginal artery.	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg Left tilt up	**Epigastric:** Johan retract small bowel to RUQ **R Lateral:** Johan grasper retract mesentery and vessel(s) caudally **RLQ:** Ultrasonic device/ Ligaclips

Rectal mobilisation	Take down R/L hypogastric nerve trunks off upper mesorectum	Elevate the rectosigmoid colon in the midline Take down hypogastric trunks off upper mesorectum The presacral space will be anterior to hypogastric nerves	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Grasper mesentery to elevate rectosigmoid colon **R lateral:** Place grasper underneath rectosigmoid to elevate **RLQ:** Ultrasonic device or standard scissors
	Divide L pelvic peritoneum	Posterior mobilisation is facilitated by dividing pelvic peritoneum on both sides Retract rectosigmoid upwards and towards right side by grasping mesentery View vessels on side wall prior to dividing peritoneum Divide peritoneum to below transection level	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** counter-traction pelvic side wall **R lateral:** Johan grasper traction rectum towards port **RLQ:** Ultrasonic device
	Divide R pelvic peritoneum	Posterior rectal mobilisation is facilitated by dividing pelvic peritoneum both sides Retract rectosigmoid upwards and towards left side by grasping mesentery View vessels on side wall prior to dividing peritoneum Divide peritoneum to below transection level	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** counter-traction pelvic side wall **R lateral:** Johan grasper traction rectum towards left side **RLQ:** Ultrasonic device

	Postero-lateral mobilisation	Elevate rectosigmoid to enter the presacral space Continue circumferential mobilisation in the mesorectal plane Optimal tissue tension allows effective division Further division of pelvic peritoneum on both sides facilitates posterior dissection Dissection extended to below the tumour level (for HAR)	Surgeon: RHS 1st assistant: RHS 2ND assistant: LHS	Trendelenburg	L lateral: Grasp rectosigmoid mesentery retract cranially R lateral: Bowel grasper elevate rectosigmoid RLQ: Ultrasonic device +/- endoscopic scissors
	High Anterior Resection (HAR) or Low Anterior Resection (LAR)?				
	HAR: Circumferentially mobilise below transection level	Continue mobilisation (if required) to 5cm below transection level Releasing air from a port allows smoke to escape and improve operative view	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Grasper mesentery to elevate rectosigmoid colon **R lateral:** Place grasper underneath rectosigmoid to elevate **RLQ:** Ultrasonic device or standard scissors

	HAR: Mesorectal division	Mesorectum must be divided to create a muscle tube prior to transection Usually start on right side. Start division 5cm below tumour level After initial incision develop plane between rectal wall and mesorectum Divide perpendicular to rectum towards left side Change to left rectal wall and match level	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Johan grasper to retract rectosigmoid upwards and cranially (2nd assistant) **R lateral:** Johan grasper under the rectosigmoid elevating anteriorly **RLQ:** Ultrasonic device
	HAR: Introduce endoscopic stapler	Introduce endoscopic stapler and angulate by pushing against abdominal wall 1st assistant may need to withdraw RLQ port slightly as stapler is inserted Entry through suprapubic port maybe preferred	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** **R lateral:** **RLQ:** Endoscopic stapler

	HAR: Intracorporeal rectal transection	Include only muscle tube within jaws of stapler Check back rectal wall Check no adjacent tissue has been caught up and left pelvic side wall clear Fire stapler More than one firing may be required Straighten stapler and withdraw Check transection line for haemostasis	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Reverse Trendelenburg	**L lateral:** Johan grasper against left pelvic side wall (2nd assistant) **R lateral:** Johan grasper to manipulate muscle tube into stapler **RLQ/ Suprapubic:** Endoscopic stapler
	Low Anterior Resection (LAR)	Continued posterior mobilisation			
	Divide R/L pelvic peritoneum to reflection	Extensive postero-lateral dissection to reflection facilitates anterior dissection Retraction for optimal tissue tension View vessels on pelvic side wall Divide peritoneum to reflection on both sides	**Surgeon: RHS** **1st assistant: RHS** **2nd assistant: LHS**	Trendelenburg	**L Lateral:** **Counter-traction pelvic side wall for L sided division** **R lateral:** **Retract rectum to opposite side to peritoneal division** **RLQ: Ultrasonic device +/- endoscopic scissors**
	Division of anterior peritoneal reflection	Commence dissection from lateral edge of lateral dissection from right to left	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L Lateral:** Bowel grapser retract anterior reflection anteriorly **R Lateral:** Bowel grasper retract rectum cranially **RLQ:** Ultrasonic device

	Continue postero-lateral mobilisation in TME plane Male or Female?	Reversion to a postero-lateral dissection in intervals facilitates anterior dissection For LAR, TME to pelvic floor is required Mobilisation continued in TME plane towards pelvic floor Difficulty of dissection will vary depending on: intra-abdominal obesity, male narrow pelvis and tumour size Open conversion may be required now or later in dissection if concerns over oncological compromise in the resection	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Bowel grasper elevating rectosigmoid anteriorly **R Lateral:** Bowel grasper elevate mesorectum anteriorly **RLQ:** Ultrasonic device +/- endoscopic scissors
	Male LAR Anterior dissection posterior to seminal vesicles	Dissection facilitated by extensive posterior-lateral dissection Anterior dissection posterior to seminal vesicles (SV)/ prostate Adequate tension between anterior rectal wall and SV essential Mesorectal plane less obvious and bulk of anterior mesorectum is variable and space for dissection often restricted Region in pelvic dissection where most parasympathetic nerve damage occurs	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Bowel grasper elevating anterior reflection **R Lateral:** Bowel grasper rectract anterior rectum cranially **RLQ:** Ultrasonic device

	Male LAR: Continue TME planar dissection postero-laterally	Posterior dissection in the TME plane is now completed to visualise the pelvic floor	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Bowel grasper elevating rectosigmoid anteriorly **R Lateral:** Bowel grasper elevate mesorectum anteriorly **RLQ:** Ultrasonic device +/- endoscopic scissors
	Male LAR: Division of anterior mesorectum	After completion of the anterior dissection, the variable anterior mesorectum is divided Purpose of this division is to expose the rectal muscle tube anteriorly	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Bowel grasper elevating anterior reflection **R Lateral:** Bowel grasper rectract anterior rectum cranially **RLQ:** Ultrasonic device
	Male LAR: Division of lateral ligaments	Lateral ligaments are bundles of connective tissue related to lateral aspect of distal rectum. Run laterally between the pelvic parietal fascia and the investing visceral fascia of the rectum May contain the middle rectal vessels Division will complete the TME dissection	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Bowel grasper retracting cut edge of reflection/ side wall **R lateral:** Bowel grasper retracting rectum cranially **RLQ:** Ultrasonic device

	Male LAR: Create muscle tube at pelvic floor	Complete dissection to allow identification of rectal tube inserting at anorectal junction Circumferential visualisation of the rectal tube is essential to allow safe transection with the endoscopic stapler Proceed to specimen delivery	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Bowel grasper elevates mesorectum anteriorly **R lateral:** Bowel grasper elevating mesorectum **RLQ:** Ultrasonic device +/- endoscopic scissors
	Female LAR: Anterior dissection posterior to vaginal vault	Dissection facilitated by extensive posterior-lateral dissection Anterior dissection posterior to posterior vaginal wall Adequate tension between anterior rectal wall and posterior vaginal wall is essential Mesorectal plane less obvious and bulk of anterior mesorectum is variable (may be absent) Region in pelvic dissection where most parasympathetic nerve damage occurs	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Bowel grasper elevating anterior reflection **R Lateral:** Bowel grasper rectract anterior rectum cranially **RLQ:** Ultrasonic device
	Female LAR: Continue TME planar dissection postero-laterally	Posterior dissection in the TME plane is now completed to visualise the pelvic floor	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Bowel grasper elevating rectosigmoid anteriorly **R Lateral:** Bowel grasper elevate mesorectum anteriorly **RLQ:** Ultrasonic device +/- endoscopic scissors

	Female LAR: Division of anterior mesorectum	After completion of the anterior dissection, the variable anterior mesorectum is divided Anterior mesorectum in females may be absent (case shown). When present, purpose of this division is to expose the rectal muscle tube anteriorly	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Bowel grasper elevating anterior reflection **R Lateral:** Bowel grasper rectract anterior rectum cranially **RLQ:** Ultrasonic device
	Female LAR: Division of lateral ligaments	Lateral ligaments are bundles of connective tissue related to lateral aspect of distal rectum. Run laterally between the pelvic parietal fascia and the investing visceral fascia of the rectum May contain the middle rectal vessels. Division will complete the TME dissection	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Bowel grasper retracting cut edge of reflection/ side wall **R lateral:** Bowel grasper retracting rectum cranially **RLQ:** Ultrasonic device
	Female LAR: Create muscle tube at pelvic floor	Complete dissection to allow identification of rectal tube inserting at anorectal junction Circumferential visualisation of the rectal tube is essential to allow safe transection with the endoscopic stapler	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Bowel grasper elevates mesorectum anteriorly **R lateral:** Bowel grasper elevating mesorectum **RLQ:** Ultrasonic device +/- endoscopic scissors

	Female LAR: Introduce endoscopic stapler	Introduced through RLQ port Pull back the articulation fin to release the articulation joint. Continue pulling back articulation fin whilst pushing against pelvic side wall for desired amount of articulation. Once in desired position, releasing fin locks the articulation joint. Suprapubic port maybe preferred for entry	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** **R lateral:** **Suprapubic/ RLQ:** Endoscopic stapler

	Female LAR: Intracorporeal rectal transection	Position across the rectum at pelvic floor Transection across the bowel from right-to-left OR antero-posteriorly (by angulating stapler and rotation of firing handle). Wait 15 seconds to reach optimal tissue compression before firing. Firing sequence needs to be completed four times 6 rows of staples delivered with knife-blade dividing rectum leaving 3 rows on each transected end. >1 reload sometimes required to complete transection Check rectal stump for haemostasis Note: Open conversion to staple required if concerns that oncological margin will be compromised	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** LHS	Trendelenburg	**L lateral:** Johan grasper against left pelvic side wall (2nd assistant) **R lateral:** Johan grasper to manipulate muscle tube into stapler **RLQ/ Suprapubic:** Endoscopic stapler

Specimen delivery	LLQ incision	Keep gas flowing. For LLQ incision, locate ASIS and make 3-4cm oblique incision Extend the incision for larger tumours if necessary Dissection in layers: skin, subcutaneous fat, anterior sheath, Retract transverses abdominis and incise peritoneum. After incising peritoneum, turn gas flow off temporarily	**Surgeon:** L/RHS **1st assistant:** Opposite side to surgeon **2nd assistant:** Between legs	Supine	Scalpel, diathermy Mcindoe Scissors, Czerny retractors
	Insert wound retractor and exteriorise transected bowel	Insert wound retractor provides atraumatic wound retraction/ protection Insert GREEN ring into abdominal cavity With assistance fold the white double barrelled retraction rings down until required exposure Exteriorise the mobilised left colon/rectum and specimen Check distal margin of resection If difficulty in removing specimen, remove retractor and extend the incision appropriately. Re-insert retractor	**Surgeon:** L/RHS **1st assistant:** Opposite side to surgeon **2nd assistant:** Between legs	Supine	Wound retractor, Babcock forceps, Scalpel & diathermy

	Division of colonic mesentery	Place haemostat on IMA transected pedicle. Choose appropriate level to divide proximal colon Score mesentery and divide Tie off vessels or use ultrasonic scissors to seal. Do not ligate the marginal artery yet	**Surgeon:** L/RHS **1st assistant:** Opposite side to surgeon **2nd assistant:** Between legs	Supine	Artery forceps, scalpel, Vicryl ties Diathermy/ Ultrasonic device
	Confirm pulsatile arterial bleeding	Divide mesentery close to inner margin of bowel to identify marginal artery Assess for pulsatile bleeding Secure distal artery forceps Place vessel between proximal artery forceps, divide vessel and assess bleeding If pulsatile flow, tie off vessel, proceed to divide colon (next step) If inadequate blood flow, resect colon back and re-assess blood flow If blood flow still inadequate staple colon with linear cutter replacing into abdominal cavity Follow further steps	**Surgeon:** L/RHS **1st assistant:** Opposite side to surgeon **2nd assistant:** Between legs	Supine	Artery forceps x2, Vicryl ties Diathermy/ Ultrasonic device, Linear cutter (maybe required)

		Is further colonic length required? YES – proceed to divide colon In patients with co-morbidity, consider LIF colostomy formation NO – Resect colon back to pulsatile bleeding If poor supply is still poor, perform mobilisation steps and re-assess bleeding or consider colostomy formation. If all mobilisation steps have been performed and colonic blood supply remains inadequate, staple colon and perform LIF colostomy			
	Divide colon	Proximal colon divided using crushing clamp Linear cutter can be used to divide colon +/- formation of colopouch following LAR Alternatively apply purse-string applicator before bowel division – demo in next step	Surgeon: RHS 1st Assistant: LHS 2nd Assistant: between legs	Supine	Crushing bowel clamp and scalpel Linear cutter Diathermy

	Apply purse string and insert anvil	Apply purse-string by hand OR applicator/ divide colon Circular stapler sizer Select stapler and detach anvil Insert anvil into bowel lumen and secure purse-string to base Clear pericolic fat/ bury any divertculae	Surgeon: RHS 1st Assistant: LHS 2nd Assistant: between legs	Supine	Purse-string applicator Circular stapler sizer Purse-string (prolene 2/0 or 3/0) and anvil
	Replace colon into abdominal cavity and close fascia or twist wound retractor	Replace colon into abdominal cavity Twist wound retractor to arrest gas leak Alternatively close peritoneum/ fascia now Does colon fall easily into the pelvis	Surgeon: RHS 1st Assistant: LHS 2nd Assistant: between legs	Supine	Wound retractor PDS 1/0 Vicryl3/0 Langenbeck retractors
	Is further colonic length required?	YES – Perform colonic mobilisation steps (axial vessel division/ SF mobilisation/ further steps) NO – Proceed to Anastomosis			

Anastomosis	Introduce circular stapler transanally	Ensure mobilised colon falls easily into pelvis 2nd assistant introduces stapler transanally. Anus may need to dilated before introducing stapler Ensure spike has not been unwound before introducing stapler Introduce under direction from surgeon to use correct effacement at transected staple line. Surgeon may need to manipulate rectum with graspers If stapler does not reach staple line, smaller sized stapler may be required Alternatively anastomosis can be fashioned with anterior wall of rectum	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** Between legs	Trendelenburg	Circular stapler (2nd assistant) **R Lateral:** Johan grasper **RLQ:** Johan grasper
	Advance trocar through transected rectum	Unwind stapler to advance spike Johan grasper to guide spike through rectal wall above or below transection Unwind fully until orange band in view Spike can be advanced through anterior rectal wall	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** Between legs	Trendelenburg	Circular stapler (2nd assistant) **R Lateral:** Johan grasper **RLQ:** Johan grasper

	Introduce anvil holder and attach to trocar	Attach anvil to spike and click to secure. Check correct orientation of bowel Re-attach if any twists present Cut edge of mesentery must lie medially along posterior abdominal wall	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** Between legs	Trendelenburg	Circular stapler **R Lateral:** Johan grasper **RLQ:** Anvil holder
	Close stapler until snug tight	Close stapler snug tight for appropriate tissue compression Again check correction of colon	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** Between legs	Trendelenburg	Circular stapler **R Lateral:** Johan grasper **RLQ:** Johan grasper
	Fire stapler	Wait 15 seconds for tissue compression before firing. Undo safety catch before firing and then re-apply after firing Open stapler with two half-turns (counter clockwise) Withdraw stapler Check doughnuts	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** Between legs	Trendelenburg	Circular stapler

	Inspect anastomosis and Perform air test	Check anastomosis for haemostasis Fill pelvis with saline above anastomosis Occlude colon proximal to anastomosis Inflate air to distend bowel Assess for escape of gas bubbles. If gas bubbles present: diverting stoma and/or re-fashion anastomosis. Suction pelvis. For LAR, consider diverting stoma. RIF trephine and exteriorise loop distal ileum. Insert Blake or Robinson drains	**Surgeon:** RHS **1st assistant:** RHS **2nd assistant:** Between legs	Trendelenburg	**Transanally:** 50ml syringe, foley catheter **R Lateral:** Johan grasper **RLQ:** Suction/ Johan grasper/ Ligaclip **RIF trephine (optional):** scalpel/ diathermy/ Czerny retractors
	Port and Wound closure	Remove ports under direct vision Arrest gas flow Formally close fascia for port wounds 1cm or more (RLQ/umbilical) Close larger wound (LLQ) in layers (Fashion diverting stoma)	**Surgeon:** L/RHS **1st assistant:** Opposite side to surgeon **2nd assistant:** Between legs	Supine	Vicryl on J-needle PDS 1-0 Vicryl 3-0 Monocryl or clips for skin Langenbeck retractors For stoma: diathermy/ suction/ vicryl rapide 2-0/3-0 Wound dressings

Appendix 5 Open Anterior Resection Voiceover

Set-up

Introduction

Correct setup is a fundamental step prior to commencing the procedure. For open anterior resection the patient is place supine in the modified L-D position.

The abdomen is prepared and draped exposing the whole abdomen. The approach to the abdominal cavity is through a vertical midline incision. A laparotomy should be performed to confirm tumour location and any presence of distant disease before retracting the small bowel to access the left paracolic gutter

The patient can be seen in the modified LD position, prepped and draped. Flowtrons have been attached to the legs before placing them in Dan Allen Stirrup with the knees slightly flexed and a urinary catheter inserted.

Ideally pre-operative stoma site marking should be performed by the stoma nurse. The ideal stoma site is placed within the rectus muscle below the level of the umbilicus away from scars, bony prominences and the belt line and it must be visible to the patient. A poorly located stoma may result in pouching problems, increased potential for leakage and skin irritation.

A vertical midline incision is made. The following structures divided to enter the peritoneal cavity are: the skin, subcutaneous fat, linea albea, transversalis fascia, extra peritoneal fat and the peritoneum. Lateral traction by the surgeon and assistant as shown allows dissection in the embryological midline

At the base of the umbilical cicatrix there is a fused layer of fibrous tissue consisting of the rectus sheath and linea alba and the transversalis fascia with the peritoneum adherent to the deep aspect of this. Dissection through the base of the umbilical cicatrix is most consistent entry point into the peritoneal cavity.

In patients who have had previous surgery there maybe omental or small bowel adhesions to abdominal wall which require careful division to access the peritoneal cavity.

The small bowel shown here is retracted out of the abdomen between moistened terry towels to the right side to allow unimpeded access to the left colon, sigmoid colon and pelvis. Additionally this manoeuvre allows access to the TC if the splenic flexure is mobilised.

Alternatively the small bowel can be retracted with a large pack or self-retaining retractor such as a Golliger or Balfour

Step 1: Mobilisation of sigmoid and descending colon

Introduction

The following subtasks in this step cover mobilisation of the sigmoid and left descending colon from the retroperitoneum through the standard lateral approach or a medial to lateral approach if pathology precludes safe access to the left paracolic gutter.

Subtask b

Following assessment of pathology and if the left paracolic gutter is accessible, the 1st assistant applies upward and medial traction of the sigmoid colon while the 2nd assistant opens up the space further by retracting the abdo wall with Morris/diva retractor. With the surgeon standing on the left side, the congenital peritoneal attachments to the sigmoid are divided close the “white line” as shown using diathermy. Alternatively the surgeon can stand on the right and retract the colon medially with the non-operative hand. As can be seen optimal tissue retraction facilitates clear haemostatic dissection under direct vision.

Division of these attachments will allow visualisation of the plane between the mesocolon and retroperitoneum.

In the following example an ultrasonic device, in this case Harmonic, is used to as the energy source, and is able to grasp tissue, dissect and cut without the need to exchange instruments.

Again in another example the diathermy tip here can be seen just on the tissue surface dividing the attachments under careful direct vision.

Subtask c

Once the congenital peritoneal attachments have been divided there is development plane between sigmoid/ left descending mesocolon and retroperitoneal structures including the left kidney which is surrounded by perinephric fat and in turn covered by Gerota’s fascia which can be seen here as the colonic mesentery is lifted off.

This is a consistent anatomical plane which is largely avascular with few vessels travelling towards the sigmoid mesentery. Important to identify this plane correctly. Dissection laterally

Again, firm traction of the colon medially by the assistant with counter-traction applied by the surgeon with the non-operating hand will facilitate development of this plane.

Subtask d

Continued Dissection in the correct anatomical plane between the colonic mesentery and retroperitoneum will enable identification of the gonadal vessels which lie laterally to the ureter.

Subtask e

The dissection now continues medially to the left of the gonadal vessels to identify the left ureter. The ureter is crossed anteriorly by the gonadal vessels and apex of the sigmoid mesocolon whilst lying laterally to the inferior mesenteric vessels.

The ureter, which is seen as a non-pulsatile whitish cord, can be distinguished from other vessels by its characteristic peristaltic activity when agitated or pinched lightly with forceps.

Subtask f

Once the left ureter and gonadal vessels have been identified the dissection is switched cranially to mobilise the left descending colonic mesentery off the anterior surface of Gerota’s fascia towards the spleen. Again a combination traction of the colon by the assistant with counter-traction by the surgeon’s non-operating hand or swab facilitates dissection in the correct anatomical plane. Further lateral peritoneal attachments are also released. The dissection is continued as far as safe access allows and the length of mobilised colon is assessed.

Subtask g

In cases where pathology precludes safe access to the left paracolic gutter the vascular pedicle is identified and a medial peritoneal window created caudally

Subtask h

With the assistant elevating the sigmoid mesocolon there is now further development of the plane between the retroperitoneum and the vascular pedicle with identification of the hypogastric trunk.

Staying anterior to the nerve trunk the gonadal vessels and ureter are identified and taken down cranially and caudally off the sigmoid mesocolon.

Subtask i

After continued cranial tissue dissection adjacent to the vascular pedicle, the inferior mesenteric artery and vein are individually skeletalised before division. Here the vein is divided between Roberts before being tied off. The IMA is divided close to its origin before being transfixed.

Subtask j

Following pedicle division, continue medial planar and cranial dissection mobilising the sigmoid and left descending colon off the renal fascia of Gerota towards the spleen and lateral peritoneal attachments. The assistant elevates the mesocolon with a Diva retractor as the surgeon uses counter-traction to enable optimal tissue tension for dissection.

Subtask k

Once the medial approach has been completed the left paracolic gutter can be accessed as shown with the non-operating hand. The remaining lateral attachments are divided. Note the splenic flexure has already been mobilised and proximal colon divided before specimen extraction of a large sigmoid mass involving the left pelvic side wall.

Step 2: Splenic flexure mobilisation

Introduction

Splenic flexure mobilisation is not necessary for all anterior resections, such as for high anastomoses or when the sigmoid colon is used as the anastomotic conduit.

However splenic flexure mobilisation is required in low anterior resections when the descending colon is used for tension-free anastomosis

Subtask a – command prompt

Sub task b

SF mobilisation can be commenced from a lateral approach by Continued cranial dissection towards the spleen mobilising the left colon mesentery off Gerota's fascia as can be seen here and divide further lateral attachments as far as safe access allows. Medial traction of the left colon and counter-traction on the retroperitoneum is crucial to allow dissection in the correct plane.

The surgeons may either choose to operate from between the legs or on the RHS.

Optimal use of assistance is important to provide access and visualise the operative field. The height of the splenic flexure is often variable and if access is difficult and the splenic flexure is high, extend the midline incision towards the xiphisternum.

In a low splenic flexure case as seen here, the flexure is reached easily.

Often when the flexure is high, the flexure is difficult to reach from a lateral approach. Attention is turned to the transverse colon and a supracolic approach

Subtask c

Once the left colon has been mobilised as far as safe access allows laterally, perform a supracolic approach to enter the lesser sac or omental bursa to gain access to the splenic flexure from above.

Reflect the greater omentum anteriorly to dissect the TC/ transverse mesocolon off the omentum

Avoid caudal traction of the greater omentum as this will tear omental attachments to the spleen resulting in capsular injuries.

The correct plane is confirmed by visualisation of the posterior wall of the stomach. In some cases entry into the lesser sac can be difficult.

In some cases entry into the lesser sac can be difficult. Anatomically, the posterior wall of the lesser sac is formed by the anterior of the two posterior layers of greater omentum. It is this layer that needs to be separated from the anterior surface of the TC and tc mesocolon as demonstrated here to enter the lesser sac

The plane is now extended here between the anterior surface of the transverse mesocolon and the greater omentum, in particular the anterior of the two posterior layers of greater momentum, which are adherent and require careful separation.
Separation of these layers eventually gains entry into the lesser sac as demonstrated here.

This space is often not completely free and at times division of adhesions between the posterior gastric wall and anterior layer of the transverse mesocolon is necessary to free up the space completely.

Adequate exposure and use of assistance is important in this step

These illustrations show a sagittal view of the lesser sac looking TOWARDS the spleen, B is the posterior wall of the stomach, and A is the anterior surface of the transverse colon and transverse mesocolon. 1-4 are the 4 layers of peritoneum forming the greater omentum. Layer 3, the anterior of the two posterior layers of greater omentum forms the posterior wall of the lesser sac and is adherent to the anterior surface of the TC and TC mesocolon. To enter the lesser sac these layers need to be separated from each other. To enter the lesser sac the greater omentum is first reflected anteriorly. The correct plane of dissection shown allows separation of layer 3 (the anterior of two posterior layers of the greater momentum) from the anterior surface of the TC and TC mesocolon (A). Entry into the lesser sac is confirmed by visualisation of the posterior wall of the stomach.

2 examples are now demonstrated. the greater omentum is reflected anteriorly while TC/ transverse mesocolon retracted caudally to off the omentum opens up the plane between the GO and TC to enter the LS

Subtask d

The greater omentum should now be dissected off the distal transverse colon towards the spleen.

In this case the dissection towards the spleen has been straightforward. However the key is to

Stay close to colon. Caudal traction on the colon and anterior elevation of GO facilitates dissection

In this next case the splenic flexure is higher and has more bulky omental attachments, and is therefore more difficult to visualise. Again caudal traction of the colon, knowing where the bowel edge is, and optimal use of assistance is crucial in this step.

Changing to an ultrasonic energy device, in this case harmonic, can also facilitate this step by achieving haemostasis and dissection without the need to change instruments. This may additionally save operating time. Tissue tension is provided by contralateral hand whilst using upward pressure on the cutting blade.

Subtask e

The supracolic and lateral dissection planes are joined to take the flexure down.

Again the examples demonstrate the variable anatomy at the SF. In this case the remaining attachments to the colonic mesentery are divided (including the attachments of the mesocolon to the pancreas.

In this case peritoneal attachments are directly attached to the spleen in this case and must be divided to take the flexure down. Once divided the remaining attachments between the colonic mesentery and gerota’s fascia are released.

Subtask f

Once the flexure has been taken down, complete splenic flexure mobilisation and left colon to the midline. Divide further attachments between the transverse mesocolon and the inferior border of the pancreas which marks the superior extent of the dissection. The IMV should be seen beneath the inferior pancreatic border.

These examples show the let colon as a midline structure following complete splenic flexure mobilisation.

The left descending colon should now be mobile enough to be used as the anastomotic conduit.

Subtask g

A supracolic approach enters the lesser sac or omental bursa then gain access to the splenic flexure from above.

Reflect the greater omentum anteriorly to dissect the TC/ transverse mesocolon off the omentum

Avoid caudal traction of the greater omentum as this will tear omental attachments to the spleen resulting in capsular injuries.

The correct plane is confirmed by visualisation of the posterior wall of the stomach.

In some cases entry into the lesser sac can be difficult. Anatomically, the posterior wall of the lesser sac is formed by the anterior of the two posterior layers of greater omentum. It is this layer that needs to be separated from the anterior surface of the TC and tc mesocolon as demonstrated here to enter the lesser sac

This space is often not completely free and at times division of adhesions between the posterior gastric wall and anterior layer of the transverse mesocolon is necessary to free up the space completely.

Adequate exposure and use of assistance is important in this step

Subtask h

The greater omentum should now be dissected off the distal transverse colon towards the spleen.

In this case the dissection towards the spleen has been straightforward. However the key is to

Stay close to colon. Caudal traction on the colon and anterior elevation of GO facilitates dissection

In this next case the splenic flexure is higher and has more bulky omental attachments, and is therefore more difficult to visualise. Again caudal traction of the colon, knowing where the bowel edge is, and optimal use of assistance is crucial in this step.

Changing to an ultrasonic energy device, in this case harmonic, can also facilitate this step by achieving haemostasis and dissection without the need to change instruments. This may additionally save operating time. Tissue tension is provided by contralateral hand whilst using upward pressure on the cutting blade.

Subtask i

The supracolic and lateral dissection planes are joined to take the flexure down.

Again the examples demonstrate the variable anatomy at the SF and relation of the actual flexure to the spleen. In this case the remaining attachments to the colonic mesentery are divided (including the attachments of the mesocolon to the pancreas.

In this case peritoneal attachments are directly attached to the spleen in this case and must be divided to take the flexure down. Once divided the remaining attachments between the colonic mesentery and gerota's fascia are released.

Go back to subtask f to complete mobilisation of splenic flexure and left colon to the midline

Step 3: Intersigmoid fossa dissection

Introduction

This step involves intersigmoid fossa dissection to enable identification of the hypogastric nerve trunk and the plane for pelvic dissection in step 5

Subtask a

The congenital peritoneal attachments found here between the lateral aspect of the pelvic mesocolon and the parietal peritoneum of the floor of the left iliac fossa need to be divided

Following this the dissection continue over the left ureter extending medially towards the superior rectal vascular package. This peritoneal incision is then continued down into the pelvis along the right pararectal space.

The peritoneal attachments between the distal sigmoid mesocolon and floor of the left iliac fossa, just above the rectosigmoid junction, are released and in particular the peritoneal cul-de-sac, named the intersigmoid fossa, is divided to allow straightening of the rectosigmoid junction.

The dissection is then continued down into the pelvis along the right pararectal space.

Attention is then turned to identifying the hypogastric nerve trunk

Subtask b

The hypogastric nerve trunks usually lie 1-2cm medial to the ureters along the posterolateral wall of the pelvis [164] further medial dissection under the pelvic mesocolon will identify the hypogastric trunk.

Just above the pelvic brim and slightly to the left of the midline, the superior hypogastric plexus bifurcates into the right and left hyogastric nerves. These nerves usually lie 1-2cm medial to the ureters along the posterolateral wall of the pelvis [164]. The nerves lie behind the parietal peritoneum in an avascular plane between the peritoneum and endopelvic fascia

The nerve trunk lie behind the parietal peritoneum in an avascular plane between the peritoneum and endopelvic fascia

The ureter and gonadal vessels lateral to the nerve can be seen here

In this next example the hypogastric nerve can be seen here.

Once the hypogastric nerve trunk has been identified to be dissected free from superior rectal vessels which often require division of mesenteric branches

A Langenbeck can be used as demonstrated to lift the superior rectal vessels to show the hypogastrics.

Step 4 – Vascular pedicle division & further colonic mobilisation steps

Introduction

This following subtasks cover dissection and ligation of the inferior mesenteric artery and and vein, assessment of marginal artery flow and division of the proximal descending colon. Other technical measures to gain colonic length are also demonstrated

Subtask b

Reflect left colon laterally and the pass the non-operating hand into the space created by the intersigmoid fossa dissection. The anterior peritoneal leaf adjacent to the inferior mesenteric vascular package can now be divided. The left ureter and gonadal vessels and hypogastric trunk will be protected with the non-operating hand.

Subtask c

The dissection is continued with division of anterior peritoneal leaf overlying vascular pedicle. The left hand can seen here steadying the pedicle.

Subtask d

IMA/IMV are now individually skeletalised and divided

The IMA, the artery of the hindgut, arises from in front of the aorta behind the 3rd part of the duodenum about 4cm above the bifurcation giving off the left colic, sigmoid and superior rectal arteries.

The IMA in this case is divided close to its origin known as a high vascular ligation between two artery forceps. Care is taken not to include any adjacent tissue in the forceps. The purely sympathetic hypogastric nerves are at risk of injury if the IMA is ligated flush on the aorta.

The artery is seen divided close to the distal artery forceps to leave a cuff of vessel proximally. The base of the artery is then transfixed. Control the proximal artery forceps to prevent avulsing the pedicle.

The IMV is subsequently ligated.

The SMV continues above the pelvic brim as the inferior mesenteric vein. The IMV run cranially well to the left of the IMA. Just below the attachment of the transverse mesocolon it lies to the left of the DJ flexure before passing under the inferior border of the pancreas.

Subtask e

Assessment of pulsatile artery flow is performed to establish if the proximal colon to be used as the anastomotic conduit has a good blood supply.

Place artery forceps on transected IMA and assess the level of bowel division. The mesentery is then divided to this level. In this case the Mesentery is divided proximal to the sigmoid branches. For pelvic anastomoses, surgeons often sacrifice the sigmoid colon because this segment can be narrowed, thick-walled and in many cases diverticulae are present.

The vessel assessed on the inner margin of the colon is marginal artery. The marginal artery is formed by the anastomosis of the ascending and descending branches of the left colic artery first with each other, and then to the left branch of the middle colic artery.

The vessel is divided just above the distal haemostat to leave cuff of vessel proximally which is tested for pulsatile flow before being tied off.

Subtask f

Mesenteric tissue is cleared from the bowel edge before division of the proximal colon at the level of the left descending colon in this case with a linear cutter. Six rows of staggered staples are delivered, three on each side of the cut line. The colour of cartridge depends on the thickness of

Only Bowel wall is included into the cutter and wait up to 15secs for tissue compression before division.

Alternatively a crushing clamp is place across the bowel wall and a scalpel used to divide the colon.

Proceed to subtasks 7b/c to apply the purse string and anvil (of the circular stapler)

Subtask g

Other technical measures may be required for gain further colonic length to perform a safe tension-free low or ultra-low pelvic anastomosis are shown in following steps 4h-4k.

Subtask h

Greater omentum would have already been freed from the distal transverse colon during splenic flexure mobilisation. However the omental attachments warrant further separation from the TC to increase mobility of the left colon. This dissection needs continued to the level of the middle colic vessels. Traction of the omentum and counter traction on the TC as shown need to be performed to allow separation of the tissues with diathermy.

Subtask i

The peritoneal attachments between the anterior layer of the transverse mesocolon and the posterior gastric wall often tether the TC distal to the origin of MCA. These attachments need to be divided by sharp dissection under direct vision.

Subtask j

Another step to gain colonic length is axial vessel division and the adjacent mesentery. The key is to stay as far away as possible from the mesenteric vascular arcade and divide vessels near their origin. Interruption of this arcade will compromise the arterial flow of the marginal artery. It is also important to appreciate the variation in colic arteries.

The first case shows ascending branch of the left colic artery tethering the mesentery and the colon. The ascending branch can come off the left colic at different levels but here it's divided close to its origin

The second case demonstrates how division of the main trunk of the left colic artery increase the colonic length. IMA pedicle is shown. This example demonstrates the short course of the left colic before dividing into the ascending and descending branches. The colon is here is being held back by the left colic artery.

Subtask k

Single ligation of the IMV may not be adequate in providing adequate colonic length. These examples show the double ligation technique.

Double ligation of the inferior mesenteric vein can significantly increase colonic length. As seen attachments of the mesocolon to the DJ flexure need to be released to allow visualisation of the IMV. The vein lies to the left of the DJ flexure before passing under the inferior border of the pancreas and travels in front of the renal vein before joining the splenic vein.

The attachments of the mesocolon to the duodenum need to be divided at the DJ flexure to allow visualisation of the IMV which lies to its left just below the attachment of the transverse colon. The IMV then passes under the inferior border of the body of the pancreas, in front of the renal vein before draining into the splenic vein.

The IMV is skeletalised to allow accurate transection between haemostats before being either tied off or transfixed.

The inferior mesenteric vein is dissected to allow accurate transaction between haemostats before being tied off.

Here you can see the redundant IMV between the double ligation at the level of IMA ligation and next to the DJ flexure.

This demonstrates the length gained after high ligation of the IMV before and after. The IMV can be seen tethering the colon and mesocolon, before division. Taking the IMV at the level of the DJ flexure results in a significant length gained.

Step 5: Rectal mobilisation

Introduction

This step covers a systematic approach to rectal mobilisation in the mesorectal plane in both the male and female pelvis for low anterior resections. This plane lies outside the fascia propria investing the rectum and mesorectum anterior to the hypogastric nerves.

Further subtasks cover mesorectal division in high anterior resections in which a total mesorectal excision is not necessary.

Subtask a

The pelvic dissection starts on the right with initial identification of the right ureter and hypogastric nerve which are both visualized and protected.

Nelson scissors are passed behind the pelvic peritoneum anterior to nerve and ureter to create the plane for dissection

Subtask b

Counter-traction of the rectum is important in this step to facilitate exposure of the correct anatomical plane and optimal use of diathermy. The pelvic dissection commences with the division of the right pelvic peritoneum as shown

Subtask c

With continued counter-traction of the rectum towards the patients left knee, the right sided mesorectal plane is developed with identification of the pelvic nerve. The rectum and mesorectum, invested in a layer of fascia propria. This lies in the plane immediately anterior to the nerve [164]. The dissection is continued antero-laterally, thus mobilising the right hemi-circumference of the rectum

Subtask d

The right lateral dissection can be extended posteriorly in the correct mesorectal plane while the rectum is reflected anteriorly towards the pubis

Subtask e

Following this the dissection focuses anteriorly. Counter traction of the rectum posteriorly towards the body of the sacrum enables tissue division using the diathermy.

There is little space anteriorly but the dissection should be behind denovilleurs fascia at the posterior aspect of the prostate and seminal vesicles in the male and posterior wall of the vaginal vault in the female.

The tip of the diathermy should be at the surface of the tissue plane to be dissected to allow identification tissue and control of blood vessels

Subtask f

The dissection of the left hemi pelvis follows the same pattern and involves counter-traction of the upper rectum to the right-hand side. The peritoneal reflection is excised and this anterior dissection is extended to allow continuity with the dissection plane already completed on the other side. The dissection of the rectum on the left-hand side is completed with further posterior dissection

Subtask g

Female

Extension of the (remove right) postero-lateral dissection in which the mesorectum is continued to be mobilized and dissected circumferentially deep in the pelvis will facilitate the anterior dissection. The anterior planes which can often be quite difficult are made more obvious by an extensive lateral pelvic dissection and here the vaginal vault can be seen being retracted anteriorly with a St Marks retractor with continued lateral and anterior dissection along the mesorectal plane that has already been .identified in the initial lateral dissection.

Reversion to a posterior dissection in intervals will (remove again) facilitate the anterior dissection

The mesorectal plane is less obvious anteriorly and the bulk of the anterior mesorectum often variable. The anterior structure(s) are the vaginal vault in the female are carefully dissected off the anterior mesorectum

Optimal tissue retraction facilitates clear haemostatic dissection under direct vision.

Subtask h

Male

The anterior dissection in the male is posterior to the seminal vesicles. Dissection in the mesorectal plane will separate the fascia propria of the rectum (with its enclosed anterior mesorectum) from Denovilliers fascia which is left intact on the SV and prostate [164].

Distinction of planes between the anterior rectal wall and prostate and seminal vesicles can be difficult, and is often compounded by restricted access for dissection in the male pelvis, and were damage to the cavernous nerves may occur [164].

The space between the anterior rectal wall and the seminal vesicles is often limited [164] and access for dissection can be restricted. Therefore optimal tissue retraction is crucial to allow clear haemostatic dissection under direct vision.

Optimal tissue retraction facilitates clear haemostatic dissection under direct vision.

Dissection deep in the pelvis, tumour size, and body habitus place the parasympathetic nerves at risk of injury in this region of the pelvis.

Following the completion of the anterior pelvic dissection, the variable anterior mesorectum is divided to expose the rectal muscle tube anteriorly.

Subtask i

The lateral ligaments are a condensation of retroperitoneal tissue that may contain small middle rectal vessels and should be divided by an appropriate energy device.

The lateral ligaments are bundles of connective tissue (of variable substance) which are related to the lateral aspect of the distal rectum and run between the pelvic parietal fascia and the investing visceral fascia of the rectum. They can contain some blood vessels, nerve fibres and lymphatics

This step is being shown in the male 1st and female in the following example. Division should be repeated on both sides.

This tissue can be excised as part of the circumferential pelvic dissection in the tme plane already identified. Division of this tissue will complete the tme dissection and create a circumferential rectal muscle tube at the pelvic floor in preparation for safe cross stapling.

Subtask j

Attention is again focussed posteriorly with further dissection to mobilise the rectum deeper into the pelvis

The long lipped St Marks retractor placed behind the mesorectum allows accurate anatomical plane dissection. This postero-lateral dissection is completed to allow visualisation of the pelvic floor musculature

The dissection is continued to allow full mobilisation of the rectum to a muscle tube of rectum visible down to the pelvic floor. Only when this has been achieved can a cross-stapler be safely applied for transaction of the rectum

Step 6 – Rectal Transection

Introduction

Following rectal mobilisation this step demonstrates transection of the rectum with using a linear or curved cutter stapler at different levels of the rectum depending on pathology

Subtask a

It is important prior the resection that the often bulky mesorectal tissue has been dissected to demonstrate the rectal tube all around. This is important as the stapling devices used are designed to safely transect the muscle tube and not the mesorectal tissue.

Subtask b

Again access and visualization of the pelvis and rectal tube is essential prior to resection and often needs the use of St Mark's retractors. This will again enable the bladder and pelvic organs to the safely retracted before introduction of the stapling device.

Whilst the surgeon straightens and applying upward tension on the rectum with his left hand, the contour curved cutter stapler is introduced into the right side of the pelvis. The stapler is then rotated to the left to include the rectal tube between the jaws of the instrument at the intended level of transection. Care must be taken so that all tissue layers to be stapled are incorporated into the closure. The manual pin placement also allows capture of all the intended rectal tissue before closure of the device. Intermediate locking position allows tissue manipulation before closing the instrument. Once the device has been closed it is important to wait 15 seconds to allow tissue oedema to settle before firing.

The stapler delivers four curvilinear rows of staples with a single cut between. This eliminates the need for a bowel clamp and scalpel. The contour is curved to conform to the natural anatomy for low anterior resections and allows placement of a 40mm staple line in the width of a 30mm space. It is important to note that the integrity of the staple line may be compromised if mesorectal tissue is included into the instrument jaws.

Example 6

The following examples again demonstrate the correct technique in using the contour stapler. One handed firing, pin-placement and closure free the other hand for use in the pelvis and therefore easier manipulation of the rectum. The curved design provided better visibility in the pelvis. The increased length of the shaft allows lower pelvic access without handle obstruction over other staplers. As mentioned before simultaneous stapling and cutting stop eliminate the need for a bowel clamp and staple.

Alternatively a right angled bowel clamp is placed on the proximal colon to be resected and a TX or TA stapler used to closure the rectal stump, and a scalpel used to transect and remove the proximal colon. There should be enough space between the stapler and clamp to allow the bowel to be cut safely. The scalpel is used a few mms above the stapler.

Step 7: Anastomosis

Introduction

To re-establish bowel continuity a double-staple technique is used where a circular intra-luminal stapler is introduced through the anus, enabling anastomosis of the proximal colon to the rectum or top of the anus in some instances

Subtask a

The anastomosis should be tension-free and so ensure the colonic tube has been sufficiently mobilised so that it reaches the pelvis easily whilst retaining good vascularity.

If this is not the case, further steps must be performed to gain adequate length, either mobilising the splenic flexure if not already done and/or performing subtasks 4h-k

Subtask b

There are numerous ways of performing a colorectal anastomosis. The examples shown here are an end-to-end anastomosis and a colonic J-pouch formation.

A purse-string suture is shown here placed is by hand using prolene 3-0 with a curved needle. Note that all layers of bowel are included in the suture and bites are a few mms apart. The assistance place Babcock's on the bowel whilst following with the suture. The anvil shaft is separated from the intra-luminal stapler. Once the purse-string has been completed the anvil shaft is introduced into the bowel lumen and the purse-string secured.

Alternatively a purse-string suture is placed at the proximal line of resection using purse-string applicator or clamp and a prolene suture on a straight needle. A bowel clamp is then placed distal to the purse-string clamp and the bowel in divided [165]. The anvil shaft is then introduced into the bowel lumen and held with a clip or Roberts so that the purse-string tied securely.

The colonic J pouch is fashioned forming a J shape with the colon secured at the proximal end with a suture. The J-pouch is usually 5-8cm in length. An enterotomy is made using diathermy at the apex of the pouch and extended either side. A linear stapler is introduced into the proximal colon and then the distal end to create the pouch. The bowel walls are orientated so that the anti-mesenteric borders are aligned and no mesentery is caught in the stapler. Once the stapler has been fired and removed, a purse-string is placed by hand using prolene 3-0 before introducing the anvil shaft

Subtask c

Once the purse-string has been applied, the anvil is inserted into the bowel lumen and the purse-string is secured to the base of the anvil

Subtask d

Mesentery or fat that is not cleaned or dissected off the tissue may compromise the anastomosis. The colonic tissue itself should be cleaned as little as possible to prevent damage to the anastomotic blood supply. Any bunched up tissue or diverticulae can be buried with a suture

Subtask e

The anus may need to be mildly dilated before the intraluminal circular stapler is introduced transanally by the assistant. Ensure the stapler is in the closed position at this stage. The stapler is advanced up the rectum to the stapled line under instruction to ensure correct enfacement. Retraction with is essential for adequate visualisation low in the pelvis.

Subtask f

The perineal assistant is then asked to unwind the spike so that the stapler trocar is advanced through the bowel wall [165], either side of the staple line or through it. The pelvic surgeon supports the staple line as the trocar comes through the bowel wall to stop rectal wall tearing using finger and thump to allow safe passage of the trocar. The trocar is fully advanced once the orange shoulder is visualized.

Subtask g

The function of the circular intra-luminal stapler is to place two concentric rings of staples, stapling the proximal colon to the rectum or anus. Simultaneously a circular knife blade (located within the inner staple rings) cuts two circular doughnuts of tissue and therefore creates a stoma, or communication between the stapled colon and rectum.

The proximal colon with the secured anvil is maneuvered into pelvis and engaged to the stapler trocar. Normally a click will be heard. It is necessary now to check to orientation of the proximal colon to make sure there are no twists before closure.

As the stapler is closed care must be taken to ensure anatomical structures such as the bladder or vaginal vault are not inadvertently caught up which can subsequently lead to fistula formation.

Ensure that the tissue is snug against the cartridge and anvil to reduce overlapping of tissue as the stapler is closed. Once closed the colon and rectum should be snug tight, but not overtightened as this may strangulate tissue.

Again the assistant should wait at least 15secs before firing to allow tissue oedema to settle. The stapler is then fired by releasing the safety button and squeezing the firing handles together until touch the central shaft

The safety button is then reattached, the stapler is then partially opened with 2 half-turn twists and carefully withdrawn.

The staple line should then be assessed for haemostasis

(The staplers come in different sizes. For instance the sizes of CDH relate to the diameter (mm) of the bowel the stapler has to pass through. Size selection can be determined with use of bowel sizers.)

Advances in rectal cancer surgery have facilitated sphincter-preserving surgery in many patients with low rectal tumours close to the anal verge [166]. Alterative techniques to the straight coloanal technique include colonic J pouch, transverse coloplasty and side-to-end anastomosis. Whilst restoring gastrointestinal continuity in these patients often results in significant bowel dysfunction such as increased urgency several RCTs have shown that CJP to be superior to SCA in bowel function outcomes for at least 18 months post surgery. Bowel function with SCA does however improve with time whilst the CJP may dilate and decompensate causing difficulty with evacuation. TC and STE have shown similar bowel functional outcomes compared to CJP [166].

Subtask h

It is now essential to test the integrity of the anastomosis. This can be achieved by filling the pelvis with saline above the level of the anastomosis. The surgeon then occludes the proximal colon with his hand. Next insufflate air into the bowel lumen through a catheter and syringe placed transanally. Occlusion of the bowel will cause distal distension and will demonstrate any air bubble signifying a leak. Continued retraction in the pelvis is also needed at this stage.

A leak results from air bubbles escaping from the anastomosis. Once a leak has been demonstrated it can either be repaired with sutures or the anastomosis may need to be taken down and re-established. A leak may also prompt the surgeon to protect the anastomosis with a covering ileostomy or colostomy.

If the leak test is positive the anastomosis can either be repaired or re-fashioned. The surgeon may elect to defunction with a covering stoma.

For a LAR, insert drains before performing a RIF trephine or to exteriorise a loop of distal ileum to defunction the low anastomosis. Ensure there are no twists and the aperture is not too tight.

Subtask i

In situations where it's not appropriate to restore bowel continuity or when the proximal colon is a does not have a good blood supply and therefore inadequate to use as an anastomotic conduit, a LIF colostomy is fashioned.

After mass closure – perform LIF trephine. After a cruciate incision is made in the rectus sheath, nelson straight scissors passes to divide peritoneum. Develop the aperture to allow the bowel to be exteriorised and fashion the stoma with interrupted vicryl rapide.

Appendix 6 Laparoscopic Anterior Resection Voiceover

Certain subtasks are grouped into sections/steps for the purpose of this VO. Some VO is taken from the open tool, particularly the animation and anastomosis subtasks. The VO does not completely follow the video sequences because some steps are repeated.

Set-up

An efficiently set-up and organised operating room is a fundamental requirement for laparoscopic anterior resection surgery.

Equipment setup:
A suitable electric operating table, with detachable leg sections, is mandatory to allow the patient to be placed in various positions for access (for example reverse trendelenburg for splenic flexure mobilization) during the procedure.

The patient is placed directly on the beanbag with a pneumatic compression device to stop sliding during the operation. Ensure the patient is moved down the table so that perineum at the end where the table breaks to allow access for circular stapler to be introduced transanally. Flowtrons attached to the lower leg over the TED stockings. The legs are then placed and secured in Allen stirrups with the knees flexed and the leg sections of the table are removed. The arms are tucked to the patient's side aided by shoulder supports

With the patient in the modified Lloyd Davies position – aspirate beanbag to fix patient into position. A urinary catheter is inserted and attached to an hourly

(This show the steep angle the patients is placed during Trendelenburg and the necessity for a beanbag to stop slippage during this manoeuvre)

After a Bair hugger has been taped into place keeping the abdomen fully exposed, the patient is prepped and draped routinely.

Ideally pre-operative stoma site marking should be performed by the stoma nurse. The ideal stoma site is placed within the rectus muscle below the level of the umbilicus away from scars, bony prominences and the belt line and it must be visible to the patient. A poorly located stoma may result in pouching problems, increased potential for leakage and skin irritation.

Two Monitors are routinely used for an anterior resection – the primary HD monitor is mounted on a mobile tower housing the high intensity light source and endoflator supplying rapid flow C02 to create and maintain pneumoperitoneum. This is positioned on patient's left towards the feet. The secondary monitor is placed on patient's right side, towards the head end. This is mainly 2nd assistant's use, whilst standing on the left-hand side for during medial and lateral approach.

If the splenic flexure requires mobilization the primary monitor is moved towards the head-end on the left if surgeon decides to operate from between the legs.

Harmonic, the energy device used for dissection and coagulation is powered by a Generator which works by converting electrical energy to mechanical motion (ultrasound vibration). This conversion takes place in the hand piece of the device. The generator is positioned to the right of mobile tower. Cables should be carefully placed so as not to impede movement of the surgical team during the operation.

Standard instrument required for port entry and endoscopic instruments are set-up on mobile instrument tables positioned at the end of the patient manned by the scrub nurse. Stapling devices are opened when required.

Initial setup for the surgical team is for the surgeon to stand on the patient's right hand side to perform an umbilical port placement to induce pneumoperitoneum with the 1st assistant opposite. After the umbilical port has been inserted and the abdomen insufflated with CO2, the camera holder (1st assistant) moves to the right hand side at the head end to the left of the surgeon. The 2nd assistant usually stands on left hand side.

Port insertions

There are various techniques to induce pneumoperitoneum. A modified Hasson method is demonstrated. Following a vertical 1cm subumbilical incision the dissection is deepened to the linea abla to identify the base of the cicatrix.

At the base of the umbilical cicatrix there is a fused layer of fibrous tissue consisting of the rectus sheath and linea alba and the transversalis fascia with the peritoneum adherent to the deep aspect of this. Dissection through the base of the umbilical cicatrix is a consistent entry point into the peritoneal cavity.

Littlewood forceps elevate the cicatrix and stay sutures placed either side if the base. A small incision is made at the base of the cicatrix before blunt forceps are used to open the peritoneum.

A purse-string may be placed around the sub-umbilical defect before insertion of a 10-12mm bladeless port.

Entry into the peritoneal cavity is confirmed before connecting gas tubing and insufflating the abdomen with C02 with intra-abdominal pressure usually set at 15mmhg. A 30 degree angled laparoscope is used to provide viewing of areas that would otherwise be blinded to a "zero degree".

Note the cannula of the port is ribbed to increase abdominal wall retention and minimising trocar slip-out.

This port will principally be used for the camera. Some surgeons however may prefer to insert a RUQ port for camera use as it can improve triangulating instruments and add more visual depth during rectal mobilisation in particular.
Variable positioning of ports. However standard port placement
Skin incision made illumination from the camera light from within the peritoneal cavity to demonstrate vessels.
Ports incisions: right and left 5mm paraumbilical ports, and right lower quadrant 10-12mm port.
The left paraumbilical port may vary depending on the height of the sigmoid colon.

The 12mm port (to allow endomechanical stapler through the port) is inserted in the RLQ 2 to 3 cm medial and superior to ASIS, lateral to inferior epigastric vessels.
Injury to the inferior epigastric vessels/ other superficial vessels can be avoided by Trans illumination and placing ports lateral to the recti muscles. The sulcus between the recti and transversus abdominis can be visualised by depressing this area.
Ports inserted by screwing motion (blameless ports) under visualisation, going through perpendicular to abdominal wall.

Right 5mm port placed about hands breadth superior to RLQ port, at approximate level of umbilicus
A 5mm left paraumbilical port is placed

Optional Epigastric port placed to left side of the falciform ligament

Medial approach

Lateral peritoneal attachments of the sigmoid colon may need to be divided initially to allow elevation of sigmoid colon and therefore the mesocolon.
Origin of IMA is seen fold/cord-like structures in peritoneum tenting up. Thin patients vessels maybe visualised.
There is normally a groove between the right or medial side of the pedicle and retro peritoneum
Once sacral promontory and origin of pedicle identified
Open peritoneum along a line above the sacral promontory cranially to right side of pedicle
Blunt dissection to lift vessels away from retroperitoneum and presacral autonomic nerves
Left ureter needs to be identified under the IMA.
Ureter should lie deep to parietal peritoneum medial to gonadal vessels, crossing iliac
If plane of dissection is too deep, iliac vessels maybe injured
If plane too lateral psoas
Ureter may also be on back of pedicle. Plane needs to stay close to pedicle
If ureter still not identified, lateral approach required

IMA identified and peritoneum underneath is divided. Division of the peritoneum usually starts above the sacral promontory and continues cranially towards the origin of IMA.
(Needs to talk about finding autonomic pelvic nerves (hypogastric) and ureter and gonadal vessels)

Lateral mobilisation

The dissection or mobilisation of the sigmoid (lateral to medial) may be the initial step, prior to medial dissection. The sigmoid mesocolon is grasped with atraumatic bowel graspers. And retracted medially and towards the right hypochondrium with the left hand instrument. This allows the peritoneal attachments between the sigmoid colon and LIF to be placed on tension. The congenital peritoneal folds/attachments to the lateral aspect of sigmoid mesocolon can now be divided - vascular plane. Note about energy sources/ harmonic requiring tissue to be placed under tension to allow dissection. Once this layer of peritoneum has been incised, the space opened by the retroperitoneal dissection (if done already) is entered. Dissection then continues along the white line of Toldt towards the splenic flexure.

This manoeuvre is facilitated by patient tilted to the right side to allow the small bowel to slide out of operative field.

The left colon mobilisation is continued up the paracolic gutter by division of the peritoneal attachments. A second Johann's or atraumatic bowel grasper introduced through the epigastric port will aid mobilisation of the sigmoid and left colon from the retroperitoneal structures. If the medial approach and posterior dissection have been complete prior to this step, mobilising the colon from the retroperitoneal structures will be made easier (bruising from the retroperitoneal mobilisation of usually be seen here). There will be some remaining attachments between mesentery of the descending colon and gerota's fascia to divide, until the splenic flexure is reached. The decision then needs to be taken whether the splenic flexure requires full mobilisation. It is advisable to assess the length of colon mobilised and whether this reaches the pelvis easily, under no tension.

If not, further steps include:
1. Splenic flexure mobilisation
2. High ligation of IMV
3. Division of axial mesentery vessels - ascending branch of left colic artery. Important to preserve the integrity of the marginal artery, commencing from the left branch of the middle colic artery.
Sequential grasping and re-grasping of the colon is essential to provide sufficient traction to allow division of lateral and posterior attachments, making the left colon and sigmoid a midline structure.

Full mobilisation of the left colon and sigmoid will allow visualisation of the ureter, gonadal vessels and gerota's fascia over the left kidney

left paraumbilical port - may be used for the lateral mobilisation, particularly near the splenic flexure

Splenic Flexure mobilization subtasks

Place the patient in the reverse Trendelenburg position to allow the transverse colon to fall away from the stomach and spleen. The patient is also rotated to the right on occasion.
Mobilisation of the splenic flexure is shown from above, by approaching the splenic flexure along the transverse colon.

Avoid caudal traction of the greater omentum as this will tear omental attachments to the spleen resulting in capsular injuries. The correct plane is confirmed here by visualisation of the posterior wall of the stomach.

The greater omentum is reflected anteriorly and towards the stomach with atraumatic bowel grasper in the epigastric (assistants) port and the distal transverse colon is retracted caudally. This exposes the avascular plane between the gastrocolic/ greater momentum and transverse mesocolon.
Incise this avascular plane to enter the lesser sac.

The lesser sac is a large pouch lying behind the stomach and lesser omentum. Entry into the lesser sac will gain access to spleen flexure from a supracolic approach.

These illustrations show a sagittal view of the lesser sac looking TOWARDS the spleen, B is the posterior wall of the stomach, and A is the anterior surface of the transverse colon and transverse mesocolon. 1-4 are the 4 layers of peritoneum forming the greater omentum.

Layer 3, the anterior of the two posterior layers of greater omentum forms the posterior wall of the lesser sac and is adherent to the anterior surface of the TC and mesocolon. To enter the lesser sac these layers need to be separated from each other.

To enter the lesser sac the greater omentum is first reflected anteriorly. The correct plane of dissection shown allows separation of layer 3 (the anterior of two posterior layers of the greater momentum) from the anterior surface of the TC and TC mesocolon (A). Entry into the lesser sac is confirmed by visualisation of the posterior wall of the stomach.

Continue the dissection towards the spleen, continually repositioning the Johann's retractors to expose the plane, dividing attachments close to the distal transverse colon.

The Surgeon may reposition to stand in between the patient's legs during this part of the procedure. Port: Harmonic in RLQ or left paraumbilical port. Alternatively camera can be placed in RLQ port and dissection through the umbilical port. The surgeons left hand: atraumatic bowel grasper to traction transverse colon caudally

Ultrasonic energy source is invaluable in splenic flexure mobilisation as it can be used as a blunt and sharp dissector.

Here the splenic flexure mobilisation is shown from above/ medially entering the lesser sac as an initial manoeuvre. Some surgeons may prefer to free the lateral attachments of the left colon before this step.

Following separation of the momentum from the left side of transverse colon/ distal TC, connection to the lateral dissection allows the splenic flexure to be fully mobilised. The colon at the flexure is retracted caudally and medially and any remaining attachments are freed [167].

Full splenic flexure mobilisation is complete when the inferior border of the pancreas visualised

Adequate exposure and use of assistance is important in this step

Take down R/L hypogastric nerves

The hypogastric nerve trunk/plexus has identified during the medial approach and mesenteric branches would have been during the dissection.
It is vital to now to re-identify the hypogastric nerves and dissect them free of the upper mesorectum

Just above the pelvic brim and slightly to the left of the midline, the hypogastric plexus bifurcates [164] in an inverted-Y into 2-3mm hypogastric nerves are often adherent by small unimportant rectal branches to the visceral fascia overlying and investing the mesorectum.

Nerves can be easily damaged if the correct plane is not entered [164], and especially if blunt dissection or bleeding occur. Damage at this level is purely sympathetic because the pelvic splanchnic nerves regents have not yet joined the bundle

The mesorectal plane is anterior to the nerves, immediately outside the fascia propria [164] investing the rectum and mesorectum.

The rectosigmoid is elevated anteriorly away from the sacrum and pelvic side wall and the nerves are carefully dissected free of the mesorectum, with the rectal branches being divided here

In this case both nerves are easily identified, with the plexus bifurcating above the pelvic brim, and are not adherent to the upper mesorectum. Nonetheless careful dissection with the nerves in direct vision is necessary to obviate injury.

The hypogastric nerves eventually leave the postero-lateral aspect of the mesorectum for the pelvic side wall. Lying deep to the peritoneum to join the inferior hypogastric plexus [164].

Creating peritoneal window and Pedicle transection

Creating a window in the mesentery on either side of the vessel allows the use of the vascular endoscopic linear cutting stapler to divide the vessel. Introduce the stapler through the right lower quadrant port. The stapler only fits though the 10-12mm port. Care needs to be taken prior to firing to ensure adjacent tissue is not caught at the tip of the stapling instrument.
Alternatively the IMA can be divided using interlocking endoscopic clips
High ligation flush to the origin of the vessel from the aorta (L3) may risk injuring the hypogastric nerve plexus

The blood supply to the rectum comes principally from the superior rectal artery, along with the middle, inferior rectal arteries and median sacral artery [168]. The SRA which is a continuation of the IMA crosses the left common iliac vessels medially descending to the level of S3 vertebrae. Here the artery divides into two branches on either side of the rectum [168] and further subdivide where they enter the muscular wall and supply the full thickness of the rectal wall, these vessels continue to the anal canal where they anastomose with the branches of the inferior rectal artery [169]. The IRA is a branch of the internal pudendal which comes off the internal iliac artery. The middle rectal vessels, a branch of the inferior vesical artery which comes off the internal iliac may be small or even absent. If present they reach the lower rectum from each side along the lateral ligaments.

The IRA supplies the rectum up to the peritoneal reflection and is the reason for the rectal stump to remain perfused after ligation of the IMA and transection of the rectum in a low or high anterior resection.

Medial planar dissection

Posterior approach or retropertitoneal mobilisation (continued medial approach)……having divided the IMA the plane between the descending colon mesentery and the retroperitoneum is developed laterally, towards the lateral attachments and superiorly/ cranially dissecting bowel off the anterior surface of the Gerota's fascia up towards the splenic flexure [167].
The right side of the mesorectum can be partially mobilised.

Postero-lateral mobilisation

Anatomy of the rectum
The rectum commences at the rectosigmoid junction approximately anterior to S3 vertebrae and ends at the anorectal junction.

Rectum turns downwards and backwards as the anal canal in front of the tip of coccyx. The anorectal junction is slung forwards by the u-loop of the puborectalis muscle. It is approximately 12cm long.
The rectum is devoid of mesentery - the visceral fascia around the rectum is known as the mesorectum.

Peritoneum covers the upper 1/3 at front and sides, and the middle third at the front only. The lower third is below the level of the peritoneum which is reflected forwards onto the upper part of the bladder to form the rectovesical pouch in the male, in the female the peritoneum is reflected onto the upper vagina to form the recto-uterine pouch. These pouches are the lowest part of the peritoneal cavity

In the male, anterior relations are the rectovesical pouch, denovilliers fascia separating rectum from prostate

In the female the anterior relations are the rectovesical pouch or POD. Lower third is vagina.

The dissection is now continued postero-laterally in the mesorectal plane anterior to the hypogastric nerves.

The dissection is continued circumferentially, dividing the pelvic peritoneum towards the anterior reflection on both sides will further facilitate further posterior dissection

Dissection is extended to at least 5cm below the level of the tumour for a high anterior resection. A total mesorectal excision in not necessary in these cases.

The surgeon and assistant need to continually elevate the rectosigmoid and upper rectum anteriorly to pre-sacral space and to facilitate effective tissue division in the correct plane.

Releasing gas intermittently from one of the ports will clear surgical smoke generated from the dissection to optimise the operative visual field. Alternatively an evacuation system can be connected to one of the ports.

Divide R Pelvic peritoneum

Posterior rectal mobilisation is facilitated by division of the pelvic peritoneum on both sides. The patient should be in the trendenburg position to allow small bowel to migrate out of the operative field.
To divide the right pelvic peritoneum the rectum and rectosigmoid are retracted upwards and towards the left side to place the peritoneum under optimal tension for division.
The vessels on the pelvic side wall are again visualised prior to division of the peritoneum with either endoscopic scissors or an ultrasonic device.

Divide L Pelvic peritoneum

Posterior rectal mobilisation is facilitated by division of the pelvic peritoneum on both sides. The patient should be in the trendenburg position to allow small bowel to migrate out of the operative field.
To divide the left pelvic peritoneum the rectum and rectosigmoid are retracted upwards and towards the right side to place the peritoneum under optimal tension for division.
The vessels on the pelvic side wall are again visualised prior to division of the peritoneum with either endoscopic scissors or an ultrasonic device. Placing a grasper through the left sided lateral port can be used for counter traction of the peritoneum and protect the pelvic side wall vessels.

Mesorectal division

With the rectosigmoid Elevated anteriorly out of the pelvis in the midline, the Mesorectal division is commenced on the right lateral rectal border with visualisation of the rectal muscle tube. When harmonic is used as the energy source it is crucial that the cutting or active blade is held above the rectal tube so as to obviate any thermal injury to the muscle.

Harmonic on a LOW setting can divide all the vessels within the mesorectum with excellent hemostasis. The dissection is continued posterior-laterally towards the left rectal wall with careful dissection in the correct plane between the mesorectum and the muscle tube. At all times the mesorectum must be divided with visualisation of the muscle tube to avoid any thermal injury.

The ultimate aim is visualisation of the rectal muscle tube circumferentially as this will aid safe stapled transection. The dissection can be seen here extending over to the left hand side of the mesorectum.

Introduce stapler

This endoscopic stapling device will transect the rectum intracorpoerally. This stapler (echelon flex) allows one-handed articulation and is demonstrated here extra corporeally. The articulation fin as shown is pulled back to release the articulation fin and allow angulation of the stapler.

The endoscopic stapler is introduced through the RLQ 12mm port in the closed position. Pull back the articulation fin before to release the articulation joint. Continued pressure on the articulation fin whilst pushing against the pelvic side wall to achieve the desired amount of articulation. Once in the desire position, releasing the fin locks the articulation joint.

Intra-corporeal transection

The Stapler is now positioned across the level of mesorectal division. Note that more than one reload may be required to complete rectal transection.
Wait 15 seconds to reach optimal tissue compression.

The firing sequence needs to be completed four times. The firing sequence can be followed by viewing the stroke indicator on the gun.
This stapler delivers 6 rows of staplers with a knife-blade dividing the rectum to leave 3 rows on each transected end.

The stapler needs to be straightened before withdrawal by pulling back on the articulation fin and reloading if necessary.

This particular case were required two reloads to complete the rectal transection.

The transected rectal stump is checked for hemostasis before a LLQ or Pf incision is made to deliver the specimen.

Ensure circumferential mobilization

An extensive pelvic dissection has already been performed but a TME is not necessary to resect this patient's rectosigmoid tumour. Adequate circumferential mobilisation of the rectum in the mesorectal plane well below the level of resection will obviate any oncological compromise in the resection. Additionally in a bulky mesorectum the level of transection can be identified and performed onto the rectal tube with much greater ease

As can be seen here the extent of dissection has way exceeded the level of resection.

Divide lateral attachment….safe access allows

Following the medial approach the dissection is continued up the paracolic gutter to divide the lateral peritoneal attachments to the sigmoid and left descending colon.

The sigmoid colon is grasped medially placing peritoneal attachments under tension. Start with division of the rectosigmoid peritoneal attachments. Once this layer of peritoneum has been incised, the space opened up by the medial planar dissection is entered (note the bruising on the retroperitoneum).continually reposition graspers during mobilisation of the sigmoid and left descending colon will provide optimal tissue tension for dissection. Although the retroperitoneal mobilisation has been completed there will still be some remaining attachments between the colonic mesentery and gerota's fascia to divide.

Switching the dissecting instrument from the RLQ port to the l lateral port will improve reach. Dissection should be continued as far as safe access allows towards the splenic flexure. Tilting the pt left side up and in reverse Trendelenburg traction of the left colon medially will enable the colonic mesentery to act as a cretin to keep small bowel out of the operative field.

The length of colon mobilised should now be assessed. In cases of distal sigmoid or rectosigmoid tumours, sufficient length may have been achieved already. However in situations when the descending colon is required as the anastomotic conduit following low anterior resection further mobilisation will be required.

Pelvic dissection

Patient returned to the trendelenburg position and the small bowel is reflected cranially [167].

Rectal mobilisation posteriorly is facilitated by incising the left and right pelvic peritoneum

Atraumatic bowel graspers are placed in right sided port (surgeon's left hand) to elevate the rectosigmoid anteriorly out of the pelvis and away from the retroperitoneal structures

Ureter and gonadals vessels should be visualised again

The rectosigmoid and rectum are retracted upwards and towards the patient's right side
Left pelvic peritoneum is divided
Left-sided port: grasper may retract pelvic side wall laterally

Elevation of the rectosigmoid colon will enable entry into the presacral space, which lies anteriorly to the hypogastric nerves

Divide R/L pelvic peritoneum to reflection

Extension of the pararectal pelvic dissection will facilitate the anterior dissection. The pelvic peritoneum on both sides are divided to the level of the peritoneal reflection.
The vessels on the pelvic side wall are again visualised or protected with a surgical prior to division of the peritoneum with either endoscopic scissors or an ultrasonic device.

Divide the left pelvic peritoneum by retracting the mesorectum upwards and towards the right side with counter-traction on the left pelvic side wall here the right pelvic peritoneum is divided to the level of the peritoneal reflection by retracting the mesorectum upwards and towards the left side.

Divide anterior reflection

Once the pelvic peritoneum has been divided on both sides to the level of the peritoneal reflection, the peritoneal dissection is extended anteriorly. This dissection is continued from the free edge of the lateral dissection from right to left to divide the anterior reflection.
The anterior dissection can either be continued or reversion to postero-lateral mobilisation before continuing the anterior dissection

Continue postero-lateral mobilization in TME plane

Reversion to a postero-lateral dissection in intervals will facilitate the anterior dissection

In low anterior resections, for mid and low rectal cancers, a total mesorectal excision (TME) to the pelvic floor is necessary. This dissection therefore continues in the mesorectal plane down towards the pelvic floor

The mesorectum is elevated anteriorly under tension to allow dissection in the mesorectal plane. Further lateral dissection will facilitate the posterior mobilisation

Difficulty of dissection will vary depending on a number of factors intra-abdominal adiposity, narrow male pelvis, and tumour size.

Open conversion may be necessary to complete the dissection if there any concerns with oncological compromise in the resection

Anterior dissection (male)

The anterior dissection which can often be quite difficult in a male is facilitated by an extensive postero-lateral pelvic dissection.
The anterior dissection in the male is posterior to the seminal vesicles and prostate and adequate tissue tension between the anterior surface of the rectum and the SV is essential.

The space between the anterior rectal wall and the seminal vesicles is often limited [164] and access for dissection can be restricted. The mesorectal plane is less obvious anteriorly and the bulk of the anterior mesorectum is variable.
Dissection in the mesorectal plane will separate the fascia propria of the rectum (with its enclosed anterior mesorectum) from Denovilliers fascia [164].
Anterior Dissection is probably where most parasympathetic nerve damage occurs. (it is therefore important to be aware that) the sacral para outflow(S2-4) condense with the hypo in the lateral pelvis before running lateral to medial, anterior to Denonvilliers fascia at the postero-lateral border of the prostate and are closely related to the anterior rectal wall.

Damage to these nerves results in sexual dysfunction.
Dissection deep in the pelvis, tumour size, and body habitus place the sacral parasym nerves at risk of injury in this region of the pelvis.

However if the hypo nerves have been preserved during posterior and lateral pelvic dissection the risk to sacral parasympathetic outflow will be minimised

Anterior dissection (female)

The anterior planes which can sometimes be quite difficult by are made more obvious by an extensive lateral pelvic dissection.
The anterior dissection in the female is posterior to the posterior vaginal wall. Careful sharp hemostatic dissection with optimal tissue tension is essential to obviate injury to adjacent structures.

Continue TME

The posterior dissection is now completed to visualise the pelvic floor.

By continuing to elevate the mesorectum anteriorly and towards the pubis, dissection continues down the presacral space in to the pelvic floor in the TME plane.

Releasing gas intermittently from one of the ports will clear surgical smoke generated from the dissection to optimise the operative visual field. Alternatively an evacuation system can be connected to one of the ports.

Division of anterior mesorectum

Anterior Dissection is probably where most parasympathetic nerve damage occurs during resectional surgery. (it is therefore important to be aware that) the cavernous nerves, branches of the pelvic plexus, run lateral to medial, anterior to Denonvilliers fascia at the postero-lateral border of the prostate and are closely related to the anterior rectal wall [164].

After the anterior pelvic dissection has been completed, the variable anterior mesorectum is divided to expose the rectal muscle tube anteriorly.

Reversion to a posterior dissection in intervals will again facilitate the anterior dissection
The mesorectal plane is less obvious anteriorly and the anterior mesorectum is thin or absent in this case. Dissection in this plane will separate the fascia propria of the rectum (with its enclosed anterior mesorectum) from posterior wall of the vagina [164].

The distance between the anterior rectal wall and the posterior wall of the vagina is short the anterior dissection may not necessarily be conducted in the same plane as the lateral and posterior dissections [164].

Divide lateral ligaments
However the tissue requires division to enable identification of the rectal tube circumferentially in the next step
Some surgeons argue that these anatomical ligaments do not exist.
The lateral ligaments are bundles of connective tissue (of variable substance) which are related to the lateral aspect of the distal rectum and run between the pelvic parietal fascia and the investing visceral fascia of the rectum. They may contain the small middle rectal vessels, nerve fibers and lymphatics [170].
This tissue can be excised as part of the circumferential pelvic dissection in the TME plane already identified. Division of this tissue will complete the TME dissection and create a circumferential rectal muscle tube at the pelvic floor in preparation for safe cross stapling.

Create muscle tube at the pelvic floor

The dissection is continued circumferentially deeper into the pelvis

Posteriorly the mesorectum is lifted up and anteriorly to allow division of waldeyers fascia (a condensation of connective tissue passing from the front of the lower sacrum to the anorectal junction)

The anorectal junction comes into view and sharp dissection allows complete mobilisation of the rectal tube. Visualisation of the pelvic floor musculature is essential.

The aim of the dissection is to for identification of the rectal tube, below the lower extent of the mesorectum, inserting at the anorectal junction

complete circumferential visualisation of the rectal tube at this level is essential to allow safe transection of the rectum with the endoscopic stapler

It's unsafe to transect the rectum with surrounding mesorectal tissue

Introduce endoscopic stapler
Same VO as for 35

Intra-corporeal transection

The Stapler is now positioned across the rectum at the pelvic floor.

The rectum in this case will be transected vertically or antero-posteriorly. Here the tip of the stapler is not visible so by rotating the stapler into a vertical line, the stapler is not pointing to the left lateral pelvic wall but towards the sacrum. Before closing recheck the gun is not pointing laterally.

Next by rotating the handle whilst holding the articulation fin the handle is maneuvered into a more ergonomic position for firing.

Wait 15 seconds to reach optimal tissue compression.

The firing sequence needs to be completed four times. The firing sequence can be followed by viewing the stroke indicator on the gun.

This stapler delivers 6 rows of staplers with a knife-blade dividing the rectum to leave 3 rows on each transected end.

The stapler needs to be straightened before withdrawal by pulling back on the articulation fin and a reload is required to complete the rectal transection. The stapler is again maneuvered into position so that the jaws are in an antero-posterior position for firing. The jaws can be seen enclosing all the remaining rectum before firing. Note this man oeuvre does require both hands. The transected rectal stump is checked for hemostasis before a LLQ or Pf incision is performed to deliver the specimen.

LLQ/ Specimen extraction

A 3-4cm left lower quadrant incision is made. Increase the incision to remove larger tumours if necessary Wound protector is inserted (reducing risk of tumour implantation in the wound)

After left lower quadrant incision made and Alexis wound protector introduced, retrieve the end of the colon/rectum and an extracorporeal resection is then performed.

Specimen exteriorized
The descending colon is divided extracorporeally

Confirm for pulsatile bleeding?
VO from open footage
Confirm the presence of pulsatile bleeding in the mesentery - marginal artery flow.

Divide colon and apply purse-string

The bowel is divided between crushing bowel clamp.
Two Babcock clamps are placed on the proximal colon

Purse-string suture is inserted with prolene 2-0, alternatively 0 polypropylene
An anvil size 29 is inserted. If bowel diameter smaller a size 25 may be more appropriate
Place a purse string suture in the proximal end of the bowel.
Insert the anvil of the circular stapling device.
Tie the purse string to the base of the anvils shaft.

Replace colon into abdominal cavity

Fascia formally closed or wound protector twisted to arrest gas leak from the fascial opening
Replace the bowel into the abdominal cavity and re-establish pneumperitoneum

Anastomosis sequences

Same VO as used for some subtasks

The proximal colon should fall easily into pelvis prior to be tension-free anastomosis

If colon keeps springing back into abdominal cavity, further mobilisation may be required
Also the colon should be checked for any twists

Inspect anastomosis and perform air test

Leak tested by filling the pelvis with saline and inflating the neorectum with air from a catheter and 50mi syringe or a proctoscope
The proximal colon needs to be occluded with an atraumatic bowel grasper and the anastomosis needs to be below saline level
If there is no evidence of leakage from the staple line (indicated by escape of fine air bubbles) the residual fluid is aspirated
Drains may be inserted if necessary and port sites close.

Appendix 7 Study Flyer was sent as an attachment via email and placed on the study website (http://www.colorectaltraining.co.uk)

Appendix 8 Study invitation opening webpage

Appendix 9 Participation Information Sheet

Multimedia Anterior Resection
Educational Tools

Log In | Consent Form | Participant Information Sheet

THE ROLE OF MULTIMEDIA IN COGNITIVE SURGICAL SKILLS ACQUISITION IN OPEN AND LAPAROSCOPIC COLORECTAL SURGERY

Participant Information Sheet

Dear Surgical Trainee,

You are invited to participate in the following educational study on 'The Role of Multimedia in Cognitive Surgical Skills Acquisition in Open and Laparoscopic Colorectal Surgery'. Please read the following Information Sheet carefully. If you decide to take part in the study, please click '**Proceed to Consent Form**' at the bottom of this page.

What is the background to this study?

Recent changes in working patterns and a reduction in training hours have imposed limitations on the opportunities to acquire surgical skills and experience in the operating room. Trainees are also in a position where they need to learn new surgical techniques and technologies with less hands-on exposure.

As a result of these constraints in training, it has become increasingly important for trainees to attend their operating sessions already primed with the necessary theoretical knowledge and relevant practical background.

Despite advances in operative competency training, there remains a lack of emphasis on innovative methods for training and assessing **cognitive** surgical skills (i.e. intra-operative decision-making, anatomical/ factual knowledge) that are integral to successful completion of operations.

What is Multimedia?

Multimedia integrates video, text, audio and animation. Multimedia may be an important adjunct to training in the operating room and has been shown to improve skills training in some sub-specialities (e.g. cardiac surgery). Multimedia advantages include creating a self-paced and trainee-centred learning environment. However, multimedia remains an underdeveloped surgical educational tool and there is little evidence-based evaluation of its role in teaching and assessment of cognitive surgical skills.

Appendix 10 Ethics Participation Consent Form

Multimedia
Anterior Resection
Educational Tools

Log In | Consent Form | Participant Information Sheet

Ethics Participation Consent Form

Title of Research Study: THE ROLE OF MULTIMEDIA IN COGNITIVE SURGICAL SKILLS ACQUISITION IN OPEN AND LAPAROSCOPIC COLORECTAL SURGERY

I confirm that I have read and understand the **'Participation Information Sheet'** explaining this research study and I have had the opportunity to email the named researcher any questions regarding the study. I understand my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any consequences. I understand the lead researcher can be contacted to clarify any issues regarding the study.

I understand that my personal information (including my training level and experience), online assessments, and evaluation form will be kept strictly confidential. I give permission for the researchers to have access to my data and results, and for this information to be used in the study report and/ or publications. I understand I will not be identifiable in any form in the study report and/ or publications.

* Having read through the Participation Information Sheet and the above statements on the consent form, **I AGREE** to take part in the study

- YES
- NO

If I am randomized to the 'multimedia' group, **I AGREE** to give consent to participate in a one-to-one interview (30 minute max.) on the usefulness of multimedia in surgical teaching and assessment. Participation in this part of the study is optional.

* **If you have AGREED to participate in the study, please enter your name and email address. You will emailed be contacted about relevant study information (e.g. randomised group allocation):**

NB Trainee Proforma and Pre-Assessment Test can be completed NOW after clicking SUBMIT

* First Name

* Surname

* Email address

Submit Consent Form

The University Of Sheffield.

Ethics Participation Consent Form

Title of Research Study: THE ROLE OF MULTIMEDIA IN COGNITIVE SURGICAL SKILLS ACQUISITION IN OPEN AND LAPAROSCOPIC COLORECTAL SURGERY

I confirm that I have read and understand the information explaining this research project and I have had the opportunity to email the named researcher any questions about the study. I understand my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any consequences. I understand the lead researcher can be contacted to clarify any issues regarding the study.

I understand that my personal information (including my training level and experience), online assessments, and evaluation form will be kept strictly confidential. I give permission for the researchers to have access to my data and results, and for this information to be used in the study report and/ or publications. I understand I will not be identifiable in any form in the study report and/ or publications.

Having read through the information sheet and the above statements on the consent form, I **agree** to take part in the study ☐

If I am randomized to the 'multimedia' group, I give consent to the one to one session/interview on the usefulness of multimedia in surgical teaching and assessment ☐

I **do not wish** to take part in the study ☐

If you have agreed to participate please enter your name and email address so can be contacted about relevant study information (randomised group allocation and study days):

NAME: ……………………………………

EMAIL ADDRESS: ……………………………………

The consent form will be stored securely on the study database

Name of Researcher: Umar Shariff

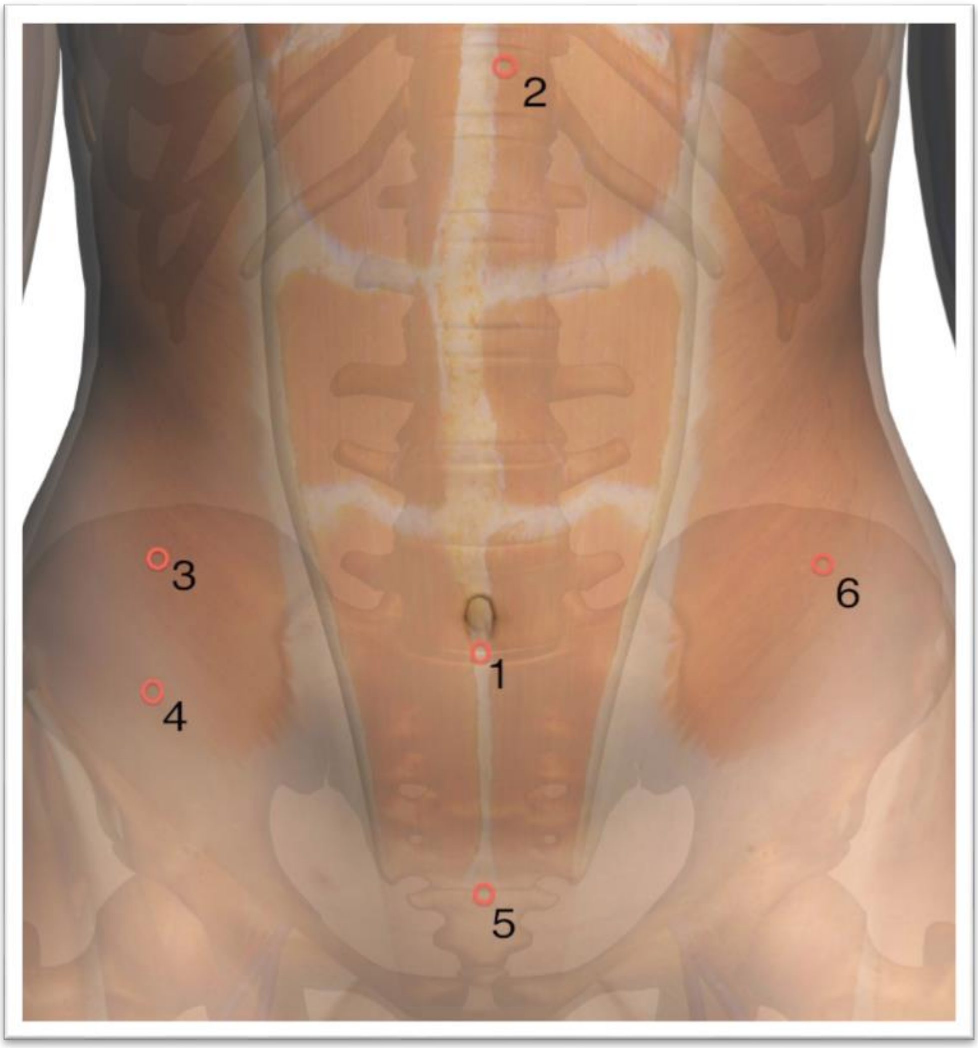
Email: umarshariff@doctors.org.uk

Mob: 07976428770

Appendix 11 Study Day Flyer

Appendix 12 Assessment tool questions

1 What are the ports used for initial laparoscopy and assessment of the medial approach onto the IMA vascular pedicle?



1,2,3,4

1,2,3,6

1,3,4,6

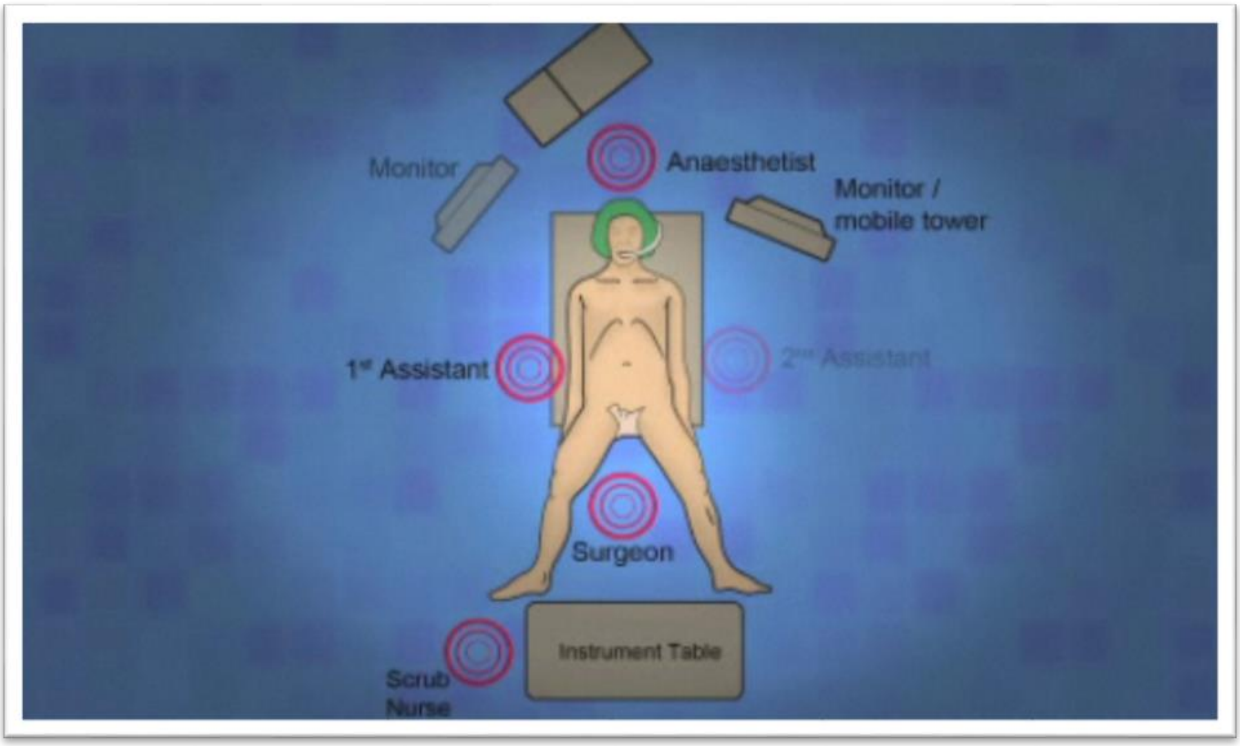
1,3,4,5

1,4,5,6

2 What is the most consistent midline entry point into the peritoneal cavity?

……

3 Which step is usually performed with the surgeon in this position?



A Initial laparoscopy

B Splenic Flexure Mobilisation

C Rectal transection

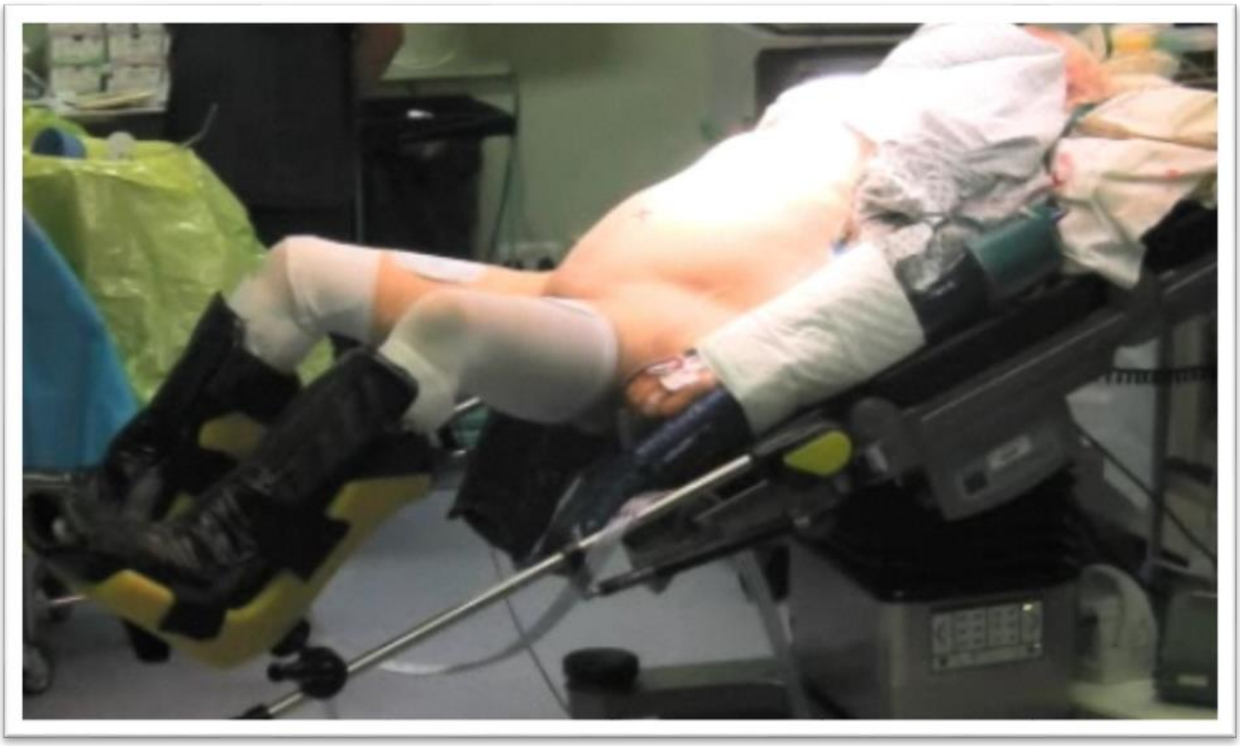
D Medial approach

4 What position should the patient be placed to facilitate small bowel migration out of pelvis in a laparoscopic procedure?

……

……

5 Which step is usually performed with the patient placed in this position?



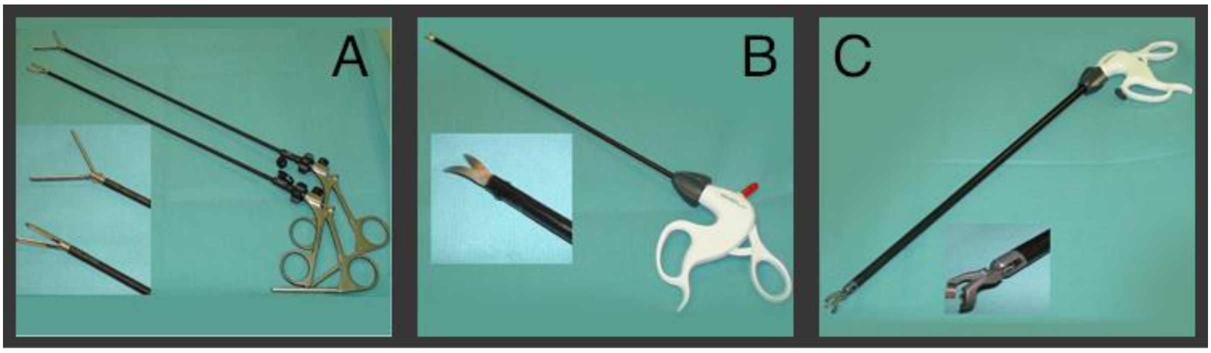
Medial approach

Rectal mobilisation

Intra-corporeal anastomosis

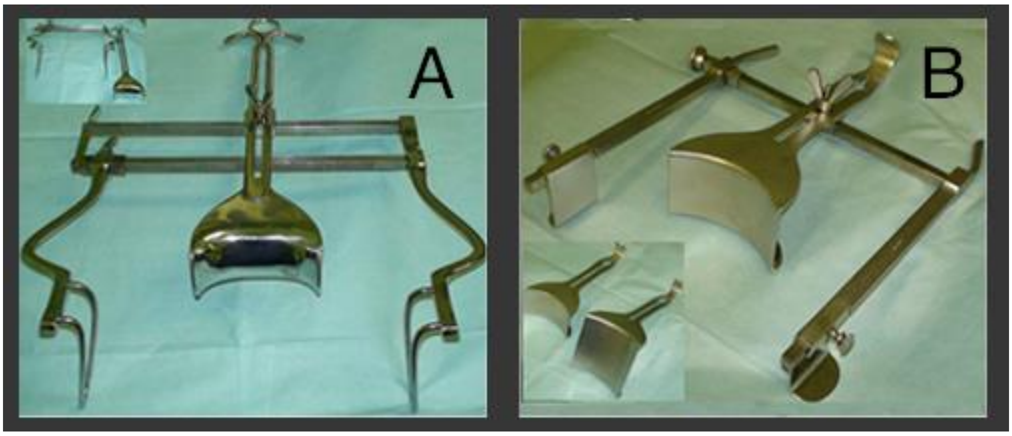
Splenic Flexure Mobilisation

6 Name instruments A, B & C



A……………………………… B……………………………… C……………………………..

7 Name instruments A & B

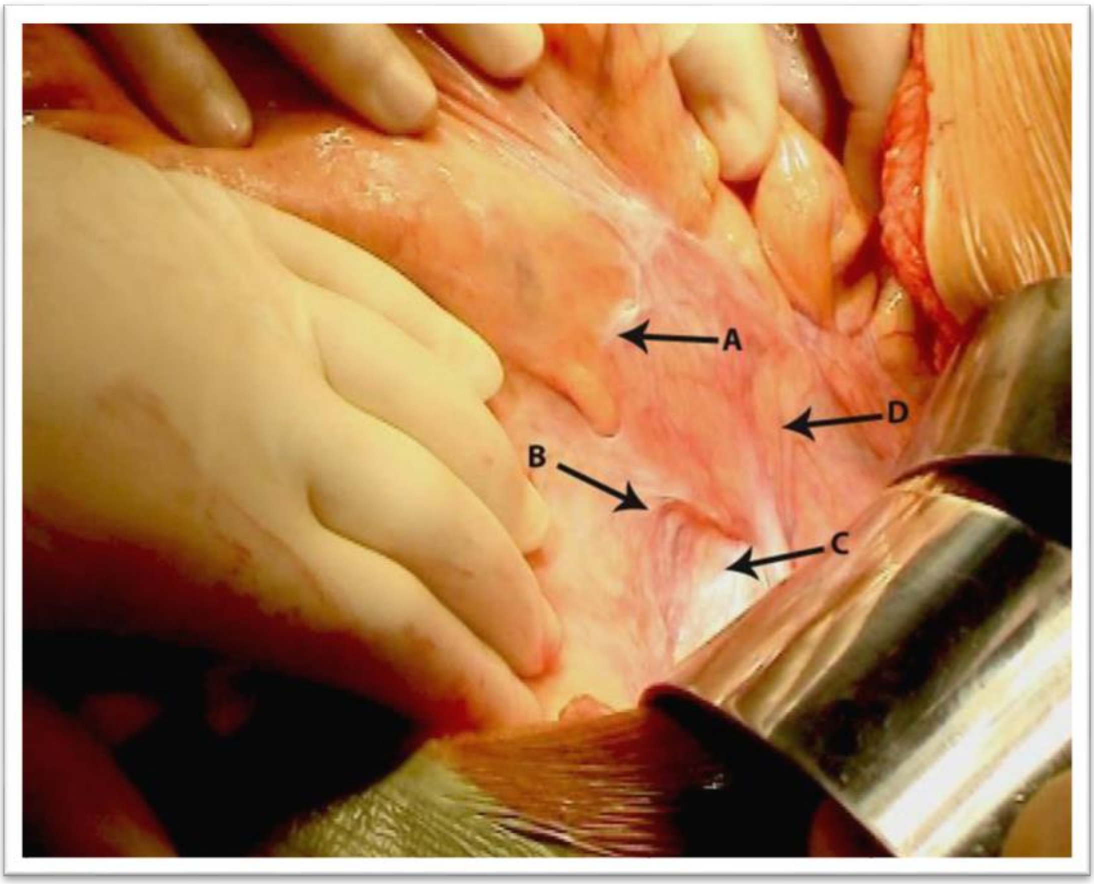


A…………..................   B…………………………..

8 Give TWO reasons for IMMEDIATE conversion of a laparoscopic anterior resection

1…………………………………………   2…………………………………………

9 What is the correct plane to commence division of the congenital sigmoid attachments?



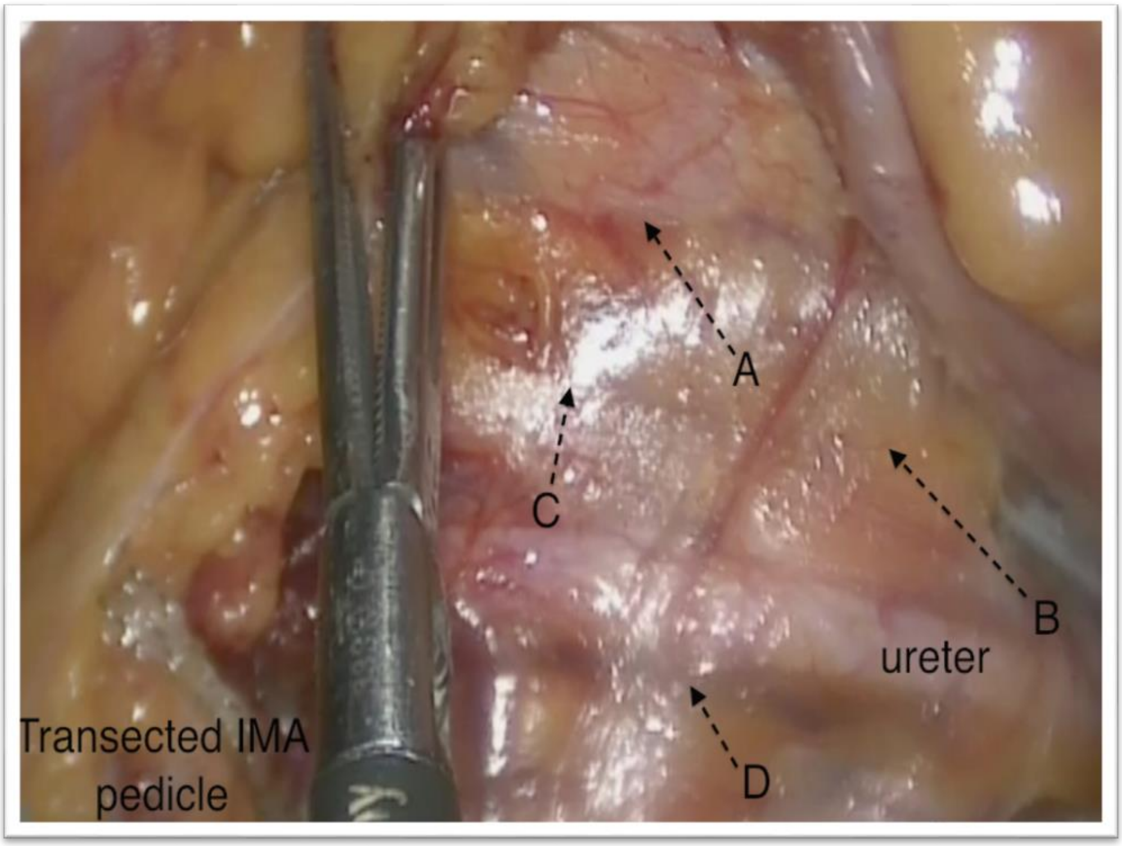
A

B

C

D

10 Which is the correct plane to continue medial dissection following division of the IMA vascular pedicle?



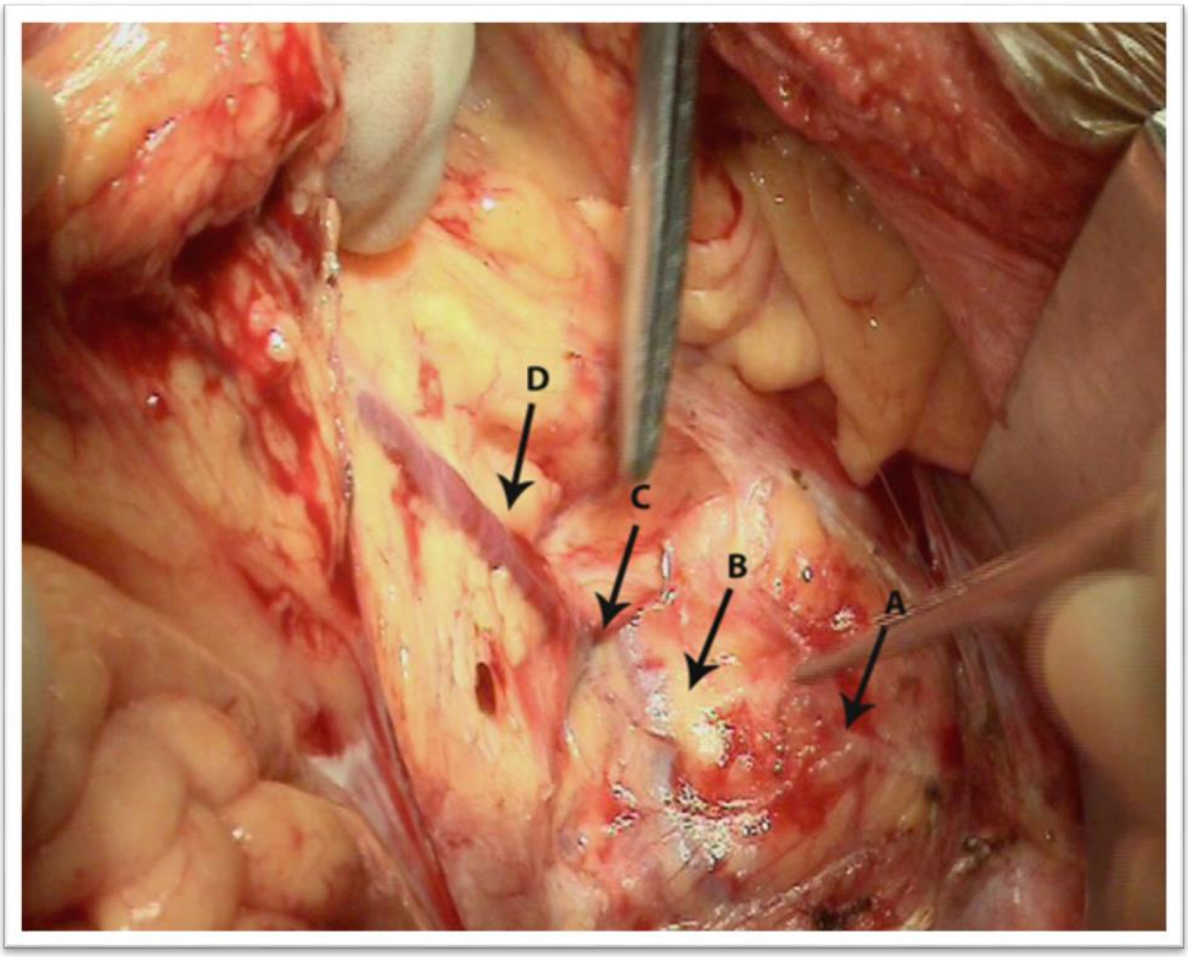
A

B

C

D

11 What is the correct plane of dissection to mobilise the colonic mesentery off Gerota's fascia?



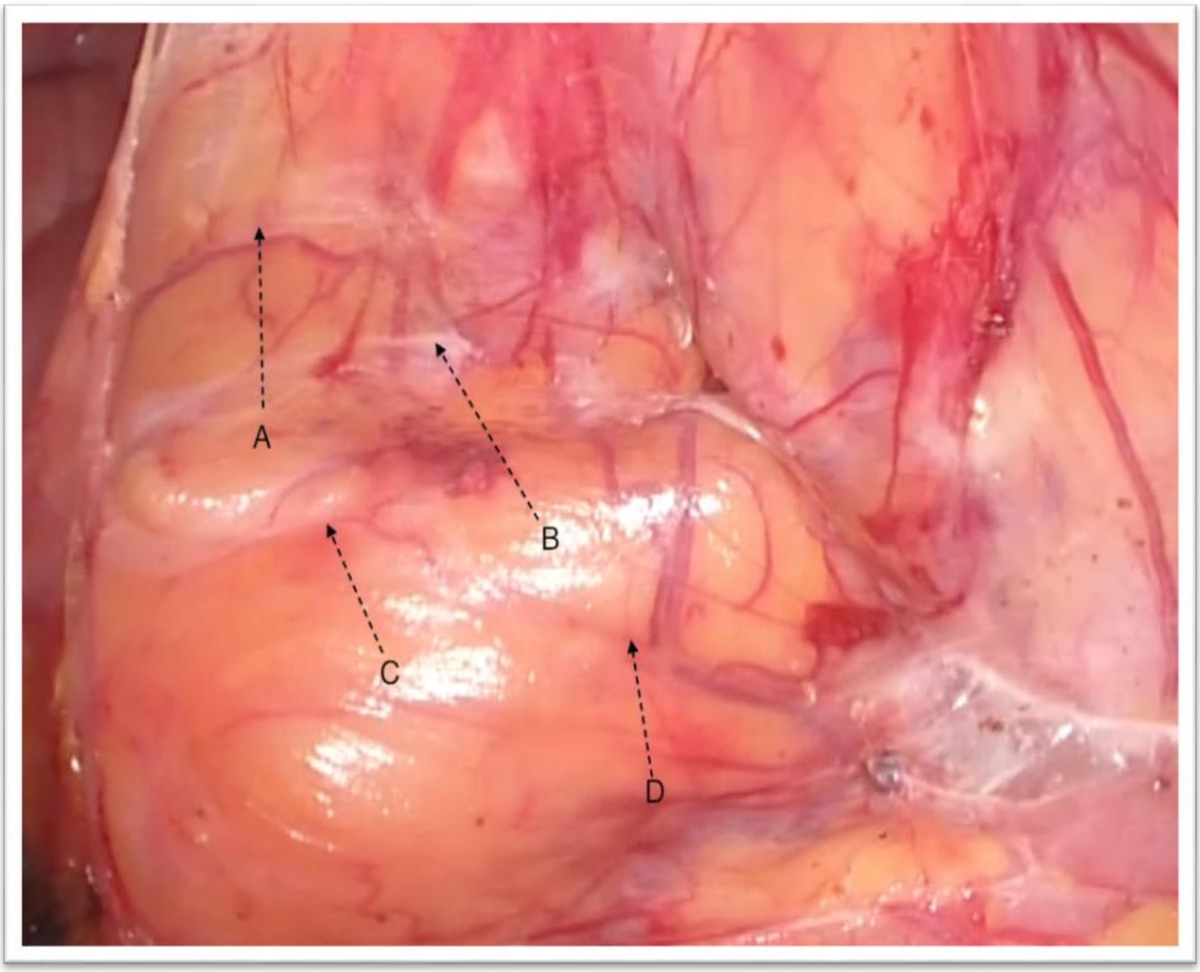
A

B

C

D

12 Choose the correct medial dissection plane to mobilise colonic mesentery off Gerota's fascia



A

B

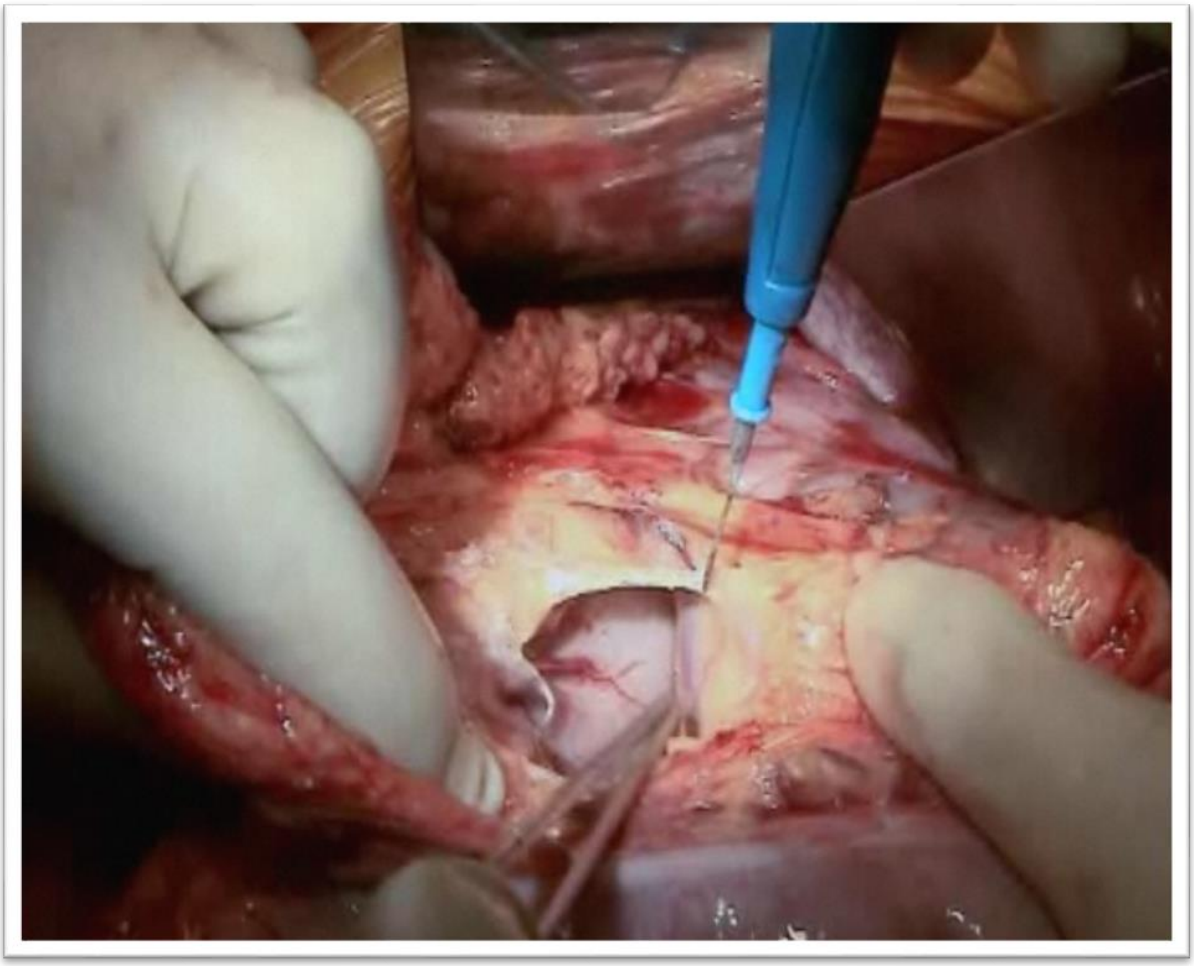
C

D

13 Why should caudal traction of the greater omentum be avoided during splenic flexure mobilisation?

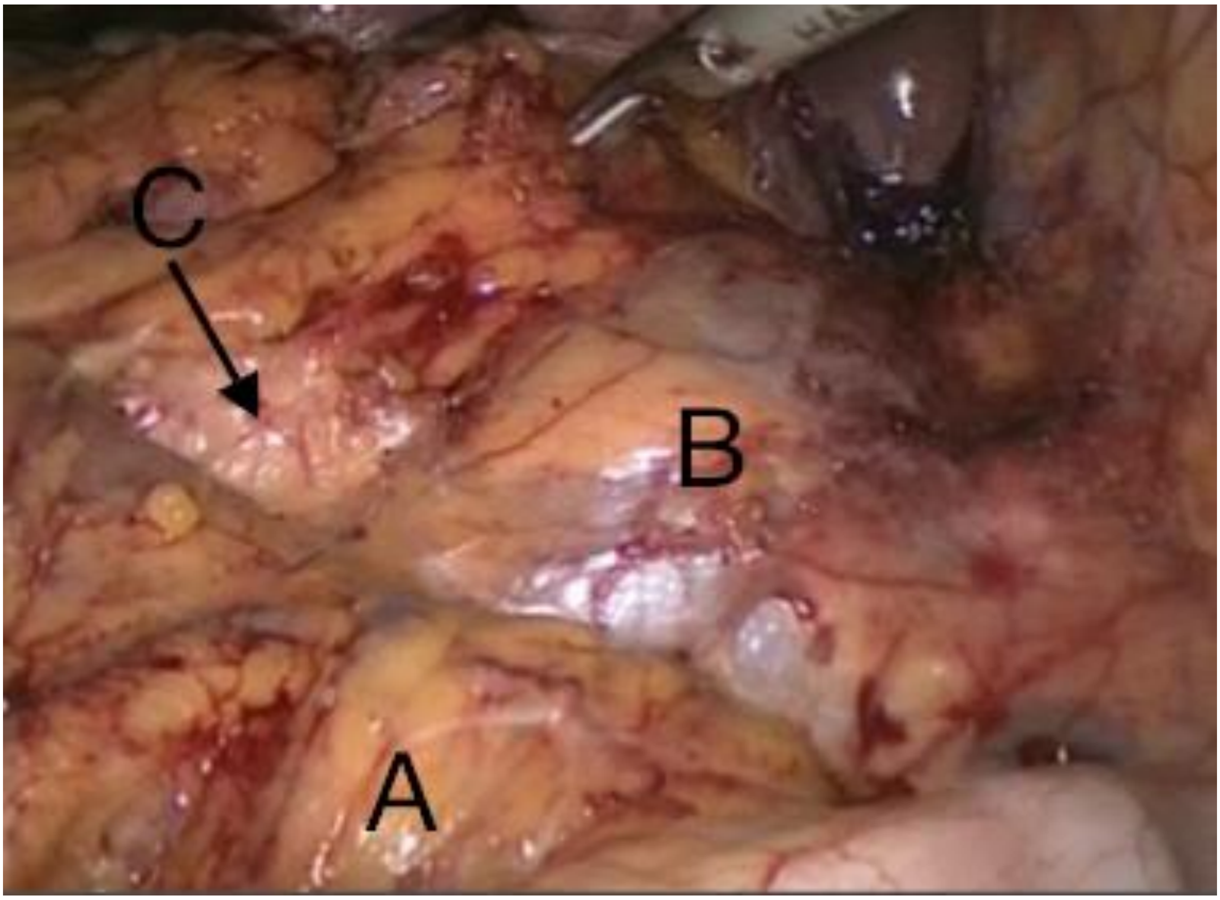
……….

14 What space has been entered?



……

15 Name structures A, B & C

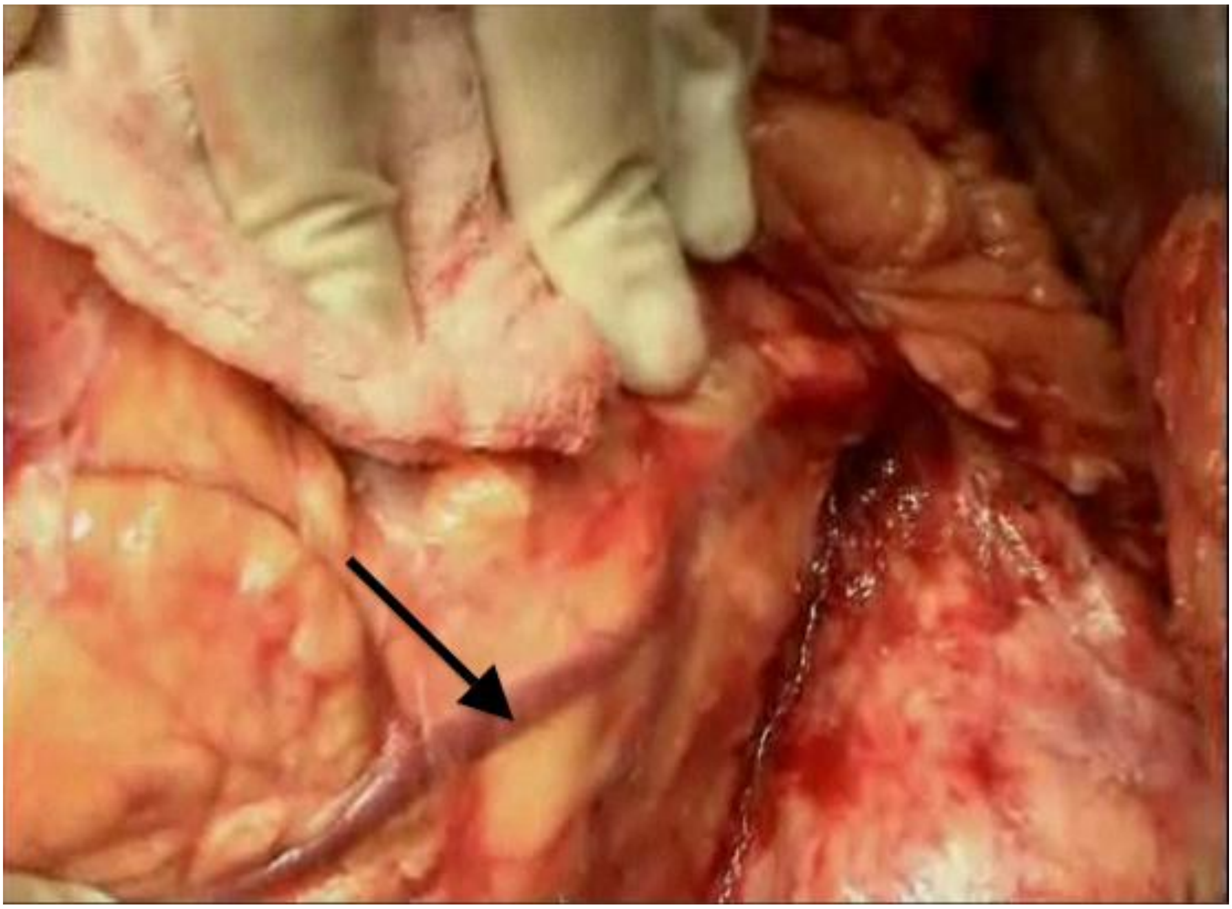


A

B

C

16 Name the vessel labelled?



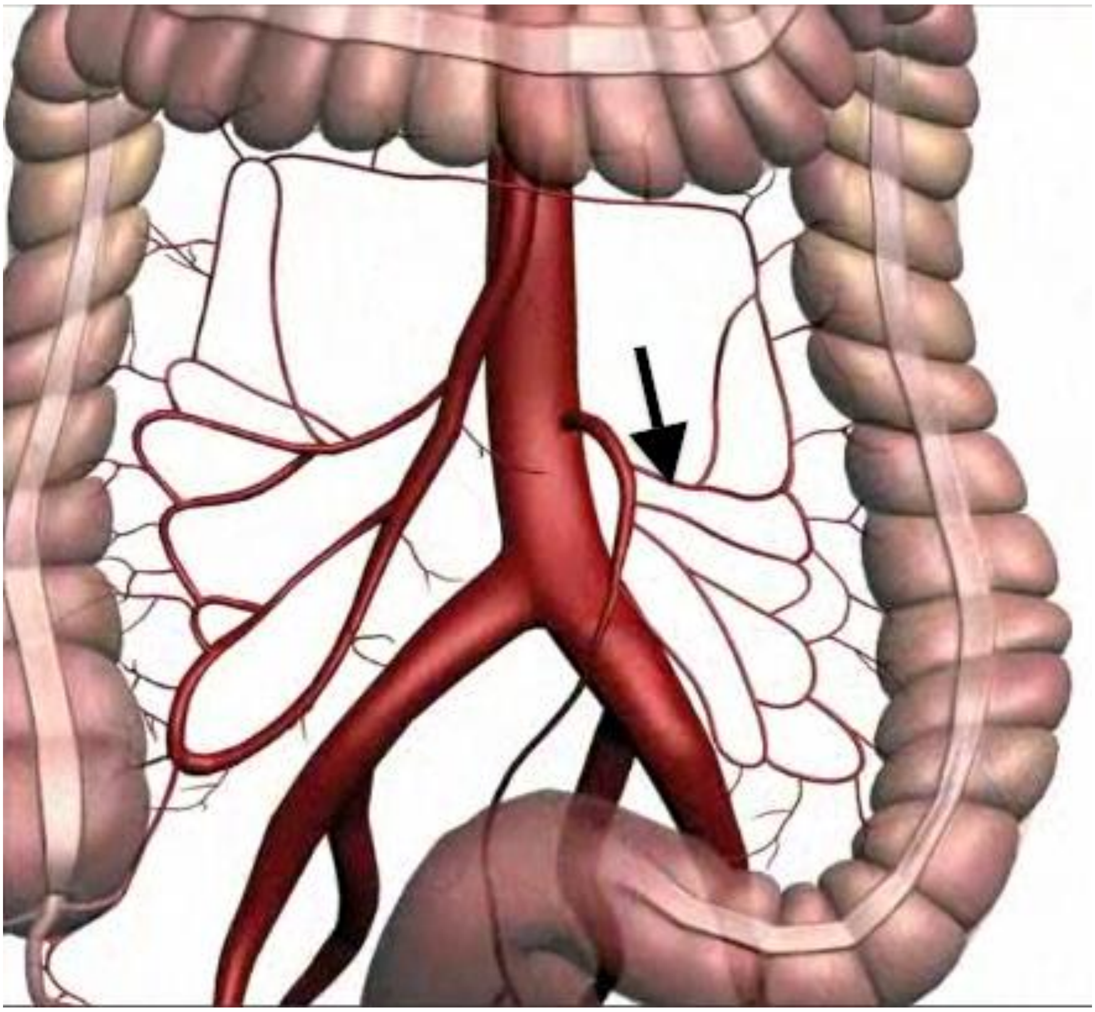
Inferior mesenteric artery

Ascending branch of left colic artery

Inferior mesenteric vein

Marginal artery

17 Which artery is labelled?



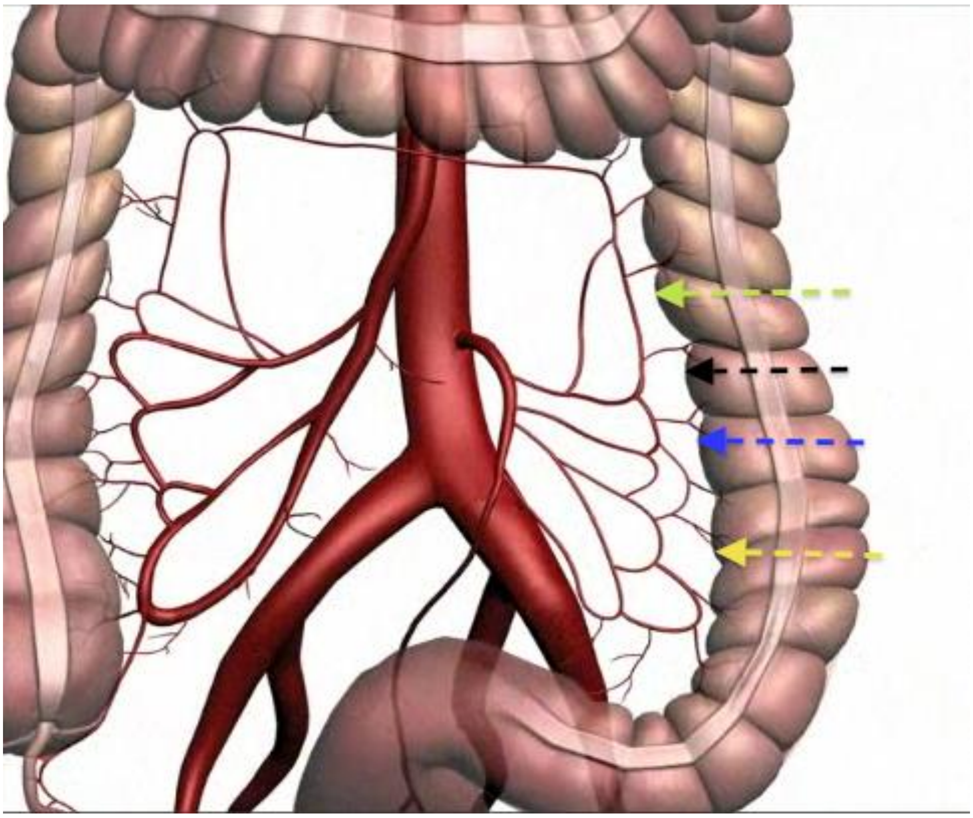
Inferior mesenteric artery

Ascending branch of left colic artery

Left colic artery

Sigmoid branches

18 What level should the bowel be divided to sacrifice the sigmoid colon?



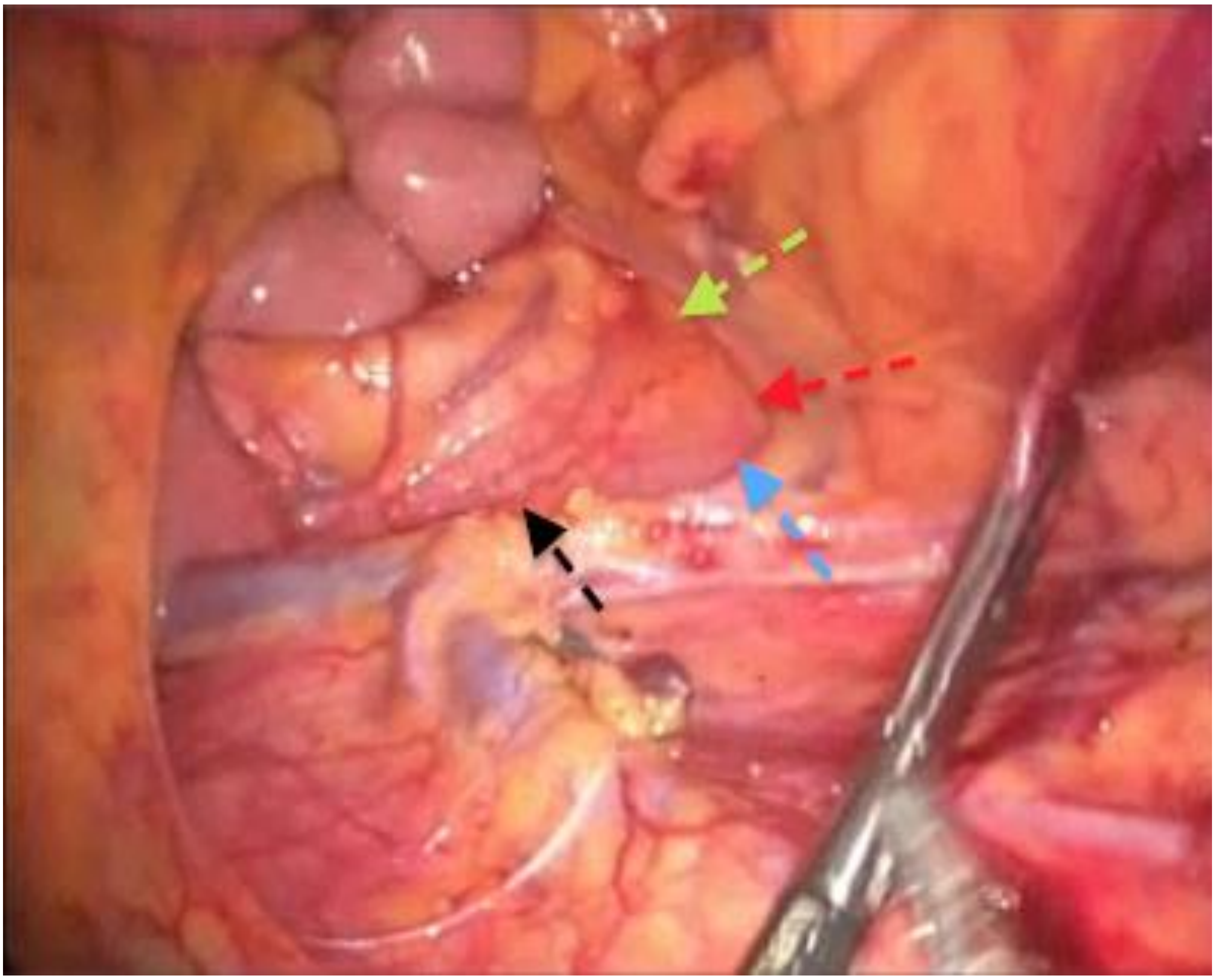
Green level

Blue level

Black level

Yellow level

19 Where should this axial mesenteric vessel be divided during mobilisation of the left colon?



- Black level
- Red level
- Green level
- Blue level

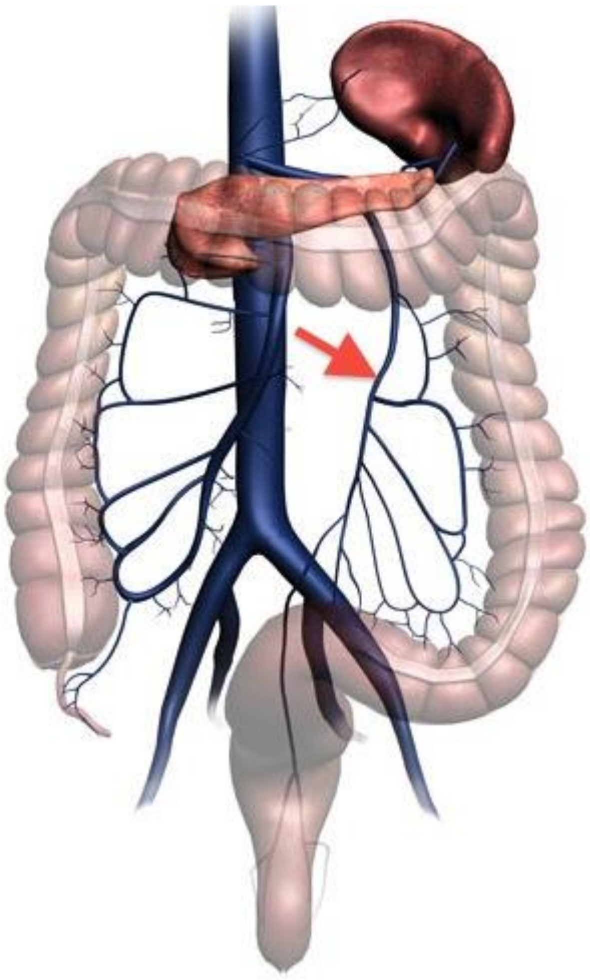
20 Assuming splenic flexure mobilisation and axial mesenteric vessel division, name THREE mobilisation steps to gain FURTHER colonic length

1

2

3

21 Which vein is labelled?



- Superior mesenteric vein
- Superior rectal vein
- Inferior mesenteric vein
- Sigmoid branches

22 In a High Anterior Resection (i.e. rectosigmoid cancer), give TWO reasons why adequate mobilisation below the level of resection is performed?

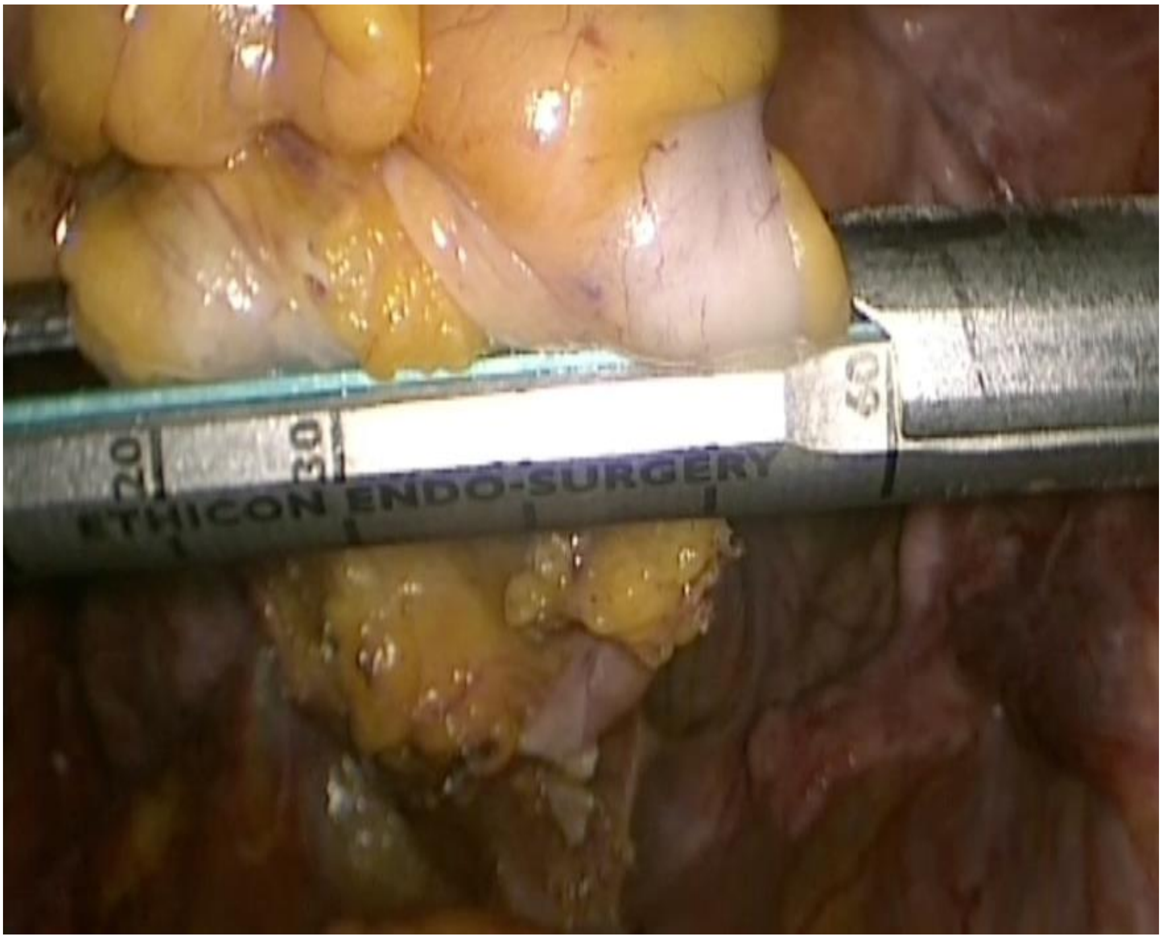
1 ……………………………………………………………………………………………..

2 ……………………………………………………………………………………………..

23 Following adequate circumferential rectal mobilisation in a High Anterior Resection, what step must be performed prior to rectal transection?

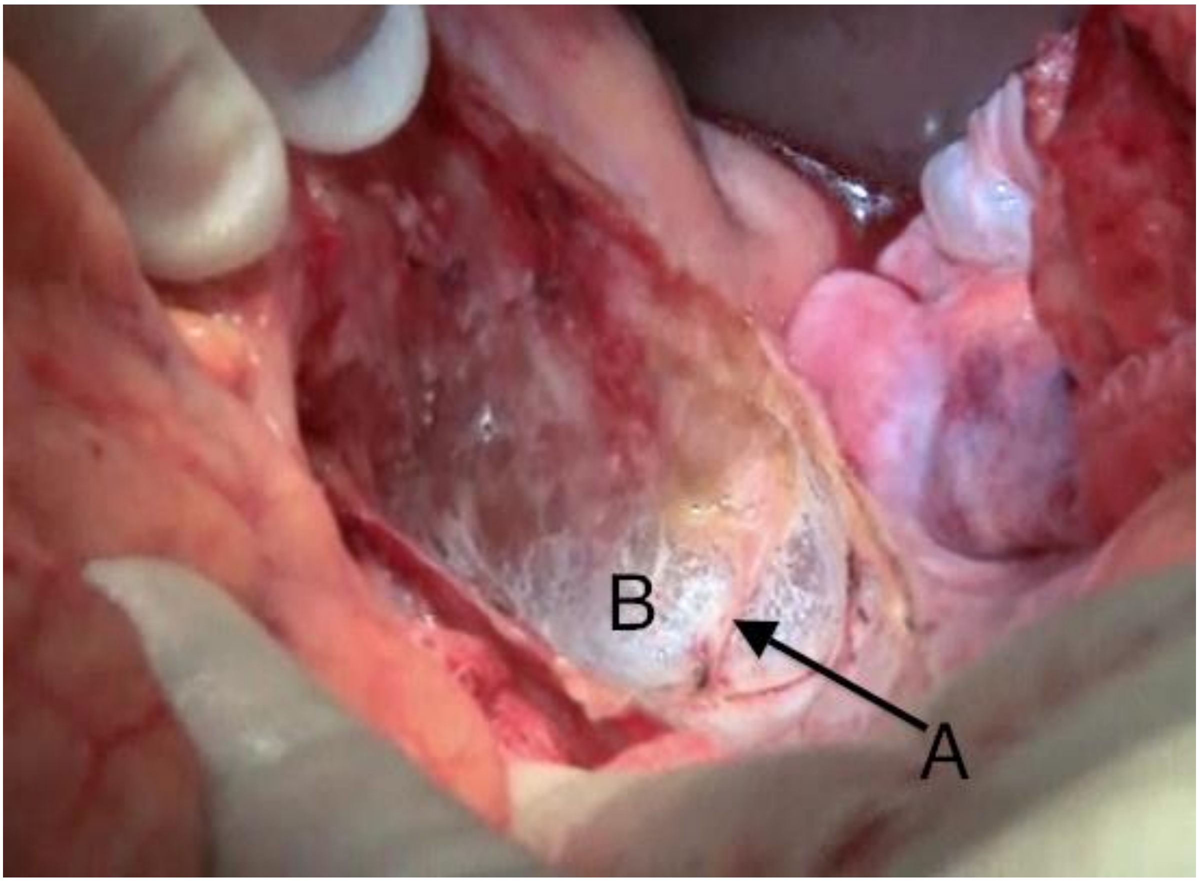
………

24 Once the stapler is in position how long should you wait for tissue compression before firing?



- Immediately fire stapler
- 15 seconds
- 30 seconds
- 1 minute

25 During postero-lateral right-sided rectal mobilisation, what are A and B?



A……….

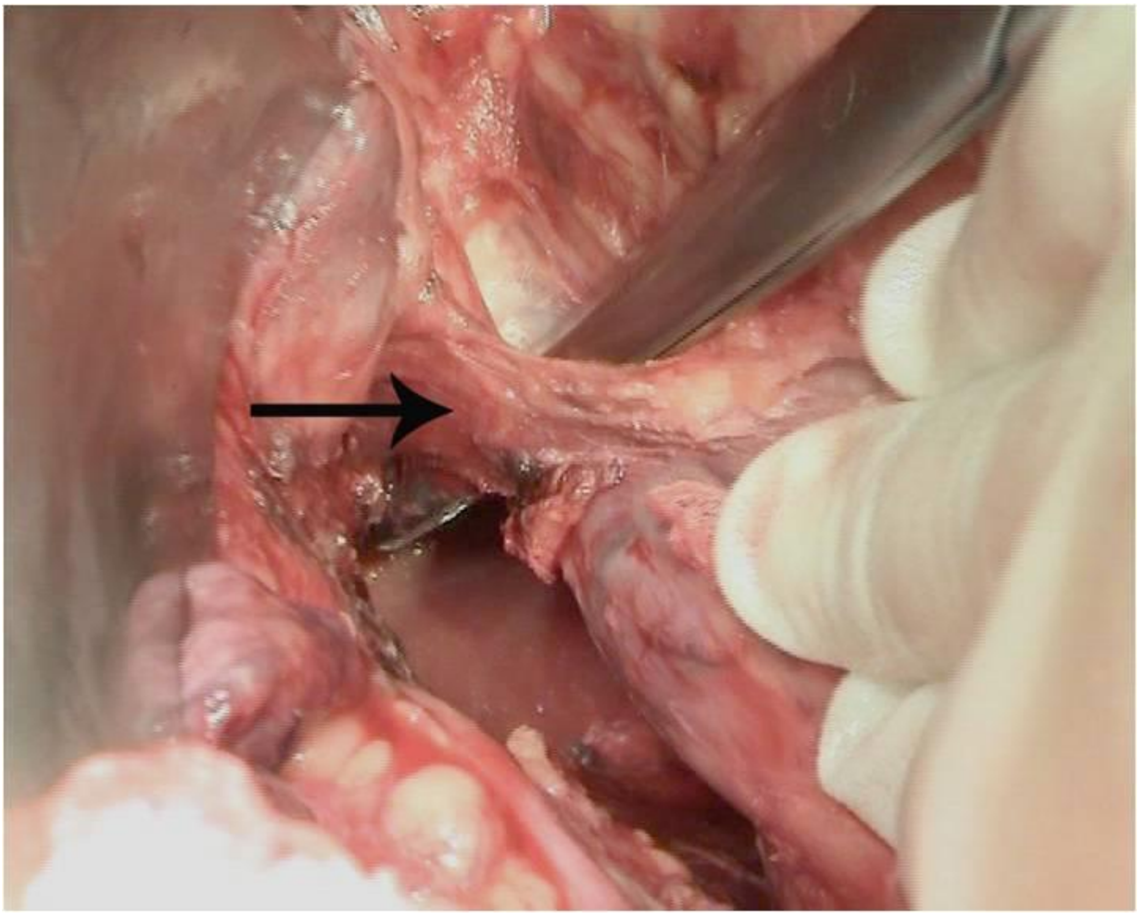
B……….

26 What structure is dissected off the anterior mesorectum in the MALE/ FEMALE:

MALE ………………………………………………………………….

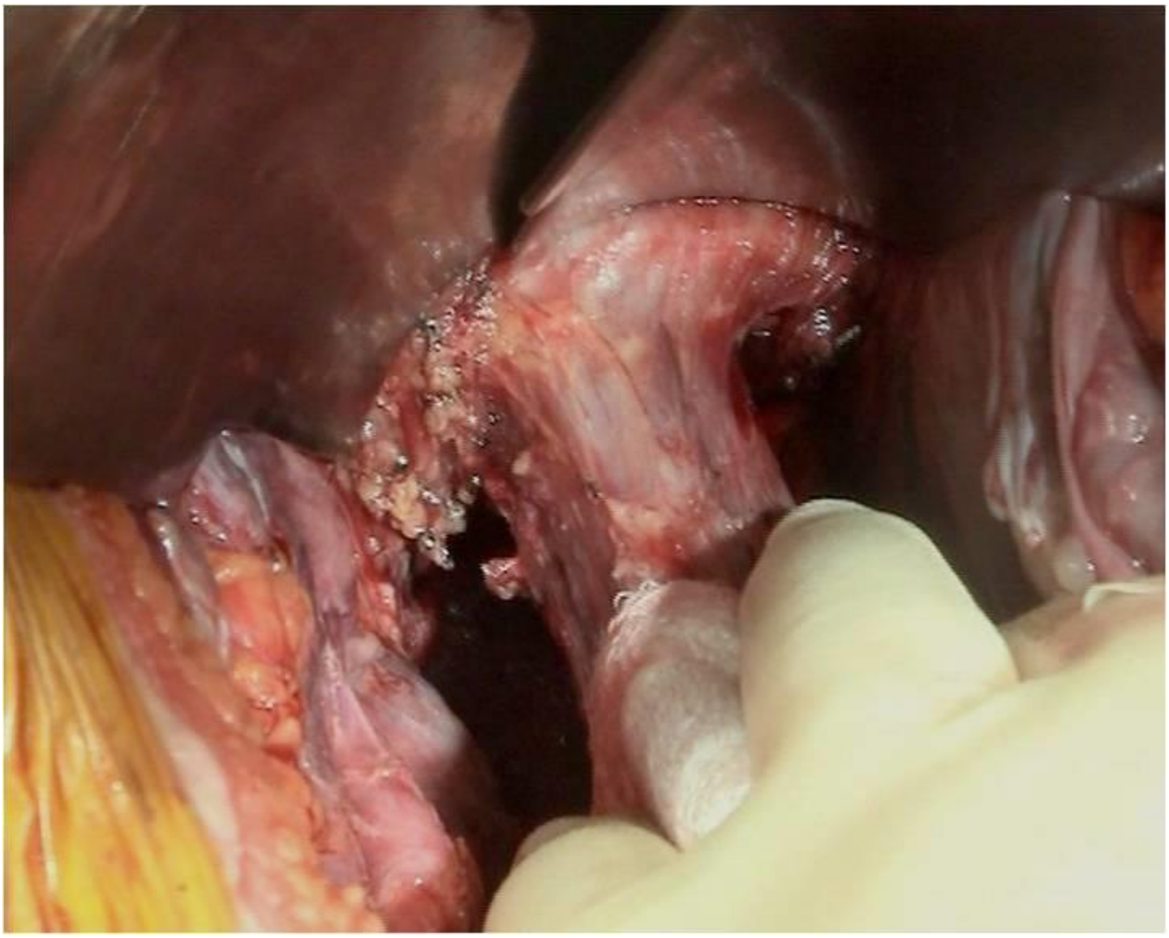
FEMALE ………………………………………………………………….

27 Name the structure labelled in this low anterior resection in a female



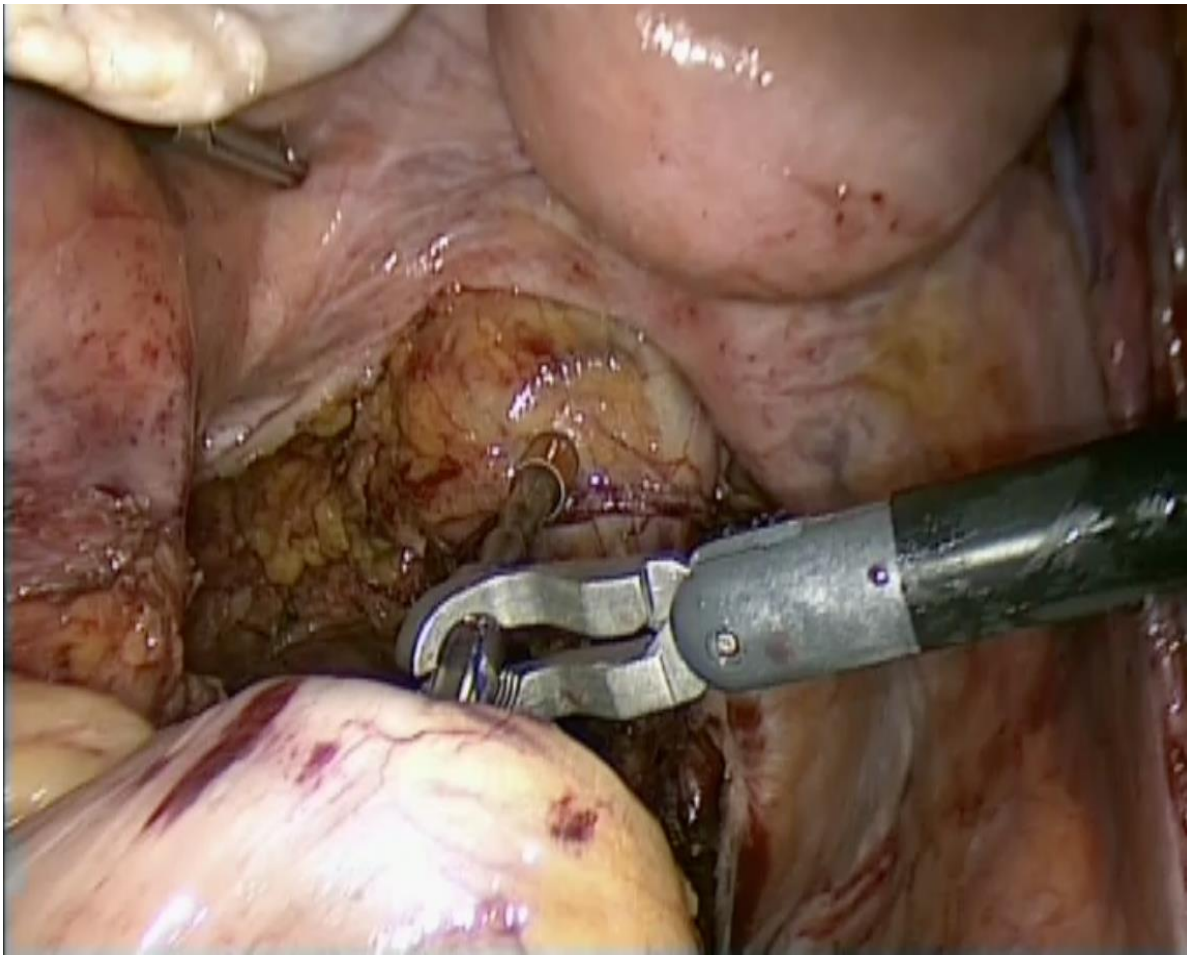
………

28 What is the purpose of exposing rectal muscle circumferentially following total mesorectal excision (TME) to the pelvic floor?



………

29 Assuming sufficient colonic length has been achieved, what should you check prior to attaching the anvil to the trocar and again before closure of the stapler?



………

30 Following this anastomosis, what should be performed prior to wound closure?

…….

Appendix 13 Multimedia Evaluation Tool for Experts

All questions (composed on Smart survey) were based on the rating Likert scale (Strongly Agree – Strongly Disagree). There was also the option to provide free-text comments after some statements.

MEDIA INTEGRATION

EASE OF USE: OPEN

The Open Multimedia Educational Tool is easy to use

EASE OF USE: LAPAROSCOPIC

The Laparoscopic Multimedia Educational Tool is easy to use

NAVIGATION: OPEN

I am able to move through to different areas of the open educational tool easily

Comments:

NAVIGATION: LAPAROSCOPIC

I am able to move through to different areas of the laparoscopic educational tool easily

LEARNING DEMANDS

It is easy to deal with the different options available and to recognise and understand the options presented

Comments:

MAPPING: OPEN

The relationship between the optional choice you make (i.e. click to view a particular subtask icon) and the educational tools response to your choice are appropriate

MAPPING: LAPAROSCOPIC

The relationship between the optional choice you make (i.e. click to view a particular subtask icon) and the educational tools response to your choice are appropriate

SCREEN DESIGN

GRAPHICS: The overall quality of the graphics is good

Comments:

ANIMATION: The overall quality of the animation is good

Comments:

TEXT: The size, format and font of the text is appropriate

Comments:

VIDEO: The general quality of the video imagery is good

Comments:

VOICEOVER: The overall quality of the voiceover is good

MEDIA INTEGRATION: OPEN

The different media (i.e. text, video, animation, graphics and voiceover) integrate well on this educational platform

MEDIA INTEGRATION: LAPAROSCOPIC

The different media (i.e. text, video, animation, graphics and voiceover) integrate well on this educational platform

LEVEL OF EDUCATIONAL CONTENT

The educational content is appropriate to ST3-8 level surgical trainees, in terms of scope and level of detail

Comments:

INFORMATION PRESENTATION

The information has been presented in an appropriate manner

Comments:

AESTHETICS

The multimedia tools are aesthetically pleasing

Comments:

OVERALL FUNCTIONALITY: OPEN

This is a good educational tool to acquire cognitive surgical skills for Open Anterior Resection

Comments:

OVERALL FUNCTIONALITY: LAPAROSCOPIC

This is a good educational tool to acquire cognitive surgical skills for Laparoscopic Anterior Resection

Comments:

LEARNING PROCESS

GOAL ORIENTATION: The educational tools focus on cognitive surgical skills acquisition

Comments:

EXPERIENTIAL VALUE: Experiential learning is the process of making meaning from direct experience. These educational tools provide relevant experience

Comments:

TEACHER ROLE: The educational tools facilitate the teacher's role

Comments:

ORIGIN OF MOTIVATION: The educational tools are intrinsically motivating

Comments:

ACCOMMODATION OF INDIVIDUAL DIFFERENCES: The educational tools accommodate a wide range of learners' individual differences

Comments:

LEARNER CONTROL: Both educational tools allow unrestricted learner control over the educational material presented

Comments:

USER ACTIVITY: The educational tools create an interactive learning experience

Comments:

TRAINING TOOL APPRAISAL

What delivery medium would be your preference to use these educational tools?

- CD-ROM/ DVD
- Online

Comments:

Is MULTIMEDIA a more effective learning tool compared to the following teaching methods for cognitive surgical skills training?

- Textbooks
- Educational courses
- Study day/ lectures
- Comments:

Do you think the multimedia educational tools can improve surgical trainees' skills acquisition?

- Visual-spatial ability
- Dexterity
- Teamwork
- Management
- Communication skills
- Decision making
- Factual and anatomical knowledge
- Anatomical plane recognition

What primary use do you think trainees would use the multimedia educational tools for?

- Exam/viva preparation

- Prior to an operating list
- Teaching junior surgical trainees
- Browsing/ referencing

Are the educational tools more appropriate for Individual or Group study?

- Individual
- Group
- Both the same

Overall, do you think that Multimedia is a useful adjunctive educational tool for surgical trainees outside the operating room?

Comments:

EDUCATIONAL CONTENT

Did you identify areas which were factual incorrect?

If so, please specify:

EDUCATIONAL CONTENT

Are there specific areas that were unclear and need clarification?

If so, please specify:

GENERAL IMPROVEMENT

Please suggest any improvements to the open and laparoscopic multimedia educational tools

…….

Appendix 14 Multimedia Evaluation Tool for Trainees

All questions (composed on Smart survey) were based on the rating Likert scale (Strongly Agree – Strongly Disagree). There was also the option to provide free-text comments after some statements.

EASE OF USE: OPEN

The Open Multimedia Educational Tool is easy to use

EASE OF USE: LAPAROSCOPIC

The Laparoscopic Multimedia Educational Tool is easy to use

NAVIGATION: OPEN

I am able to move through to different areas of the open educational tool easily

Comments:

NAVIGATION: LAPAROSCOPIC

I am able to move through to different areas of the laparoscopic educational tool easily

LEARNING DEMANDS

It is easy to deal with the different options available and to recognise and understand the options presented

Comments:

MAPPING: OPEN

The relationship between the optional choice you make (i.e. click to view a particular subtask icon) and the educational tools response to your choice are appropriate

MAPPING: LAPAROSCOPIC

The relationship between the optional choice you make (i.e. click to view a particular subtask icon) and the educational tools response to your choice are appropriate

SCREEN DESIGN

GRAPHICS: The overall quality of the graphics is good

Comments:

ANIMATION: The overall quality of the animation is good

Comments:

TEXT: The size, format and font of the text is appropriate

Comments:

VIDEO: The general quality of the video imagery is good

Comments:

VOICEOVER: The overall quality of the voiceover is good

MEDIA INTEGRATION: OPEN

The different media (i.e. text, video, animation, graphics and voiceover) integrate well on this educational platform

MEDIA INTEGRATION: LAPAROSCOPIC

The different media (i.e. text, video, animation, graphics and voiceover) integrate well on this educational platform

LEVEL OF EDUCATIONAL CONTENT

The educational content is appropriate to ST3-8 level surgical trainees, in terms of scope and level of detail

Comments:

INFORMATION PRESENTATION

The information has been presented in an appropriate manner

Comments:

AESTHETICS

The multimedia tools are aesthetically pleasing

Comments:

OVERALL FUNCTIONALITY: OPEN

This is a good educational tool to acquire cognitive surgical skills for Open Anterior Resection

Comments:

OVERALL FUNCTIONALITY: LAPAROSCOPIC

This is a good educational tool to acquire cognitive surgical skills for Laparoscopic Anterior Resection

Comments:

LEARNING PROCESS

GOAL ORIENTATION: The educational tools focus on cognitive surgical skills acquisition

Comments:

EXPERIENTIAL VALUE: Experiential learning is the process of making meaning from direct experience. These educational tools provide relevant experience

Comments:

TEACHER ROLE: The educational tools facilitate the teacher's role

ORIGIN OF MOTIVATION: The educational tools are intrinsically motivating

Comments:

ACCOMMODATION OF INDIVIDUAL DIFFERENCES: The educational tools accommodate a wide range of learners' individual differences

Comments:

LEARNER CONTROL: Both educational tools allow unrestricted learner control over the educational material presented

Comments:

USER ACTIVITY: The educational tools create an interactive learning experience

Comments:

TRAINING TOOL APPRAISAL

What delivery medium would be your preference to use these educational tools?

- CD-ROM/ DVD
- Online

Comments:

Advantages of the online Multimedia Educational Tools compared to traditional teaching methods (i.e. Study Day Lectures) include:

- Continual access to educational material
- Greater flexibility over time to learn
- Independent self-management of learning (i.e. learn at own pace)
- Less demand on instructor/ lecturer time
- Lack of cost/ travel time for Study Day

Disadvantages of the online Multimedia Educational Tools compared to traditional teaching methods (i.e. Study Day Lectures) include:

- Lack of feedback
- Lack of interactivity (with instructor/ lecturer)
- Lack of motivation due to absence of instructor/ lecturer
- Technical issues with online Tools

Is MULTIMEDIA a more effective learning tool compared to the following teaching methods for cognitive surgical skills training?

- Textbooks
- Educational courses
- Study day/ lectures

Comments:

Do you think the multimedia educational tools can improve surgical trainees' skills acquisition?

- Visual-spatial ability
- Dexterity
- Teamwork
- Management
- Communication skills
- Decision making
- Factual and anatomical knowledge
- Anatomical plane recognition

What primary use do you think trainees would use the multimedia educational tools for?

- Exam/viva preparation
- Prior to an operating list
- Teaching junior surgical trainees
- Browsing/ referencing

Are the educational tools more appropriate for Individual or Group study?

- Individual

- Group
- Both the same

Overall, do you think that Multimedia is a useful adjunctive educational tool for surgical trainees outside the operating room?

Comments:

EDUCATIONAL CONTENT

Did you identify areas which were factual incorrect?

If so, please specify:

EDUCATIONAL CONTENT

Are there specific areas that were unclear and need clarification?

If so, please specify:

GENERAL IMPROVEMENT

Please suggest any improvements to the open and laparoscopic multimedia educational tools

Appendix 15 Block randomisation table

Group	**Percentile Group of random by rep group**
<34, ST5 or less, less twelve months	On-line
<34, ST5 or less, less twelve months	study day
<34, ST5 or less, less twelve months	study day
<34, ST5 or less, less twelve months	On-line
<34, ST5 or less, less twelve months	On-line
<34, ST5 or less, less twelve months	On-line
<34, ST5 or less, less twelve months	study day
<34, ST5 or less, less twelve months	study day
<34, ST5 or less, less twelve months	On-line
<34, ST5 or less, less twelve months	On-line
<34, ST5 or less, less twelve months	study day
<34, ST5 or less, less twelve months	study day
<34, ST5 or less, less twelve months	On-line
<34, ST5 or less, less twelve months	On-line
<34, ST5 or less, less twelve months	study day
<34, ST5 or less, less twelve months	study day
<34, ST5 or less, twelve months or more	On-line
<34, ST5 or less, twelve months or more	study day
<34, ST5 or less, twelve months or more	On-line
<34, ST5 or less, twelve months or more	study day
<34, ST5 or less, twelve months or more	study day
<34, ST5 or less, twelve months or more	On-line
<34, ST5 or less, twelve months or more	On-line
<34, ST5 or less, twelve months or more	study day

<34, ST5 or less, twelve months or more	study day
<34, ST5 or less, twelve months or more	On-line
<34, ST5 or less, twelve months or more	study day
<34, ST5 or less, twelve months or more	On-line
<34, ST5 or less, twelve months or more	On-line
<34, ST5 or less, twelve months or more	study day
<34, ST5 or less, twelve months or more	On-line
<34, ST5 or less, twelve months or more	study day
<34,St 6 or more, less than twelve month	On-line
<34,St 6 or more, less than twelve month	study day
<34,St 6 or more, less than twelve month	study day
<34,St 6 or more, less than twelve month	On-line
<34,St 6 or more, less than twelve month	On-line
<34,St 6 or more, less than twelve month	study day
<34,St 6 or more, less than twelve month	On-line
<34,St 6 or more, less than twelve month	study day
<34,St 6 or more, less than twelve month	On-line
<34,St 6 or more, less than twelve month	On-line
<34,St 6 or more, less than twelve month	study day
<34,St 6 or more, less than twelve month	study day
<34,St 6 or more, less than twelve month	On-line
<34,St 6 or more, less than twelve month	study day
<34,St 6 or more, less than twelve month	study day
<34,St 6 or more, less than twelve month	On-line
<34, St6 or more, twelve months or more	On-line
<34, St6 or more, twelve months or more	On-line
<34, St6 or more, twelve months or more	study day
<34, St6 or more, twelve months or more	study day
<34, St6 or more, twelve months or more	study day

<34, St6 or more, twelve months or more	study day
<34, St6 or more, twelve months or more	On-line
<34, St6 or more, twelve months or more	On-line
<34, St6 or more, twelve months or more	study day
<34, St6 or more, twelve months or more	study day
<34, St6 or more, twelve months or more	On-line
<34, St6 or more, twelve months or more	On-line
<34, St6 or more, twelve months or more	study day
<34, St6 or more, twelve months or more	On-line
<34, St6 or more, twelve months or more	study day
<34, St6 or more, twelve months or more	On-line
34+,st5 or less, less than twelve months	study day
34+,st5 or less, less than twelve months	On-line
34+,st5 or less, less than twelve months	study day
34+,st5 or less, less than twelve months	On-line
34+,st5 or less, less than twelve months	study day
34+,st5 or less, less than twelve months	On-line
34+,st5 or less, less than twelve months	On-line
34+,st5 or less, less than twelve months	study day
34+,st5 or less, less than twelve months	On-line
34+,st5 or less, less than twelve months	study day
34+,st5 or less, less than twelve months	study day
34+,st5 or less, less than twelve months	On-line
34+,st5 or less, less than twelve months	study day
34+,st5 or less, less than twelve months	study day
34+,st5 or less, less than twelve months	On-line
34+,st5 or less, less than twelve months	On-line
34+,st5 or less, twelve months plus	On-line
34+,st5 or less, twelve months plus	study day

34+,st5 or less, twelve months plus	study day
34+,st5 or less, twelve months plus	On-line
34+,st5 or less, twelve months plus	On-line
34+,st5 or less, twelve months plus	study day
34+,st5 or less, twelve months plus	study day
34+,st5 or less, twelve months plus	On-line
34+,st5 or less, twelve months plus	On-line
34+,st5 or less, twelve months plus	study day
34+,st5 or less, twelve months plus	study day
34+,st5 or less, twelve months plus	On-line
34+,st5 or less, twelve months plus	On-line
34+,st5 or less, twelve months plus	On-line
34+,st5 or less, twelve months plus	study day
34+,st5 or less, twelve months plus	study day
34+,st6 or more, less than twelve months	study day
34+,st6 or more, less than twelve months	study day
34+,st6 or more, less than twelve months	On-line
34+,st6 or more, less than twelve months	On-line
34+,st6 or more, less than twelve months	On-line
34+,st6 or more, less than twelve months	study day
34+,st6 or more, less than twelve months	study day
34+,st6 or more, less than twelve months	On-line
34+,st6 or more, less than twelve months	On-line
34+,st6 or more, less than twelve months	On-line
34+,st6 or more, less than twelve months	study day
34+,st6 or more, less than twelve months	study day
34+,st6 or more, less than twelve months	study day
34+,st6 or more, less than twelve months	study day
34+,st6 or more, less than twelve months	On-line

34+,st6 or more, less than twelve months	On-line
34+,st6 or more, twelve months plus	On-line
34+,st6 or more, twelve months plus	study day
34+,st6 or more, twelve months plus	study day
34+,st6 or more, twelve months plus	On-line
34+,st6 or more, twelve months plus	On-line
34+,st6 or more, twelve months plus	On-line
34+,st6 or more, twelve months plus	study day
34+,st6 or more, twelve months plus	study day
34+,st6 or more, twelve months plus	On-line
34+,st6 or more, twelve months plus	study day
34+,st6 or more, twelve months plus	On-line
34+,st6 or more, twelve months plus	study day
34+,st6 or more, twelve months plus	study day
34+,st6 or more, twelve months plus	On-line
34+,st6 or more, twelve months plus	study day
34+,st6 or more, twelve months plus	On-line

Statistician also provided a sheet with extra four block randomizations. So if a group fills up:

1. Insert four extra lines at the bottom
2. Copy a block of four from the extras
3. Paste that into the lines at the end of the group
4. Delete the block from the extras sheet

Appendix 16 Randomised trial results relating to all participants

No	Age	Level	Junior or senior level	Colorectal experience (months)	Sub-specialty interest?	Colorectal interest	Group	Included in final analysis?	Reasons for exclusion from final analysis	ITT Group	PP Group	Pre-Score Rater 1	Pre-Score Rater 2	Mean Pre-Score	Post-score Rater 1	Post-score Rater 2	Mean difference pre_post scores
1	32	ST4	Junior	12	Colorectal	yes	Study day	Yes		1	1	19	19	19		22	2.5
2	30	ST3	Junior	6	Colorectal	yes	Multimedia	No	No further contact			17	17	17			
3	33	ST5	Junior	12	Colorectal	yes	Study day	No	Unable to attend Study Day			21	21	21			
4	30	ST5	Junior	12	Colorectal	yes	Multimedia	Yes		2	2	27	26	26.5		33	6.5
5	31	ST5	Junior	18	Colorectal	yes	Multimedia	Yes		2	2	24	23	23.5		31	7.5
6	37	ST6	Senior	18	Colorectal	yes	Multimedia	Yes		2	2	23	24	23.5		27	3.5
7*	35	ST6	Senior	12	Colorectal	yes	Study day	Yes		1	2	25	25	25		25	0
8	32	ST5	Junior	0	Upper GI	no	Study day	No	Unable to attend Study Day			17	16	16.5			
9	32	ST4	Junior	6	Colorectal	yes	Study day	No	No further contact								
10	30	ST3	Junior	6	Not sure yet	no	Multimedia	Yes		2	2	25	26	25.5		26	-0.5
11	34	ST3	Junior	6	Vascular	no	Multimedia	Yes		2	2	16	16	16		33	16.5

12 *	35	ST6	Senior	24	Colorectal	yes	Study day	Yes		1	2	28	28	28		29	1
13	30	ST3	Junior	12	Colorectal	yes	Study day	Yes		1	2	20	20	20		30	9.5
14	35	ST6	Senior	18	Colorectal	yes	Multimedia	No	No further contact			20	22	21			
15	36	ST7	Senior	18	Colorectal	yes	Multimedia	Yes		2	2	26	25	25.5		29	2
17	31	ST5	Junior	12	Upper GI	no	Multimedia	No	No further contact								
18	31	ST4	Junior	12	Colorectal	yes	Multimedia	Yes		2	2	12	13	12.5		15	2.5
19	37	ST4	Junior	12	Upper GI	no	Multimedia	Yes		2	2	20	20	20		32	12
20	33	ST5	Junior	18	Colorectal	yes	Study day	Yes		1	1	20	18	19		25	6
21	34	ST4	Junior	0	Not sure yet	no	Study day	Yes		1	1	14	15	14.5		19	4.5
22	31	ST3	Junior	0	Colorectal	yes	Multimedia	Yes		2	2	21	20	20.5		29	8.5
23	32	ST4	Junior	6	Colorectal	yes	Study day	No	Unable to attend Study Day								
24	39	ST7	Senior	12	Upper GI	no	Multimedia	Yes		2	2	27	25	26		27	2
25	32	ST4	Junior	12	Colorectal	yes	Study day	Yes		1	1	19	19	19		25	6.5
26	35	ST5	Junior	3	Colorectal	yes	Multimedia	Yes		2	2	24	26	25		32	7.5
27	35	ST8	Senior	24	Upper GI	no	Study day	Yes		1	1	19	20	19.5		18	-1

28	34	ST5	Junior	3	Upper GI	no	Multimedia	No	Post-Assessments/ Evaluation not completed								
29	31	ST3	Junior	12	Not sure yet	no	Multimedia	Yes		2	2	31	30	30.5		37	6.5
30	29	ST3	Junior	0	Colorectal	yes	Study day	Yes		1	1	16	15	15.5		26	10
31	31	ST5	Junior	6	Not sure yet	no	Study day	Yes		1	1	21	21	21		25	4
32	35	ST7	Senior	24	Colorectal	yes	Study day	Yes	Unable to attend Study day			26	26	26			
33	39	ST8	Senior	>36	Colorectal	yes	Multimedia	Yes		2	2	24	24	24		24	0
34	32	ST5	Junior	12	Colorectal	yes	Multimedia	Yes		2	2	20	19	19.5		37	17
35	35	ST4	Junior	6	Not sure yet	no	Study day	No	No further contact								
36	39	ST7	Senior	>36	Colorectal	yes	Study day	Yes		1	1	27	28	27.5		32	4.5
38	35	ST6	Senior	24	Colorectal	yes	Multimedia	Yes		2	2	21	20	20.5		26	5.5
39	36	ST5	Junior	24	Colorectal	yes	Study day	Yes		1	1	24	25	24.5		30	5.5
40	30	ST3	Junior	6	Vascular	no	Study day	Yes		1	1	14	15	14.5		15	0
41	31	ST7	Senior	6	Vascular	no	Multimedia	Yes		2	2	15	15	15		19	4
42	32	ST3	Junior	0	Vascular	no	Multimedia	No	Post-Assessments/ Evaluation not			13	13	13			

									completed								
43	32	ST3	Junior	12	Not sure yet	no	Multimedia	Yes		2	2	13	14	13.5		21	7
44	33	ST5	Junior	24	Colorectal	yes	Multimedia	Yes		2	2	22	22	22		21	0
45	34	ST5	Junior	12	Not sure yet	no	Study day	No	Unable to attend Study day								
46	36	ST5	Junior	18	HPB	no	Multimedia	Yes		2	2	27	26	26.5		38	11.5
47	37	ST4	Junior	18	HPB	no	Multimedia	Yes		2	2	6	6	6		19	13
48	30	ST4	Junior	12	Not sure yet	no	Study day	Yes		1	1	22	22	22		26	4
49	38	ST6	Senior	6	Colorectal	yes	Study day	Yes		1	1	20	21	20.5		29	8.5
50*	36	Post CCST	Senior	>36	Colorectal	yes	Study day	Yes		1	2	32	32	32		33	1
51	31	ST3	Junior	6	Vascular	no	Study day	Yes		1	1	15	13	14		27	12.5
52	35	ST3	Junior	3	Not sure yet	no	Study day	Yes		1	1	17	16	16.5		24	7
53	34	ST4	Junior	0	Endocrine	no	Multimedia	No	Post-Assessments/ Evaluation not completed			13	14	13.5			
54	33	ST4	Junior	6	Not sure yet	no	Multimedia	Yes	Post-Assessments/ Evaluation not completed			18	19	18.5			

55 *	38	ST7	Senior	30	Colorectal	yes	Study day	Yes		1	2	23	23	23		34	10
56	31	ST3	Junior	12	Colorectal	yes	Multimedia	No	Post-Assessments/ Evaluation not completed			8	8	8			
57	27	ST3	Junior	6	Colorectal	yes	Multimedia	Yes		2		18	18	18		24	6
58	29	ST4	Junior	0	Not sure yet	no	study day	Yes		1		13	13	13		17	4.5
59	31	ST3	Junior	0	Colorectal	yes	Study day	Yes		1		20	20	20		22	2
60	31	ST3	Junior	6	Colorectal	yes	Multimedia	No	Post-Assessments/ Evaluation not completed								
61	31	ST3	Junior	6	Colorectal	yes	Study day	Yes		1		23	24	23.5		29	5

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