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Digitalisation in Healthcare: The Future of Surgical Training

Thesis presented by

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Declaration

"This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism and intellectual property."

Abstract

Introduction

The impact of digital technology and artificial intelligence (AI) has a daily impact on our lives. Healthcare as an industry is at the forefront of technological innovation. The application of novel technology to aid performance and enhance training in surgery is key. Challenges in surgical training owing to an increase in trainee numbers, a reduction in working hours, increase in complexity and variety of surgeries performed have become major issues in surgical education. The COVID-19 pandemic further compounded these concerns between 2020 and 2022 where there was significant disruption and reduction in elective surgical activity.

Methods

Five studies examining the challenges in surgical training in gynaecology and their potential solutions were designed. These comprised of a national cross-sectional trainee and trainer survey on the current challenges of surgical training in gynaecology and in training during the COVID-19 pandemic. Potential solutions examined were a trial of the application of artificial intelligence to the grading of surgical performance and two randomised controlled trails of the application of transcranial direct current stimulation (tDCS) to enhance surgical performance in laparoscopic and robotic surgery.

Results

Our results showed significant challenges in surgical training over the last decade with a significant reduction in trainee confidence and experience in operative gynaecology. The COVID-19 pandemic had a significant impact on operative volumes of both trainees and trainers. Trainees failed to increase their self-reported confidence in performing common gynaecology procedures over the pandemic period. AI grading of operative performance was shown to be a potential means of enhancing trainee feedback and reducing workload for trainers. tDCS was shown to decrease rates of excessive velocity events during novice laparoscopic training setting it out as a potential solution to maximise training opportunities. tDCS was not shown to enhance robotic surgical performance.

Conclusion

While the current training environment is challenging in operative gynaecology, potential solutions to augment and accelerate training exist. Further study is required to assess the best means of implementing these solutions to ensure continued access to high quality surgical training.

Dedication

To Declan for your unending support in everything

I will always be indebted to the constant support and encouragement of my supervisor and mentor Prof. Barry O Reilly.

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Chapter 1: Introduction

1.1 Background

Obstetrics and gynaecology is the medical specialty concerned with the provision of medical and surgical care to women during pregnancy (obstetrics) and outside of pregnancy (gynaecology) throughout their lifespan. It is a broad specialty encompassing a wide range of medical interventions and procedures which trainees must gain competence in prior to graduation as specialist doctors. Trainees in obstetrics and gynecology face unique challenges balancing the need to develop both obstetrics and gynaecology skills. In contrast, trainees in other surgical specialties have a more focused scope of practice. The often-competing interests of a busy obstetric service and gynaecology care proves a challenging training landscape. Many trainees find this difficult to navigate when starting out in obstetrics and gynaecology training. Studies have shown that increasing obstetric activity in a unit comes at the detriment to gynaecology training leading to service provision at the expense of training.(1)

Medical training, specifically procedural based specialties, face significant challenges in ensuring that trainees develop adequate skills to begin to practice independently. The volume and complexity of surgical procedures performed has developed dramatically globally over the last 30 years. We now care for older, sicker, more complex patients than at any other point in surgical practice. The rapid expansion and variety of surgical procedures performed mandates that we continue to train expert surgeons to a high standard.

The training environment is currently quite challenging at present for both trainers and trainees. Several challenges have been highlighted in the surgical training environment: reduction in procedure volumes, increase in procedure complexity, increase in trainee numbers and a reduction in trainee working hours.

Trainee numbers in obstetrics and gynaecology have significantly increased in Ireland over the last decade. The Royal College of Physicians in Ireland coordinate both the basic and higher specialist training programs. The number of trainees in the higher specialist training program has expanded from 33 in 2014 to 98 in 2022.(2) This expansion arises from a number of workforce planning reports which highlight Irelands relatively low number of consultants in obstetrics and gynaecology per capita.(3) At 0.09 per 1000 population in 2021, Ireland is 32nd from 34 countries in the OECD in terms of consultant numbers in obstetrics and gynaecology per capita.(4)

Consequently, training numbers and consultant post numbers have been expanded over the last decade. This has a significant impact on the availability of training opportunities for trainees on the higher specialist training scheme. Several new posts have been created in units which did not previously have specialist registrars (SpRs) in training. There has also been a significant expansion of trainee numbers in all units.(2) This dilutes the potential opportunities for training as access to theatre lists must be shared between a larger number of trainees than previously. This is particularly true for gynaecology as the majority of trainees will work in units which have a busy obstetric commitment. (2) Figure 1.1 below show the structure of maternity care provision in Ireland. Not featured are training locations in tertiary general hospitals in Dublin which provided gynaecology training for SpRs. These are St Vincent's University Hospital, The Mater Misericordia University Hospital, St James' Hospital and Connolly Hospital. These four units are the only SpR training allocations which do not also have an obstetric commitment. All obstetric units with the exception of St Luke's Hospital Kilkenny are approved training sites for SpR trainees.

Figure 1.1: Map of maternity units in Ireland (NPEC 2023)

Expansion of fellowship programs in Ireland have also had an impact on the training opportunities for higher specialist trainees. Overseas and post CSCST fellowship numbers have expanded.(5) These fellowships are largely in gynaecology and its subspecialties of urogynaecology, gynaeoncology, minimally invasive surgery and infertility. Therefore, this has impacted the access to training opportunities for trainees on the general obstetrics and gynaecology higher specialist training scheme as operative experience is preferentially given to those enrolled in fellowship programmes who are often overseas fellows who will take their experience home.

Since 2014 time spent in training has significantly reduced owing to the implementation of stricter controls on working hours.(6) The impact of reducing working hours in medical training has been seen globally. While there are undoubtedly benefits to patient safety, work-life balance, and trainee wellbeing; there has not been a consequent increase in training time to account for the loss of training opportunities.

In 2022, the Health Service Executive in Ireland agreed a new contract addendum with the Irish Medical Organisation (IMO). This has now capped shift length at 13 hours and placed strict controls on the number of consecutive days of working permitted.(7) This has caused a significant shift in working patterns with many units now adopting night shift patterns rather than traditional on call arrangements which existed previously. Trainees report fears that this will significantly impact on their access to training. This is particularly true for gynaecology training as much of the clinical activity on night shifts relates to acute obstetric care.

An informal survey caried out by the author at their workplace shows that three quarters of trainees surveyed feel that the proposed changes will not improve their quality of life or work-life balance. 83.3% of trainees surveyed reported that they felt their training would disimprove as a result of the proposed changes.

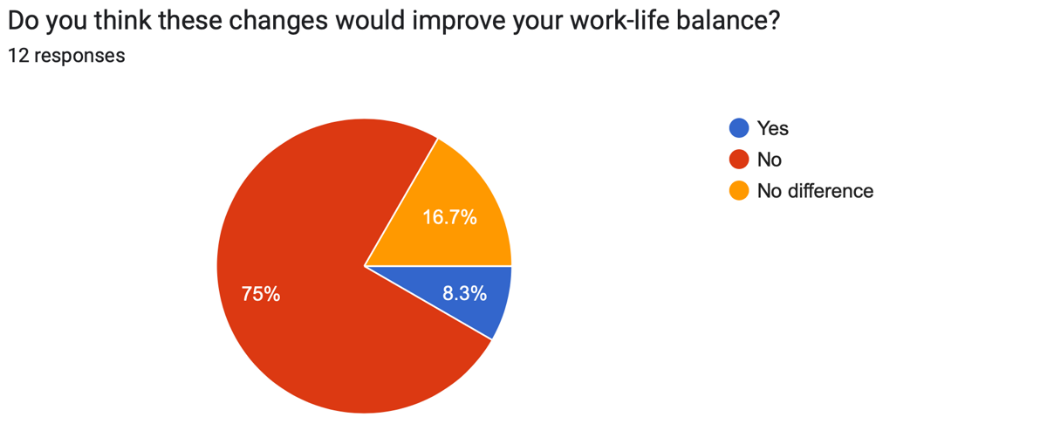

Figure 1.2: Workplace survey response on implementation of new working patterns

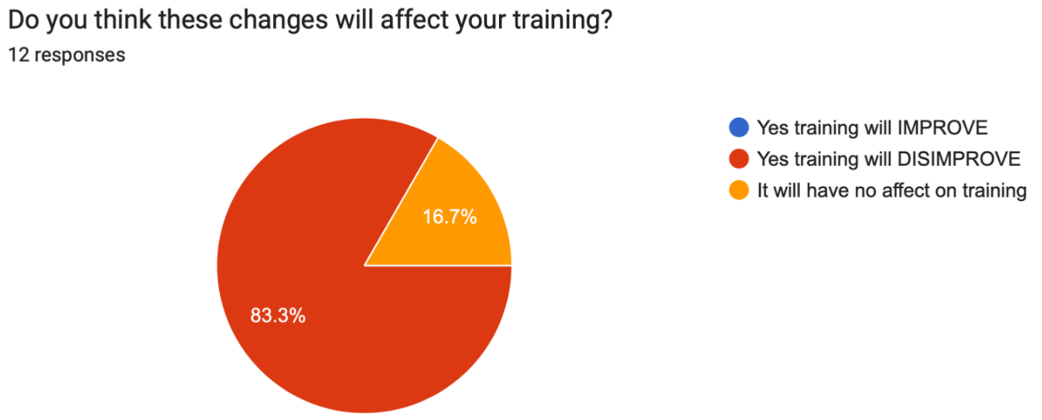

Figure 1.3: Workplace survey response on impact of new working patterns on training

The training environment in Ireland has been shown to have difficulties with recruitment and retention of medical trainees. Specifically in obstetrics and gynecology, it has been demonstrated that negative media outcomes, highly litigious practice environment and difficult working environment contribute to difficulties in recruitment and retention of specialist trainees in obstetrics and gynecology.(8,9)

Attrition rates from training in obstetrics and gynaecology have been reported to be up to 30%.(10) Negative media reports of the specialty have had an impact on this attrition rate. 86.7% of respondents to one survey reported that the media had a negative impact on those receiving care in obstetrics and gynaecology.(9)

The medicolegal environment also has been shown to have a negative impact on trainee's wellbeing and training choices. 54% of Irish trainees report being involved in a legal complaint. 71% of trainees have considered leaving the specialty and up to 35% consider this at least monthly. Nearly three quarters of trainee's report regretting choosing the specialty to some extent.(9)

In addition to these challenges, an increasing number of medical students are graduating from postgraduate programs in Ireland. In contrast to direct entry undergraduate students, postgraduate medical students in Ireland graduate at an older average age, are more likely to have children and more likely to seek flexible or part time training as a result.(11) This has a particular impact on trainees in obstetrics and gynaecology where 80% of trainees are female. Female trainees are significantly more likely to seek flexible or job-sharing training arrangements further prolonging the duration of their training.(2,3,11) This has a negative impact on recruitment and retention in obstetrics and gynaecology which is not perceived as a "lifestyle friendly" specialty by trainees.

1.2 Medical training

Here I will provide an overview and comparison of the training structure of postgraduate medical education in gynaecology in a variety of comparable international training environments. The purpose of this is to outline the differences and potential alternative approaches which could be adopted in Ireland. This information will inform the studies which we undertake examining trainee preferences, experiences in training and proposed solutions for the training challenges in Ireland at present.

1.2.1 Overview

There is a great variety in the structure of specialty training programs globally. While the majority are structured similarly, the duration of training, expected surgical volumes, access to subspecialty training, and the methods of competence assessment vary internationally. Outlined below are a variety of training programs in the English speaking developed world in which Irish trainees often access training. The wide variety of programme structures can be clearly seen. It remains unclear what method of assessment and duration of training is optimal for the development of high-quality gynaecology surgeons.

1.2.2 Ireland

Medical training in Ireland can be entered either as an undergraduate or postgraduate. Primary medical degrees range from four-year postgraduate degrees to six-year undergraduate degrees. Following completion of medical school, graduates must complete a mandatory internship which lasts 12 months and generally comprises of six months of medical training and six months of surgical training prior to full registration with the medical council.(12) After internship, doctors may apply to formalized training schemes in a variety of medical specialties. These range from four-year General Practice specialty training to eight-year specialist training programs in medical and surgical subspecialities. (13,14)

Training in obstetrics and gynecology in Ireland comprises of a three-year basic specialty training program following which there is a competitive application process to a five-year higher specialist training program.(13,15) In total, medical school graduates must spend a minimum of nine years in training prior to obtaining a certificate of satisfactory completion of specialist training (CSCST) in obstetrics and gynaecology. Including medical school, the minimum time in training to become an obstetrics and gynaecology consultant is thirteen years. This does not account for intercalated research degrees, fellowship training or other appointments which are often undertaken to improve skills or competitiveness for consultant posts. Trainees complete this training by rotating through a number of posts in twenty-three of the units which provide obstetric and gynecological care in Ireland.

Figure 1.4: Structure of the Royal College of Physicians in Ireland Specialist training programme in obstetrics and gynaecology (RCPI, 2017)

Following completion of the eight-year specialist training program and obstetrics and gynaecology many trainees opt to undertake subspecialty fellowships or a higher research degree program to improve their academic or clinical skills in order to prepare further for independent consultant practice. Current trainees are only permitted to take out of program clinical experience (OPCE) once they have completed three years of the higher specialist training program.(14)

1.2.3 United Kingdom

Following completion of medical school trainees in the United Kingdom must complete a two-year foundation program rotating through a variety of medical subspecialties. The obstetrics and gynecology training program, under the supervision of the Royal College of Obstetricians and Gynecologists (RCOG), is a seven-year run-through scheme. Following completion of five years of core training trainees in the UK in the United Kingdom may opt to undertake subspecialty training or advanced training skills modules in a variety of subspecialty areas of obstetrics and gynecology training. These advanced training skills modules (ATSMs) are offered in a variety of specialty areas of interest including areas such as advanced labour ward practice, high risk pregnancy, infertility, benign gynaecology and urogynaecology.

Subspeciality training may also be incorporated into the final two years of the RCOG training programme. This contrasts with Ireland where subspeciality training must be undertaken as an out of programme experience or following award of a certificate of satisfactory completion of specialist training. Trainees in Ireland can receive a maximum of 1 year incremental credit for out of programme experience and they must finish in a general Obstetrics and Gynaecology job in Ireland for their final 6 months of training.(14) RCOG subspeciality training allows for the development of skills in areas such as urogynaecology, fetal medicine, maternal medicine or gynaeoncology. Trainees undertaking subspeciality training aim to focus their consultant practice on these areas of obstetrics and gynaecology and require additional training to meet the technical and organisational demands of subspeciality practice.

Exit from the training program and the award of a certificate of satisfactory completion of specialist training is determined by the annual review of competence progression process. Trainees who satisfy the curriculum requirements including the completion of advance training modules or subspeciality training will be issued with a certificate of completion of training which allows progression to independent consultant practice.(16)

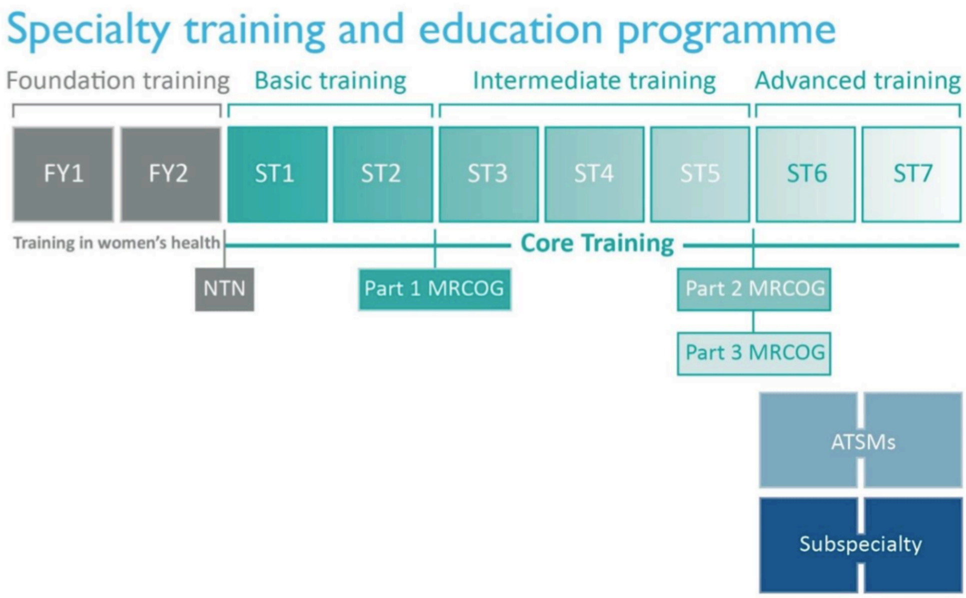

Figure 1.5: Royal College of Obstetrics and Gynaecology specialty training programme (RCOG 2023)

1.2.4 Australia and New Zealand

The Royal Australian and New Zealand College of Obstetrics and Gynaecology (RANZCOG) provide the training accreditation for trainees in obstetrics and gynaecology in Australia and New Zealand. Similar to the United Kingdom, following completion of medical school and two years of postgraduate training medical trainees may apply for a six-year run through training scheme. The RANZCOG obstetrics and gynecology training program consists of a four-year basic training Scheme followed by two years of advanced training. This advanced training can again be in a number of subspeciality areas of obstetrics and gynaecology. Many trainees go on to complete subspeciality fellowships in five approved areas accredited by RANZCOG. These areas are gynaeoncology, maternal/fetal medicine, gynaecology ultrasound, reproductive endocrinology and infertility, and urogynaecology.(17) Final assessment involved the completion of a written and workplace based assessments. RANZCOG approved fellowships conclude in the awarding of a certificate of completion of subspecialist training in the relevant practice area (e.g. Certificate of urogynaecology (CU))

1.2.5 North America

In North America entry to medical school training is entirely postgraduate. An appropriate undergraduate degree is required for admission. Following completion of medical school, graduates compete through a competitive matching program for residency posts.(18) Obstetrics and Gynaecology residency is four years in duration. Graduates from North American residency programs who wish to pursue a subspeciality practice often pursue formalised fellowship programs accredited by the American College of Obstetricians and Gynaecologists (ACOG) in subspecialty areas of obstetric or gynaecology practice such as urogynecology, minimally invasive gynecological surgery (MIGS) or gynaeoncology. In recent years there has been increasing evidence of a reduction of skill levels, particularly in gynaecology, in residents graduating from their residency programs. (19,20) Weekly hours worked in residency training are capped at 80-hours per week. This is significantly higher than weekly hours compliant with the European Working Time Directive therefore allowing a shorter time in specialist training.

1.2.5 Summary

In summary, there are a variety of approaches to becoming a specialist in obstetrics and gynaecology worldwide. On average the minimum duration of postgraduate training varies from four years to nine years depending on the jurisdiction of training. Outside of Ireland, most jurisdictions allow for the inclusion of specialist training into the final years of training before independent practice.

Table 1.1: Comparison of specialist training in various jurisdictions

Location	Medical school	Specialist training	Subspecialist training	Minimum duration (from medical school graduation)	Minimum duration (including medical school)
Ireland	• Undergraduate ○ 5-6 years • Postgraduate ○ Primary degree 3-4 years ○ Medical degree 4 years	• Intern year ○ 1 year • Basic Specialist training ○ 3 years • Higher Specialist Training ○ 5 years	• 2-3 years depending on speciality • Only 1 year can count towards specialist training • Can not exit program in subspeciality training	• General obstetrician and gynaecologist ○ 9 years • Subspecialist ○ 11 years	• General obstetrician and gynaecologist ○ 13 years • Subspecialist ○ 15 years
United Kingdom	• Undergraduate ○ 5-6 years • Postgraduate ○ Primary degree 3-4 years ○ Medical degree 4 years	• Foundation programme ○ 2 years • Specialist training ○ 7 years	• Incorporated into specialist training programme ○ Competitive application process ○ 2-3 years	• General obstetrician and gynaecologist ○ 9 years • Subspecialist ○ 9 years	• General obstetrician and gynaecologist ○ 13 years • Subspecialist ○ 13 years

Australia and New Zealand	• Undergraduate ○ 5-6 years • Postgraduate ○ Primary degree 3-4 years ○ Medical degree 4 years	• Postgraduate medical training ○ 2 years • Specialist training ○ 6 years	• Incorporated into specialist training programme ○ Competitive application process ○ 2-3 years	• General obstetrician and gynaecologist ○ 8 years • Subspecialist ○ 8 years	• General obstetrician and gynaecologist ○ 12 years • Subspecialist ○ 12 years
North America	• Postgraduate ○ Primary degree 3-4 years ○ Medical degree 4 years	• Residency ○ 4 years	• 2-3 years depending on speciality	• General obstetrician and gynaecologist ○ 4 years • Subspecialist ○ 6 years	• General obstetrician and gynaecologist ○ 8 years • Subspecialist ○ 10 years

1.3 Training in surgery

There are significant challenges facing modern surgical trainees and trainers. The number of surgical trainees has risen significantly.(21,22) This has long been recommended by many workforce planning reports and is required to meet a growing population's need for expert surgical care.(3) It does however, dilute the potential training opportunities available to surgical trainees. This expansion in training numbers demands innovative solutions to provide equivalent training outcomes for these trainees which has been difficult to achieve to date.

The European Working Time Directive (EWTD) has also had an impact on the training of surgical trainees. The reduction in working hours, while very welcome in terms of patient safety and doctor well-being, has had an impact on the time spent operating prior to independent practice as a consultant.(23) Although most surgical training posts do not comply with EWTD regulations and many surgical trainees continue to work onerous shift patterns, working hours have reduced when assessed globally.(6) While trainees are generally able to adapt their work schedules to accommodate elective operating lists, the global reduction in working hours further dilutes potential for training opportunities. As highlighted above, the move towards night shift patterns of work as opposed to traditional "on-call" arrangements has a negative impact on the ability of trainees to adapt their working patterns to avoid missing training opportunities in gynaecology.

Current models of surgical training rely primarily on trainees performing a certain number of surgical procedures under direct supervision and having their mentor or dedicated trainer sign off their competence using some form of structured assessment. When training is undertaken as part of a training program there is often oversight from national training bodies which base their assessments on the trainee logbooks and feedback from nominated trainers.(14)

In some jurisdictions there has been a move towards outcome-based assessment which does not predefine a specific number of required procedures but sets a minimum standard of skill required to be considered competent. Workplace based assessments and completion of structured assessments of technical and non-technical skills form the basis of assessment.(24) Training bodies do continue to set out a minimum duration of training and minimum procedure numbers for core procedures therefore training cannot usually be accelerated for trainees who meet their competencies earlier in training. The variable and rotational nature of training in Ireland gives rise to challenges in ensuring equal access to training opportunities. Some trainees may be fortunate to rotate through posts which have greater access to gynaecology training than others. This makes outcome-based assessment a challenge as it may be difficult to gain the required experience to develop and prove their competence particularly in gynaecology.

1.4 Surgical training in gynaecology in Ireland

Surgical training in gynaecology is based on the Higher Specialist Training (HST) curriculum which is developed and overseen by the Royal College of Physicians in Ireland and the Institute of Obstetricians and Gynaecologists.(14) This curriculum sets out the expected standard required for a trainee to exit the training program. With respect to surgical training, the curriculum sets out the minimum expected number of procedures performed in a variety of gynaecology procedures. Regarding the commonly performed major gynecological procedures, trainees are expected to perform a minimum of ten operative laparoscopies, five total abdominal hysterectomies, five vaginal hysterectomies, ten ovarian cystectomies and ten pelvic floor repairs. These are the minimum numbers expected to be performed and training is assessed based on the use of objective structured assessments of training (OSATS) in combination with feedback from nominated consultant trainers. This method of assessment is undertaken by the trainees' nominated trainer following direct observation of the trainee undertaking a procedure. These numbers appear to be determined arbitrarily as the learning curve required for safe and independent performance of many of these surgical skills is greater than the minimum training programme requirements. Studies show that outcomes are better with high volume surgeons and that the learning curve for hysterectomy in terms of operating time and blood loss plateaus at approximately 15 cases.(25,26) Training is also assessed by the completion of objective structured assessments of training in surgery (OSATS).

Allocation of trainees to posts is performed by the National Specialty Directors (NSDs) who coordinate and supervise the higher specialist training program.(27) Allocation of trainees to specific trainers is performed by the individual hospital units. Therefore, it is possible that a trainee would move through the training programme without being allocated to a trainer who has a high-volume gynaecology practice. Not all consultant trainers practice gynaecology and many Maternal and Fetal Medicine subspecialists have no gynaecology commitment at all. It is less common for a gynaecology subspecialist to have no obstetric commitment as most continue to provide acute obstetric cover on call. A small number of specialists in Ireland working in gynaeoncology and complex benign gynaecology have no obstetric commitment and work solely in gynaecology units, typically in large tertiary general hospitals.(3) A recent study shows that gynaecology trainees perform significantly worse than equivalent general surgical trainee on all aspects of basic laparoscopic skills. This perhaps underlines the need to adapt our training programs to enhance the acquisition of core surgical skills at an earlier career point.(28)

1.5 Impact of the coronavirus pandemic on surgical training

In the last three years, we have also seen the unique challenges that the Coronavirus pandemic imposed on surgical training. The almost complete cessation of elective surgical procedures in many areas for much of this time has had a huge impact on surgical training.(29,30) The pandemic has exposed a weakness in our training models which do not allow for rapid access to high fidelity simulation as a means of offsetting the reduced access to hands-on operative training time.(31) In other high performance fields, such as aviation, simulation training intensified significantly during the pandemic to account for this shortfall.(32) Many trainees in advanced or subspecialty training have been forced to extend their training to accommodate this lack of clinical exposure.(33) This was particularly true in areas of benign gynaecology, where there was almost a complete cessation of elective surgical work during the initial phase of the pandemic. In the United Kingdom, urogynaecology trainees reported significant difficulties in completing the ATSM and subspeciality training modules, often requiring extensions to training duration.(33) As we move into a post-pandemic era, it remains urgently necessary to enhance and develop access to surgical simulation training to allow the continued development of surgical skills in the face of future crises.

1.6 Potential solutions

In the following section I will outline potential solutions to improve or enhance the provision of high-quality training in surgical gynaecology. Using these proposed solutions, we have developed a series of studies to assess their potential impact which forms the basis for this thesis.

1.6.1 Simulation

Simulation has the potential to bridge the gap of the many challenges facing modern surgical trainees. High fidelity simulation training has been widely adopted in many industries. The ability to rehearse surgical techniques in a risk-free environment is invaluable to trainees. Unfortunately access to surgical simulation facilities remains limited for many surgical trainees. Lack of standardisation of simulation techniques, methods and equipment also impacts on this.(34,35)

The welcome formation of surgical simulation centres in many universities both nationally and internationally has provided access to this type of training.(36–38) National training bodies and individual surgical training schemes should provide frequent access to this type of training for their trainees. Currently the majority simulation training takes place during a limited number of mandatory courses for senior trainees.(14) Early and frequent access to surgical simulation could improve trainees learning from early in their careers.(39,40)

In May 2021 the Royal College of Obstetricians and Gynaecologists released a “Training Recovery Plan” for gynaecological surgical training in the United Kingdom.(33) This plan heavily stresses the importance of formal simulation training programs for trainees that are integrated on a local and national level. It discussed the importance of hands -on simulation training days but also of at-home access to laparoscopic simulation outside of formal simulation training days.

The lack of ubiquitous access to surgical simulation, particularly for the early phase surgical trainees, has been identified as a barrier to surgical training internationally.(41) Trainees need regular access to surgical simulation to build the coordination and skill required to perform begin to perform surgical procedures under direct supervision. These skills were traditionally developed using box trainers as seen in figure 1.6.

Figure 1.6 Laparoscopic box trainer (Laparo 2023)

These low fidelity models provide basic skills tasks which allows trainees to develop the coordination required to progress their surgical skill. Evidence shows that the skills formed during these surgical simulation sessions are transferable to the operating room and provide trainees with the confidence to begin to practice under direct supervision.(42)

Basic skills programs form the basis of many surgical skill training programs globally. Perhaps the most well-known, is the fundamentals of laparoscopic surgery (FLS) programme which is a validated educational programme for the development of the type of basic laparoscopic skills required to begin in vivo laparoscopic training.(43) A number of training programmes mandate these type of basic skills programs prior to trainees being eligible to commence direct patient contact.

The assessment of the development of these basic surgical skills is primarily graded subjectively by expert trainers who observe the trainees performing a variety of surgical skills tasks in a simulated training environment. This gives trainees direct feedback and allows time for coaching and mentorship. However, this method of assessment provides little objective evidence of improvement over time as the grading is based solely on subjective assessment by expert observers.(44) Potential solutions to this challenge are outlined below.

There are a variety of other types of simulation training which are effective at developing surgical skills which can then be applied in patient contact. For a significant period of time surgical skills were developed in cadaveric training. This type of training allows for the safe development of surgical skills without exposing live patients to operative risk. The drawback with cadaveric training is its limited availability and the expense involved in maintaining a cadaveric donation program.(45) The use of cadaveric training is now predominantly reserved for the development of complex surgical skills through well-structured training programs such as the Anatomy of Complications Workshop.(46)

Animal models have also been developed for certain procedure types and the use of live anaesthetised or recently euthanised porcine models is common in surgical simulation centres globally. For example a recent paper describes a poultry model for simulation of robotic assisted laparoscopic sacrocolpopexy.(47)

1.6.2 Automated performance assessment

Artificial intelligence (AI) or machine learning is having impacts in many areas of our lives. It allows for automation and in-depth analysis on large volumes of data. It has the potential to influence how we review and assess surgical performance. A number of studies have shown the potential application of AI to surgical practice.(48,49) A recent review by Garrow et al. examined the various applications of machine learning techniques for phase segmentation of surgical videos.(50) It is possible to teach a machine to interpret surgical video and break it down into predefined surgical steps. This has been employed for commonly performed general surgical procedures such as laparoscopic cholecystectomy and appendicectomy. The phase segmentation allows reviewers to quickly review key components or technically challenging aspects of the surgical procedure. For example, ligation of the cystic duct at the time of cholecystectomy. This phase segmentation also allows surgical trainees to easily review their surgical performance and identify anomalies or difficult steps.(51)

The reason that these techniques have predominantly been applied to laparoscopic cholecystectomy procedures is that large publicly available video databases exist for this procedure. These were created with the intention of allowing deep machine learning techniques to analyse surgical video.(52) No such public dataset exists at present for gynaecology procedures such as laparoscopic hysterectomy.

Companies such as Touch Surgery provide intraoperative recording solutions for laparoscopic and robotic procedures.(53) Some surgical units have adopted a policy of recording all procedures which allows for their use in training and education, complication review and performance improvement. As these large datasets of surgical video begin to be created, the expansion of AI analysis and insights will likely begin to be incorporated into our routine surgical practice.

Phase segmentation has been achieved using techniques such as instrument recognition. The AI algorithm can identify and differentiate between laparoscopic surgical instruments which are used for specific steps in the procedure. The algorithm can then segment video based on the presence of these instruments. For example, the presence of a clip applicator during a laparoscopic cholecystectomy may indicate that the surgical step being performed is the clipping of the cystic duct.

Surgical video can also be analysed by artificial neural networks which identify changes in colour, texture and environment to identify structures and intraoperative events. With a large enough dataset this allows for interpretation of surgical video and segmentation of surgical steps. It may also allow identification of bleeding events and other complications.(50,54,55)

A number of commercially available platforms have adopted these techniques for a limited number of surgical procedures and it is possible to generate a surgical performance reports for trainees within these platforms.(53)

Real time integration of AI techniques into laparoscopic and robotic surgery has not yet been achieved. AI interpretation of live surgical video for the purposes of identifying anatomical structures and improving safety has been proposed. A number of proof-of-concept papers have examined this with successful procedural step and anatomical structure identification.(56)

A further limitation of these AI techniques is that they cannot be applied globally to any surgical technique. The algorithm must be developed specifically to assess a particular surgical procedure and without easy access to large volumes of surgical video and a standardised recording technique its application to open or vaginal surgery is limited at present. Video capture and analysis is more challenging for open or vaginal procures due to the lack of an established video feed or standardised positioning of a camera compared with laparoscopic procedures. This may limit the application of AI to open or vaginal gynaecology procedures in future.

Further applications of AI and machine learning lie in the use of analytic surgical simulators to assess a trainees performance based on predefined metrics for a particular task. We identified the Laparo analytic system as a novel means of assessing surgical performance. This system is a box trainer similar to other basic skills trainers however the laparoscopic ports have custom inbuilt analytic sensors which allow trainees to review the movement of their instruments as they complete the assigned task.(57)

Figure 1.7: Laparo analytic system (Laparo 2023)

The analytic system provides large volumes of data on instrument movement which allows for analysis of trainee performance and objective monitoring of improvement. Instrument movement can be assessed based on acceleration, velocity, jerk, and total distance traveled. Other metrics such as clamp count and instrument visibility also provide valuable insight into performance.

Working through the predefined Basic Surgical Skills programme allows trainees to review their performance over time and see the quantitative improvement in their performance.

We felt that this in-depth analysis of a surgical trainee's performance would provide valuable feedback to the trainee as they developed their skills. For this reason, we incorporated the Laparo analytic system into our study protocols as described below.

1.6.3 Remote proctoring and mentorship

Trainees and novice surgeons may often find it difficult to obtain supervision and feedback during simulation practice. Owing to the often busy clinical practice of consultant supervisors, time to supervise simulation training is not guaranteed. Platforms to allow for augmented reality telepresence to provide remote mentorship have been developed, such as Proxime.(58) These platforms allow for trainers to remotely observe a trainees' laparoscopic simulation sessions, by linking to the camera feed of the box trainer, and to provide real time feedback. These platforms have also been integrated in operating theatres to allow for remote intraoperative consultation with expert surgeons to help overcome operative challenges when encountered and to provide real time training for novice surgeons.(59)

1.6.4 Transcranial direct current stimulation

Arising from a collaboration with the sports science group LERO in University of Limerick we identified transcranial direct current stimulation (tDCS) as a potential means of enhancing surgical performance. tDCS is a neuromodulatory technique which involves passing a low amplitude current over a targeted cortical area of a user's scalp. First described in 1964, tDCS has been used to enhance motor function and performance in several areas.(60–62) Initially arising from studies in neuroscience tDCS was shown to enhance the acquisition and retention of complex motor skills. (63)

Cortical targets for the application of tDCS vary by the intended benefit. The M1 motor cortex is a typical target employed in neuromodulation of complex motor tasks.(64) tDCS has also been applied to the dorsolateral prefrontal cortex which has functions of executive and motor planning of complex motor tasks.(65) Other applications of tDCS include treatment of mild major depressive disorder.(66)

Evidence for the application of tDCS to motor tasks exists particularly in the domain of sports science. Studies have shown the that the application of tDCS can improve sprint cycling speeds, golf swing technique, target acquisition in competitive video gaming and piano performance accuracy. (67–69)

We felt that tDCS could be applied to enhance the performance and skill acquisition of surgical trainees. We particularly wished to focus on novice trainees who were beginning the development of their surgical skills. We hoped that tDCS would allow more rapid acquisition and retention of surgical skills for those starting their surgical careers. Owing to the training challenges in surgical gynaecology outlined above, it was hoped that tDCS would allow trainees to maximise their training opportunities and feel more confident when entering the operating room for the first time.

1.7 Proposed research

In this thesis my intention is to set out the current challenges facing surgical trainees in operative gynaecology in Ireland. The aim of this body of work is to identify current barriers to good surgical training in Ireland and to examine the application of potential solutions to enhance training.

In the first study which we undertook (Chapter 2), we performed a cross-sectional survey of all higher specialist trainees in obstetrics and gynecology in Ireland examining their current surgical abilities, their opinions on the training challenges they face and their suggestions for potential means to improve in surgical training in gynaecology. This study built on data from training surveys in 2014 and 2017.

The second study (Chapter 3) assessed specifically the challenges relating to the COVID-19 pandemic for surgical trainees in Ireland. This was a unique uniquely challenging time in surgical training as outlined above. We again performed a national cross-sectional survey to assess the impact of the coronavirus pandemic on surgical training in gynecology.

Our third study (Chapter 4) involved the application of the Laparo analytic system to basic laparoscopic skills training. We compared the use automated means of assessment with assessment by expert reviewers. The aim was to examine if novice surgeons could be accurately assessed by AI analytics.

Our fourth and fifth studies (Chapter 5 and 6) involved two double-blind randomised controlled trials assessing the use of M1 motor cortex tDCS stimulation compared to a sham stimulation to enhance the acquisition and retention of basic laparoscopic and robotic surgical skills. The application of the advanced analytic system during basic laparoscopic and robotic skills training combined with the application of tDCS allowed valuable insights to be drawn regarding the impact of tDCS on surgical learning.

Chapter 2: A National Survey of Gynaecological Surgical Training: 2014-2021

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2.1 Introduction

Over the last decade barriers to surgical training have been identified internationally in a wide variety of surgical specialties including gynaecology. These barriers include reduced access to supervised operating time during training (71), increasing medical complexity of the major surgical procedures being performed(72,73), increasing numbers of trainees (23) and a reduction in working hours since the introduction of the European Work Time Directive (EWTD) (6). These challenges in accessing surgical training have been further compounded by the coronavirus pandemic in the last two years (29,31). Increasingly, common gynaecological presentations which may previously have required major surgery can now be managed medically or with minor surgical procedures, further reducing access to training opportunities particularly for major surgical procedures in gynaecology (74,75). For example, the introduction of hormonal intrauterine devices have greatly reduced the numbers of hysterectomies and laparoscopic tubal ligations performed over time (76).

Despite these challenges, national training bodies have a responsibility to continue to provide high quality training to trainees in gynaecology to continue to meet the increasing volume and complexity of patients requiring gynaecological care. In 2021, The Royal College of Obstetrics and Gynaecology in the United Kingdom published a recovery plan for gynaecology surgical training (33). This recovery plan was prompted by the rapid decrease in training opportunities as a result of the coronavirus pandemic, although it also highlighted ongoing challenges in the provision of high-quality gynaecology training. It emphasized the importance of simulation training and prioritisation of a trainee's access to surgical lists with a designated trainer.(33)

In Ireland, the Royal College of Physicians of Ireland's (RCPI) training programme in Obstetrics and Gynaecology is divided into a three year basic training scheme and a five year higher specialist training scheme.(14) Trainees are required to keep a logbook of their training activities, complete Objective Structures Assessments of Technical Skills (OSATS) with their named trainer and attend a variety of mandatory courses in order to progress through the training programme. Progress through the training programme is assessed annually through logbook review with the national speciality directors. Most training posts combine responsibilities in both obstetrics and gynaecology. Trainees in obstetrics and gynaecology often report difficulty in accessing training opportunities in gynaecology (1,77). The dual nature of the speciality makes accessing gynaecology experience for trainees more difficult, owing to the competing nature of an often busy obstetric service. (1)(78)

The most recent Irish consultant workforce reports show that there are 3.6 consultants in Obstetrics and Gynaecology per 100,000 population(3). The report also estimated that to provide a service compliant with the EWTD would require 4.9 consultants per 100,000 population. (3) This shortfall underlines the importance of the continued provision of high-quality training to provide expanded consultant numbers.

As a result of the identified shortfall in practising consultants, the number of trainees enrolled on the Royal College of Physicians of Ireland's (RCPI) Higher Specialist Training Programme (HST) in Obstetrics and Gynaecology has expanded. Numbers have increased from approximately 50 trainees enrolled in 2012 to approximately 100 enrolled in 2022 (14). Increasing rates of flexible and part-time training have also been a feature of training in the last decade. Studies have highlighted an ongoing demand for less than full time training which poses additional challenges in ensuring the development of surgical competence by the end of the training programme. (11)

A number of previous studies have addressed the issue of trainees' surgical confidence in gynaecology and a variety of other surgical specialities.(1,77,79–82) These studies tend to offer a single snapshot of trainees' confidence in performing a variety of common surgical procedures. None of these studies assessed potential solutions to challenges in surgical training. A 2016 systematic review of studies reporting on surgical trainees' confidence found that confidence was lower than historical controls.(83)

We identified only one research group who undertook repeat surveys to assess trainees' confidence over time. Fonseca et al. reported on general surgical residents' confidence in 2011 and again in 2014. They showed a decreased in self-reported confidence for independent practice from 72% to 52%.(84,85) We did not identify any repeated surveys with respect to gynaecology surgical training making this a novel study design.

This study was a national cross-sectional survey of both trainees and trainers on the RCPI Higher Specialist Training Programme (HST) in Obstetrics and Gynaecology. We designed a survey which aimed to identify trends in gynaecology surgical training over the eight-year period studied and also to identify barriers to adequate surgical training. We also aimed to assess both trainer's and trainee's perceptions of gynaecological surgical training in Ireland, to identify confidence levels and challenges and to highlight potential areas for future improvement in gynaecology training.

2.2 Materials and Methods

A survey was developed and distributed to all trainees registered with the Royal College of Physicians of Ireland's (RCPI) Higher Specialist Training Programme (HST) in Obstetrics and Gynaecology (see appendix 1). The development of the survey was following a review of previously published surveys assessing trainee confidence in gynaecology and other surgical specialities. (1,77,79,81) Additional questions regarding barriers to training and potential means to improve training were added to address our study aim. This survey was distributed at 3 time points: in 2014, 2017 and in 2021. It consisted of 44 questions relating to the participant's training in gynaecology including participant demographics, self-reported ability to perform a variety of common gynaecological surgical procedures, training experience to date and training expectations by the end of the training programme. Participant's opinions on barriers to training and suggestions to improve the training programme were also sought. These data were captured using multiple choice questions, Likert scale responses and free text where appropriate. Participation was voluntary and the responses were anonymised.

In addition, a separate survey was developed and distributed to Consultant Trainers on the HST programme (see appendix 2). This survey was distributed in 2017 and 2021. It consisted of 53 questions relating to participant demographics, clinical practice, experience providing training, their current trainee's ability to perform a variety of common gynaecological surgical procedures and the trainer's expectations of their trainee's ability by the end of the training programme. Participant's opinions on barriers to training and suggestions to improve the training programme were also sought. These data were captured using multiple choice questions, Likert scale responses and free text where appropriate. Participation was voluntary and the responses were anonymised.

Surveys were distributed electronically on the SurveyMonkey (San Mateo, Ca, USA) platform through the RCPI obstetrics and gynaecology mailing list (86). The survey was distributed as part of routine communication from RCPI to trainees and trainers. All members of this mailing list had provided prior consent to contact for the purpose of distribution of research and educational resources.

Data are reported as simple descriptive statistics where appropriate. The Chi-squared test was used to compare categorical variables. Statistical significance was considered to be reached where $p<0.05$. Statistical analysis was performed using IBM SPSS version 27.

Thematic analysis was performed on free text responses to open questions.(87) The primary author reviewed responses generated initial codes for the data. The primary author then identified the initial themes, a co-author reviewed these and agreed with the themes included in the final analysis.

2.3 Results

2.3.1 Questionnaire responses

In total 174 individual anonymous questionnaire responses were collected across the three time points surveyed. 98 were trainee responses and 75 were trainer responses. The trainee questionnaire response rate was 44.1%. The trainer questionnaire response rate was 43.6%.

2.3.2 Trainee demographics

Table 2.1 outlines the demographic details of trainee participants. No significant differences in demographics were demonstrated across the three time points surveyed. Trainees reported a similar duration of training when they answered the survey across all groups (2014=7.3years±2.5, 2017=7.4years±2.8, 2021=7.2years±2.6). A similar proportion of senior trainees' (HST Year 4 or 5) responses were captured at each time point.

Table 2.1: Trainee demographics

Trainee demographics				
		2014 (n=22)	2017 (n=41)	2021 (n=35)
Age grouping	25-34	8	25	22
	35-44	14	16	13
Gender	Male	22.73%	21.9%	25.7%
	Female	77.27%	78.1%	74.3%
Years of experience in obstetrics and gynaecology	Mean ± 1 SD	7.3 ± 2.5	7.4 ± 2.8	7.2 ± 2.6
Average year of HST training	Mean ± 1 SD	3 ± 1.2	2.9 ± 1.2	2.8 ± 1.2
%Year 4 and 5		27.2%	26.8%	28.5%

2.3.3 Trainer demographics

Table 2.2 outlines the demographics of the consultant trainer participants. No significant differences were demonstrated between the two groups at either time point surveyed.

Table 2.2: Trainer demographics

Trainer demographics			
		2017 (n=40)	2021 (n=35)
Age grouping	35-44	8 (20%)	8 (22.9%)
	45-54	20 (50%)	17 (48.6%)
	55-64	12 (30%)	10 (28.5%)
Gender	Male	17 (42.5%)	15 (42.9%)
	Female	23 (57.5%)	20 (57.1%)
Years of experience as consultant trainer	Mean ± 1 SD	13.8±10.1	12.5±7.7
Subspecialty	Maternal/Fetal Medicine	8	8
	Gynae-oncology	4	2
	Urogynaecology	5	6
	Minimally Invasive surgery	10	8
	Paediatric gynaecology	0	1
	None/General Obstetrics and gynaecology	13	10
Practice type	Full time clinical	30	27
	Part time clinical	1	1

	Full time clinical and academic	9	7

2.3.4 Trainee experience

Table 2.3 outlines trainees' responses to the question "Can you currently perform the following procedures independently?". For operative hysteroscopy participants reported an increasing current ability across the study period however this increase was not statistically significant (40.9% vs 60.6%, χ^2=2.06, p=.15). For all other procedures, participants reported a reduction in current ability when comparing 2021 data with 2014 data. Significant reductions in current ability were seen with total abdominal hysterectomy (40.9% vs 15.2%, χ^2=4.61, p=.03) and vaginal hysterectomy (31.8% vs 12.1%, χ^2=4.58, p=.03)

Table 2.3 Trainee's current ability to perform procedures

	% 2014	% 2017	% 2021	% change (2014-2021)	p-valve (2014 vs. 2021)
Operative hysteroscopy	40.91	58.54	60.61	+19.7	.15
Laparoscopic salpingectomy	81.82	78.05	66.67	-15.15	.19
Laparoscopic ovarian cystectomy/oophorectomy	54.55	53.66	33.33	-21.22	.11
Total abdominal hysterectomy	40.91	31.71	15.15	-25.76	.03
Vaginal hysterectomy	31.82	24.39	12.12	-19.7	.03

Table 2.4 outlines trainees' responses to the question "Do you think you will be able to perform the following procedures independently by the end of your training?" For operative hysteroscopy participants reported an increase in expected ability across the study period however this increase was not statistically significant (72.7% vs 87.9%, χ^2=2.04, p=.15). For all other procedures, participants reported a reduction in expected ability when comparing 2021 data with 2014 data. The largest reduction in expected ability was seen with vaginal hysterectomy however this was not statistically significant (68.2% vs 54.6%, χ^2=2.08, p=.15).

Table 2.4 Trainees' expected ability by end of training

	% 2014	% 2017	% 2021	% change (2014-2021)	p-valve (2014 vs. 2021)
Operative hysteroscopy	72.73	78.05	87.88	+15.15	.15
Laparoscopic salpingectomy	100	100	93.94	-6.06	.75
Laparoscopic ovarian cystectomy/oophorectomy	95.45	95.12	87.88	-7.57	.33
Total abdominal hysterectomy	86.36	85.37	78.79	-7.57	.48
Vaginal hysterectomy	68.18	78.05	54.55	-13.63	.14

Figure 2.1 shows a comparison of senior trainees' (HST year 4 and 5) current and expected ability to perform total abdominal hysterectomy and vaginal hysterectomy. At all time

points, senior trainees reported a shortfall between their current ability and what they expect to achieve by the end of their training programme. In 2021, comparing current and expected ability, there was a 40% shortfall in ability to perform total abdominal hysterectomy (50% vs 90%, χ^2=3.80, p=.05) and a 50% shortfall in ability to perform vaginal hysterectomy (10% vs 60%, χ^2=5.49, p=.01).

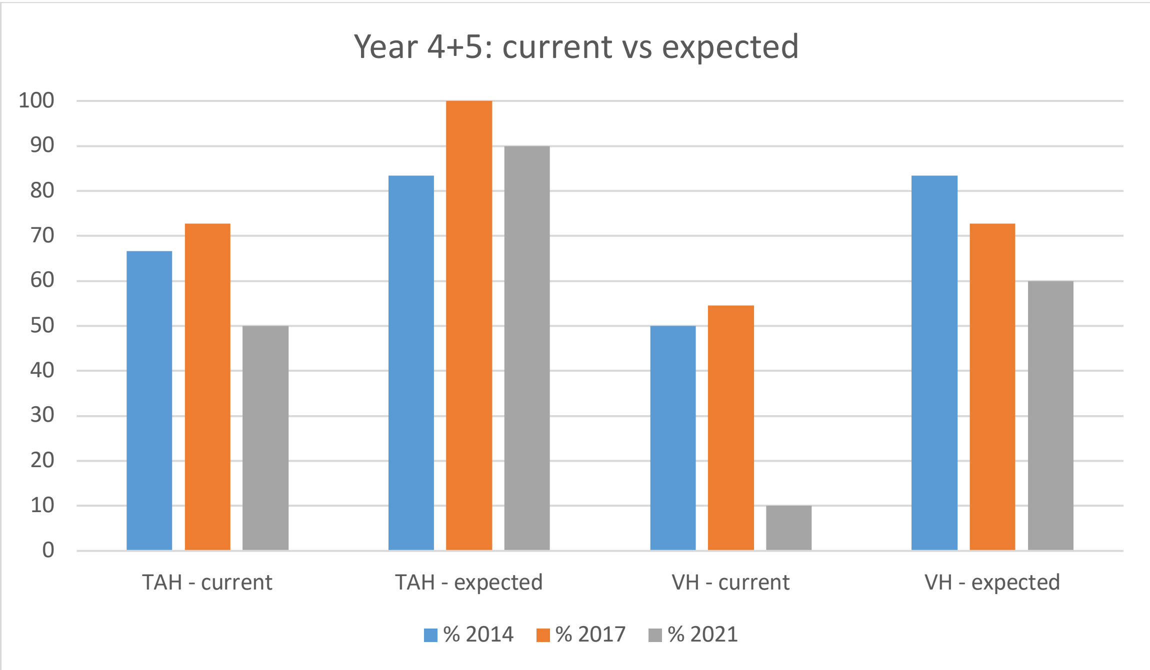

Figure 2.1: Year 4 and 5 trainees' current vs expected ability

Figure 2.2 shows trainee participants' responses to two Likert style questions asked as part of the 2021 survey. All participants (n=35) either disagreed or strongly disagreed with the statement that "gynaecology is given the time it requires in the training programme". A majority (n=22/35, 62.9%) agreed that they would not have enough exposure to gynaecology to practice as a consultant.

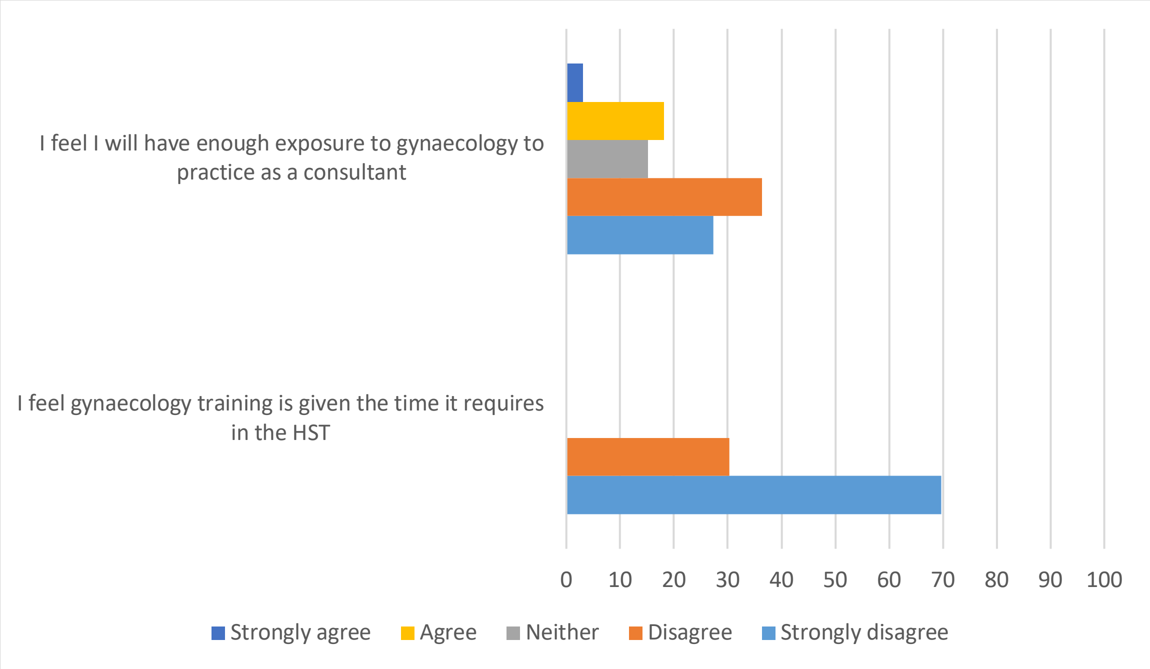

Figure 2.2 Trainee Likert responses to training quality question

2.3.5 Trainer experience

Tables 2.5 outlines trainers' perceptions of trainees' current ability. Instances where the trainer had not observed their trainee performing the surgical procedure were excluded. There were no significant differences between 2017 and 2021 with respect to trainers' perceptions of trainees' current ability.

Table 2.5 Trainers' perception of their trainees' current ability to perform procedures.

	% 2017	% 2021	% change (2017-2021)	p-Value
Operative hysteroscopy	58.8	60	+1.2	.94
Laparoscopic salpingectomy	56.25	72	+15.75	.29
Laparoscopic ovarian cystectomy/oophorectomy	20	33.33	+13.33	.37
Total abdominal hysterectomy	12.5	9.1	-3.4	.66
Vaginal hysterectomy	15.79	22.22	+6.43	.45

Tables 2.6 outlines trainers' perceptions of their trainee's ability by the end of the training programme. Participants were asked if they felt their trainee would be competent to perform a variety of procedures independently by the end of their training. Again, instances where the trainer had not observed the trainee performing the surgical procedure were excluded. For vaginal hysterectomy there was a statistically significant increase in the number of trainers who reported their trainee would be independent by the end of the training programme (20% vs 52.38%, χ^2=4.63, p=.03). No other statistically significant differences were observed.

Table 2.6 Trainer's perception of their trainees' ability to perform procedures by end of training programme.

	% 2017	% 2021	% change (2017-2021)	p-Value
Operative hysteroscopy	85	85.19	+0.19	0.95
Laparoscopic salpingectomy	89.47	92.31	+2.84	0.89
Laparoscopic ovarian cystectomy/oophorectomy	78.95	86.96	+8.01	0.59
Total abdominal hysterectomy	26.32	50	+23.68	0.11
Vaginal hysterectomy	20	52.38	+32.38	0.03

In the 2021 survey 74.3% (n=26/35) of trainee participants reported that surgical simulation courses could help improve their practice and training in gynaecology. Participants were asked to rank their preferred type of surgical training course from the following five options: Cadaveric, animal model, dry lab, online or lecture-based courses. Cadaveric simulation courses received the most first preferences (n=13) followed by dry lab simulation (n=10). Animal model and online courses each received 1 first preference. Lecture based courses received no first preference votes.

2.3.6 Qualitative analysis

Both trainees and trainers were asked an optional free text response question regarding improvements which could be made to gynaecology training. Thematic analysis of trainees' and trainers' responses identified 3 common themes: Improvement in dedicated access to the operating theatre (n=27/135, 20%), increasing simulation training (n=18/135, 13.3%) and subspecialisation in gynaecology near the end of training (n=14/135, 10.3%).

Table 2.7: Suggested improvements in training, by theme

Theme	Participant quotes
Access to operating theatre	"Ensure adequate theatre time and avoid missing theatre due to pre/post call sessions" - Trainer "Protected operating time - most lists are interrupted with registrar having to do emergency sections and losing out on main list" - Trainee "Maintain regular theatre sessions with willing trainers over service sessions" - Trainee
Increase simulation training	"Add 2 hours per week of simulation training to each trainees week " - Trainer "Little attention focussed on clinical skills simulated training currently" - Trainee "We will need to invest more in simulated surgical skills training" - Trainer
Subspecialisation in training	"I believe that the scheme in the final years should become more focused on

	subspeciality. Maybe even dividing it into gynaecology and obstetrics." - Trainee "Gynaecologists with sub speciality should be encouraged" - Trainer "Split speciality after year 3 if you want to focus on gynae" - Trainee

Theme 1: Improvement in dedicated access to the operating theatre was the most commonly cited theme in suggestions to improve gynaecology training. In particular, it was reported that protecting access to theatre from competing clinical demands on trainees could be important to improve training. Participants reported interruption of lists for emergency obstetric cases and on-call commitments as common reasons for difficulty in accessing training opportunities.

Theme 2: Increase in simulation training was the second most common theme identified in participants responses. Participants reported a desire for formalised simulation sessions to be incorporated regularly into gynaecology surgical training.

Theme 3: Subspecialisation in training was the third theme identified. Participants expressed a desire for subspecialisation to occur at later stages of training. Participants reported splitting late-stage training into either obstetrics or gynaecology focused jobs as potential solutions to improve training.

2.4 Discussion

2.4.1 Main findings

We surveyed obstetrics and gynaecology trainees and trainers at three time points to identify trends in gynaecology surgical training over the eight-year period studied and also to identify barriers to adequate surgical training. Our main findings from this study show that over the last 8 years there has been a significant fall in trainees' ability to perform major gynaecological surgical procedures. This was most notable with respect to abdominal and vaginal hysterectomy. Trainees reported that gynaecology was not given sufficient priority during their training and that they would not be prepared for independent practice by the end of their training programme.

We showed that there was a shortfall between late-stage trainees' self-reported current ability and their expected ability by the end of training. The difference in these metrics has increased greatly across the time period surveyed which demonstrates a decrease in confidence amongst senior trainees. This shortfall is again most notable with respect to major gynaecological surgical procedures. This poses difficulties for trainees expecting to achieve certification of completion of specialist training and begin independent consultant practice at the end of their training programme. Where recent graduates of the training programme are continuing to develop their independent surgical skills in the early phase of their consultant careers this may further dilute training opportunities for trainees currently enrolled on the training programme.

A majority of trainee respondents reported that they would not have sufficient experience in gynaecological surgery to practice independently as consultants. All respondents reported that gynaecology was not given sufficient time during the training programme. As a result, further post-specialisation training may be required for those who intend for gynaecology to form a large part of their ongoing consultant practice. This requirement for additional post-specialisation training is despite obstetrics and gynaecology training, at a minimum of 9 years postgraduation from medical school, already having one of the longest postgraduate training programmes from entry to specialisation.(14) This is compared to other specialities such as anaesthesia, radiology or most general medical specialities which have a minimum range of postgraduate experience from 6 to 8 years.(13,88,89)

Although there was no fall in trainers' confidence in trainees' expected ability by the end of the training programme, they reported that only half of trainees would finish the programme with the ability to perform major operative gynaecological procedures.

There was an increase in trainees self-reported current ability in operative hysteroscopy over the study period. This may reflect the development of ambulatory gynaecology clinics nationally which have improved access to training for common ambulatory procedures such as diagnostic and operative hysteroscopy. This is a positive trend as the roll out of ambulatory clinics is to be prioritised nationally as a means of reducing delayed diagnosis and reducing inpatient surgical waiting lists.(90)

Thematic analysis revealed 3 themes regarding ways of overcoming challenges in gynaecological surgical training. The most common theme identified was that there should be improved access and dedicated time allocated to allow trainees to attend theatre with their nominated trainer. The benefits of mentorship in surgical education are well described but maintaining the mentor/mentee relationship may be difficult in practice as a result of rostering and service provision concerns.(91) Ensuring that both trainers and trainees are given dedicated time to meet frequently to discuss training goals and progress is one way which could improve this relationship. It is also important that those creating rosters for trainees prioritise their allocation to operating theatre sessions with their named trainer.

The second most common theme was that there should be an increase in access to simulation training to make up the shortfall in hands-on clinical experience. This finding was borne out by trainees' responses to questions on the use of simulation courses, where a majority replied that simulation training was valuable to their development. There was a strong preference expressed for cadaveric courses which provide opportunity to develop anatomical knowledge and surgical techniques away from the bedside. Cost concerns and limited access may limit the utility of cadaveric simulation however relatively simple laparoscopic box simulators have been shown to directly improve operative performance (92). The incorporation of surgical simulation must be supported by the provision of a curriculum for simulation training and the provision of dedicated time for access to simulation sessions for trainees (93)(94).

Thirdly, respondents reported that there should be an increased focus on subspecialisation towards the end of the training programme. This would allow trainees who intend for gynaecology to form a major part of their consultant practice to develop their surgical skills in a focused way, providing they have met the basic competencies of a general obstetrician and gynaecologist as set out by the training body. Likewise, trainees whose interests lie in other specialist areas of obstetrics and gynaecology could focus their training on, for example, maternal-fetal medicine or labour ward practice. This would ensure training opportunities are aligned with trainees' interests and intended practice area.

Internationally, the option of incorporating advanced practice modules or sub-specialisation at a late stage of training has been widely adopted. Both the UK's RCOG and RANZCOG in

Australia and New Zealand have incorporated advanced training modules into their training programmes (95)(17). This allows trainees to tailor training to their interests and future practice at a later stage in their program when more general obstetric and gynaecological competencies have been reached. Likewise the fellowship programmes accredited by the American College of Obstetrics and Gynaecology offer additional advanced training at the end of a comparatively shorter period of general Obstetrics and Gynaecology training achieved in residency.(96)

2.4.2 Strengths and limitations

The main strength of our study is the repeated cross-sectional nature of the data which has allowed the examination of changing trends in gynaecology training over the last 8 years.

The limitations of this study are the retrospective nature of the response data which may be subject to recall bias. A prospective longitudinal survey of trainees exiting the training programme would be useful to detect trends and changes in training experience and ability.

Response rates in similar previously published work reviewed varied from 9.6% - 77%.(1,77,79–81) Our response rate of 44%, while lower than expected, was in keeping with previous studies. We feel it was an adequate response rate from both trainers and trainees to get a clear understanding of the current state of gynaecology training in Ireland.

There was no objective assessment of trainees' ability as part of this study and we relied on trainees' self-assessment to determine their current and expected ability. Trainees tend to underestimate their performance on self-assessment.(97) Female trainees tend to further underestimate their performance which is relevant as the majority of our respondents were female.(98)

Obstetrics training was not assessed at the same time as this study as the focus was on assessment of gynaecological surgical training. Due to the dual nature of the speciality, including an assessment of obstetrics training may have given useful insights into the challenges of training in both aspects of the speciality.

2.4.3 Conclusion

In conclusion there has been a significant change in the experience and ability of gynaecology trainees during the timeframe of this study. If there is to be continued provision of high-quality gynaecological care, a concerted effort must be made to foster the development of gynaecology skills throughout the training programme. Dedicated access to theatre time, increasing access to simulation and late-stage specialisation provide potential solutions to the training challenges in gynaecology.

Chapter 3: A National Survey on the Impact of the Coronavirus Pandemic on Gynaecological Surgical Training

***Under review**: International Journal of Gynecology and Obstetrics, December 2023*

3.1 Introduction

The coronavirus disease (COVID-19) pandemic has had a global impact on surgical training in gynaecology.(33) This global pandemic has had a significant impact on the provision of surgical care with a reduction in outpatient clinics, non-urgent elective surgery and at the beginning of the pandemic, a reduction in emergency surgical presentations. (99–102) There was a significant reduction in elective surgical activity nationally in Ireland from the onset of pandemic restrictions in March 2020.(103) The Irish government entered into agreements with 18 private hospitals for a period of time from late March 2020. (104) This allowed some urgent elective procedures to continue however the overall volume of surgeries performed nationally was significantly less than a comparable period before the pandemic.(105)

Any reduction of elective surgery has a natural impact on the potential for training opportunities for trainee surgeons. A number of studies from general surgery and other surgical subspecialties bear this out.(106–108) The need to minimise personnel present for procedures owing to the risk of SARS-CoV-2 viral transmission and the need for social distancing has reduced access further. In one study 40% of surgical trainees reported they were excluded from attending theatres where cases were considered high risk for transmission of SARS-CoV-2. (109)

A 2021 systematic review reported on the impact of the COVID-19 pandemic on surgical training, trainees' wellbeing and education. This review included on 29 articles which assessed the impact of the pandemic on surgical trainees. All included studies reported reductions in operative experience for surgical trainees. The impact on gynaecology surgery was excluded from their analysis. (110). However, studies have examined the impact of the coronavirus pandemic on obstetrics and gynaecology training. These studies report a significant reduction in elective gynaecology activity ranging from 67-88.9%. (111,112)

With this study we aimed to assess the impact of the coronavirus pandemic on gynaecology training. We examined the trainees' exposure to various types of procedures both before and after the pandemic. We also determined their confidence in performing common gynaecology surgical procedures and their trainers' confidence in their ability to do so. Finally, we assessed the impact of the pandemic on participants wellbeing and normal work practices.

3.2 Material and methods

This was a cross-sectional study, with a non-validated online questionnaire distributed using the SurveyMonkey (San Mateo, Ca, USA) platform.(86) The survey was developed following review of similar previously published surveys.(31,112,113) It formed part of a larger survey based study assessing gynaecology training in Ireland between 2014 and 2021.(70) In addition to the questions derived from previously published work in the area, further questions to address our study aims of assessing the impact of the COVID-19 pandemic were developed. The survey was distributed to all trainees and trainers registered on the RCPI's higher specialist training (HST) programme in March 2021. This circulation was part of a routine communication from the RCPI and all members of the mailing list had provided prior consent for contact. In Ireland the HST programme is a five year programme for the training of obstetricians and gynaecologists co-ordinated by the Royal College of Physicians of Ireland (RCPI).(14) This is completed after a three year basic specialist training (BST) programme. Typically the majority of operative gynaecology surgical experience is gained during the HST programme as the BST programme is focused on the development of basic obstetric and gynaecological skills. (15) Responses were anonymised and it was not possible to identify individual trainers or trainees based on their responses. All participants provided explicit consent to the use of their data for the purpose of this study.

The survey distributed to trainees consisted of 40 questions. (Appendix 3) The topics included: demographic factors, details of level training to date, volume of surgical procedures performed before and since the pandemic, confidence in performing various gynaecological procedures before and since the pandemic and questions regarding the impact of the pandemic on wellbeing and work practices. Procedure types were classified as minor (Diagnostic Hysteroscopy, Cystoscopy, Diagnostic laparoscopy), intermediate (Operative hysteroscopy, Simple operative laparoscopy) and major (Total abdominal hysterectomy, Total laparoscopic hysterectomy, Pelvic floor repair, Vaginal hysterectomy) according to complexity.

The survey distributed to trainers consisted of 39 questions. (Appendix 4) The topics included: demographic factors, details of type of clinical practice and subspecialty interest, volume of surgical procedures performed before and since the pandemic, confidence in their trainees' ability to perform various gynaecological procedures before and since the pandemic and questions regarding the impact of the pandemic on their wellbeing and work practices.

Both surveys consisted primarily of multiple choice and Likert scale response questions. A number of free text response questions were also included. Data are reported as simple descriptive statistics where appropriate. Comparison of Likert scale responses for paired pre and post pandemic questions was performed using the Wilcoxon signed rank test. The Chi-squared test was used to compare categorical variables. Statistical analysis was performed using IBM SPSS version 27.

3.3 Results

3.3.1 Characteristics

A total of 61 completed questionnaires were returned by participants, 26 from trainees and 35 from trainers. This gave a response rate of 34.3% (n=61/178). Demographic details of both groups are outlined in tables 3.1 and 3.2 below.

Table 3.1: Trainee demographics

Trainee demographics			
Age grouping	25-34	16	61.5%
	35-44	10	38.5%
Gender	Male	7	26.9%
	Female	19	73.1%
Years of experience in obstetrics and gynaecology		7.4±2.85	Mean ± 1 SD
Current year of training scheme	Year 1	4	15.4%
	Year 2	5	19.2%
	Year 3	4	15.4%
	Year 4	5	19.2%
	Year 5	3	11.6%
	Out of programme	5	19.2%

Table 3.2: Trainer demographics

Trainer demographics			
Age grouping	35-44	8	22.9%
	45-54	17	48.6%
	55-64	10	28.5%
Gender	Male	15	42.9%
	Female	20	57.1%
Years of experience		12.5±7.7	Mean ± 1 SD
Subspecialty	Maternal/Fetal Medicine	8	22.9%
	Gynae-oncology	2	5.7%
	Urogynaecology	6	17.1%
	Minimally Invasive surgery	8	22.9%
	Paediatric gynaecology	1	2.9%
	None/General Obstetrics and gynaecology	10	28.5%
Practice type	Full time clinical	27	77.1%
	Part time clinical	1	2.9%
	Full time clinical and academic	7	20%

3.3.2 Impact on training

100% (n=26) of trainees and 97.1% (n=34) of trainers reported that the pandemic had a negative impact on training. Only one trainer reported that there was no impact on training. No respondent reported that there was a positive impact on training. In response to the open questions as to why they felt training had been negatively impacted common themes were: cancellation of gynaecology surgical lists (85.2%, n=52), cancellation of gynaecology clinic (18%, n=11) and cancellation of face-to-face training courses (8.2%, n=5).

3.3.3 Volume of procedures

3.3.3.1 Trainees

In the 12 months prior to the onset of the pandemic trainees most commonly reported performing >40 minor procedures (n=12), 0-10 intermediate procedures (n=9) and 1-5 major procedures (n=9). In the 12 months since the onset of the COVID-19 pandemic trainees reported performing 0-10 minor procedures (n=8), 0-10 intermediate procedures (n=13) and 1-5 major procedures (n=9).

Analysis showed a reduction in the number of minor procedures performed by trainees (z=-2.7, p=.007). No differences were seen with respect to the volume of intermediate or major procedures.

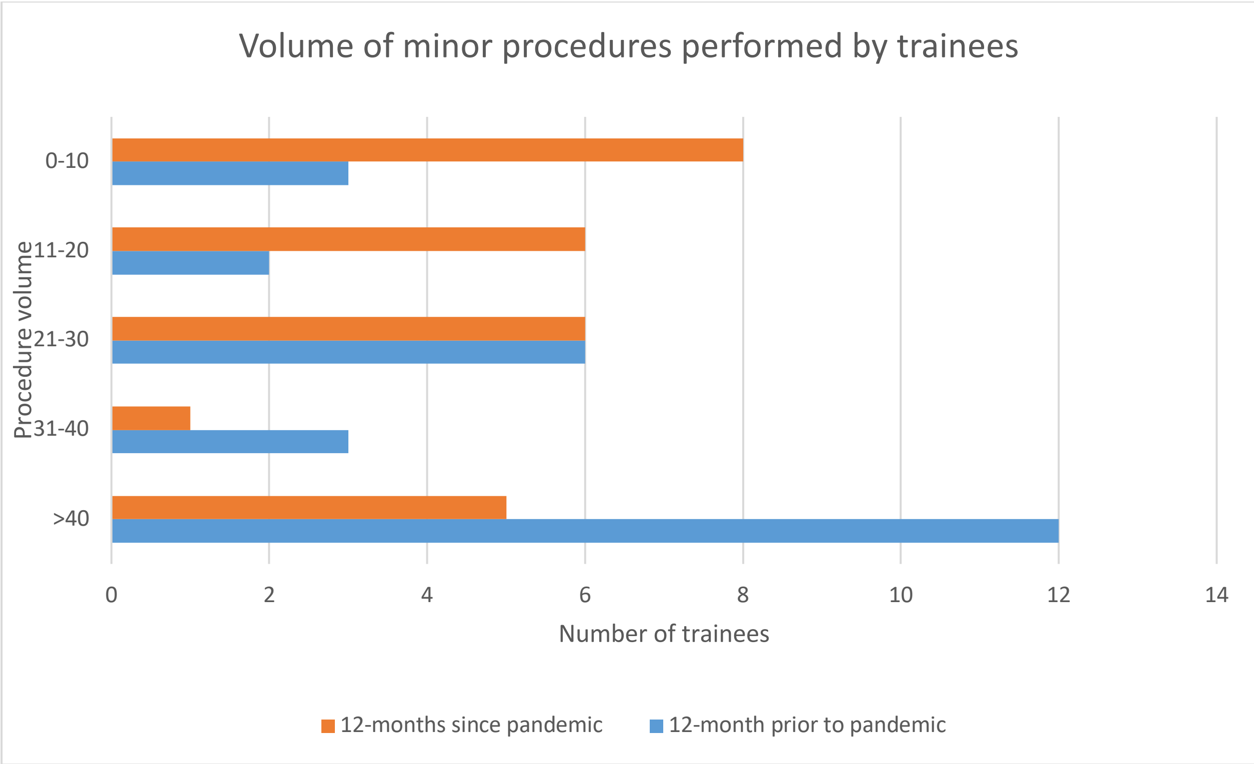

Figure 3.1: Volume of minor procedures performed by trainees

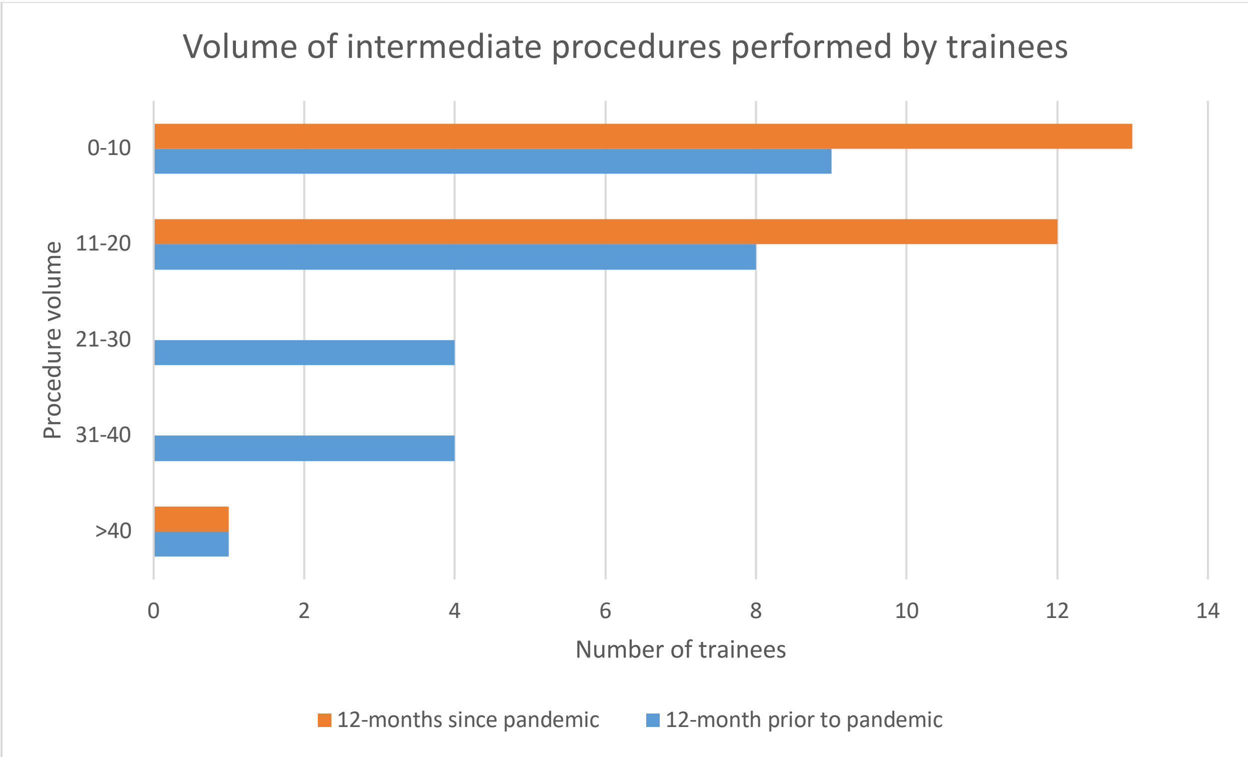

Figure 3.2: Volume of intermediate procedures performed by trainees

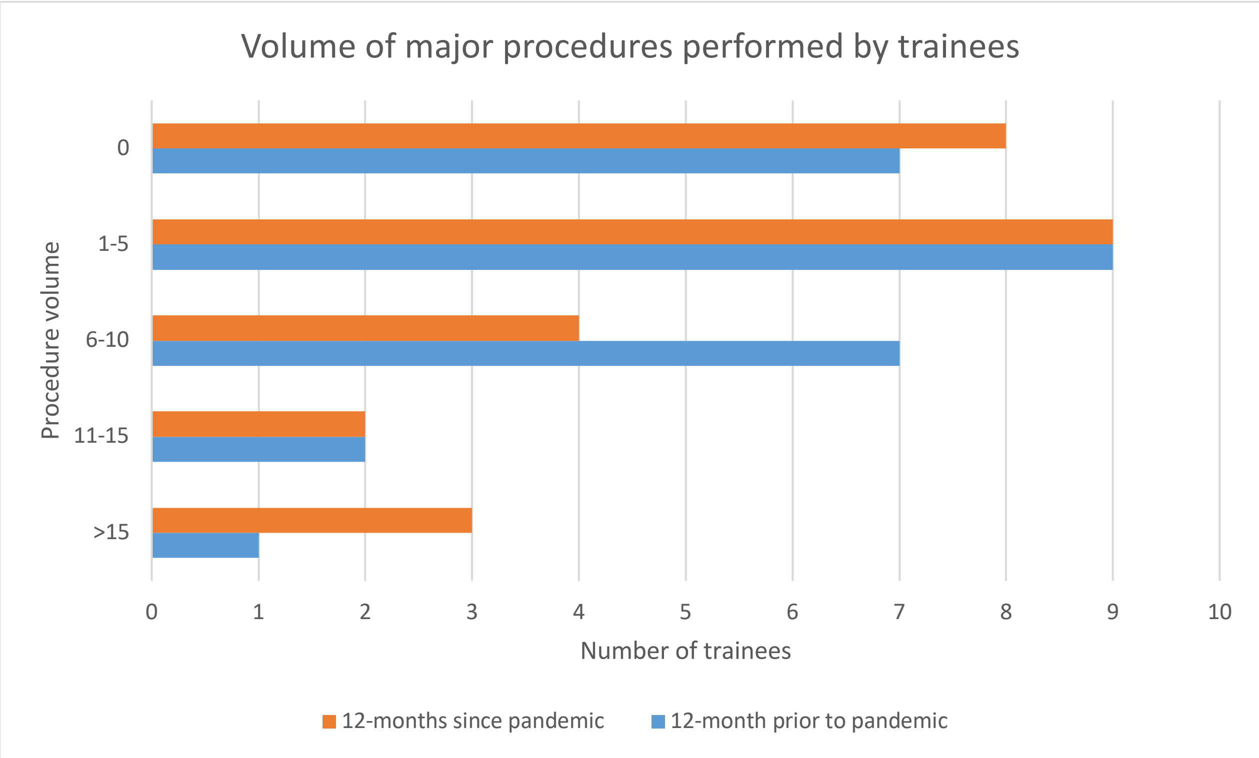

Figure 3.3: Volume of major procedures performed by trainees

3.3.3.2 Trainers

In the 12 months prior to the pandemic trainers most commonly reported performing >40 minor procedures (n=29), >40 intermediate procedures (n=13) and 0-10 major procedures (n=11). Since the onset of the pandemic trainers reported performing >40 minor procedures (n=14), 0-10 intermediate procedures (n=13) and 0-10 major procedures (n=23)

Analysis showed a significant reduction in the number of all procedure types performed by trainers (minor procedures z=-3.78, p=<.001; intermediate procedures z=-4.48, p=<.001; major procedures z=-3.69, p=<.001).

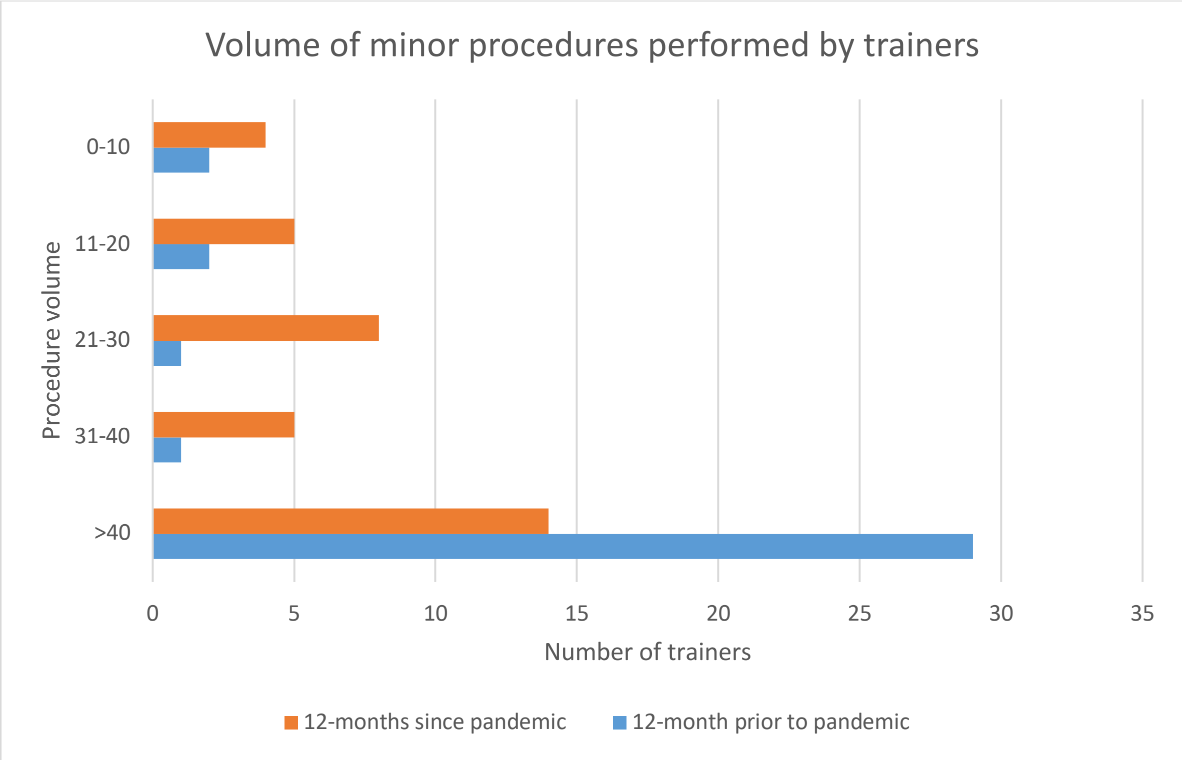

Figure 3.4: Volume of minor procedures performed by trainers

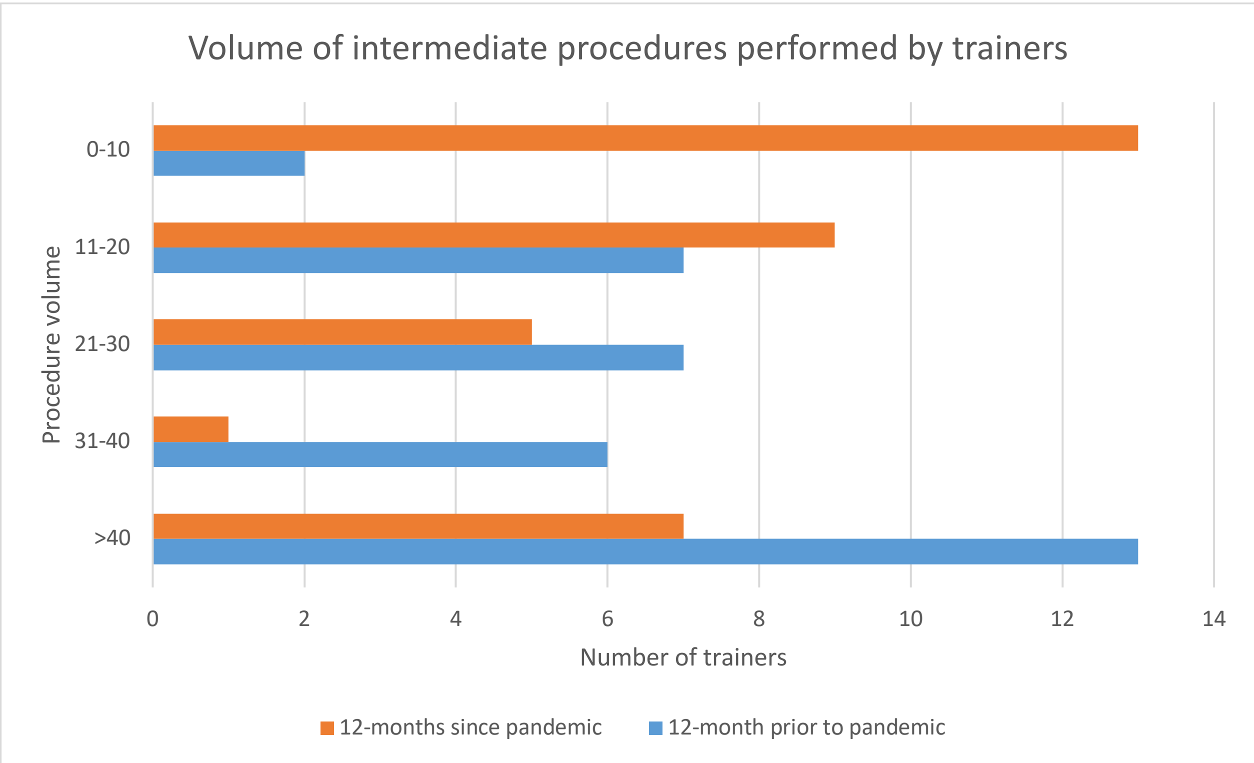

Figure 3.5: Volume of intermediate procedures performed by trainers

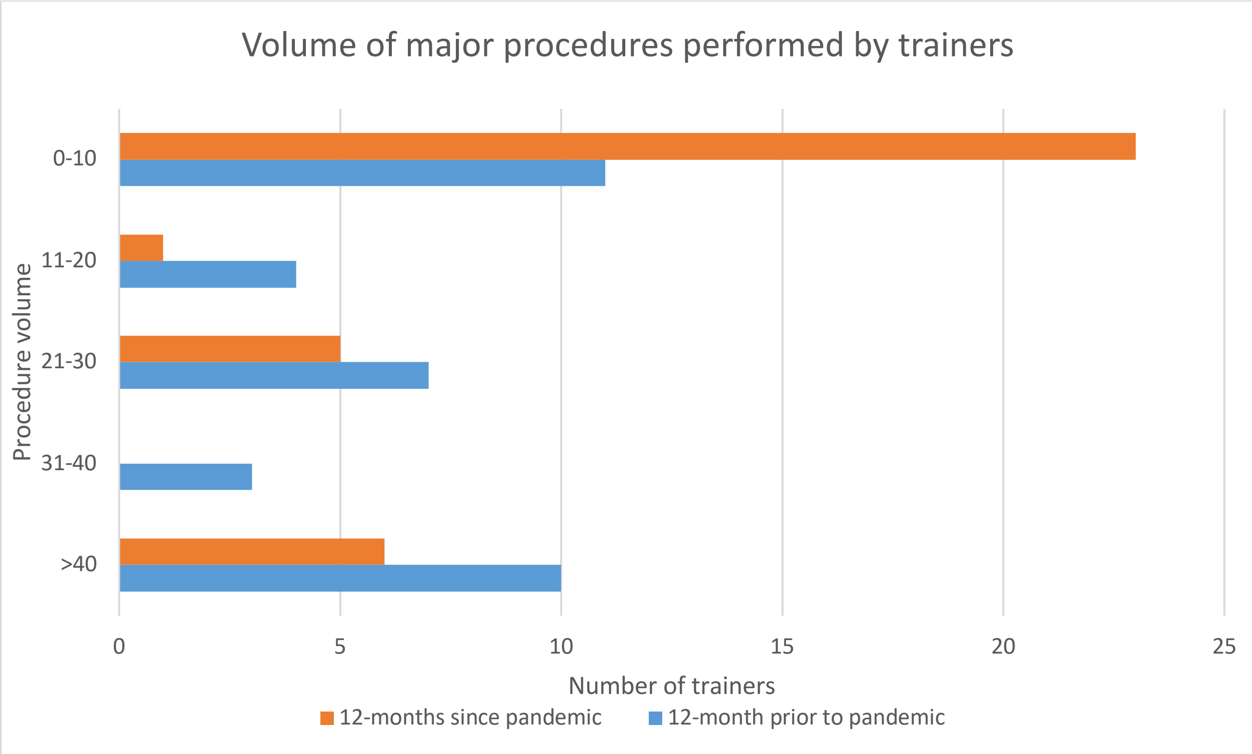

Figure 3.6: Volume of major procedures performed by trainers

3.3.4 Trainees' confidence

Figures 3.7 and 3.8 below show trainees' Likert scale responses regarding their confidence performing various gynaecological procedures in the 12 months before and since the onset of the pandemic respectively. Statistical analysis showed no significant difference in trainees reported confidence in any of the procedures.

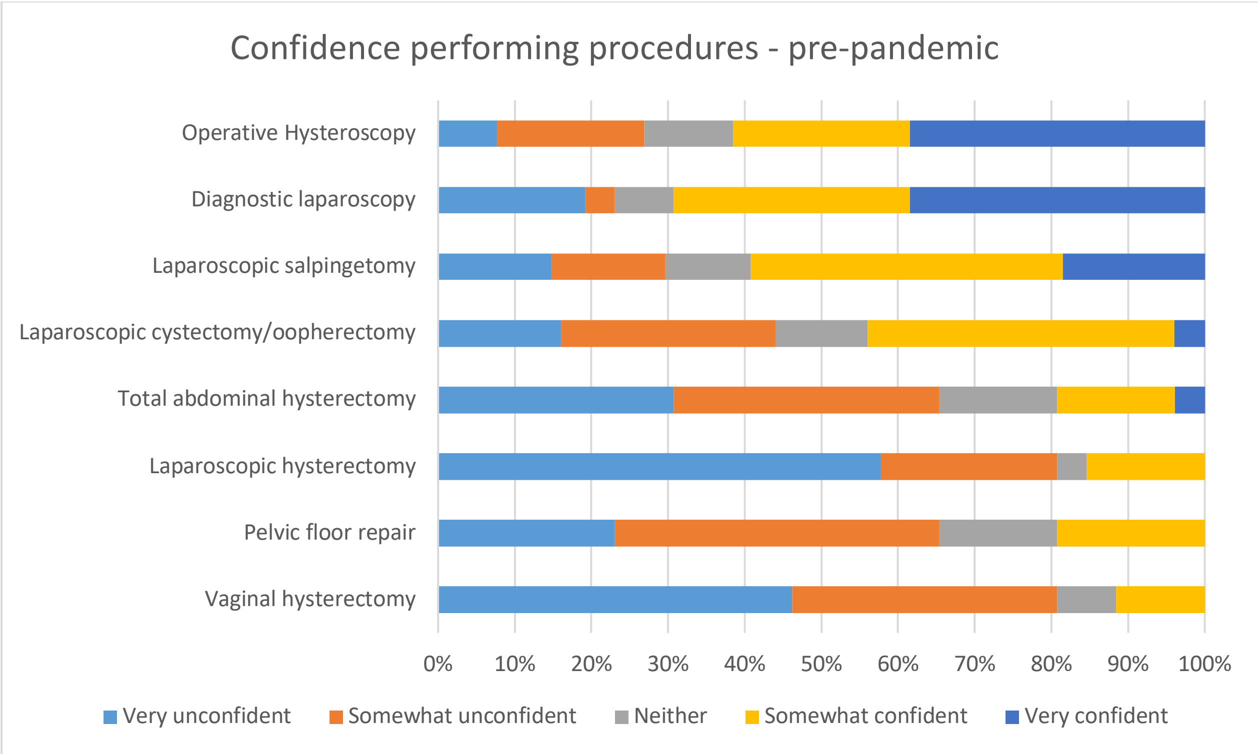

Figure 3.7: Trainees' confidence performing procedures - pre-pandemic

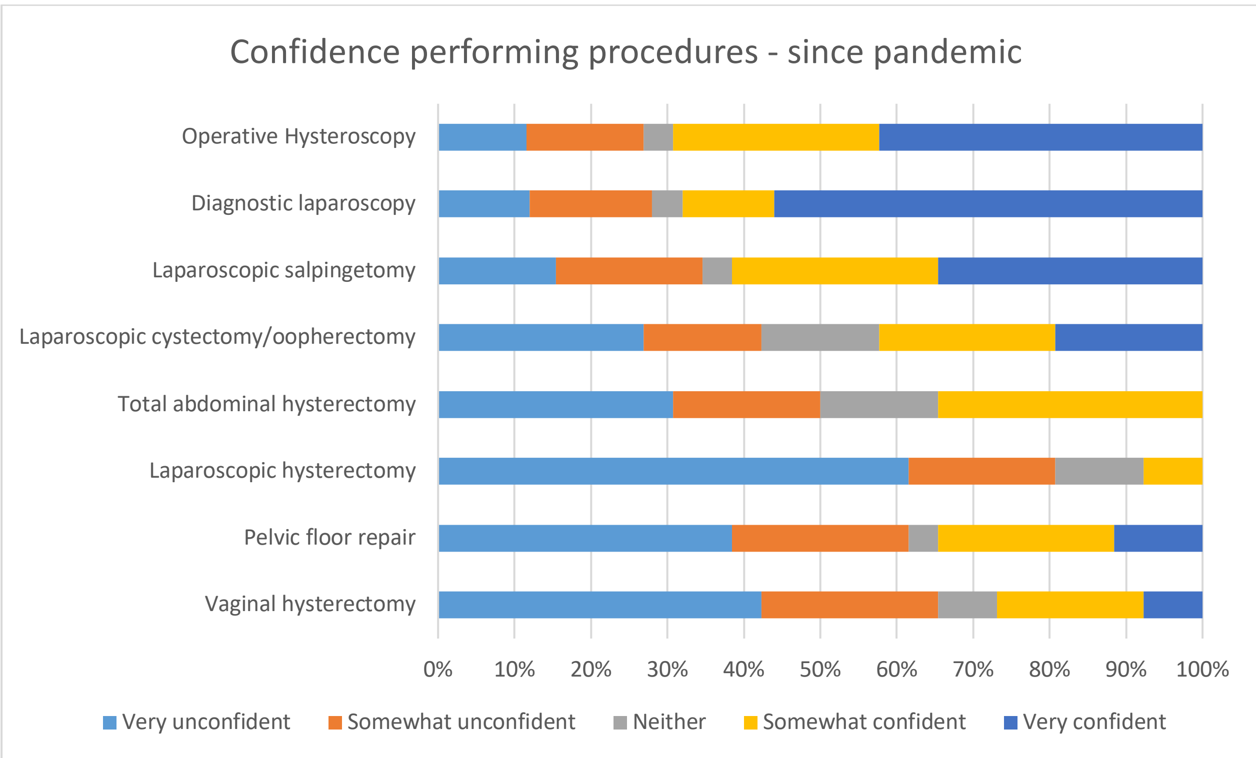

Figure 3.8: Trainees' confidence performing procedures – since pandemic

3.3.5 Trainers' confidence in trainees' ability

Figures 3.9 and 3.10 below show trainers' Likert scale responses regarding their confidence in their trainees' ability to perform various gynaecological procedures in the 12 months before and since the onset of the pandemic respectively.

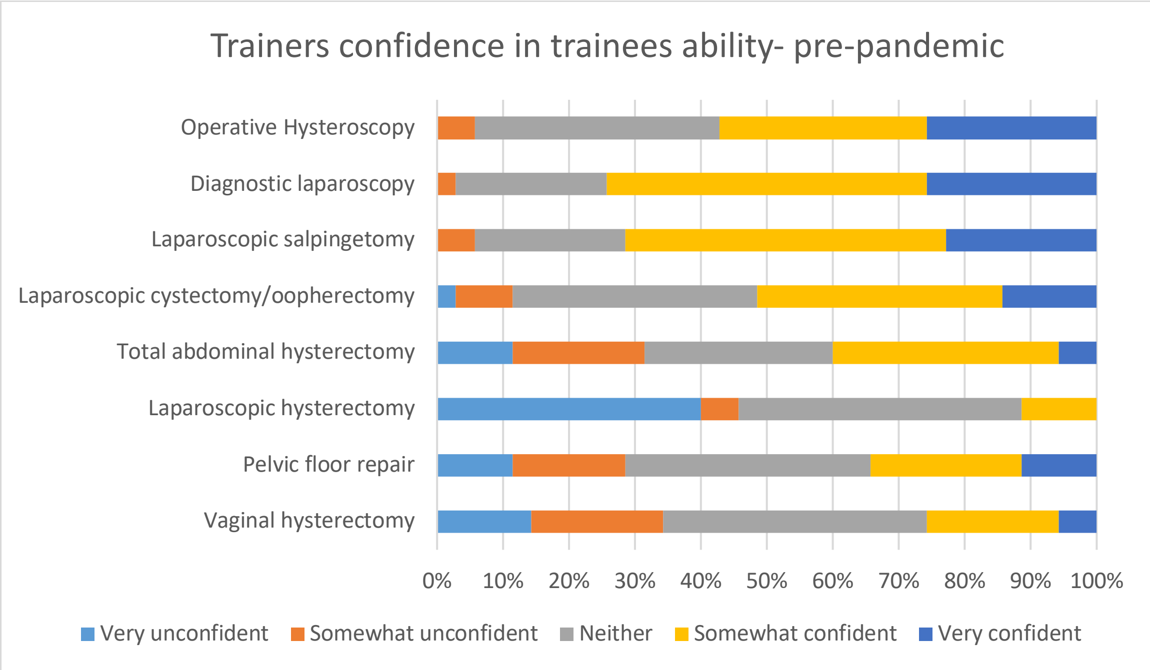

Figure 3.9: Trainers' confidence in trainees' ability: pre-pandemic

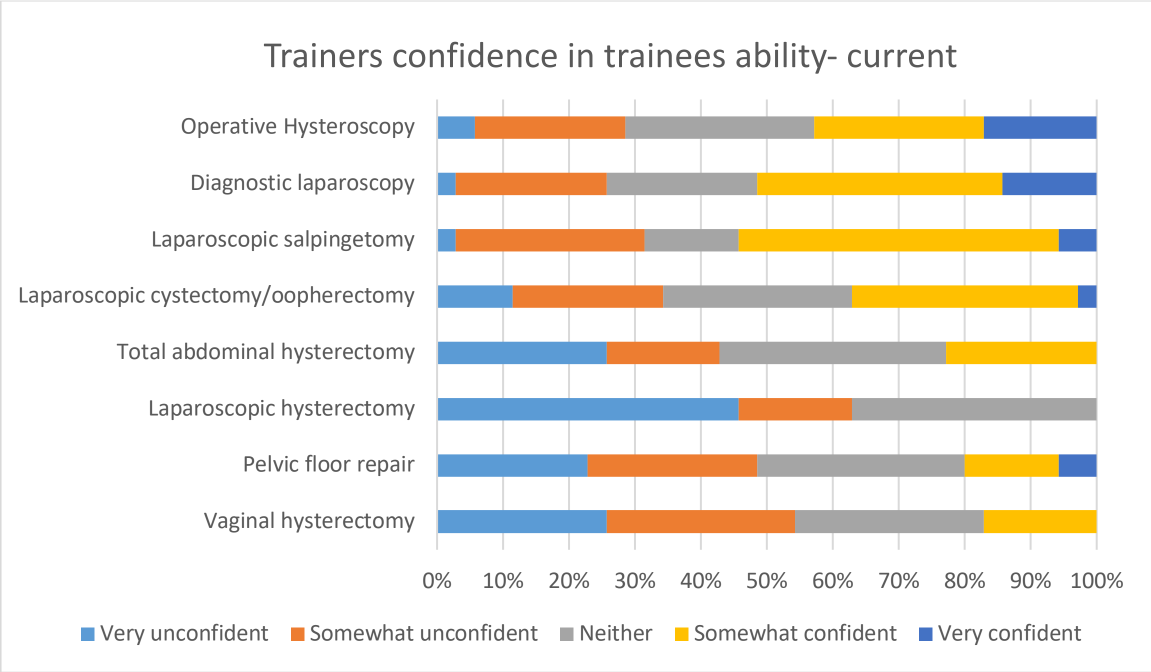

Figure 3.10: Trainers' confidence in trainees' ability: current

Analysis of pre and post pandemic responses for all procedures showed a statistically significant reduction in trainer confidence in their trainees' ability in the 12 months since the pandemic. The results of this analysis are outlined in table 3.3.

Table 3.3: Wilcoxon signed rank test analysis results for trainers' pre vs post pandemic confidence

Procedure Type	Wilcoxon signed rank test:	
	z=	p=
Operative hysteroscopy	-2.62	.009
Diagnostic laparoscopy	-3.07	.002
Laparoscopic salpingectomy	-2.85	.004
Laparoscopic cystectomy/oophorectomy	-2.55	.011
Total abdominal hysterectomy	-2.75	.006
Laparoscopic hysterectomy	-2.52	.012
Pelvic floor repair	-2.99	.003
Vaginal hysterectomy	-2.94	.003

3.3.6 Impact of the pandemic

Figures 11 and 12 below show trainee and trainer Likert scale responses to a variety of statements regarding the impact of the pandemic on their wellbeing and work practices. The majority of respondents reported they had less time for research and audit, were less able to attend courses or conferences and worried about the impact of their work on their families. Trainees were significantly more likely to have to provide cover for colleagues at short notice than trainers (73% trainees vs 31.4% trainers agree or strongly agree, p=0.004). There were no other significant differences in responses between trainees and trainers for shared statements.

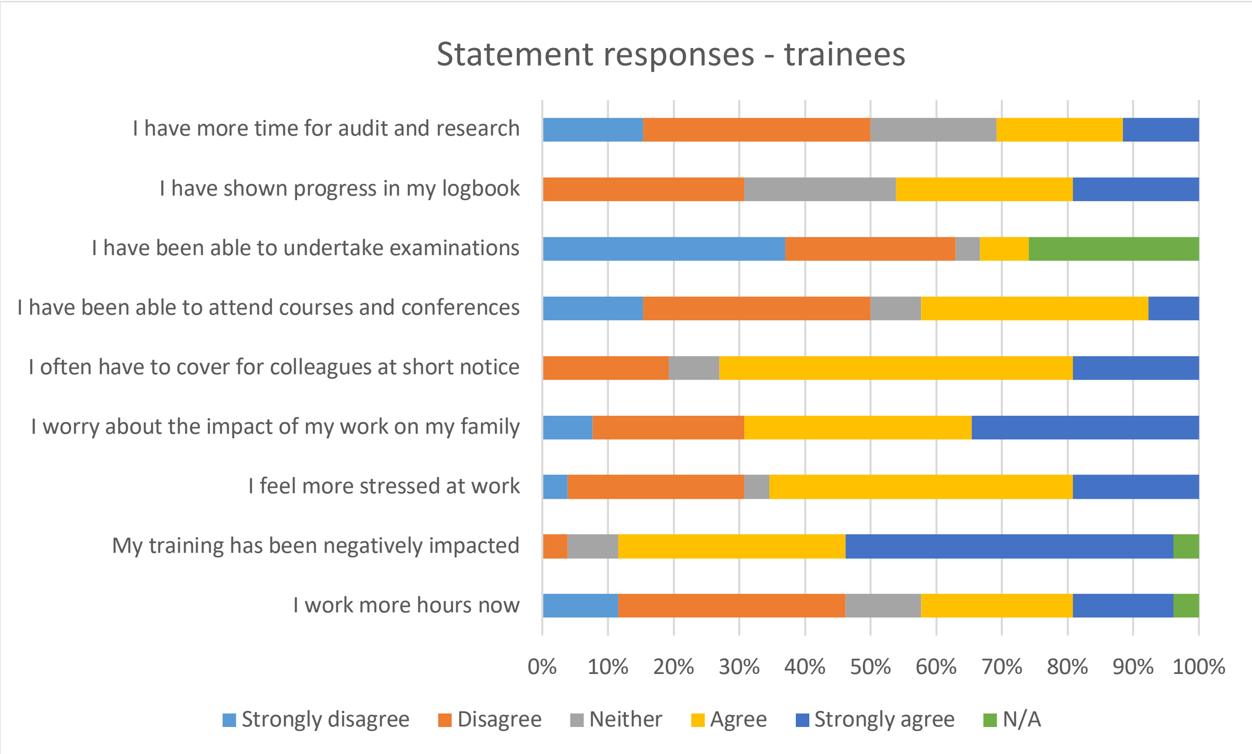

Figure 3.11: Trainee responses on impact of the pandemic

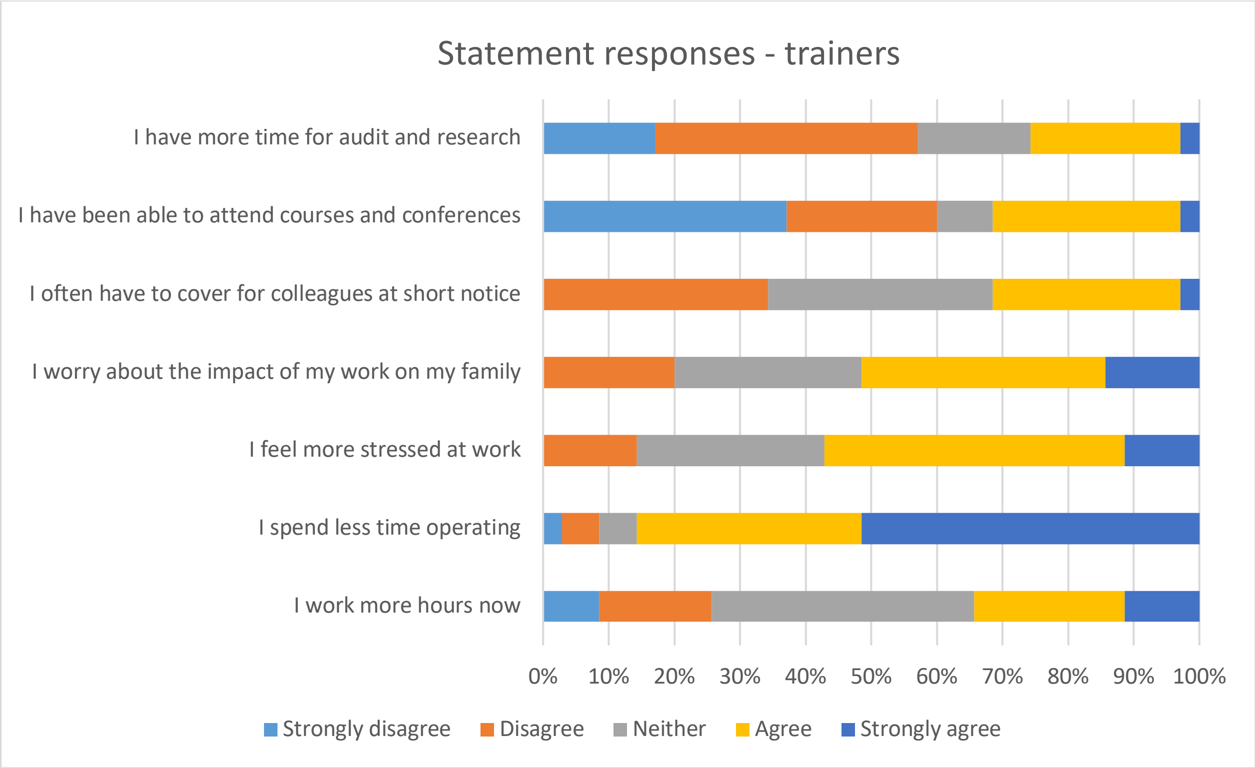

Figure 3.12: Trainee responses on impact of the pandemic

Trainees were significantly more likely than trainers to have had an unplanned absence from work as a result of COVID-19 infection or self-isolation (54% vs 26%, $p=0.02$). Overall, 37.7% of all respondents reported an absence from work as a result of COVID-19 or self-isolation.

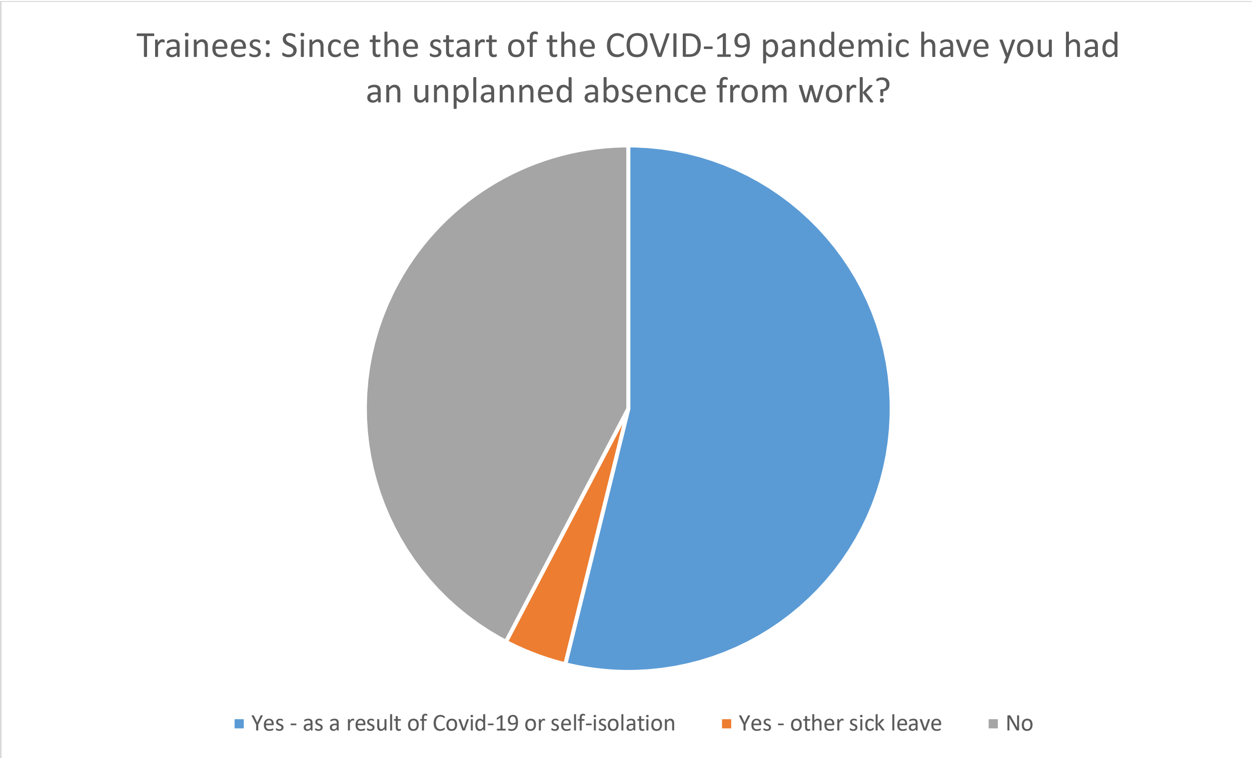

Figure 3.13: Trainees' unplanned work absence since onset of pandemic

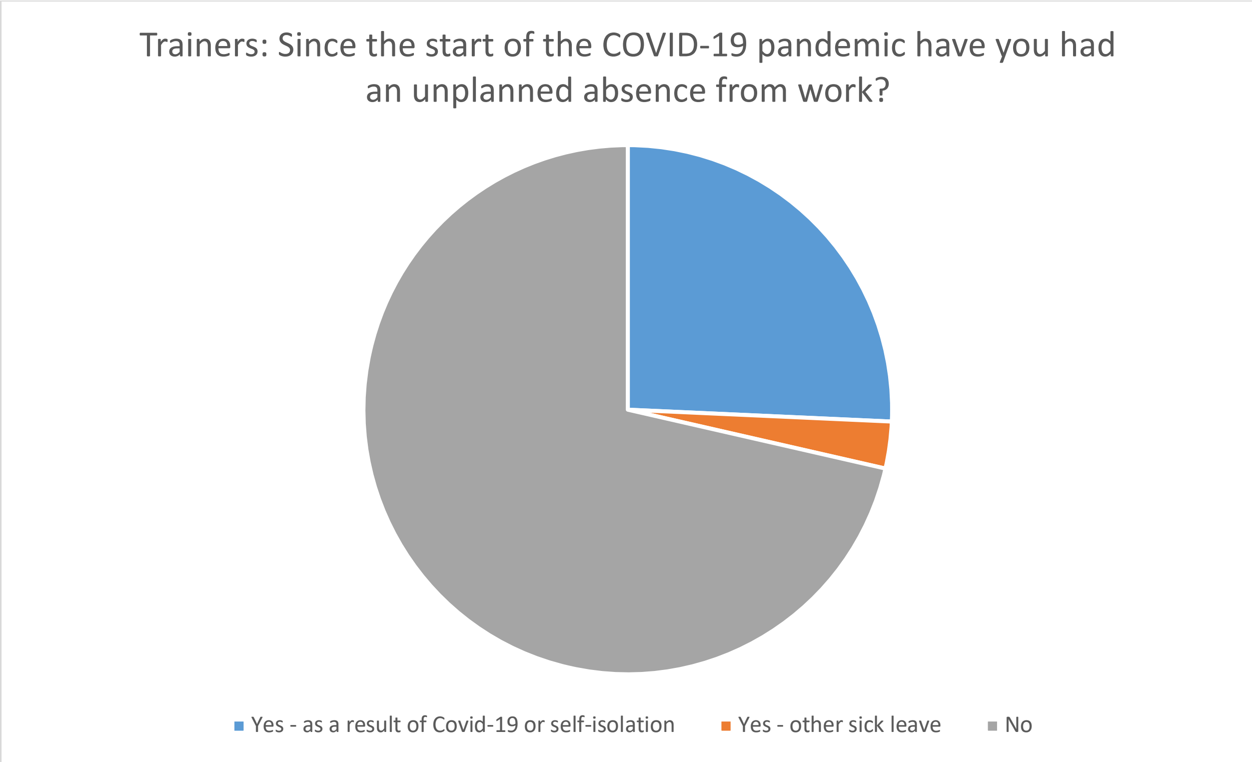

Figure 3.14: Trainers' unplanned work absence since onset of pandemic

3.4 Discussion

3.4.1 Main findings

In this study we surveyed trainers and trainees on the RCPI's HST scheme in Obstetrics and Gynaecology to assess the impact of the coronavirus pandemic on their surgical training in gynaecology. The main findings were that both trainers and trainees experienced a significant reduction in operative volumes for most procedure types. Trainers experienced a significant reduction in all procedure types assessed. No significant difference was seen with respect to intermediate or major procedures for trainees. It should be noted however that the pre-pandemic surgical volumes for these types of procedures was low in the gynaecology trainees surveyed. The majority of these trainees reported performing between 0 and 5 major procedures in the 12 months prior to the pandemic. This may be as a result of other challenges in accessing surgical training such as increasing trainee numbers, reducing hysterectomy rates and a reduction in working hours for trainees.(6,23,76)

This reduction in operative volume has an impact on the acquisition of surgical skills as there is a need for frequent hands-on practice under the supervision of a surgical mentor to develop surgical skills.(91) Literature in other surgical specialities reports a similar reduction in training opportunities as a result of the pandemic. Operative volumes were reduced in all studies included in a systematic review of the impact of the pandemic on general surgical specialities.(110) A study from Italy noted the reduction in operative volumes particularly affected 'medium-complexity' operations where surgical trainees were often the primary operator under supervision allowing them to develop their surgical skills.(114) The significant reduction in trainers' operative volume may also have an impact for patients.

Studies show that perioperative outcomes, surgical time, the use of minimally invasive techniques and blood loss are improved for high volume surgeons. (115)

Trainees did not experience an increase in their self-reported confidence in the 24-month period under consideration as part of this study. Typically surgical confidence improves as trainees move through a surgical training programme as they develop independence with more minor and intermediate procedures and gain exposure to complex or major procedures under supervision.(116)

Trainers' confidence in their trainees' surgical ability fell significantly for all procedure types. Possible causes for this reduction in confidence include the reduction in the trainers' operative volumes or a reduction in low and intermediate complexity procedures suitable for trainees to perform under supervision. However, the reasons for the fall in confidence were not assessed in this study. Previously published work in this area has not examined trainees' or trainers' confidence making this a novel finding.(106,113,117)

It was also noted that the pandemic has had an impact on respondent's normal work practices and wellbeing. The majority of respondents reported that they had less time for audit, research and examinations. Respondents reported difficulty in attending courses and conferences as a result of cancellation or move to online provision of courses. A majority of respondents also said that they felt increased stress in the workplace and had concerns for the impact of their work on their family and home life.

Previous work has shown that surgical trainees have experienced significantly increased stress.(106) Another study showed that up to 20% of orthopaedic surgical trainees accessed mental health supports since the onset of the pandemic.(118)

In the post-pandemic phase, where clinical activities have mostly returned to normal, there are significant challenges facing trainees, trainers and training bodies responsible for gynaecology training.(33) The cohort of trainees who have been exposed to significantly reduced surgical training opportunities may struggle to achieve competence prior to the end of their training programmes. In order to avoid extensions to training time, efforts must be made to identify trainees who are struggling to meet expected standards and support them in accessing simulation and surgical training opportunities to prepare them for independent practice.(33,119)

3.4.2 Strengths and limitations

This was a national cross-sectional survey which surveyed a wide range of trainees and trainers making the findings generalisable. To our knowledge this is the first study to focus specifically on the challenges of gynaecology training in the COVID-19 pandemic. Prior studies either exclude gynaecology as a surgical speciality or incorporate it with obstetric training in analysis.

Survey questions regarding surgical confidence were retrospective in nature and self-assessed. Trainees typically underestimate their abilities on self-assessment.(97)

The response rate was lower than anticipated. Many previously published studies on the impact of the pandemic on surgical specialities do not report their response rate.(107,109) Of the studies which do report this, rates ranged from 20% - 90.9%. (120,121)

3.4.3 Conclusions

In conclusion this study has highlighted the current difficulties facing surgical trainees in gynaecology as a result of the COVID-19 pandemic. These challenges have compounded an already challenging training environment for gynaecology trainees. Efforts must be made to continue to provide high-quality tailored training to ensure the development of the next generation of gynaecological surgeons.

Chapter 4: Laparoscopic Skills Assessment in the Digital Age: Evaluating the Laparo Analytic System Versus Human Expertise

***Under review:** Journal of Minimally Invasive Gynecology. November 2023*

4.1 Introduction

Laparoscopy is the cornerstone of most gynaecological surgery and lends itself to assessment and observation more readily than open or vaginal approaches. Laparoscopic surgery training is a continually evolving field, faced with the dual challenges of accommodating an increasing number of trainees and grappling with reduced access to operating room experiences.(122) This convergence impacts the process of acquiring and retaining critical surgical skills. At present, a blend of simulation and real-world intraoperative exposure assists in nurturing these competencies.(123)

Prior to stepping into real surgical environments, trainees often immerse themselves in standardised simulation programmes.(122) These curriculums, designed to escalate in complexity, cover tasks ranging from peg transfer to the nuanced skills of pattern cutting and suturing. One notable programme, the Fundamentals of Laparoscopic Surgery (FLS), which commenced in 1997, revolves around such tasks.(124) It stands as an obligatory milestone for those aspiring for membership in The American Board of Surgery, specifically targeting general surgeons.

However, evaluating the efficacy of trainees in these programmes is not without its challenges. Trainers must invest significant time either in direct observation or through a retrospective analysis of video recordings.(125) But technology has offered a promising avenue; Since FLS's inception, technological strides now allow for real-time grading of surgical performances, potentially negating the necessity of hands-on observation by a seasoned trainer. The implications of such advancements are twofold: trainers benefit from reduced time commitments, and trainees receive instantaneous feedback.

A notable advancement in this arena is the Laparo Surgical Simulators.(126) Beyond being a conventional laparoscopic simulator, it boasts specialized ports equipped with a myriad of sensors. These sensors capture data concerning the laparoscopic instruments' movements, precisely gauging an instrument’s orientation within a three-dimensional space. Such precision paves the way for analysing kinematic metrics like velocity, acceleration, and task smoothness, among others. By juxtaposing these metrics with benchmarks set by experts, the system formulates a performance score, granting trainees the ability to monitor their progress over repeated sessions. While this new laparoscopic system shows promise, no work to date has evaluated the accuracy with which it can distinguish between surgeons of varying expertise.

The objective of our study is to evaluate the validity of the Laparo Surgical Simulator system. Specifically, we aim to discern if its assessments resonate with what has traditionally been deemed the gold standard: the keen observation of an adept surgeon.

4.2 Methods

4.2.1 Participants

Forty-nine participants, naïve to laparoscopic training, were recruited from the medical student population of University College Cork. All participants were provided with written information on the study protocol. Each participant provided informed written consent to participate. The study was approved by the Clinical Research Ethics Committee of the University Teaching Hospitals at University College Cork in accordance with the declaration of Helsinki.

4.2.2 Testing and training environment

All testing and training sessions took place at the ASSERT surgical simulation lab at University College Cork using the Laparo Analytic laparoscopy trainer (Laparo Medical Simulators, Poland). Stations equipped with laparoscopic box trainers (Laparo Aspire, Laparo Medical Simulators, Poland) were set up on the left side of the room for training sessions.

4.2.3 Study protocol

Day 1

Demographic details were recorded and participants completed baseline mood (BRUMS-32) and sleep (PSQI) questionnaires (See appendix 5 and 6). These validated tools allowed comparison between mood and sleep quality at baseline and prior to the retesting session, ensuring low mood or poor sleep quality did not impact on participant performance. Participants were required to refrain from consuming caffeine or alcohol six and 24 hours prior to assessment respectively.

Participants then undertook a baseline assessment of laparoscopic surgical skills on the Laparo Analytic laparoscopy trainer. Participants were assessed on their ability to complete a predefined training module. This testing was on a bead transfer task where participants were required to move 22 rubber beads from a large central pot to 6 smaller pots and 4 posts within a ten-minute time limit (Figure 4.1).

Figure 4.1: Bead transfer task

They were required to first grasp each bead with their left-hand grasper, transfer it to their right-hand grasper and then place the bead. The analytic system allowed the capture of detailed kinematic data from the students' performance including time to complete, acceleration, velocity, clamp count and hand oscillation. The analytic system provided an overall grading to each student with a maximum of 10 points. This grading was generated by the system using a proprietary algorithm predefined by the manufacturer. Video recording of the task completion was taken by the in-built camera on the analyser.

Training sessions

Participants then undertook five ten-minute training sessions over five consecutive days. This training was performed on a laparoscopic box simulator which was identical to the training environment on the analytic machine. Participants were advised to complete the task as smoothly and efficiently as possible and as many times as possible in each ten-minute training session. Each participant was provided with standardised advice and coaching by the author (DG) throughout the training sessions.

Retesting

Following the fifth training session, participants were reassessed on the completion of the bead transfer task using the Laparo Analytic system. The system again provided detailed kinematic data and an overall grading assessment. Video recording of the task completion was again taken.

4.2.4 Blinding and video assessment

Task completion videos from baseline and from after the training protocol (N=98) were independently blinded using computerised randomisation so that neither reviewer (DG/DMcK) was aware of the assessment session type which they were grading (trained vs untrained). All video recordings were graded independently by both reviewers. Each task completion was graded using the Global Operative Assessment of Laparoscopic Skills (GOALS) tool which grades performance in five areas giving a cumulative score with a maximum of twenty-five points (see appendix 7).(127) Blinding was only revealed following completion of grading of all training videos by both reviewers.

4.2.5 Statistical analysis

Wilcoxon signed ranks testing was used to compare the mood and sleep questionnaires (BRUMS-32 and PSQI) at baseline and prior to retesting. Overall scores for the GOALS and the analytic software outputs were analysed using a receiver operator curve to determine their performance at distinguishing between trained and untrained participants. Variables where a lower value implied higher proficiency were inverted for analysis. An area under the curve (AUC) of ≥0.8 was considered to represent good ability to distinguish between trained and untrained participants. Cohen's kappa (κ) was used to assess interrater agreement between the two reviewers. A p-value of ≤0.05 was considered significant.

Results from the computerised grading were translated into a rounded 0-25 scale to allow comparison between computerised and reviewer grading. Cohen's kappa results were interpreted according to guidelines from Altmann (1991) where κ of ≥ 0.8 was considered to represent very good agreement between observers.

4.3 Results

4.3.1 Demographics, mood and sleep

Forty-nine participants were recruited (N=49, 27 female). The average age of participants was 23.4±2.9 years. There were no differences in most mood parameters at base line or prior to retesting. There was a significant reduction in levels of confusion and significantly improved sleep quality with lower BRUMS-32 confusion scores (1.46 vs 0.83, p=0.037) and PSQI scores (9.3 vs 7.4, p=0.008) respectively at the retesting session.

4.3.2 Expert reviewer's ability to grade experience

The ROC analysis, illustrating the expert reviewers' capability to distinguish between trained and untrained assessments, is presented in Figure 4.2. The area under the curve (AUC) for each reviewer's total GOALS score was 0.990 and 0.991 respectively. Further details on the AUC measures for each GOALS assessment component can be found in Appendix 8.

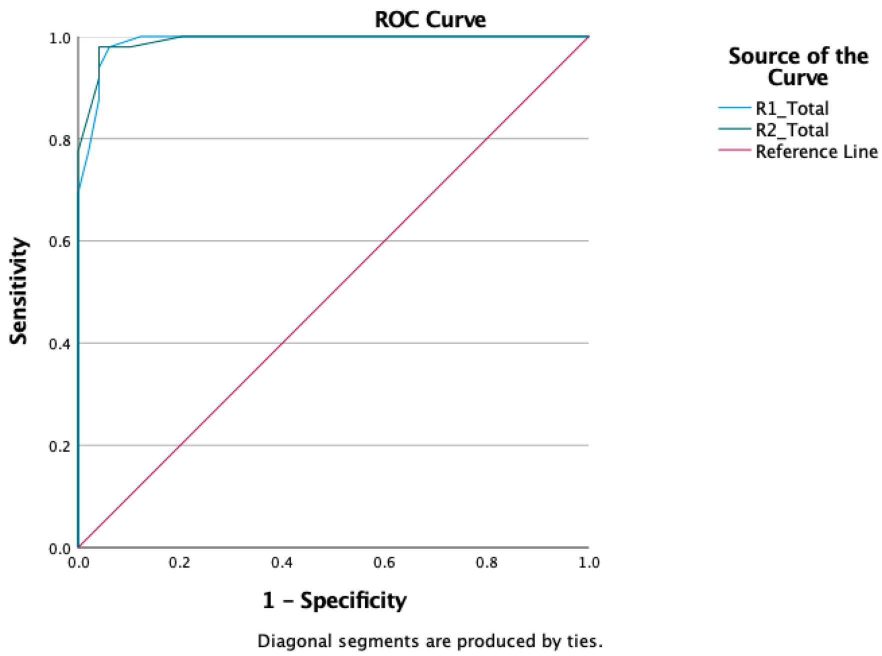

Figure 4.2: ROC analysis of overall GOALS score for reviewer 1 and reviewer 2

4.3.3 Analytic system's ability to grade experience

ROC analysis for the analytic system's ability to discriminate between trained and untrained assessments can be seen in figure 4.3.

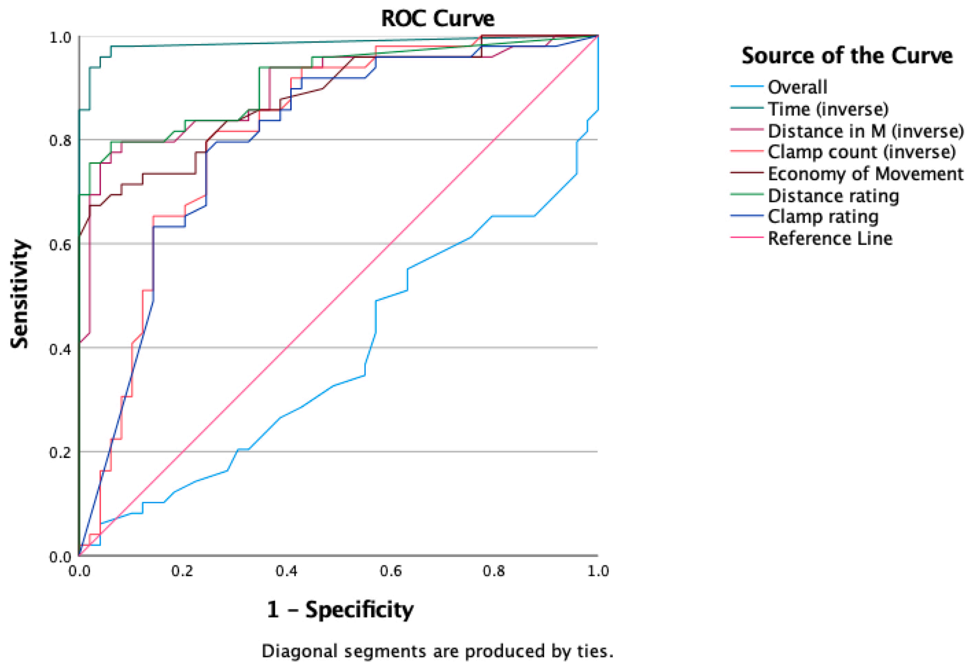

Figure 4.3: Receiver operator curve (ROC) analysis of computerised assessment scores

The area under the curve (AUC) for the overall analytic system score was 0.380. For more comprehensive results on various aspects of the analytic assessment, refer to Table 4.1. Of note, time, distance travelled and clamp count all showed AUC >0.8. Detailed AUC measures for all components of the analytic system assessment are in Appendix 9.

Table 4.1: AUC measures for aspects of analytic system assessment

	AUC
Overall	0.380
Time (inverse)	0.985

Distance in M (inverse)	0.899
Clamp count (inverse)	0.816
Distance rating	0.914
Economy of movement	0.883
Clamp rating	0.800
Distance symmetry	0.797

AUC – Area under the curve

4.3.4 Interobserver agreement – expert reviewers

Cohen's kappa (κ) values for the GOALS subgroups and the overall score are detailed in Table 4.2. The results showed excellent agreement between observers for each subgroup (κ ≥ 0.8). However, for the overall score, the agreement was moderate with a Cohen's kappa of 0.571.

Table 4.2: Cohen's kappa results of interrater agreement

	R1 Mean score ± SD	R2 Mean score ± SD	κ-value ± SD	Level of agreement
Depth perception	3.22 ± 1.6	3.19 ± 1.5	0.87 ± 0.04	Excellent
Bimanual dexterity	3.60 ± 1.3	3.58 ± 1.6	0.86 ± 0.04	Excellent
Efficiency	3.19 ± 1.4	3.19 ± 1.3	0.85 ± 0.04	Excellent
Tissue handling	2.73 ± 1.2	2.71 ± 1.1	0.85 ± 0.04	Excellent
Autonomy	3.35 ± 1.3	3.33 ± 1.2	0.89 ± 0.04	Excellent

Overall GOALS score	16.1 ± 5.5	16.03 ± 5.3	0.57 ± 0.05	Moderate

SD – standard deviation
R1 – reviewer 1
R2 – reviewer 2
GOALS - Global Operative Assessment of Laparoscopic Skills

4.3.5 Agreement between computer and reviewer

Comparing the overall computerised grading and the grades of reviewer 1 and reviewer 2 the Cohen's kappa ratings were 0.02 and 0.06 respectively. This indicated poor level of agreement between these pairs of raters.

4.4 Discussion

In this study, we aimed to evaluate the effectiveness of the Laparo Analytic system as a tool for assessing laparoscopic skills. Our results clearly delineated a difference between human expert evaluations and the computerized system. While human experts consistently agreed in their assessments and aptly distinguished between trained and untrained participants, the computerized system's results were more varied. Notably, despite its overall performance not always aligning with human precision, the analytic system did show promise in specific parameters.

Laparoscopic skill assessment inherently presents complex challenges. Traditional methods, which predominantly rely on the direct observation by experienced surgeons, are resource-intensive and can be subject to personal biases.(125) This problem was magnified by recent challenges like the COVID-19 pandemic, which drastically reduced hands-on training opportunities.(128) Here, the importance of information technology (IT) in medical training became even more pronounced, as institutions turned to digital platforms and remote assessment tools, underscoring the pressing need for reliable, objective, and automated grading systems.(129)

Our observations are consistent with prior research on the efficacy of computerized laparoscopic grading systems.(130) Although these automated systems do not always match the granularity of human expertise, certain parameters within them have shown reliability.(130–132) This points to the significant potential of IT-enhanced grading systems, especially when they are developed in collaboration with surgical experts.

The potential of Artificial Intelligence (AI) further elevates this.(133) AI, with its capability for deep data analysis and adaptability, can be tailored to recognize intricate patterns in laparoscopic procedures.(134) Infused with surgical insights and built on robust IT platforms, AI algorithms could craft grading tools that are detailed, adaptable, and align with human assessments.(135)

A collaborative approach remains imperative. Merging feedback from experienced surgeons with insights from both IT and data science provides a comprehensive path to refine grading systems. Ensuring these tools are technically robust and clinically relevant, we can edge closer to an assessment paradigm that reflects real-world surgical excellence.

As the medical landscape becomes more digitized, the judicious integration and harnessing of both IT infrastructure and AI innovations become pivotal.(136) This convergence of IT systems, AI analytics, and surgical expertise heralds a promising paradigm in training methodologies.

4.4.1 Strength and limitations

One of the primary strengths of our research was the rigorous methodology, ensuring a fair comparison between human and automated grading methods. Additionally, our benchmarking against expert reviewers solidified the validity of our observations. However, we do acknowledge limitations. Focusing exclusively on the Laparo Analytic system may affect the extrapolation of our findings to other platforms and sourcing participants mainly from a singular academic institution could pose a selection bias. While the blinding of the task videos was fully maintained until all grading was completed it may have been possible for the graders to assume that task completion videos which had shorter time to completion were from trained participants potentially limiting the blinding of the grading process. While it was generally true that there was a shorter time to completion in the trained participants this was not always the case.

4.4.2 Conclusion

Our research underscores the challenges and opportunities of automated grading systems in laparoscopic training. While no singular tool can supplant the discernment of an expert surgeon, combining surgical insights with IT and AI advances holds promise. As we forge ahead, iterative refinement of these tools remains essential for an evolving, consistent, and versatile training landscape.

Chapter 5: M1 transcranial Direct Current Stimulation augments laparoscopic surgical skill acquisition

***Published in:** Scientific Reports. August 2023* (137)

5.1 Introduction

The acquisition of basic surgical skills is a key component of medical education for medical students and junior surgical trainees. Laparoscopic surgery is a minimally invasive surgical technique that involves the introduction of trocars and instruments through small incisions in the patient's abdomen.(138) The operative field is visualised using a camera inserted through the patient's umbilicus. Laparoscopy has many advantages over traditional open surgery particularly in terms of recovery time, blood loss and pain. Therefore, laparoscopy has been adopted widely in many surgical subspecialities and trainee surgeons must now acquire laparoscopic surgical skills as part of surgical training programs.(139,140)

Trainees in laparoscopic surgery typically begin developing their skills using simulation box trainers. Simulation of basic surgical tasks provides a safe platform for surgical trainees to develop the requisite cognitive and motor skills with no risk to patient outcomes. A variety of tasks can be administered and specific programs such as the Fundamentals of Laparoscopic Surgery (FLS) have been developed and incorporated into surgical training curricula worldwide.(141) Despite the advantages of simulation surgical training, access to training can be difficult for many trainees. Clinical workloads, the availability of simulation facilities and competing demands for limited resources have been highlighted as obstacles hindering the ability for trainees to access simulated surgical training.(142,143) Recently, the coronavirus pandemic has further impacted on the ability to provide training and accommodate the volume of trainees.(144) This limited exposure to training resources has the potential to hinder surgical performance and patient health. (145,146) As such, there is an increasing appetite in medicine to explore methods that may either increase both access to and the effectiveness of simulated surgical motor skill training on surgical performance.

In recent years, one technique that has shown promise as an adjunct to the deliberate practice of motor skill is transcranial electric stimulation (tES). Typically administered as a direct current (tDCS), this form of neurostimulation involves passing small electrical currents (1-3 mA) over the scalp to modulate the excitability of underlying cortical neurons for up to 60 minutes following stimulation.(60,63,147) When applied over the relevant limb representation of the motor cortex, tDCS has shown to accelerate improvements of various motor skills following training, including musical skills and sport skills.(61,67,148,149) As a result of the promise of this technique, commercially available tDCS devices have become available and received both FDA and CE approval. One such device is the Halo Neuroscience tDCS device (FlowNeuroscience™) which has been recently shown to accelerate training induced performance improvements of motor skill in video gaming tasks.(68)

Over the past 5 years, emerging research has been conducted examining the impact of tDCS on surgical skill acquisition. The few studies to date vary not only according to their methodological rigour but also by the site of neurostimulation, the tasks experimenters evaluated and the metrics that were used to quantify performance. For example, stimulation has largely been administered over the prefrontal cortex (65,150), primary motor cortex (64,151,152) or supplementary motor area (152), with most manually evaluating basic metrics of performance including the time to complete the task (65,153) or a score related to the number of errors made. (150–152,154) However, research highlighting the need for more robust and objective metrics to quantify surgical performance has shown that the inclusion of biomechanical measures such as instrument movement efficiency, velocity, and positioning can provide a more complete description of surgical skill. (48,155,156)

One such system that incorporates software that can integrate with traditional simulation box trainers to provide surgical trainees with biomechanical kinematic data of the implements during simulated surgical tasks has been developed by the company, LAPARO (Laparo analytic, Laparo Medical Simulators, Poland). Since its inception in 2015, this system has now been integrated in medical settings in over 90 countries around the world in over 1000 hospitals, medical schools, and simulation centres.(126) Despite its widespread acceptance, no study to date has assessed the effect of tDCS on laparoscopic skill acquisition incorporating performance metrics from the LAPARO software. By determining the kinematic markers of surgical skill improvement and the effect that tDCS can have on these markers across training, we can better understand how to evaluate surgical skill and coach surgical trainees.

The purpose of this study was to assess the impact that tDCS may have on the training induced improvement and retention of traditional time and kinematic based laparoscopic surgical skill metrics. We hypothesised that those receiving tDCS applied over the hand region of M1 would show greater training-mediated improvements in the time required to complete simulated surgical tasks, in the distance implements travelled over the course of the task, in the average velocity of the implements across tasks and through a reduction in the number of excessive velocity events, compared to those receiving a sham stimulation.

5.2 Materials and Methods

5.2.1 Participants

Fifty-three (N=53; 27 Female) young healthy adult participants aged 23.43±2.96 years (Mean±SD) were recruited from the University College Cork medical student population. All participants were naïve to laparoscopic skills training. Planned sample size was derived from previously published work in the area of tDCS neuromodulation. Each participant was provided with a study information leaflet and provided informed written consent prior to participating in the study. The experiment was approved by the University research ethics board in accordance with the Declaration of Helsinki.

5.2.2 Testing and Training Environment

All testing and training sessions were conducted at the ASSERT surgical simulation lab at University College Cork. In the centre of the room, a laparoscopic skill analyser was used to assess performance on surgical tasks at baseline, post-training and retention sessions (Laparo analytic, Laparo Medical Simulators, Poland). On the left side of the room, stations were set up to accommodate the 3 box trainers (identical to that used at the laparoscopic analyser station; Laparo Aspire, Laparo Medical Simulators, Poland) for training sessions, and on the right side of the room, 2 stations were allocated to the neurostimulation component of the experimental protocol.

5.2.3 Questionnaires

Upon entering the simulation lab on Day 1, participants completed a questionnaire that captured information regarding their age, sex and the number of hours they reported video gaming on average per week. Their handedness was assessed using the Edinburgh Handedness Scale. Participants were excluded if they reported any diagnosed neurological or neuromuscular disorder or if they were left-handed (1 excluded). To mitigate any confounding effects of caffeine, participants were asked to refrain from caffeine within 4-

6 h (157) of attending each daily experimental session and an experimenter recorded whether or not they had consumed any caffeine upon arriving to the lab each day.

On the first and final training days participants also completed the 32-item Brunel Mood State (BRUMs) questionnaire (158) and the Pittsburgh Sleep Quality Index (PSQI). (159) The BRUMs questionnaire comprises 32 different mood descriptors and participants were asked to indicate the extent to which each descriptor matched their current mood on a Likert scale from 1 to 4. The PSQI is a questionnaire that poses questions regarding a participant's sleep over the previous month. The questions in the PSQI were modified for participants on their final training day to inquire about their sleep over the previous week while enrolled in the study.

5.2.4 Baseline, Post and Retention testing

All participants performed the Baseline (Day 1), Post (Day 5) and Retention (Day 10) tests using a laparoscopic skill analytic system. This system allows for detailed capture of a kinematic data from the laparoscopic instruments during completion of the assigned tasks. Participants were assessed on their ability to complete 2 predefined training modules. These were a bead transfer (BEAD) task and a threading task (THREAD). During the bead transfer task, participants were required to transfer 22 beads from a large central pot to 6 small pots and 4 posts by initially grasping the bead with their left instrument, transferring it to their right instrument and then placing the bead appropriately. Participants were asked to complete the task in a clockwise fashion. During the threading task, participants were required to thread a rubber thread through a predefined course consisting of 9 pegs (Figure 5.1).

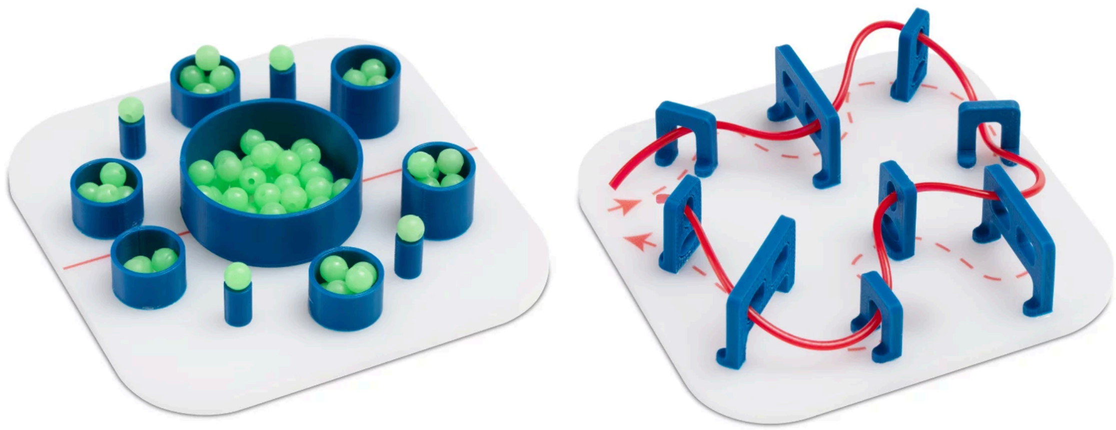

Figure 5.1: Bead transfer task (left) and threading task (right)

5.2.5 Neurostimulation Groups

Each participant was randomly assigned to either an active (n=26) or sham (n=23) tDCS stimulation group for the duration of the study at the time of their enrolment. All participants were blinded to the condition they were assigned to, as was the experimenter responsible for administering the testing and training sessions. Participants in both neurostimulation groups wore a custom headset (HALO Neuroscience™) designed to deliver transcranial Direct Current Stimulation (tDCS) to the cortical neurons of the M1 area responsible for controlling hand and arm movement. (68) Nasion, inion and aural landmarks were used to locate the vertex (Cz) on every participant to ensure consistent headset positioning. (160,161)

Participants in the active (STIM) neurostimulation group received 2.1 mA of anodal stimulation for a duration of 20 min whereas participants in the sham (SHAM) neurostimulation group received an anodal current that ramped from 0mA to 1mA and then back to 0 mA over two 30s intervals before remaining at 0 mA for the following 19 min. This stimulation protocol has been demonstrated previously to not affect the long-term excitability of the underlying cortical neurons (162). Participants in both groups completed a crossword puzzle task to control the cognitive engagement of participants and mitigate differences in underlying cortical network activity between neurostimulation groups during the 20-minute SHAM and STIM protocols immediately prior to training. (163,164)

5.2.6 Protocol

On the first day (Day 1) participants completed their questionnaires, performed their baseline evaluation of the bead transfer and threading tasks on the laparoscopic skill analyser, completed their neurostimulation protocol, and performed 20 minutes of laparoscopic training in the box trainer. On days 2, 3 and 4, participants simply completed the neurostimulation protocol and performed 20 minutes of laparoscopic training in the box trainer. On Day 5, after completing the BRUMs and PSQI questionnaires a second time, they received the appropriate neurostimulation protocol and trained a final time for 20 minutes. Following this training session, participants performed their Post evaluation of the bead transfer and threading tasks on the laparoscopic skill analyser. Participants then returned to the lab 5 days later (Day 10) to complete a final Retention evaluation of their bead transfer and threading task performance on the laparoscopic skill analyser and were asked to report which stimulation group they thought they had been assigned (manipulation check) (see Figure 5.2 for an illustration of the experimental protocol). Participants who did not complete the Post evaluation or missed 2 training sessions were excluded from the study (3 participants were excluded in this way). Overall, 49 participants were brought forward for data processing and analysis.

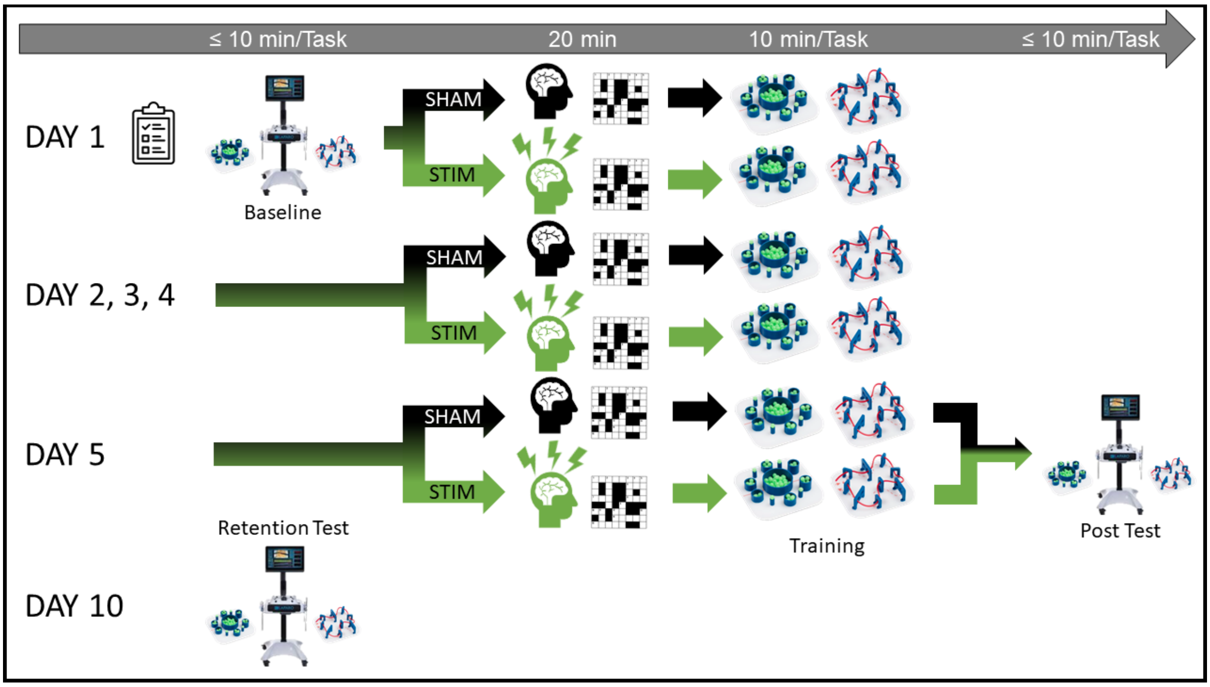

Figure 5.2: Illustration of the experimental protocol. Both bead transfer and threading tasks were completed for a maximum of 10 minutes each one after the other at Baseline, Post and Retention test evaluations on the laparoscopic skill analyser.

5.2.7 Data Processing

Four primary performance metrics were recorded from each of the Baseline, Post and Retention laparoscopic evaluations. The Time to Complete (TTC) each task was determined from the time the instruments were inserted into the laparoscopic box trainer to either the time when they were removed after completing the task or when 10 minutes had expired. The Distance Travelled metric described the total distance each implement travelled between the time of insertion and either the time of removal or the expiry of the 10-minute time limit. The average velocity of each implement was recorded between the start and end of each task as was the number of excessive velocity events, calculated as the number of instances that the instantaneous velocity of an implement exceeded two standard deviations of the average velocity.

5.2.8 Analyses

All statistical analyses were conducted using SPSS v25 statistical software. Data normality was verified by Shapiro-Wilk analysis and observation of Q-Q plots and histograms. For any metrics where data residuals were not normally distributed, outlying data beyond 1.5x the inter quartile range were excluded prior to conducting parametric analyses. Independent t-tests were conducted to evaluate where data for any of our metrics differed between males and females. Where Mauchly's sphericity tests indicated the variance was significantly heterogeneous among groups, Greenhouse-Geisser alpha corrections were applied when conducting ANOVAs and ANCOVAs. Three-way ANOVAs (Session x Condition x Implement) were conducted to test whether performance differed across sessions, between stimulation conditions, or between implements. Where a main effect of condition or interaction between session and condition was found, 3-way ANCOVAs were conducted, controlling for baseline scores, to establish whether a significant effect of session (Post and Retention), stimulation condition, implement, or the interaction between these variables existed.

5.3 Results

Independent sample t-tests revealed no significant differences between male and female participants for any performance metric in both the bead transfer and threading tasks.

5.3.1 Time to Complete (TTC)

The effect of session ($F_{(1.608,\ 107.724)}=525.407$, $p<.001$, $\eta^2=.887$) and the interaction effect between session and stimulation condition ($F_{(1.608,\ 107.724)}=5.788$, $p=.007$, $\eta^2=.080$) were both significant for TTC in the bead transfer task. Post hoc comparisons revealed that participants in both stimulation conditions significantly reduced the time required to complete the bead transfer task after 5 days of training ($p<0.001$) and that this reduction was maintained at the retention test 5 days after the Post test (Post vs. Retention: Stim; $p=0.063$, Sham; $p=0.972$). After confirming no significant difference in baseline TTC performance between stimulation conditions, ANCOVA analysis revealed that after controlling for variations in baseline performance, a significant main effect of condition was found ($F_{(1, 66)}$=5.028, p=.028, η^2=.071) where those in the stim group were able to reduce their bead transfer completion time by 38.989±17.389s more than those in the sham group (Figure 5.3A).

In the threading task, a significant main effect of session was found ($F_{(2, 168)}$=280.318, p<.001, η^2=.769) for TTC in the threading task (Figure 5.3B). Post hoc comparisons revealed that all participants were able to improve their performance by 185.804±10.791s between Baseline and Post sessions and by a further 48.030±9.347s between Post and Retention sessions (all p<0.001). No main effect was found for stimulation condition or implement, nor were any significant interaction effects found.

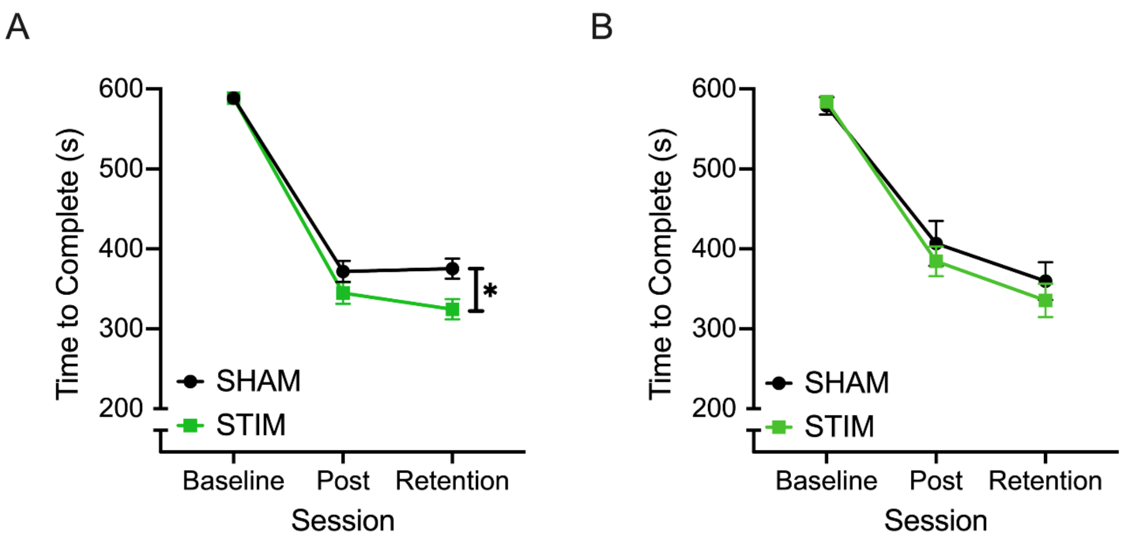

Figure 5.3: The average (±SE) time (in seconds) required to complete the bead transfer (A) and threading (B) tasks at Baseline, Post and Retention sessions by participants who received active tDCS (STIM; green) and sham tDCS (SHAM; black). **** represents significant differences between neurostimulation groups at an alpha level of 0.05.***

5.3.2 Distance Travelled

For Distance Travelled, both the main effect of session ($F_{(1.439, 96.401)}$=191.134, p<.001, η^2=.740) and interaction between session and stimulation condition were significant, ($F_{(1.439, 96.401)}$=4.704, p=.020, η^2=.066). Post hoc comparisons revealed that participants in both stimulation conditions significantly reduced the distance their implements travelled to complete the bead transfer task after 5 days of training (p<0.001). Moreover, while this reduction was maintained at the retention test 5 days after the Post test for the sham group (Post vs. Retention: Sham; p=0.081), further improvements were observed at retention for the stim group (Post vs. Retention: Stim; p<0.001). After confirming no significant difference in baseline TTC performance between stimulation conditions, ANCOVA analysis revealed that after controlling for variations in baseline performance, a significant main effect of implement was found ($F_{(1, 66)}$=9.326, p=.003, η^2=.124). While the effect of condition was not significant ($F_{(1, 66)}$=3.088, p=.084, η^2=.045), there was a trend for participants in the stim group to reduce the amount their instruments travelled for in Post and Retention sessions by 77.449cm more than those in the sham group (Figure 5.4A).

In the threading task, a significant main effect of session was found ($F_{(2, 166)}$=122.697, p<.001, η^2=.596) for TTC in the threading task. Post hoc comparisons revealed that participants were able to reduce the amount their implements travelled during the task by 3.751±.357m between Baseline and Post sessions and by a further 1.347±.268m between Post and Retention sessions (all p<0.001). No main effect was found for stimulation condition or implement, nor were any significant interaction effects found (Figure 5.4B).

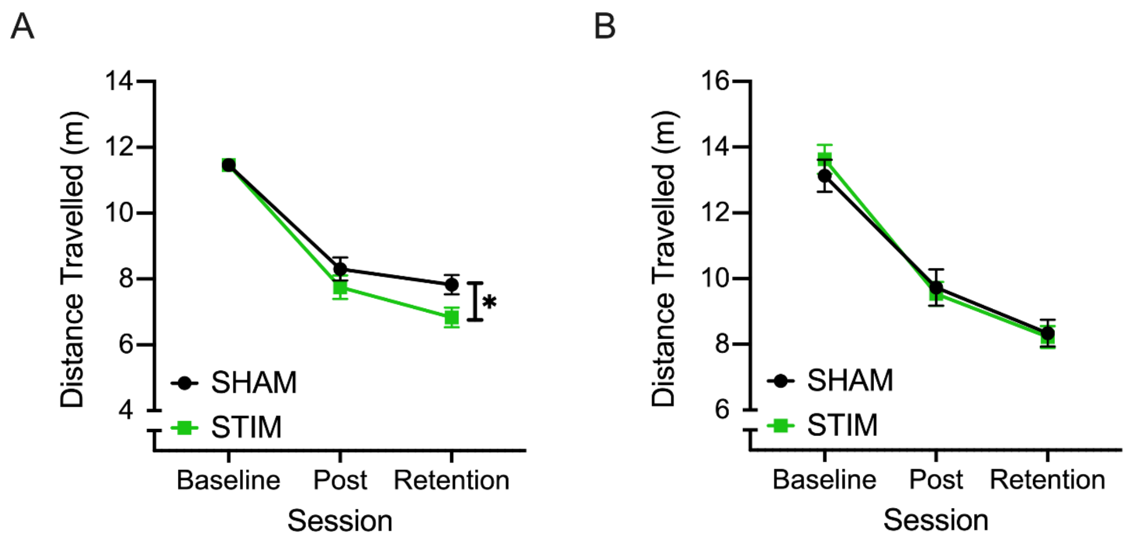

Figure 5.4: The average (±SE) distance travelled (in metres) by both implements during completion of the bead transfer (A) and threading (B) tasks at Baseline, Post and Retention sessions by participants who received active tDCS (STIM; green) and sham tDCS (SHAM; black). **** represents significant differences between neurostimulation groups at an alpha level of 0.05.***

5.3.3 Velocity

When considering the average velocity of the implements during the bead transfer task, the effect of session ($F_{(1.582, 106.026)}$=29.716, p<.001, η^2=.887), implement ($F_{(1, 67)}$=33.101, p<.001, η^2=.331) and the interaction between these two variables ($F_{(1.582, 106.026)}$=16.509, p<.001, η^2=.198) were all significant. Post hoc comparisons revealed that while the average velocity of the Grasper in the left hand did not significantly differ across sessions (all p>.126), the velocity of the Dissector, in the right hand, significantly increased between Baseline and Post sessions (p<.001) and then decreased between Post and Retention sessions (p<0.001) while remaining higher than the velocity at baseline (p<0.001)(Figure 5.5A). No effect of stimulation condition was found for velocity during the bead transfer task.

In the threading task, a significant effect of session was found ($F_{(1.734, 143.962)}$=6.083, p=.003, η^2=.068) with post hoc comparisons revealing that the average speed of participants' implements was significantly higher during the Post session compared to the Baseline (p=.007) but not Retention (p=.482) sessions (Figure 5.5B).

5.3.4 Excessive Velocity Events

In the bead transfer task, main effects of implement ($F_{(1, 67)}$=4.449, p=.039, η^2=.062), session ($F_{(2, 134)}$=94.522, p<.001, η^2=.585), and condition ($F_{(1, 67)}$=4.618, p=.035, η^2=.064) were all significant, as was the interaction between session and stimulation condition ($F_{(2, 134)}$=4.604, p=.012, η^2=.064). Post hoc analyses revealed that in the Retention session, the stimulation group had significantly fewer excessive velocity events compared to the sham group. After confirming no significant difference in baseline TTC performance between stimulation conditions, ANCOVA analysis revealed that after controlling for variations in baseline performance, a significant main effect of condition was found ($F_{(1, 66)}$=6.848, p=.011, η^2=.094) where those in the stim group were able to significantly reduce the number of excessive velocity events by 3.490±1.334s more than those in the sham group (Figure 5.5C).

In the threading task, significant main effects of session ($F_{(2, 166)}$=123.218, p<.001, η^2=.598) and implement ($F_{(1, 83)}$=4.791, p=.031, η^2=.055) were found. Post hoc comparisons showed that 1.851±.846 fewer excessive velocity events were detected for the dissector in the right hand compared to the grasper in the left hand. Moreover, participants were able to significantly reduce the number of excessive velocity events during task completion across all 3 testing sessions (all p=.001) (Figure 5.5D).

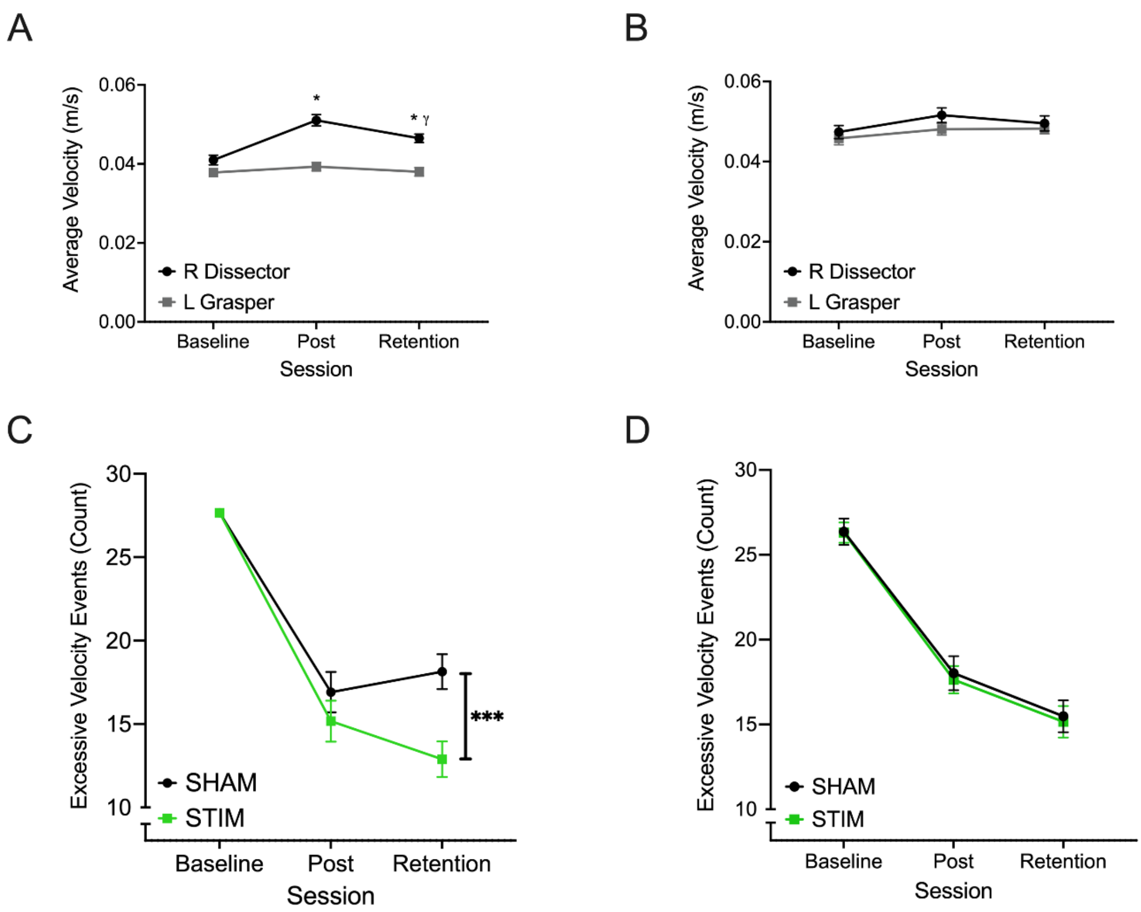

Figure 5.5: A & B: The average (±SE) velocity of the left (grey) and right (black) implements during completion of the bead transfer (A) and threading (B) tasks across Baseline, Post and Retention sessions. C & D: The average (±SE) number of excessive velocity events by both implements during completion of the bead transfer (C) and threading (D) tasks at Baseline, Post and Retention sessions by participants who received active tDCS (STIM) and sham tDCS (SHAM). **** and γ represent significant differences from Baseline and Post sessions respectively at an alpha level of 0.05. *** represents significant differences between neurostimulation groups at an alpha level of 0.001.***

5.4 Discussion

The purpose of this study was to assess the impact of tDCS on the training induced improvement and retention of laparoscopic surgical skill. Two commonly used tasks were assessed, a bead transfer, and a threading task. Participants in both the sham and stimulation groups significantly improved their performance on both tasks following a training protocol that involved 5 sessions each 20 minutes in duration (10 minutes per task). While no significant difference in the level of improvement on the threading task between participants in the sham and stimulation groups was found, we did find that those participants who received anodal tDCS applied over the hand region of M1 improved both their time and kinematic based performance metrics on the bead transfer task to a greater extent than those who trained whilst receiving a sham stimulation. Furthermore, this enhanced improvement observed among the stimulation group was maintained 5 days later at the retention test. We discuss these findings within the context of training induced sensory-motor skill improvements, the effect of tDCS on the enhancement of motor skill and the future implications of enhancing surgical skill through neuromodulation techniques on the medical profession.

In this study, novice surgical participants in both stimulation conditions significantly reduced the time required to complete the bead transfer task and this reduction was maintained at the retention test 5 days following completion of the Post test. However, the stim group demonstrated a 5% improvement in time to completion compared to the sham group. This 5% equates to a 30 second faster time to complete the bead transfer task compared to the sham group at the retention time point. This finding corroborates the work by Cox and colleagues who showed the added improvement of tDCS over the SMA on a surgical peg transfer task to be 3% when compared to sham stimulation. (152) Furthermore, Friehs and colleagues reported a 4.5% improvement on a digital stop-signal game measuring response inhibition. (165)

On the threading task both groups significantly improved over the course of training from pre to post/retention but there was no significant effect of neurostimulation. The stim group did, on average however, complete the task 17 seconds quicker than the sham group. Turning to the findings for implements distance travelled, participants in both stimulation conditions significantly reduced the distance their implements travelled to complete the bead transfer task after 5 days of training. Moreover, while this reduction was maintained at the retention test 5 days after the Post test for the sham group, further improvements were observed at retention for the stim group. A smaller distance of travel by the implements would indicate a safer more efficient laparoscopic procedure. Other surgical skills research reports a decrease in error scores coupled with quicker completion times. (65,152) In the threading task, participants were able to reduce the amount their implements travelled during the task between Baseline and Post sessions and between Post and Retention sessions but the stim and sham groups did not significantly differ.

Finally, we sought to examine the steadiness or smoothness with which participants controlled the implements during the completion of both tasks and were able to do so by measuring implement velocity and defining excessive velocity events. In the bead transfer task, main effects of implement, session, and condition were all significant, as was the interaction between session and stimulation condition. Post hoc analyses revealed that in the Retention session, the stimulation group had significantly fewer excessive velocity events compared to the sham group. After confirming no significant difference in baseline TTC performance between stimulation conditions, we showed that after controlling for variations in baseline performance, a significant main effect of neurostimulation was found where those who received tDCS were able to significantly reduce the number of excessive velocity events more than those in the sham group over the course of training (Figure 5.5C). In the threading task, significant main effects of session and implement were found but again the effect of neurostimulation was not significant (Figure 5.5D).

The observed improvements by the stimulation group over and above those receiving sham stimulation equate to a significant time improvement, coupled with reduced instrument travel distance and improved implement control (increase in movement smoothness observed as a reduction in EVEs). These reductions are similar to training induced improvements in other sensory-motor and digital tasks (68,165) as well as surgical training tasks.(152) For example, Toth noted a 6.1- 8.9% improvement for the M1 tDCS stim group (high skill/ low skill groups) over a sham group for a target acquisition task over the same time course of training (5 days x 10 mins per day training x 20 mins of stim/ sham).(68)

However, while the beads task was able to successfully demonstrate a significant positive effect of M1 stimulation, the threading task did not. For now, we hypothesize that it may be that the beads task is a highly repetitive highly consistent spatio-temporal task that may be more conducive to the effects of brain stimulation during training. The threading task is more complex and variable from a sensorimotor standpoint where the movement and positioning of the implements appear to differ more greatly across multiple attempts at completing the task. Previous work has shown that as task complexity increases, brain activation extends towards prefrontal, parietal and temporal areas. (166,167) As a result, neurostimulation of M1 may not be sufficient to modulate more complex task performance over the time-period observed in this study. This hypothesis fits well with existing work showing a lack of an effect of tDCS during more complex tasks. (168) Overall, future work may look to characterising the variability or complexity of various surgical tasks to better establish optimal time-periods over which the effects of tDCS may manifest, or also explore to a greater extent the efficacy of multisite neurostimulation protocols on exacerbating the benefits of neurostimulation to the development and maintenance of surgical expertise.

The findings and implications from this research may be applied to several research areas and real-world situations. For example, when learning a new task, we replicate that performance can vary considerably in novice performers. (169) Awareness of this knowledge may provide encouragement and facilitate resilience in novice performers who may be prone to frustration and decreased motivation due to their initially high-performance variability when learning a new skill. This knowledge also can be applied into existing self-regulated learning models of deliberate practice. (170) Secondly, since more time and effort are required to manifest appreciable increases in performance as expertise increases, cognitive strategies such as mental practice (171) and action observation (172) may be implemented given their previously shown effectiveness for augmenting performance. The use of motor simulation strategies like mental practice and action observation may be especially relevant in surgical skills training, where the effect of these cognitive strategies on performance has yet to be investigated with any rigour. Thirdly, our work has corroborated previous research in showing that tDCS is highly efficacious for skill acquisition among novice performers. (169) Overall, tDCS is a promising technique in both performance and clinical contexts and we encourage future research to continue to explore its merit.

5.5 Conclusion

Overall, this study demonstrates that magnitude of performance improvement on two laparoscopic training skills, bead transfer and threading, among novice surgical trainees over the course of 1 week of training (100 mins). Secondly, we showed that transcranial direct current stimulation (tDCS) can accelerate motor performance improvements, and that the effect of tDCS was potentially confined to the bead transfer task over the training period examined due to its simplicity compared to the threading task. This work significantly contributes to a growing body of research investigating the effects of neurostimulation on sensory-motor performance and demonstrates laparoscopic simulation training as a fruitful avenue to study motor learning and the effects of neurostimulation on motor skill development.

Chapter 6: A single blind randomised controlled trial of M1 transcranial direct current stimulation for the enhancement of robotic surgical skill acquisition

6.1 Introduction

Surgical proficiency is essential for the development of surgical trainees. Robotic-assisted surgery, a refined version of minimally invasive procedures, amplifies surgical precision, flexibility, and control.(173) Although traditional laparoscopy offers advantages over open surgery, robotic surgery further elevates these benefits, emphasizing better visualization, enhanced dexterity, and reduced surgeon fatigue.(174) Thus, trainees must master both laparoscopic techniques and robotic-assisted surgeries.(175)

Training in robotic surgery often employs simulators tailored for this modality, offering a safe environment for trainees. Established curriculums like the Robotic Training Network (RTN) underline the significance of structured training programs.(176) However, challenges emerge due to trainee commitments, limited simulator access, resource constraints and recent global health crises.(176–179) These challenges might jeopardize surgical results and patient well-being, amplifying the need to boost the quality and accessibility of robotic surgical training.

An innovative method to augment motor skill development is transcranial electric stimulation (tES).(180) Using a mild electric current and delivered primarily as direct current (tDCS), tDCS, a form of tES, can modify the activity of specific brain regions, aiding various motor learning tasks.(147,181,182)

Research has explored tDCS's potential in surgical skill acquisition, especially in laparoscopy.(152,182) These studies have diverse approaches in terms of stimulation sites, methods, tasks, and performance metrics. The surgical community increasingly favours more precise metrics for assessing surgical skills.(156,183)

LAPARO, responding to this need, designs software for robotic surgical simulators that provide intricate biomechanical feedback. A notable study utilizing LAPARO that investigated the impact of tDCS on laparoscopic surgical skill acquisition, found that while tDCS improved certain task performances, it didn't benefit others, suggesting task complexity might play a role.(137)

There exists a research gap concerning tDCS's effect on robotic surgery skill development with LAPARO's metrics. In this study, we aimed to evaluate tDCS's influence on the enhancement and retention of traditional time-based and biomechanical metrics specific to robotic surgery skills. Our hypothesis posits that tDCS recipients would outperform those receiving placebo stimulation in various measures.

6.2 Materials and methods

6.2.1 Participants

Twenty-five (N=25; 13 Female) young healthy adult participants aged 24.44 ± 2.39 years (Mean ± SD) were recruited from the University College Cork medical student population. All participants were naïve to robotic surgery skills training. Eleven participants had undertaken laparoscopic skills training previously. Each participant was provided with a study information leaflet and provided informed written consent prior to participating in the study. The experiment was approved by the clinical research ethics committee of the Cork Teaching Hospitals at University College Cork as well as the University of Limerick research ethics board in accordance with the Declaration of Helsinki.

6.2.2 Testing and Training Environment

All testing and training sessions were conducted at the ASSERT surgical simulation lab at University College Cork. The DaVinci surgical robot was used to conduct all testing and training sessions. The robot interfaced with a laparoscopic skills analyser (Laparo analytic, Laparo Medical Simulators, Poland) using custom 3D printed laparoscopic ports which allowed the analyser to capture the movement of the robotic instruments. Participants operated the surgical robot using the remote surgeons' console (Figure 6.1) 2 stations were allocated to the neurostimulation component of the experimental protocol.

Figure 6.1: da Vinci robotic system. Participant in surgeon's console.

6.2.3 Questionnaires

Upon entering the simulation lab on Day 1, participants completed a questionnaire that captured information regarding their age, sex, the number of hours they reported video gaming on average per week and if they had any previous laparoscopic or robotic training experience. Their handedness was assessed using the Edinburgh Handedness Scale. Participants were excluded if they reported any diagnosed neurological or neuromuscular disorder (0 excluded). To mitigate any confounding effects of caffeine, participants were asked to refrain from caffeine within 4-6hrs (157) of attending each daily experimental session and an experimenter recorded whether they had consumed any caffeine upon arriving to the lab each day.

On the first and final training days participants also completed the 32-item Brunel Mood State (BRUMs) questionnaire (158) and the Pittsburgh Sleep Quality Index (PSQI).(159) The BRUMs questionnaire comprises 32 different mood descriptors and participants were asked to indicate the extent to which each descriptor matched their current mood on a Likert scale from 1 to 4. The PSQI is a questionnaire that poses questions regarding a participant's sleep over the previous month. The questions in the PSQI were modified for participants on their final training day to inquire about their sleep over the previous week while enrolled in the study.

6.2.4 Baseline, Post and Retention testing

All participants performed the Baseline (Day 1), Post (Day 3) and Retention (Day 8) tests using the robotic system interfaced with the laparoscopic analytic system. This system allows for detailed capture of a kinematic data from the robotic instruments during completion of the assigned tasks. Participants were assessed on their ability to complete 3 predefined training modules. These were a bead transfer (BEAD) task, a threading task (THREAD) and an elastic band stretching task (BAND).

During the bead transfer task, participants were required to transfer 22 beads from a large central pot to 6 small pots and 4 posts by initially grasping the bead with their left instrument, transferring it to their right instrument and then placing the bead appropriately. Participants were asked to complete the task in a clockwise fashion.

During the threading task, participants were required to thread a rubber thread through a predefined course consisting of 9 pegs.

During the band stretching task participants were asked to stretch six rubber bands around six posts on the training module (Figure 6.2).

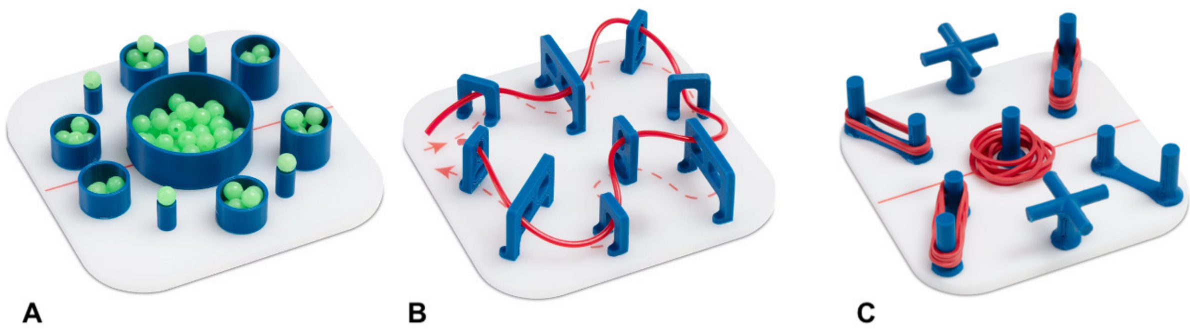

Figure 6.2: Bead transfer task (A), threading task (B) and band stretching task (C)

6.2.5 Neurostimulation Groups

Each participant was randomly assigned to either an active (n=12) or sham (n=13) tDCS stimulation group for the duration of the study at the time of their enrolment. All participants were blinded to the condition they were assigned to, as was the experimenter responsible for administering the testing and training sessions. Participants in both neurostimulation groups wore a custom headset (HALO Neuroscience™) designed to deliver transcranial Direct Current Stimulation (tDCS) to the cortical neurons of the M1 area responsible for controlling hand and arm movement.(68) Measurement of nasion, inion and aural landmarks were used to locate the vertex (Cz) on every participant to ensure consistent headset positioning. (160,161)

Participants in the active (STIM) neurostimulation group received 2.1 mA of anodal stimulation for a duration of 20 min whereas participants in the sham (SHAM) neurostimulation group received an anodal current that ramped from 0mA to 1mA and then back to 0 mA over two 30s intervals before remaining at 0 mA for the following 19 min. This stimulation protocol has been demonstrated previously to not affect the long-term excitability of the underlying cortical neurons.(162) Participants in both groups completed a wordsearch puzzle task to control the cognitive engagement of participants and mitigate differences in underlying cortical network activity between neurostimulation groups during the 20-minute SHAM and STIM protocols immediately prior to training.(163,164)

6.2.6 Protocol

On the first day (Day 1) participants completed their questionnaires, performed their baseline evaluation of the three tasks on the robotic laparoscopic skill analyser, completed their neurostimulation protocol, and performed 30 minutes of robotic training. On day 2 participants simply completed the neurostimulation protocol and performed 30 minutes of robotic surgery training in the robotic laparoscopy analyser. On Day 3, after completing the BRUMs and PSQI questionnaires a second time, they received the appropriate neurostimulation protocol and trained a final time for 30 minutes. Following this training session, participants performed their post-training evaluation of the three tasks on the robotic laparoscopic skill analyser. Participants then returned to the lab 5 days later (Day 8) to complete a final Retention evaluation of their performance on the robotic laparoscopic skill analyser and were asked to report which stimulation group they thought they had been assigned (manipulation check) (see Figure 6.3 for an illustration of the experimental protocol). Participants who did not complete the Post evaluation or missed a training session were excluded from the study (0 participants were excluded in this way). Overall, 25 participants were brought forward for data processing and analysis.

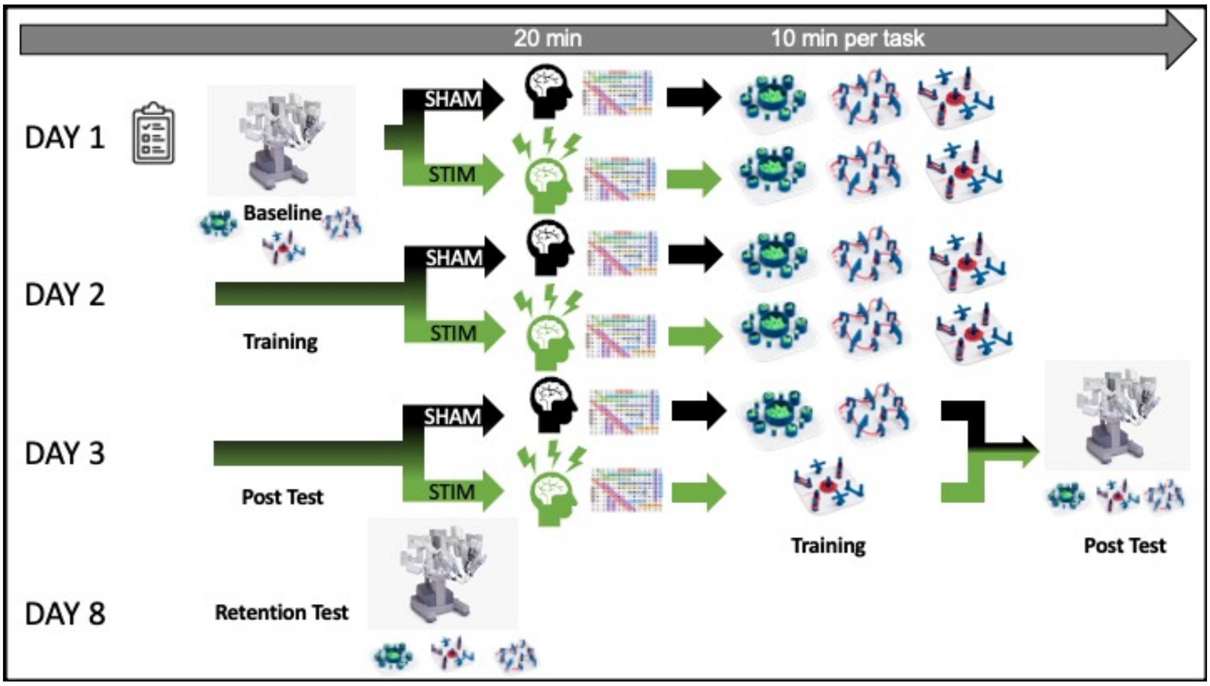

Figure 6.3: Illustration of the experimental protocol. Each task was completed for a maximum of 10 minutes each one after the other at Baseline, Post and Retention test evaluations on the laparoscopic skill analyser.

6.2.7 Data Processing

Four primary performance metrics were recorded from each of the Baseline, Post and Retention laparoscopic evaluations. The Time to Complete (TTC) each task was determined from the time the time the task began until the task was completed or when 10 minutes had expired, whichever occurred sooner. The Distance Travelled metric described the total distance each implement travelled between the time of insertion and either the time of task completion or the expiry of the 10-minute time limit. The average velocity of each implement was recorded between the start and end of each task as was the number of excessive velocity events, calculated as the number of instances that the instantaneous velocity of an implement exceeded two standard deviations of the average velocity.

6.2.7 Analyses

All statistical analyses were conducted using SPSS v25 statistical software. Data normality was verified by Shapiro-Wilk analysis and observation of Q-Q plots and histograms. For any metrics where data residuals were not normally distributed, outlying data beyond 1.5x the inter quartile range were excluded prior to conducting parametric analyses. Independent t-tests were conducted to evaluate where data for any of our metrics differed between males and females. Where Mauchly's sphericity tests indicated the variance was significantly heterogeneous among groups, Greenhouse-Geisser alpha corrections were applied when conducting ANOVAs. Two-way ANOVAs (Session x Condition x Implement) were conducted to test whether performance differed across sessions, between stimulation conditions, or between implements.

6.3 Results

Independent sample t-tests revealed no significant differences between male and female participants for any performance metric in any task. There were no baseline demographic differences between the two stimulation condition groups.

6.3.1 Bead Transfer task

Time to Complete (TTC)

The effect of session ($F=100.24$, $p<.001$, $\eta^2=.676$) was significant for TTC in the bead transfer task. Overall, participants reduced their TTC after 3 days of training (Baseline vs. Post) by 247.02±107.37s ($P<0.001$). No main effect was found for stimulation condition or implement, nor were any significant interaction effects found.

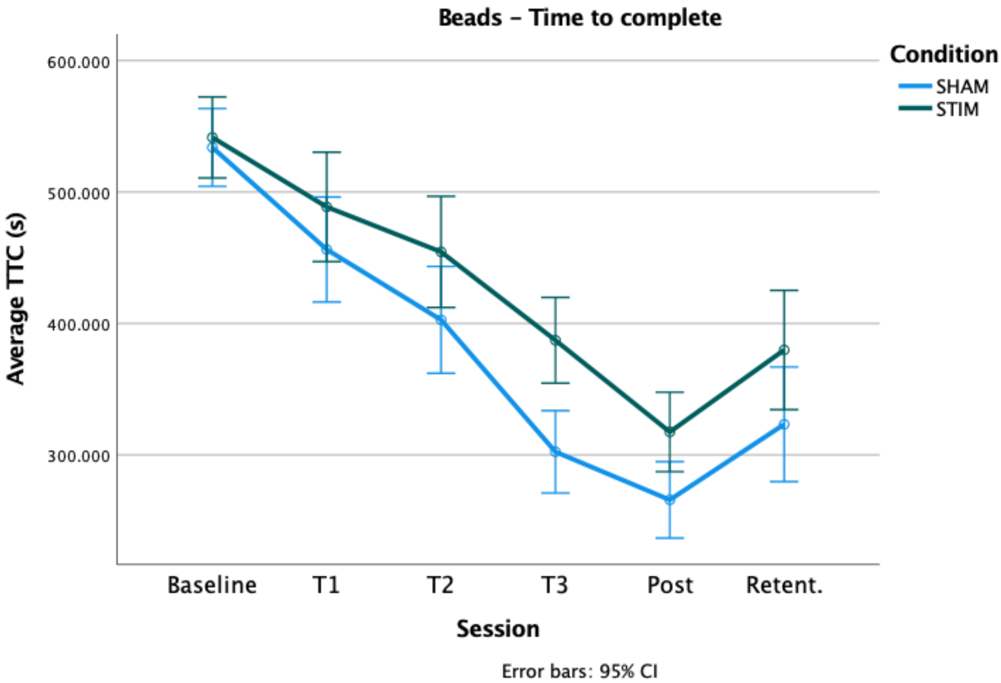

Figure 6.4: Beads task time to complete analysis

Distance travelled (m)

The effect of session (F=556.488, p<.001, η^2=.541) was significant for distance travelled in the bead transfer task. Overall, participants reduced their total distance travelled after 3 days of training by 0.55±0.37m(p<0.001). No main effect was found for stimulation condition or implement, nor were any significant interaction effects found.

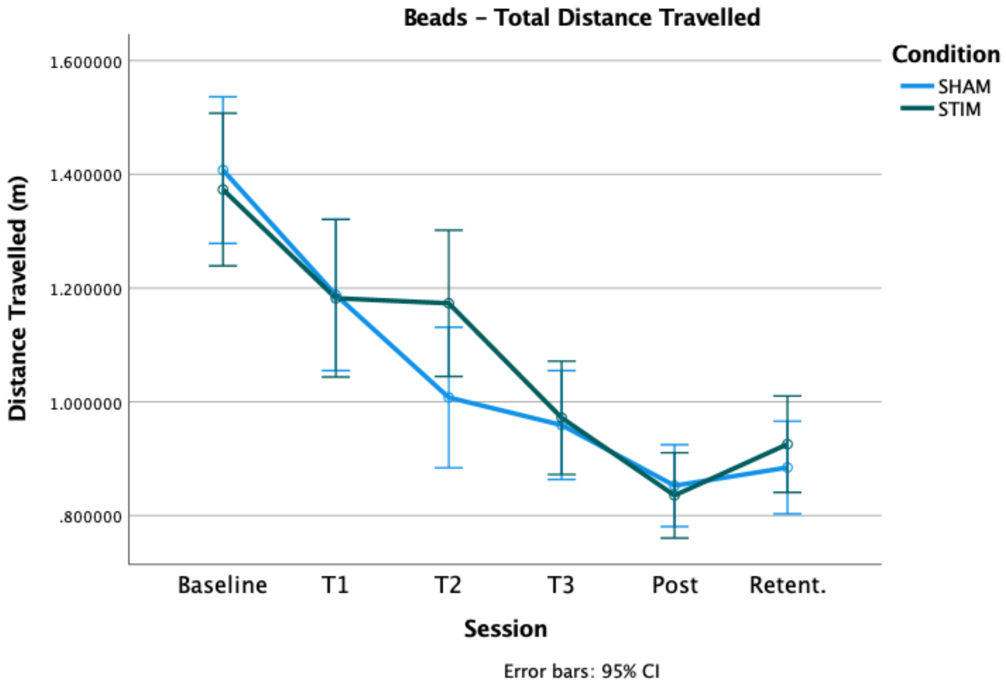

Figure 6.5: Beads task distance travelled analysis

Excessive velocity events

The effect of session (F=49.311, p<.001, η^2=.507) was significant for a reduction in excessive velocity events in the bead transfer task. Overall, participants reduced their total number of excessive velocity events after 3 days of training by 62.38±43.73 events (p<0.001). No main effect was found for stimulation condition or implement, nor were any significant interaction effects found.

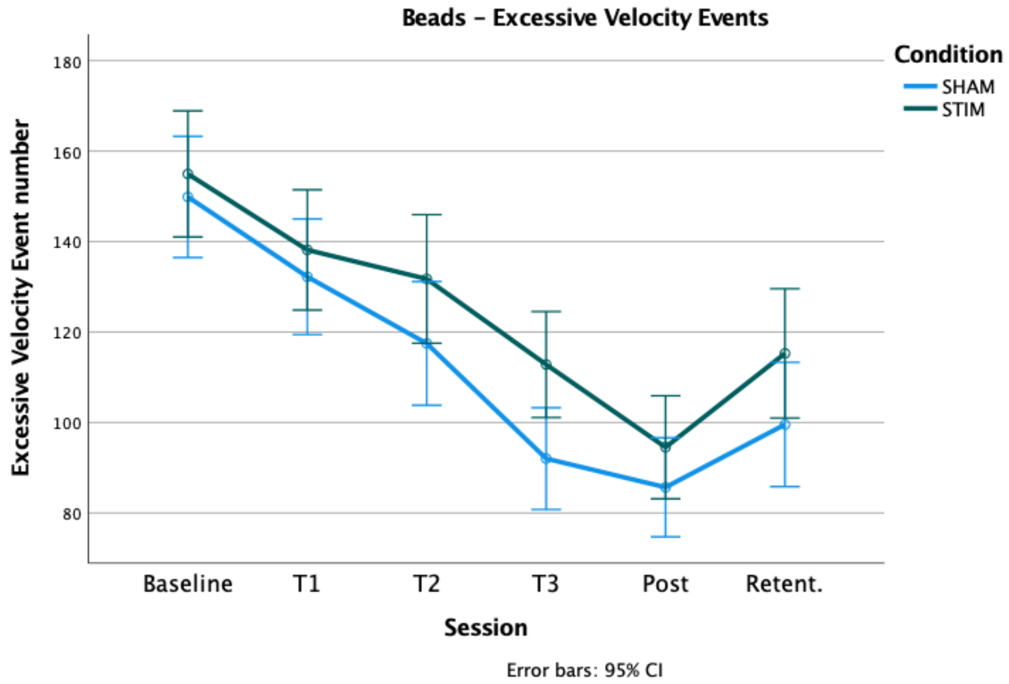

Figure 6.6: Beads task excessive velocity events analysis

6.3.2 Threading task

Time to Complete (TTC)

The effect of session (F=54.07, p<.001, η^2=.53) was significant for TTC in the threading task. Overall, participants reduced their TTC after 3 days of training (Baseline vs. Post) by 191.17±179.14s (P<0.001). No main effect was found for stimulation condition or implement, nor were any significant interaction effects found.

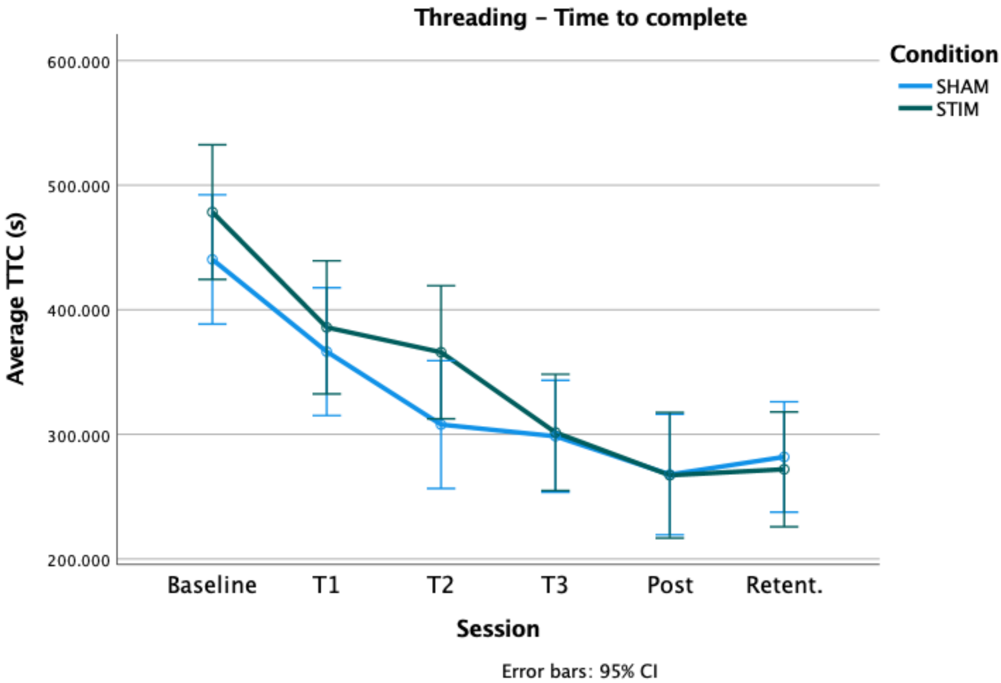

Figure 6.7: Threading task time to complete analysis

Distance travelled (m)

The effect of session (F=16.877, p<.001, η^2=.26) was significant for distance travelled in the threading task. Overall, participants reduced their total distance travelled after 3 days of training by 0.61±1.05m(p<0.001). No main effect was found for stimulation condition or implement, nor were any significant interaction effects found.

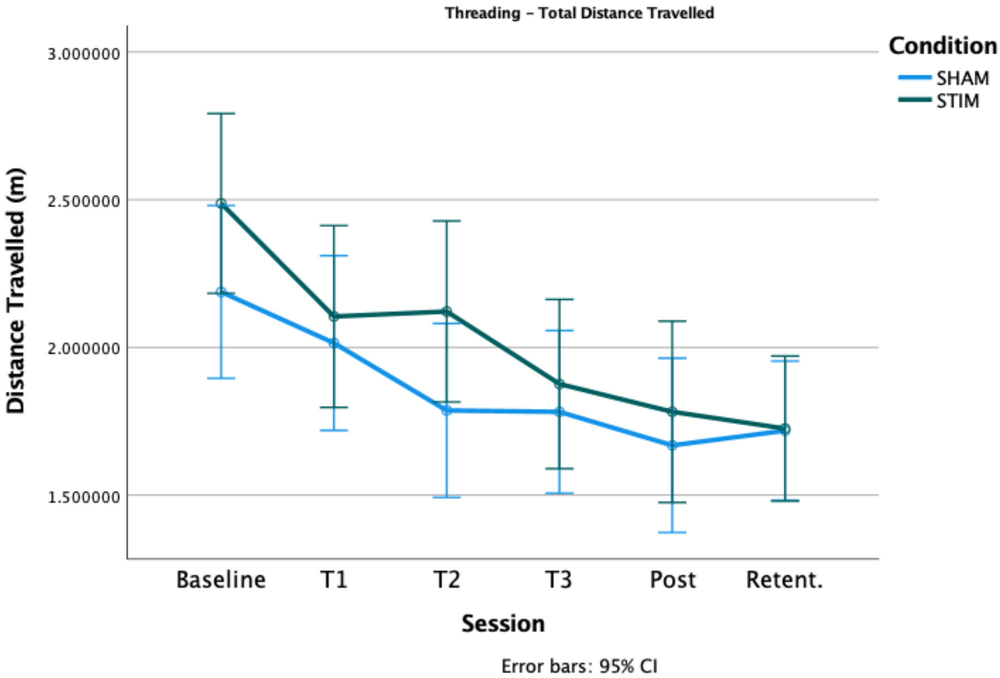

Figure 6.8: Threading distance travelled analysis

Excessive velocity events

The effect of session (F=33.24, p<.001, η^2=.409) was significant for a reduction in excessive velocity events in the threading task. Overall, participants reduced their total number of excessive velocity events after 3 days of training by 53.24±59.16 events (p<0.001). No main effect was found for stimulation condition or implement, nor were any significant interaction effects found.

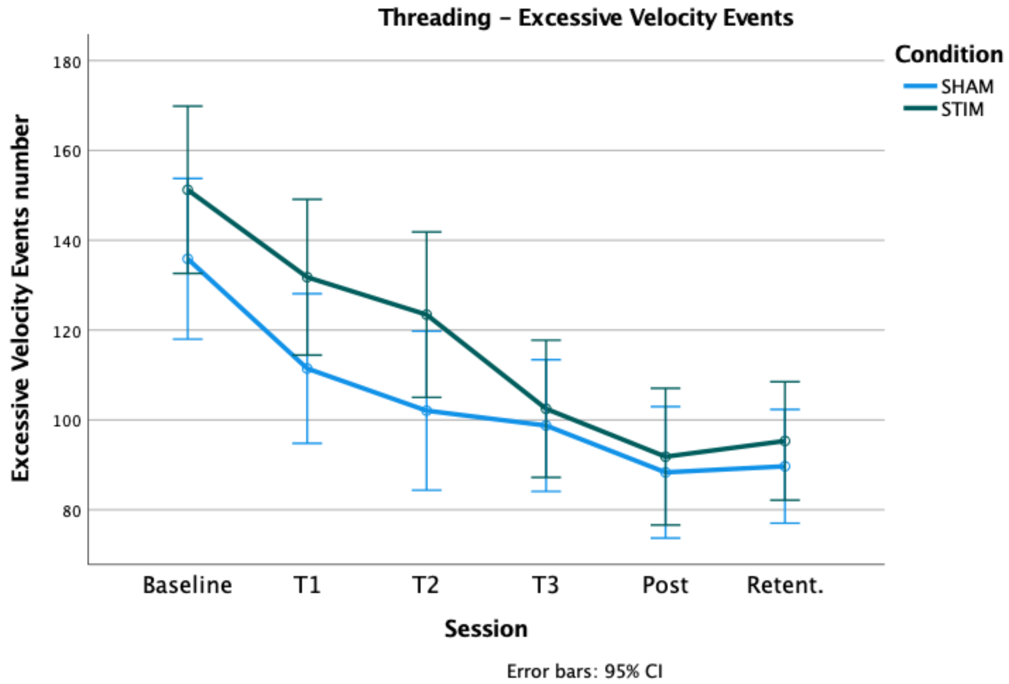

Figure 6.9: Threading excessive velocity events analysis

Band stretching task

Time to Complete (TTC)

The effect of session (F=138.94, p<.001, η^2=.743) was significant for TTC in the band stretching task also. Overall, participants reduced their TTC after 3 days of training (Baseline vs. Post) by 146.38±61.64s (P<0.001). No main effect was found for stimulation condition or implement, nor were any significant interaction effects found.

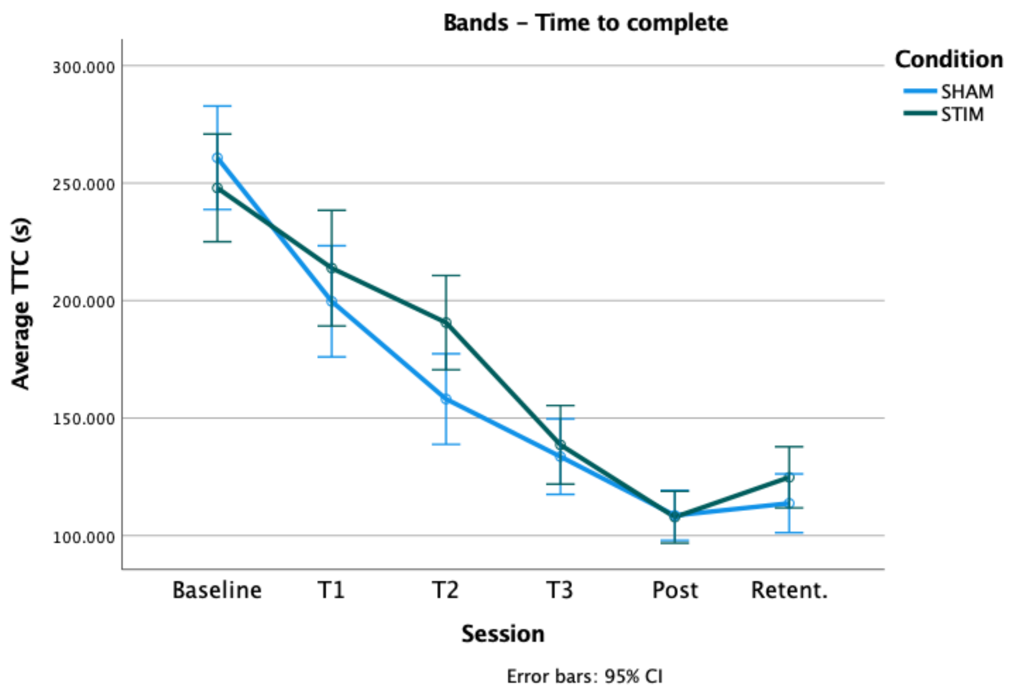

Figure 6.10: Band stretching task time to complete analysis

Distance travelled (m)

The effect of session (F=56.488, p<.001, η^2=.541) was significant for distance travelled in the band stretching task also. Overall, participants reduced their total distance travelled after 3 days of training by 0.55±0.37m(p<0.001). No main effect was found for stimulation condition or implement, nor were any significant interaction effects found.

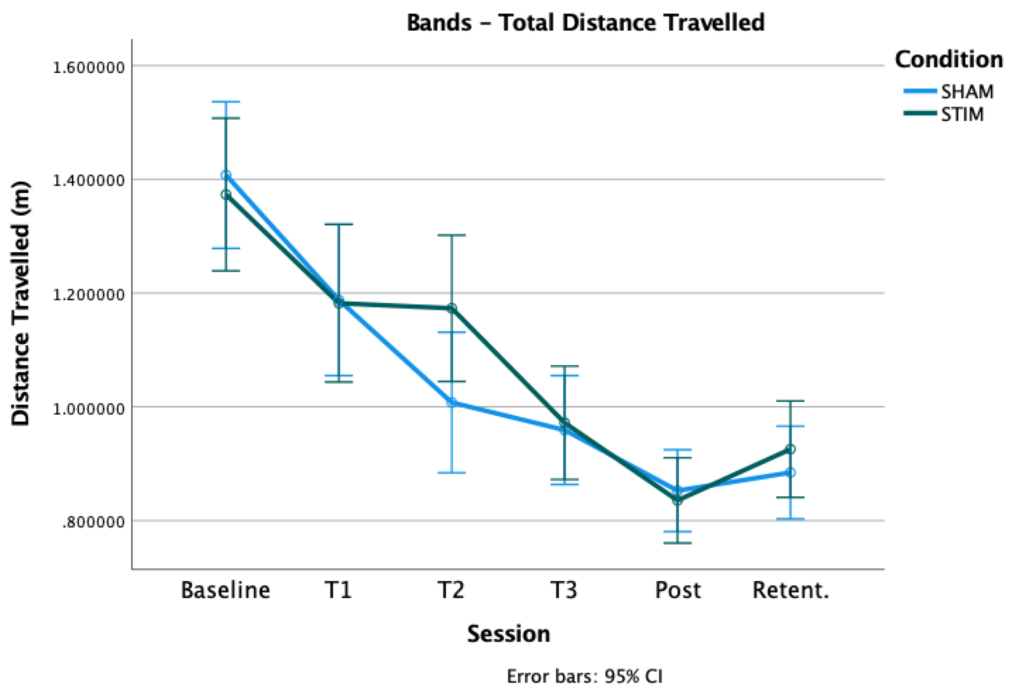

Figure 6.11: Band stretching task distance travelled analysis

Excessive velocity events

The effect of session (F=97.171, p<.001, η^2=.669) was significant for a reduction in excessive velocity events in the bead transfer task. Overall, participants reduced their total number of excessive velocity events after 3 days of training by 46.74±24.92 events (p<0.001). No main effect was found for stimulation condition or implement, nor were any significant interaction effects found.

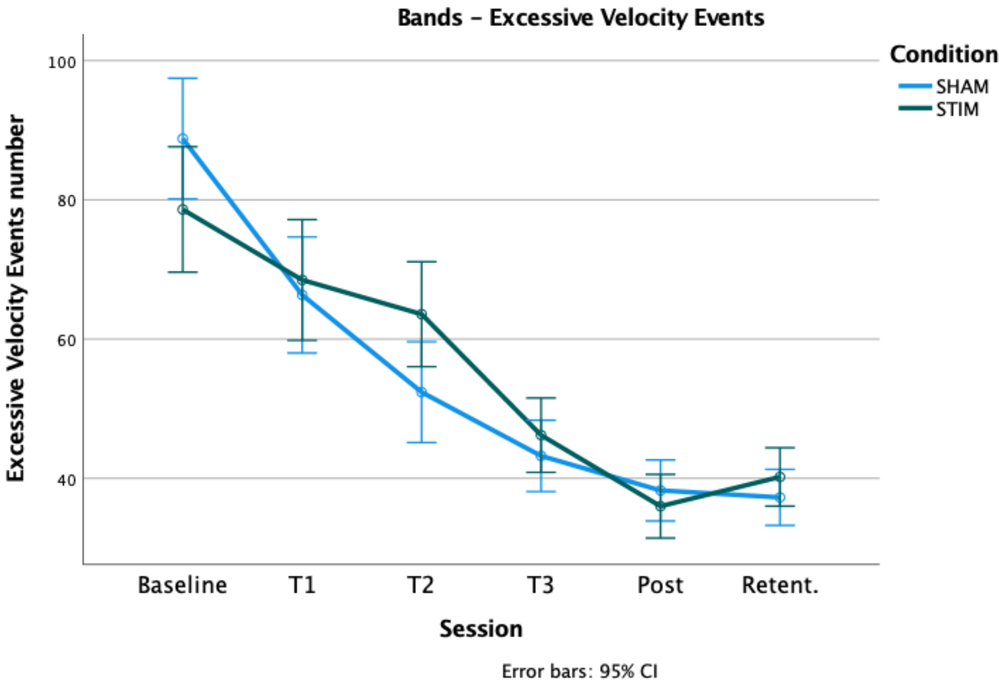

Figure 6.12: Band stretching task excessive velocity events analysis

6.4 Discussion

The main findings of this study shows that participants naïve to robotic laparoscopic training improve significantly following three 20-minute training sessions. This improvement was maintained on retention testing for all parameters we assessed. We did not show any significant difference between groups based on their neurostimulation status. Our study protocol directly measured the movement of the robotic instruments using the bespoke adaption of the surgical analytic machine as described above. The DaVinci robotic surgical system applies corrective technology eliminating tremor and excessive or jerky movement of the surgical instruments.(184) It is possible that this motion correction influenced the findings of our study. We did not directly measure participant movement or use a surrogate marker of performance when assessing the impact of tDCS on performance.

A previous study of tDCS in laparoscopic surgery showed a significant reduction in excessive velocity events.(137) If the benefit of tDCS lies in the reduction of excessive velocity movements or tremor, then this would not have been captured by the direct measurement of the robotic system. In future research regarding the utility of tDCS in robotic surgery, direct measurement of participant hand motion or the measurement of surrogate markers of surgical performance (e.g. knot tensile strength) may be more appropriate than direct measurement of the movement of the surgical robot itself. The only other published study to date examining the application of tDCS to robotic surgical skills measured knot tensile strength as an end point and showed a significant improvement of knot strength in participants exposed to active prefrontal cortex tDCS versus a sham protocol.(185)

The strength of our study lies in the adherence to a robust study protocol. Participants were randomised and blinded to their stimulation allocation. This is a novel application of tDCS advances knowledge around the utility of neuromodulation in surgical training. Owing to the expansion of robotic surgery and the reduction in training opportunities efforts must be made to enhance and maximise surgical training.(186,187)

We acknowledge limitations within our study. The participant recruitment from a single medical school reduces the generalisability of our findings. Some participants had experience of laparoscopic surgical training in the past and therefore were not fully naïve to endoscopic surgery which may have influenced their performance as previous studies have shown skill transfer between laparoscopic and robotic surgery.(188)

Further study is required to fully elucidate the impact of tDCS on performance in robotic surgery. There is significant variation in stimulation protocols and targets among previous studies in laparoscopic and robotic surgery. Work to determine the most effective stimulation protocols in terms of stimulation frequency, timing and intensity is necessary. Alternative targets for stimulation such as the dorsolateral prefrontal cortex or bilateral motor cortex stimulation are also avenues for future research.

6.5 Conclusion

In conclusion, this study did not show any significant difference in the measured performance metrics in those exposed to active M1 tDCS stimulation compared to a sham stimulation protocol. There is significant heterogeneity in study findings examining the application of tDCS to surgical performance and further study is required to determine the optimal stimulation targets and duration.

Chapter 7: Discussion

7.1 Concluding remarks

In this thesis I have laid out a series of papers which illustrate the importance of the integration of new technology in the provision of high-quality surgical training. I have also outlined the significant challenges which face surgical trainees in gynaecology over the last decade. For most trainees, the challenges include the increased number of trainees, the difficulty in accessing surgical training lists and the reduction in working hours prior to the completion of specialist training.(6,23,71) The COVID-19 pandemic has significantly compounded these impacts over the last three years and stands as a significant barrier to facilitating high quality surgical training.(108) While this type of international pandemic event is unlikely to occur again soon it highlighted the deficiencies in our training system and also accelerated the use of artificial intelligence and technology enhanced learning.

The impact in the reduction in working hours and increase in trainee numbers has been significant over the last decade. The rapid expansion of trainee numbers at all grades has diluted the available training opportunities for trainees. Strict adherence to the European Working Time Directive has reduced the number of hours that trainees work leading to a reduction in the clinical experience by the end of training. In my view, there should be a mechanism to allow trainees to opt out of strict adherence to this directive to access training opportunities. Should this be implemented there would need to be safeguards to prevent employers using training exemptions to provide service.

The proposal of the integration of digital technology into the gynaecology training curriculum offers promise of improved training, surgical skill acquisition and an improved trainee experience. The ability to integrate artificial intelligence and machine learning in the assessment of surgical training offers the ability for trainees to continue to advance their training in their own time without the input of an expert surgical mentor. Further improvement in the speed of acquisition of surgical skills, by the implementation of tDCS motor cortex stimulation protocols, offers the promise of rapid improvement in the early phase of surgical training for trainees in gynaecology.

In this discussion, I propose to outline my research in the context of its findings and the overall current body of work regarding surgical training in gynaecology. I feel that it is imperative that we continue to assess and improve our training processes to ensure that we continue to meet the demands of women's healthcare in Ireland. As we continue to have one of the lowest rates of women's health specialists per capita in the OECD, the rapid expansion and emphasis of gynaecology training is more important now than ever before.(4) The population in Ireland is aging, with many women living as long in their post reproductive years than in their reproductive years the need for Irish women to have access to high quality gynaecology care will continue to grow over the coming decades.(189) It is important that we rise to the challenge of meeting those demands. Many women will need both medical and surgical intervention to correct problems which arise in this post-menopausal period. Up to 20% of women may undergo some form of pelvic floor surgery in their lifetime.(190) The significant impact of common gynaecological conditions on quality of life, the ability to continue in employment and maintain independence underlines the importance of these health problems for women in Ireland.

Through my work, I have shown that trainees face significant challenges in accessing the training they want. The gynaecological subspecialties form a significant part of trainee preferences for their training direction. Trainees wish to access high quality training in the gynaecology surgical subspecialties. To meet this need, particularly with the rising trainee numbers, I feel that emphasis on surgical training should begin at the very outset of the basic specialist training (BST) programme. Currently, basic surgical skills form a minor part of the BST curriculum despite the clearly surgical nature of much of our specialty. There is no formalized programme for the acquisition of basic surgical skills as part of the BST programme and the provision of this education relies on a single course day or trainees pursuing further training on their own time. There is no specific access to laparoscopic surgical skills simulation outside of the higher specialist training programme. Trainees often pursue training courses on their own time and expense as a result. This is compounded by the lack of access to surgical simulation at the training sites. There is a need for a basic specialist training program to equip trainees with the skills needed to progress to more advanced training. One potential solution would be the amalgamation of the BST and HST into a single run through scheme as seen in other jurisdictions. This would require strict metrics of progress (e.g. formalised trainer feedback, postgraduate examinations, annual assessments) and the willingness of the training body to deny progression to trainees who do not meet the required standards. It should be expected that not all trainees who enter a run through training scheme would complete it. There would be a natural attrition as trainees leave the specialty to pursue other career goals (e.g general practice). However, it must also be acknowledged that not all trainees may meet the standard required to practice independently as consultant obstetricians and gynaecologists.

The incorporation of a formal research degree as part of specialist training has also been a point of discussion over time. I feel that this is not something the training scheme should mandate but should encourage trainees who wish to pursue this and accredit their time in research as they currently do.

7.2 Research in context

7.2.1 Chapter 2

Chapter 2 underlines the significant challenges facing gynaecological surgery trainees over the last 10 years. I have shown that there has been a significant fall in trainees' ability to perform major gynaecological surgical procedures. This fall was most notable in relation to open and vaginal major surgical procedures including vaginal hysterectomy, total abdominal hysterectomy, and pelvic floor repairs. Trainees at a late stage in their training also reported a significant shortfall in current ability compared with the types of procedures they expected to be able to perform by the end of their specialist training.

I would propose that the integration of advanced training and skills modules for all late-stage higher specialist trainees would bring a positive benefit to their training. The findings of our study underline trainees' desire for specialization within the training programme. To meet the demands of trainees for surgical training, the integration of advanced training modules similar to the Royal College of Obstetricians and Gynaecologists would benefit Irish trainees. Irish trainees often take out of programme experience to complete fellowship training programmes. However, they must then return to a general obstetrics and gynaecology training scheme to complete their higher specialist training. This puts surgical trainees at a disadvantage, as if they do not continue to perform the advanced surgical skills which they may gain in fellowship training, they may find resumption of these skills difficult when they begin independent practice as a consultant.(191,192) Were it possible to integrate advanced training into the final years of the higher specialist training programme, trainees could continue to employ their surgical skills throughout training and the transition to independent practice.

When assessing year four and five trainees, who are immediately prior to the completion of their higher specialist training, I showed a significant decrease in their confidence over the last ten years. This decrease was most significantly seen with respect to the major open and vaginal procedures outlined above. A majority of these trainees feel they would not have enough exposure to gynaecology surgery to practice independently as consultants at the end of their training. This has led to the increase of post-specialization fellowship programmes in benign gynaecology.(193) While the integration of structured benign gynaecology training is to be welcomed, it pushes the opportunity for acquisition of surgical skill out of the higher specialist training programme in a formalized way. Trainees who would previously have been exposed to these training opportunities at the end of their higher specialist training programme are now competing with post-specialization fellows for the same surgical opportunities. If these fellowships could be integrated into the end of training, without the need to return to general obstetric and gynaecological practice, it may allow trainees to move from specialist training to fellowship to independent practice in a more streamlined way.

Another topic of frequent discussion is the separation of the specialties of obstetrics and gynaecology. In the 2021 version of the questionnaire in this study, I asked trainees and trainers if they felt that the specialties should be separated. 20% of trainees and 40% of trainers supported the separation. The obvious benefits of separation for gynaecology are the condensation of operative skills and experience to a smaller group of interested trainees who intend to provide comprehensive gynaecological care as specialists. Similarly, were training, particularly late stage training (HST year 4-5), separated into obstetrics and gynaecology it would allow trainees to focus on their interests and carry this condensed training into specialist practice.

However, the specialties are complementary, and both require a certain degree of knowledge of the other to practice safely and holistically. Separation of the specialties entirely would pose significant challenges for smaller and peripheral units in attracting enough consultants with the requisite skills to provide a safe service.

A study shows that many residents graduating from general surgical residency in the United States lack confidence in a variety of surgical skills, particularly in open surgery.(84) This finding is in keeping with the findings of our study which showed a reduction in confidence with open and vaginal surgical skills over time.

Our study is the only study in the literature, to our knowledge, which repeatedly examined training performance and trainees' ability at three separate time points. This lends strength to the findings and clearly demonstrates a reduction in ability over time.

Other studies examining surgical educational performance have highlighted similar difficulties. In 2011, the American College of Graduate Medical Education (ACGME) instituted changes to resident working hours and patterns. This reduction in working hours had a negative impact on residents' surgical education, perception of their clinical ability and ability to independently manage patients. It must also be noted the quality-of-life improvements and a reduction in physician burnout were seen in this study, highlighting the impact of onerous working patterns on surgeons in training.(194) However, due to the burden of service provision over training in an Irish context this reduction in working hours may further compound an already challenging training environment.

Studies also show that trainees are spending less time engaged in surgical training in the early phase of their careers. This is similarly seen in gynaecology. These studies highlight the need to maximize training opportunities when they arise and the integration of high-quality simulation to reduce the impact of this reduction in exposure.(195,196)

These studies also show that at specialist registrar level there is a reduction in the amount of elective surgery performed. Specialist registrars continue to provide similar cover for emergency procedures but their exposure to elective operating lists has been reduced over time.(196) Perhaps with the introduction of shift-based work patterns trainees are missing the opportunity to work consistently with the same surgical mentor.

7.2.2 Chapter 3

In chapter three, I outlined the significant challenges which COVID-19 posed to the provision of gynaecology surgical training. We need to continue to rebuild robust training programmes with an emphasis on surgical simulation to avoid a repeat of the lack of training which we identified over the initial pandemic period. Investment in simulation facilities in all gynaecology training units is more important now than ever. The resilience of the training programme must be developed, to guard against any further disruption which may be caused in the future by further pandemics or interruption in access to elective operating theatres.

Due to the growing population numbers in Ireland the healthcare system is often under significant strain with demand for acute care often exceeding supply. One can see this most acutely when looking at the number of patients waiting in trolleys in emergency rooms for admission.(197) The curtailment of elective work to compensate for this is often the proposed short-term solution. Benign gynaecology is particularly vulnerable to this curtailment and for this reason over the busy winter period there may be a significant reduction in training opportunities for trainees in some units. The ability to maintain skill by high quality simulation will be key to combating this in the future.

The RCOG training recovery plan clearly outlines the strategies which training units should adopt to combat increasing difficulties in gynaecology training. It emphasizes the need for regional simulation training facilities to be developed. It also highlights the need for consultant work plans to allow time for the provision of surgical teaching and simulation training.(33) In Ireland, there are two simulation hubs which run surgical skills courses. Trainees' access to these simulation facilities is limited and usually only available as part of structured training days.(37,38) In 2023, the Health Service Executive published a report on the implementation of simulation in clinical sites.(198) It makes little reference to the provision of surgical simulation facilities. It predominantly discusses the implementation of scenario based multi-professional simulation which is a welcome addition. It does not however, address the need of surgical trainees to develop their surgical skills in a structured way, with frequent access to training. Studies show that surgical trainees benefit from frequent and easily accessible simulation training, particularly with respect to laparoscopic skills training.(199)

Of particular concern in our study was the fact that trainees surveyed did not increase their confidence in most of the surgical procedures which we assessed. There now exists a cohort of trainees who received minimal training in gynaecology surgery for 12 to 18 months. As they now come to completion of training it further compounds the effect of what I showed in the training challenges paper in chapter 2. Trainees in surgery build confidence by repeated exposure to similar clinical scenarios supported by mentorship and feedback.(91) Internal and external factors influence the development of surgical confidence. Trainees' personal experiences (including operative experience), personal expectations and self-perception have been identified as internal factors. The provision of feedback, good patient outcome and positive relationships with trainers and staff are identified as some of the external factors which influence the development of surgical confidence.(200)

7.2.3 Chapter 4

In this paper we showed how the integration of digital technology and surgical training can provide advantage for trainees in terms of real time feedback on performance improvement. Studies show that trainees value real time feedback particularly in the early phase of the skill acquisition.(91) While artificial intelligence and machine learning will not replace the benefit of an expert coach or mentor it can fill a gap where access to regular coaching is not feasible or available to trainees.

The ability of a trainee to track their progress and receive performance analysis in an automated way improves the utilization of expert surgical trainers. It takes them away from the provision of basic surgical skills training and allows for the trainer to provide more nuanced and specific training to address gaps in a trainees' ability.

The promise of large datasets of training events allows for the further the refinement of these methods of skill assessment. We showed that many of the metrics which are examined by automated laparoscopic skill analyzers provide accurate distinction between trained and non-trained trainees. The metrics assessed also allow the demonstration of progressive improvement throughout training. The integration of scoring systems and automated feedback allows trainees to focus their training on areas of weakness.

Other studies addressing automated assessments of laparoscopic skills have also shown their utility. Although they generally fail to match the nuance of expert reviewers, automated grading systems can provide reliable distinction between novices and experienced operators.(130–132) Further refinement of these grading systems in collaboration with software developers will enhance their utility in the future.

Credentialing of surgeons based solely on automated assessment is not what I would propose however it does allow for the maximization of training opportunities. With larger datasets, machine learning will continue to refine the scoring systems in use for these skills. The integration of feedback from experienced surgeons, perhaps using remote mentoring software such as Proximie, with insights from AI and data science, will allow us to continually refine these grading systems ensuring that they are robust and clinically relevant tools to assess surgical skills. While no singular tool can supplant the mentorship and training of an expert surgeon, combining their insights holds significant promise.

7.2.4 Chapter 5

In this chapter we showed the novel application of transcranial direct current stimulation (tDCS) on the improvement and retention of laparoscopic surgical skills. We showed that participants who received anodal tDCS over the M1 motor cortex improved their time and kinematic performance on some surgical tasks.

This paper was novel in the sense that it had access to a wide range of kinematic data from the surgical skills analyzer. We were able to show a significant reduction in excessive velocity events and in surgical training time for novice trainees completing a surgical skills task. The impact of tDCS, in the particular on the early phase of surgical skill acquisition, is a potential solution to the challenges which I have outlined in this thesis. Trainees must maximize each training opportunity to iteratively improve their surgical skills. Due to the rigorous demands of the provision of clinical care, training opportunities are sometimes sidelined. Therefore, the ability to maximize each training episode is a potential boon to trainees. While tDCS may not be a silver bullet to solve all training problems, in combination with other training enhancements, it may provide a partial solution.

Further work is needed to delineate the benefit of tDCS in a variety of surgical training situations. It has previously been examined for open surgical skills, such as knot tying, and early phase laparoscopic skills. It has shown benefit in both areas, however the specific stimulation target and protocol remains variable among reported studies.(65,152) Further study is required to examine how best to integrate this into surgical skills training.

The reduction in excessive velocity events which we saw in our study offers promise of improving early surgical skills. With further study, integration of this into clinical practice perhaps would protect against complications related to inadvertent injury of anatomical structures.

Other studies in this area have employed a variety of stimulation targets and protocols with varying results. Most studies show improvement in the acquisition of laparoscopic and open surgical skills. There has also been variation in the tasks performed and the metrics used to assess performance. The prefrontal cortex, the primary motor cortex and the supplementary motor area have all been targets for stimulation.(64,65,150–152) There are no comparative studies of the benefit of stimulation of one area over the other which is perhaps an area for further study in future.

7.2.5 Chapter 6

In this chapter I also examined the application of tDCS to robotic surgical skills training. Robotic surgical skills training is an area which very few trainees have access to. The access to this training is dependent on the availability of a surgical robot in the unit which the trainee is assigned. In Ireland currently, only 5 units which accept gynaecology trainees have access to a surgical robot for training. It is possible that many trainees will rotate through units where they do not have any exposure to this type of surgical skill. Worldwide, the rates of robotic surgery continue to climb.(201) Robotic surgery has benefits both in terms of patient recovery and in surgeon ergonomics and career longevity.(174,202) Therefore, I feel that it would be a huge benefit to trainees to have a formalized way to access these surgical skills. While not every gynaecologist will perform robotic surgery as a consultant, this further underlines the need to streamline and focus late-stage training to provide the experiences and opportunities for trainees to build their independent practice.

We did not show any specific benefits to tDCS in any of the performance metrics which we analyzed in this study. However, the surgical robot employs corrective technology to scale down motion inputs, reduce tremor and, minimize excessive velocity and jerky movements.(203) The reduction in these jerky or excessive velocity movements was the benefit we demonstrated with our tDCS laparoscopic study.

The only other published study in this area showed an improvement in robotic surgical knot tying skills and a reduction in error rates. The prefrontal cortex was targeted in this study and significantly faster completion times were noted in the active tDCS arm of the study.(185) This is a contrast to our study which did not show a reduction in time to complete or in error rates with the primary motor cortex as the stimulation target.

Further work is required to assess the utility of tDCS in robotic surgical skills acquisition. Owing to the limited access of trainees to robotic surgery it would be imperative that each training opportunity is maximized to develop surgical skills and retain them. tDCS potentially provides an avenue for the maximization of these skills if the benefits can be proven and the most effective stimulation targets and protocols determined.

7.3 Areas for further study

I feel that I have outlined a significant body of work examining the current state of surgical training in gynaecology in Ireland and some potential solutions to enhance the training provision and skill acquisition.

In relation to training challenges, it is imperative that we continue to assess this on an ongoing basis, so that we can examine trends overtime. A study of the trainees graduating from the higher specialist training programme would provide valuable insight into the skill mix with which they leave the programme and their intended areas of specialist practice. While we still need to train general obstetricians and gynaecologists, many trainees may wish to develop a subspecialty interest to improve their competitiveness for consultant posts, to fulfill personal career goals or to direct type of care which they wish to provide their patients. The role of the general gynaecologist who can perform a wide variety of basic gynaecologic procedures is being eroded and the provision of these procedures increasingly falls to subspecialist gynaecologists. For example, urogynaecologists now perform a significant proportion of primary pelvic organ prolapse repair in many units. In the past these primary repairs would have been performed by general gynaecologists and the more complex or recurrent procedures reserved for the subspecialist.

Analysis of trainees leaving the training programme would provide valuable insight into whether the training programme is meeting the needs of trainees. While all trainees will exit the programme with a minimum level of exposure to operative gynaecology, this does not always translate to the ability or confidence to practice independently. Where clinicians are then attempting to gain these skills in a post-specialization fellowship, or in the early phase of their consultant careers, it further removes these training opportunities from junior gynaecology trainees.

Studies assessing the availability of surgical simulation facilities to gynaecological surgery trainees in Ireland would be useful to assess the deficits in training availability and identify areas for investment in training. Examining the ease of access to training facilities, laparoscopic box trainers and appropriate supervision would give valuable insight into the trainees' experience.

In relation to my work on the integration of AI assessment in laparoscopic skills training, further work examining the best approach to grading students is required. Building on the data which I have shown, further integration of the metrics which do provide good discrimination between trained and untrained operators would allow the refinement of automated scoring systems. A collaborative approach with industry and with computer science specialists is key here. If we are to build on these findings and iteratively improve the assessment provided by automated skills analyzers, then collaboration with a broad range of professionals is required.

In relation to tDCS, further work in the area is required to elucidate the specific benefits of tDCS in surgical skills training. I would propose to examine alternative stimulation sites, such as the dorsolateral prefrontal cortex, bilateral motor cortex stimulation or the supplementary motor area. These targets have been assessed in other realms of performance enhancement and offer a potential target for further improvement of surgical skills.(204,205) The integration of tDCS into robotic surgical training is an avenue which warrants further study. This would benefit those wishing to enhance the acquisition of robotic surgical skills and would allow us to characterize the specific benefits, if any, of tDCS in this realm. Focusing on the direct kinematic measurement of participants rather than the motion of participants would be preferable owing to the motion smoothing effects of the robotic system.

Further work examining how surgical skills simulation of basic tasks can translate and enhance the performance of major surgical procedures is required. Most studies examining surgical skills performance use tests of dexterity as surrogate makers of surgical performance. There remains a reliance on an apprenticeship model of training and assessment for major operating. This model cannot be replaced by simulation alone however, given the difficulties in training outlined in this thesis, perhaps simulation can enhance this training. High fidelity simulation, particularly for laparoscopic and robotic procedures, exists already. Simulated laparoscopic and robotic hysterectomies are now available to trainees and provide relatively true to life simulated operating experience allowing trainees to familiarize themselves with the surgical steps of these procedures.

Overall, we must continue to attempt to improve our training processes so that we will continue developing high quality, patient focused, and empathetic gynaecological surgeons of the future. In doing so, we must examine this through the process of research and innovation to ensure that any changes we make are evidence based and rooted in the needs of trainees and in the women that they provide care for.

7.4 Dissemination of research findings

Two of the chapters (Chapter 2 and Chapter 5) are already published in peer reviewed Q1 and Q2 journals. Chapter 3 and 5 are under peer review at present in Q1 and Q2 journals. It is intended to submit chapter 6 for peer review in early 2024.

Chapter 2:

Published: European Journal of Obstetrics, Gynaecology and Reproductive Biology 2023

Galvin D, O'Reilly B, Greene R, O'Donoghue K, O'Sullivan O. A national survey of surgical training in gynaecology: 2014-2021. Eur J Obstet Gynecol Reprod Biol. 2023 Sep; 288:135-141. doi: 10.1016/j.ejogrb.2023.07.013. Epub 2023 Jul 26. PMID: 37517105

Chapter 3:

Under review: International Journal of Gynecology and Obstetrics

Chapter 4:

Under review: Journal of Minimally Invasive Gynaecology

Chapter 5:

Published: Scientific Reports

Galvin D, Toth AJ, O'Reilly B, O'Sullivan R, Campbell MJ. M1 transcranial direct current stimulation augments laparoscopic surgical skill acquisition. Sci Rep. 2023 Aug 23;13(1):13731. doi: 10.1038/s41598-023-40440-x. PMID: 37612337; PMCID: PMC10447451.

Chapter 6:

Ready for submission: Surgical Endoscopy

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Appendix 1: Trainee survey

1. Age:
2. Gender:
    a. Male
    b. Female
    c. Other (please describe):
3. How many years are you qualified (since medical school graduation)?
4. How many years have you been working in Obstetrics and Gynaecology?
5. What year of the SPR scheme are you in?
    a. If out of programme, what role are you in?
6. Excluding internship, have you worked in any other specialty prior to training in Obstetrics and Gynaecology?
    a. If yes, please specify area and duration:
7. During training have you held a gynaecology-only post?
8. How long have you spent in gynaecology-only posts in total?
9. Which year of the training scheme did your gynaecology-only post occur?
10. What type of posts have you held since commencing your HST training programme?
11. What are your areas of interest?
12. Do you plan to complete a fellowship?
    a. If yes where would you plan to complete this?
    b. If yes, please specify area and duration:
13. Do you plan on taking time out of programme to do a research degree?
    a. If yes where would you plan to complete this?
    b. If yes, please specify preferred subject area and duration of degree:

14. What type of consultant post would you like to hold at the end of your training?
    a. Full time clinical
    b. Part time clinical
    c. Full time clinical/academic
    d. Part time clinical/academic
    e. Other:
15. Please elaborate on factors which affect you decisions regarding the type or structure of consultant post you would wish to hold:
16. Do you think Obstetrics and Gynaecology should be separate specialities?
17. Currently can you perform an operative hysteroscopy independently?
    a. Do you think by the end of training you will be competent in performing an operative hysteroscopy independently?
18. Currently can you perform a laparoscopic salpingectomy independently?
    a. Do you think by the end of training you will be competent to perform a laparoscopic salpingectomy?
19. Can you currently perform a laparoscopic ovarian cystectomy independently?
    a. Do you think by the end of training you will be competent in performing a laparoscopic ovarian cystectomy independently?
20. Currently can you perform an abdominal hysterectomy independently?
    a. Do you think by the end of training you will be competent in performing an abdominal hysterectomy independently?
21. Currently can you perform a laparoscopic or robotic hysterectomy independently?
    a. Do you think by the end of training you will be competent in performing a laparoscopic or robotic hysterectomy independently?

22. Can you currently perform an anterior or posterior repair independently?
    a. Do you think by the end of training you will be competent in performing an anterior or posterior repair independently?
23. Can you currently perform a vaginal hysterectomy independently?
    a. Do you think by the end of training you will be competent in performing a vaginal hysterectomy independently?
24. How confident do you feel recognising and dealing appropriately with following intraoperative complications?
    a. Cystotomy
    b. Ureteric injury
    c. Bowel injury
    d. Vascular injury
    e. Haemorrhage
25. Please respond to the following statements with respect to gynaecology training. (Likert scale; 1= Strongly disagree, 5=Strongly agree)
    a. I feel gynaecology training is given the time it requires in the HST
    b. Medicolegal issues put me off training in gynaecology
    c. I have a good understanding of what is expected of me for my level of training
    d. My trainer is interested in teaching me
    e. I feel I will have enough exposure to gynaecology to practice as a consultant
26. Is your current post EWTD compliant?
27. How do you think EWTD has affected training?
28. If you believe that EWTD has positively affected training: How do you think it has improved?

29. If you believe that EWTD has negatively affected training: How do you think it has disimproved?
30. What other issues most affect your access to gynaecology surgical training?
31. Have you ever attended a gynaecological surgery training course?
32. What types of course have you attended?
33. Please describe the location, duration and format of any surgical skills courses you have attended:
34. Do you feel surgical simulation courses help improve your practice and training in gynaecology?
35. Please rank your preference for format of surgical skills courses (1= Highest preference):
    a. Didactic lecture
    b. Interactive workshop
    c. Simulation training
    d. Cadaveric workshop
    e. Surgical skills training
36. Do you think a university awarded postgraduate diploma or masters programme in gynaecological surgery would be a useful addition to your training if available?
37. Are you satisfied with your training to date
38. Do you have any comments or suggestions about how gynaecology surgical training can be improved?

Appendix 2: Trainer questionnaire

1. Age?
2. Gender:
    a. Male
    b. Female
    c. Other (please describe):
3. How many years have you been a consultant?
4. What is your subspecialty area of interest?
5. What type of contract do you have?
    a. Full time clinical
    b. Part time clinical
    c. Full time clinical/academic
    d. Part time clinical/academic
    e. Other:
6. Do you routinely perform operative hysteroscopy?
    a. If yes on average how many do you perform per year?
7. Do you routinely perform laparoscopic salpingectomy?
    a. If yes on average how many do you perform per year?
8. Do you routinely perform laparoscopy for ovarian cystectomy?
    a. If yes on average how many do you perform per year?
9. Do you routinely perform total abdominal hysterectomy?
    a. If yes on average how many do you perform per year?
10. Do you routinely perform laparoscopic or robotic hysterectomy?
    a. If yes on average how many do you perform per year?

11. Do you routinely perform anterior or posterior pelvic floor repair?
    a. If yes on average how many do you perform per year?
12. Do you routinely perform vaginal hysterectomy?
    a. If yes on average how many do you perform per year?
13. Are you currently a trainer for an SPR? (If no please answer subsequent questions with respect to your most recent trainee)
14. Is your trainee currently doing a special interest module?
    a. If yes, which area is it in
15. Do you recommend your trainees to undertake subspecialist fellowship training?
    a. If you feel that not all trainees should undertake fellowship training, who should?
16. Do you recommend your trainees to undertake a higher degree through research (PhD/MD)?
    a. If you feel that not all trainees should undertake a higher degree, who should?
17. What year of the scheme is your current trainee?
    a. If out of programme, what are they doing?
18. Can your current trainee perform an operative hysteroscopy independently?
    a. If no, do you think by the end of training the trainee will be competent in performing an operative hysteroscopy independently?
19. Can your current trainee perform a laparoscopic salpingectomy independently?
    a. If no, do you think by the end of training the trainee will be competent to perform a laparoscopic salpingectomy?

20. Can your current trainee currently perform a laparoscopic ovarian cystectomy independently?
    a. If no, do you think by the end of training the trainee will be competent in performing a laparoscopic ovarian cystectomy independently?
21. Can your current trainee perform a total abdominal hysterectomy independently?
    a. If no, do you think by the end of training the trainee will be competent in performing a total abdominal hysterectomy independently?
22. Can your current trainee perform a laparoscopic or robotic hysterectomy independently?
    a. If no, do you think by the end of training the trainee will be competent in performing a laparoscopic or robotic hysterectomy independently?
23. Can your current trainee perform an anterior or posterior pelvic floor repair independently?
    a. If no, do you think by the end of training the trainee will be competent in performing an anterior or posterior pelvic floor repair independently?
24. Can your current trainee perform a vaginal hysterectomy independently?
    a. If no, do you think by the end of training the trainee will be competent in performing a vaginal hysterectomy independently?
25. Do you feel that your trainee's ability matches their stage of training?
26. How confident (Scale 1-5; 1=not confident at all, 5=Very confident) are you that your trainee can recognise and appropriately manage the following intraoperative complications
    a. Cystotomy
    b. Ureteric injury

c. Bowel injury

d. Vascular injury

e. Haemorrhage

27. Since the introduction of EWTD how has training being affected?

28. Do you think your current trainees post is EWTD compliant?

29. If you think that training has improved by EWTD, in what areas are these improvements?

30. If you believe the EWTD has negatively affected training. What do you think can be done to combat this?

31. Have you ever attended a gynaecological surgery training course?

32. What types of course have you attended?

33. Have you ever been a faculty member of a gynaecological surgery training course?

    a. If no, would you be interested in being faculty at a gynaecological surgery training course?

34. Do you recommend trainees attend a gynaecological surgery training course?

35. What types of courses would/do you recommend they attend?

36. Rank these surgical skills course formats in order of most to least useful for trainees. (1=Most useful)

    a. Didactic lecture

    b. Interactive workshop

    c. Simulation training

    d. Cadaveric workshop

    e. Surgical skills training

37. Do you think in the future Obstetrics and Gynaecology should be separate specialities?
38. Please elaborate on your answer above:
39. Are you satisfied with the current training courses trainees receive from the RCPI?
40. Please leave any comments you think would be beneficial regarding training in Obstetrics and Gynaecology

Appendix 3: Trainee survey – COVID 19 training experience

1. Age:
2. Gender:
    a. Male
    b. Female
    c. Other (please describe):
3. How many years are you qualified?
4. How many years have you been working in Obstetrics and Gynaecology?
5. What year of the SPR scheme are you in?
6. How do you think the COVID-19 pandemic has affected training?
    a. Positive impact
    b. No impact
    c. Negative impact
7. If you believe that the COVID-19 pandemic has positively affected training: How do you think it has improved?
8. If you believe that the COVID-19 pandemic has negatively affected training: How do you think it has disimproved?
9. In the 12-months before the COVID-19 pandemic estimate how many minor gynaecological procedures you have performed? (e.g. Diagnostic Hysteroscopy, Cystoscopy, Diagnostic laparoscopy etc)
    a. 0-10
    b. 11-20
    c. 21-30
    d. 31-40
    e. >40

10. Since the beginning of the COVID-19 pandemic estimate how many minor gynaecological procedures you have performed? (e.g. Diagnostic Hysteroscopy, Cystoscopy, Diagnostic laparoscopy etc)
    a. 0-10
    b. 11-20
    c. 21-30
    d. 31-40
    e. >40
11. In the 12-months before the COVID-19 pandemic estimate how many intermediate gynaecological procedures you have performed? (e.g. Operative hysteroscopy, Simple operative laparoscopy)
    a. 0-10
    b. 11-20
    c. 21-30
    d. 31-40
    e. >40
12. Since the beginning of the COVID-19 pandemic estimate how many intermediate gynaecological procedures you have performed? (e.g. Operative hysteroscopy, Simple operative laparoscopy)
    a. 0-10
    b. 11-20
    c. 21-30
    d. 31-40
    e. >40
13. In the 12-months before the COVID-19 pandemic estimate how many major gynaecological procedures you have performed? (e.g. TAH, TLH, Pelvic floor repair, Vaginal hysterectomy)

a. 0
b. 1-5
c. 6-10
d. 11-15
e. >15

14. Since the beginning of the COVID-19 pandemic estimate how many major gynaecological procedures you have performed? (e.g. TAH, TLH, Pelvic floor repair, Vaginal hysterectomy)
    a. 0
    b. 1-5
    c. 6-10
    d. 11-15
    e. >15
15. Immediately before the onset of the COVID-19 pandemic how confident did you feel performing the following procedures?
    a. Operative Hysteroscopy
    b. Diagnostic laparoscopy
    c. Laparoscopic salpingectomy
    d. Laparoscopic cystectomy/oophorectomy
    e. Total abdominal hysterectomy
    f. Laparoscopic hysterectomy
    g. Pelvic floor repair
    h. Vaginal hysterectomy
16. Please rate how confident you would feel performing the following procedures today?
    a. Operative Hysteroscopy
    b. Diagnostic laparoscopy
    c. Laparoscopic salpingectomy

d. Laparoscopic cystectomy/oophorectomy
e. Total abdominal hysterectomy
f. Laparoscopic hysterectomy
g. Pelvic floor repair
h. Vaginal hysterectomy

17. Please rate your response to the following statements in relation to the impact of the COVID-19 pandemic on your work and training:
    a. I work more hours now
    b. My training has been negatively impacted
    c. I feel more stressed at work
    d. I worry about the impact of my work on my family
    e. I often have to cover for colleagues at short notice
    f. I have been able to attend courses and conferences
    g. I have been able to undertake examinations
    h. I have found it difficult to demonstrate progress in my logbook
    i. I have more time for audit and research
18. Since the start of the COVID-19 pandemic have you had an unplanned absence from work?
    a. Yes - as a result of COVID-19 or self-isolation
    b. Yes - other sick leave
    c. No
    d. Other (please specify)

Appendix 4: Trainer survey – COVID 19 training experience

1. Age
2. Gender
   a. Male
   b. Female
   c. Other (please describe):
3. How many years have you been a consultant?
4. What is your subspecialty area of interest?
   a. Labour ward
   b. Fetal medicine
   c. Maternal medicine
   d. Early pregnancy
   e. Gynae-oncology
   f. Minimally invasive surgery
   g. Benign gynaecology
   h. Urogynaecology
   i. Fertility
   j. Adolescent gynaecology
   k. General Obstetrics and Gynaecology
   l. Other:
5. What type of contract do you have?
   a. Full time clinical
   b. Part time clinical
   c. Full time clinical/academic
   d. Part time clinical/academic

    e. Other:

6. How do you think the COVID-19 pandemic has affected training?
    a. Positive impact
    b. No impact
    c. Negative impact
7. If you believe that the COVID-19 pandemic has positively affected training: How do you think it has improved?
8. If you believe that the COVID-19 pandemic has negatively affected training: How do you think it has disimproved?
9. In the 12-months before the COVID-19 pandemic estimate how many minor gynaecological procedures you have performed? (e.g. Diagnostic Hysteroscopy, Cystoscopy, Diagnostic laparoscopy etc)
    a. 0-10
    b. 11-20
    c. 21-30
    d. 31-40
    e. >40
10. Since the beginning of the COVID-19 pandemic estimate how many minor gynaecological procedures you have performed? (e.g. Diagnostic Hysteroscopy, Cystoscopy, Diagnostic laparoscopy etc)
    a. 0-10
    b. 11-20
    c. 21-30
    d. 31-40
    e. >40

11. In the 12-months before the COVID-19 pandemic estimate how many intermediate gynaecological procedures you have performed? (e.g. Operative hysteroscopy, Simple operative laparoscopy)
    a. 0-10
    b. 11-20
    c. 21-30
    d. 31-40
    e. >40
12. Since the beginning of the COVID-19 pandemic estimate how many intermediate gynaecological procedures you have performed? (e.g. Operative hysteroscopy, Simple operative laparoscopy)
    a. 0-10
    b. 11-20
    c. 21-30
    d. 31-40
    e. >40
13. In the 12-months before the COVID-19 pandemic estimate how many major gynaecological procedures you have performed? (e.g. TAH, TLH, Pelvic floor repair, Vaginal hysterectomy)
    a. 0-10
    b. 11-20
    c. 21-30
    d. 31-40
    e. >40
14. Since the beginning of the COVID-19 pandemic estimate how many major gynaecological procedures you have performed? (e.g. TAH, TLH, Pelvic floor repair, Vaginal hysterectomy)
    a. 0-10

b. 11-20

c. 21-30

d. 31-40

e. >40

15. Immediately before the onset of the COVID-19 pandemic how confident did you feel in your trainees ability to perform the following procedures?

    a. Operative Hysteroscopy
    b. Diagnostic laparoscopy
    c. Laparoscopic salpingectomy
    d. Laparoscopic cystectomy/oophorectomy
    e. Total abdominal hysterectomy
    f. Laparoscopic hysterectomy
    g. Pelvic floor repair
    h. Vaginal hysterectomy

16. How confident would you feel in your trainees ability to perform these procedures today?

    a. Operative Hysteroscopy
    b. Diagnostic laparoscopy
    c. Laparoscopic salpingectomy
    d. Laparoscopic cystectomy/oophorectomy
    e. Total abdominal hysterectomy
    f. Laparoscopic hysterectomy
    g. Pelvic floor repair
    h. Vaginal hysterectomy

17. Please rate your response to the following statements in relation to the impact of the COVID-19 pandemic on your work:

    a. I work more hours now

b. I spend less time operating

c. I feel more stressed at work

d. I worry about the impact of my work on my family

e. I often have to cover for colleagues at short notice

f. I have been able to attend courses and conferences

g. I have more time for audit and research

18. Since the start of the COVID-19 pandemic have you had an unplanned absence from work?

    a. Yes - as a result of COVID-19 or self-isolation

    b. Yes - other sick leave

    c. No

    d. Other (please specify)

Appendix 5: The Brunel Mood Scale Questionnaire

Below is a list of words that describe feelings people have. Please read each one carefully and then circle the answer that best describes **HOW YOU FEEL RIGHT NOW**. Make sure you respond to every word.

	Not at all	A little	Moderately	Quite a bit	Extremely	SCORING FOR THE BRUMS-32 (Add the responses for the responses to each of the subscales)		
1. Active	0	1	2	3	4	**Subscale**	**Scores**	**Total**
2. Alert	0	1	2	3	4	**Anger**	ANGRY (3) ___+ ANNOYED (4)___ + BAD TEMPERED (6) ___ + BITTER (7) ___	
3. Angry	0	1	2	3	4			
4. Annoyed	0	1	2	3	4			
5. Anxious	0	1	2	3	4			
6. Bad tempered	0	1	2	3	4	**Tension**	ANXIOUS (5)___+ NERVOUS (20)___ + PANICKY (21)___ + WORRIED (30) ___	
7. Bitter	0	1	2	3	4			
8. Calm	0	1	2	3	4			
9. Cheerful	0	1	2	3	4			
10. Composed	0	1	2	3	4	**Depression**	DEPRESSION (13) ___ + DOWNHEARTED (14) ___ + MISERABLE (19) ___ + UNHAPPY (28) ___	
11. Confused	0	1	2	3	4			
12. Contented	0	1	2	3	4			
13. Depressed	0	1	2	3	4			
14. Downhearted	0	1	2	3	4	**Vigour**	ACTIVE (1) ___+ ALERT (2) ___ + ENERGETIC (15) ___ + LIVELY (18) ___	
15. Energetic	0	1	2	3	4			
16. Exhausted	0	1	2	3	4			
17. Happy	0	1	2	3	4			
18. Lively	0	1	2	3	4	**Fatigue**	EXHAUSTED (16)___ + SLEEPY (25) ___ + TIRED (26) ___ + WORN-OUT (29) ___	
19. Miserable	0	1	2	3	4			
20. Nervous	0	1	2	3	4			
21. Panicky	0	1	2	3	4			
22. Relaxed	0	1	2	3	4	**Confusion**	CONFUSED (11)___ + UNCERTAIN (27)___ + MIXED-UP (31)___ + MUDDLED (32) ___	
23. Restful	0	1	2	3	4			
24. Satisfied	0	1	2	3	4			
25. Sleepy	0	1	2	3	4			
26. Tired	0	1	2	3	4	**Happy**	CHEERFUL (9)___ + CONTENT (12)___ + HAPPY (17) ___+ SATISFIED (24)___	
27. Uncertain	0	1	2	3	4			
28. Unhappy	0	1	2	3	4			
29. Worn-out	0	1	2	3	4			
30. Worried	0	1	2	3	4	**Calmness**	CALM (8) ___+ COMPOSED (10)___ + RELAXED (22)___ + RESTFUL (23)___	
31. Mixed-up	0	1	2	3	4			
32. Muddled	0	1	2	3	4			

Total your scores here:

Sub-scales of the BRUMS	Current score	Goal
Anger		
Tension		
Depression		
Vigour		
Fatigue		
Confusion		
Happy		
Calmness		

Appendix 6: Pittsburgh Sleep Quality Index

PITTSBURGH SLEEP QUALITY INDEX (PSQI)

INSTRUCTIONS: The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1. During the past month, when have you usually gone to bed at night?

   USUAL BED TIME ______________________

2. During the past month, how long (in minutes) has it usually take you to fall asleep each night?

   NUMBER OF MINUTES ______________________

3. During the past month, when have you usually gotten up in the morning?

   USUAL GETTING UP TIME ______________________

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spend in bed.)

   HOURS OF SLEEP PER NIGHT ______________________

INSTRUCTIONS: For each of the remaining questions, check the one best response. Please answer all questions.

5. During the past month, how often have you had trouble sleeping because you...

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
(a) ...cannot get to sleep within 30 minutes	☐	☐	☐	☐
(b) ...wake up in the middle of the night or early morning	☐	☐	☐	☐
(c) ...have to get up to use the bathroom	☐	☐	☐	☐
(d ...cannot breathe comfortably	☐	☐	☐	☐
(e) ...cough or snore loudly	☐	☐	☐	☐
(f) ...feel too cold	☐	☐	☐	☐
(g) ...feel too hot	☐	☐	☐	☐
(h) ...had bad dreams	☐	☐	☐	☐
(i) ...have pain	☐	☐	☐	☐

(j) Other reason(s), please describe

____

____

How often during the past month have you had trouble sleeping because of this?	☐	☐	☐	☐

PSQI Page 1

	Very good	Fairly good	Fairly bad	very bad
6. During the past month, how would you rate your sleep quality overall?	☐	☐	☐	☐

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
7. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?	☐	☐	☐	☐
8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?	☐	☐	☐	☐

	No problem at all	Only a very slight problem	Somewhat of a problem	A very big problem
9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	☐	☐	☐	☐

	No bed partner or roommate	Partner/ roommate in other room	Partner in same room, but not same bed	Partner in same bed
10. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	☐	☐	☐	☐

If you have a roommate or bed partner, ask him/her how often in the past month you have had...

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
(a) ...loud snoring	☐	☐	☐	☐
(b) ...long pauses between breaths while asleep	☐	☐	☐	☐
(c) ...legs twitching or jerking while you sleep	☐	☐	☐	☐
(d) ...episodes of disorientation or confusion during sleep	☐	☐	☐	☐
(e) Other restlessness while you sleep; please describe	☐	☐	☐	☐

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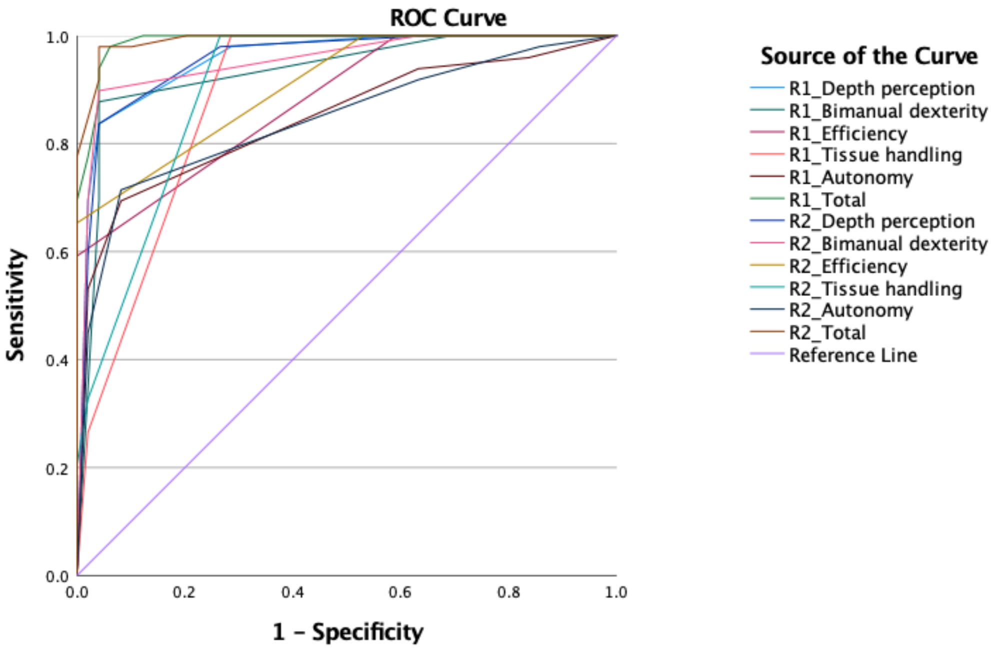
Appendix 7: Global Operative Assessment of Laparoscopic Skills (GOALS) grading tool

Global rating scale	Grade (0-5)
Depth perception	1. Constantly overshoots target, wide swings, slow to correct 2. 2. ↓ 3. Some overshooting or missing of target, but quick to correct 4. ↓ 5. Accurately directs instruments in the correct plane to target
Bimanual dexterity	1. Uses only one hand, ignores nondominant hand, poor coordination between hands 2. ↓ 3. Uses both hands, but does not optimize interaction between hands 4. ↓ 5. Expertly uses both hands in a complimentary manner to provide optimal exposure
Efficiency	1. Uncertain, inefficient efforts; many tentative movements; constantly changing focus or persisting without progress 2. ↓ 3. Slow, but planned movements are reasonably organized 4. ↓ 5. Confident, efficient and safe conduct, maintains focus on task until it is better performed by way of an alternative approach
Tissue handling	1. Rough movements, tears tissue, injures adjacent structures, poor grasper control, grasper frequently slips 2. ↓ 3. Handles tissues reasonably well, minor trauma to adjacent tissue (i.e., occasional unnecessary bleeding or slipping of the grasper) 4. ↓

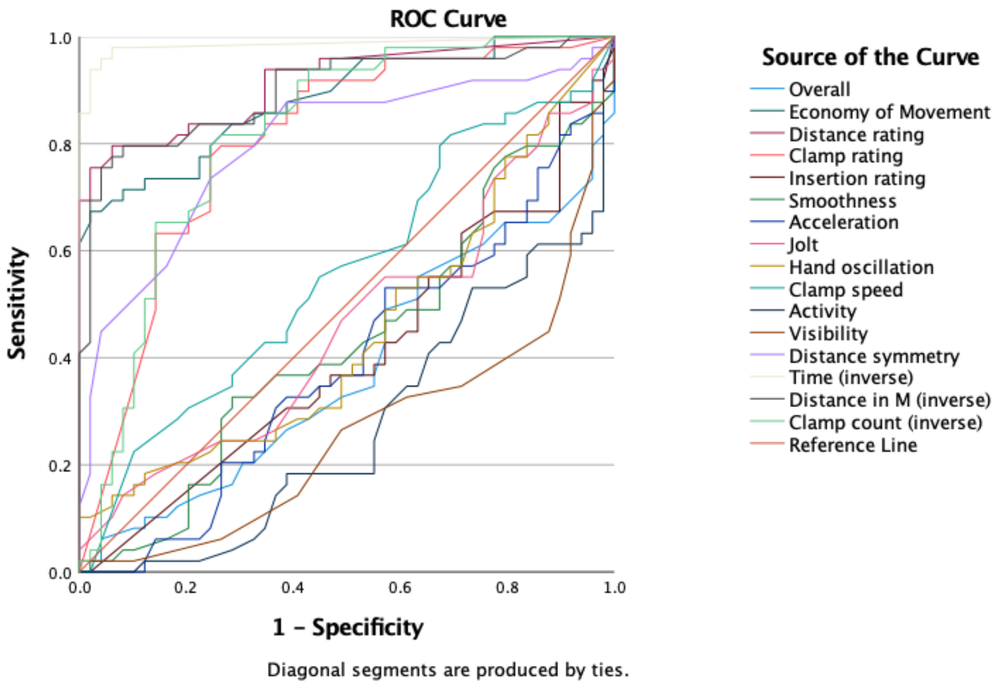
	5. Handles tissues well, applies appropriate traction, negligible injury to adjacent structures
Autonomy	1. Unable to complete entire task, even with verbal guidance 2. ↓ 3. Able to complete task safely with moderate guidance 4. ↓ 5. Able to complete task independently without prompting
Total GOALS score	/25

Appendix 8: Receiver operator curve analysis for human grading



Test variable	AUC
R1 Depth Perception	.956
R1 Bimanual Dexterity	.933
R1 Efficiency	.879
R1 Tissue handling	.885
R1 Autonomy	.846
R1 Total	.990
R2 Depth Perception	.955
R2 Bimanual Dexterity	.952
R2 Efficiency	.908
R2 Tissue handling	.903
R2 Autonomy	.844
R2 Total	.991

Appendix 9: Receiver operator curve analysis of analytic system grading



Test variable	AUC
Time	.985
Economy of movement	.883
Distance rating	.914
Clamp rating	.800
Insertion rating	.406
Smoothness	.429
Acceleration	.391
Jolt	.459
Hand Oscillation	.448
Clamp speed	.557
Activity	.277
Visibility	.261
Distance symmetry	.797
Total distance travelled	.899
Clamp count	.816