

Simulation for early years surgical training

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Abstract

The shift from traditional apprenticeship models to competency-based curricula, compounded by working hour restrictions and rapid advances in surgical technology, has altered the delivery of early years surgical training. Simulation has been widely incorporated in other high-risk, high-reliability industries, but it has only just begun to be embedded in surgical programmes over the last two decades. In this article, we review key concepts in surgical simulation. Using Scotland's Core Surgical Training Programme as an example, we demonstrate the implementation of these concepts into a national integrated simulation strategy for early years surgical training. We highlight other global examples of simulation use in surgical curricula. The key messages for all stakeholders in surgical training are: (i) simulation is an adjunct to clinical training, (ii) simulation is a tool; however, it is not the tool that should be the main object of interest, but the learning for which it is used, and (iii) in the absence of a constructively aligned and purposeful programme that is valued by trainees, trainers and the training system, it is not enough to issue the kit, no matter how good the simulators are.

Keywords

Simulation; surgical training; resident training; surgical education; laparoscopy; deliberate practice; curriculum; non-technical skills;

INTRODUCTION

The Halstedian apprenticeship model remains the mainstay of early years surgical training, and with justification, for there can be no complete substitute. However, solely relying on this traditional approach, without adjuvant modalities, may leave us with training that is too opportunistic, too inconsistent, and insufficiently efficient to deliver the task of training individuals, working in teams, to safely deliver complex medical care including surgery.¹ This task has been significantly altered in the last two decades by legislative changes to working hours, postgraduate curricular changes,² and the rapid evolution of surgical practices. Without the use of simulation, the possibility of accelerating the acquisition of foundational technical and non-technical skills, or of preparing for infrequently met challenges, may be missed. Too many lessons may continue to be learned the long way by harsh experience, sometimes at patients' expense.

Readers may have various ideas and experiences of what surgical simulation includes. Many first think of wet labs employing animal tissues for technical, operative skills training, or of laparoscopic box trainers (whether purely physical, virtual, or hybrid), or synthetic part-task trainers such as a thoracostomy or a urethroscopy model, or of human cadaveric operating. In some countries or states, simulation involving operations on live animals is permitted. Nowadays, robotic operating systems include simulation software packages, and endoscopy virtual reality (VR) simulators are similarly well-established technologies.^{3,4}

Simulation also includes non-technical skills training for individuals and/or teams using immersive scenarios (e.g. resuscitation, intra-operative crisis, a ward round, or a consultation).⁵ Here, volunteer patients, actors or mannequins may be used; sometimes hybrid setups with actors and part-task trainers; or a setup as simple as a series of simulated phone calls. Virtual reality, augmented reality and mixed reality simulation are also emerging rapidly. Non-technical skills taxonomies may be used in the all-important debrief^{6,7} and learning outcomes can include advanced skills behaviours such as team reflexivity.⁸ In situ simulation can be used to test and improve facilities and systems as well as people.⁹

The field has seen rapid and exciting innovation. This is not to propose simulation as a substitute for apprenticeship training, but rather as an essential adjuvant modality, in the same way that chemo- and radiotherapy may be used as adjuvants to enhance outcomes of cancer surgery. In short, it is a tool; however, it is not the tool that should be our main object of interest, but the task for which it is used.

KEY CONCEPTS IN SIMULATION

Constructive alignment

With “constructive alignment” (Figure 1) the stated, intended learning outcomes determine the content of the intervention, followed by opportunity for cycles of practice and feedback, and reinforced or incentivised by assessment (formative or summative).¹⁰ This can apply to a one-off event, to a syllabus of deliberate practice, or to a multi-year training programme.

Learning outcomes ought to be determined by needs and informed by curricula. Classically, they are written using “Bloom’s taxonomy”, e.g. “By ... participants will be able to ...”¹¹ However, in our experience (as in non-medical fields of higher education) there may be particular power in the learner’s discovery of a seemingly additional or unexpected learning outcomes.¹⁰ These may be knowledge, skills, or even attitudes. For example, a trainee in a prioritisation exercise declared “Oh so you want to know about this even at 3am?”¹²

In our experience and that of other groups internationally, there are innumerable examples of seemingly attractive simulation-based education projects (often beginning with the purchase of kit rather than the recognition of a need) which founder or gather dust, because they lack structured programmes that include constructive alignment and fail to provide the essential requirements for effective simulation-based education in healthcare. Table 1 shows 10 such essential features published by Issenberg et al in a “Best Evidence in Medical Education” review in 2005, which remain as relevant today.¹³

Put simply, in the absence of a constructively aligned and purposeful programme that is valued by trainees, trainers and the training system, it is not enough to issue the kit, no matter how good the simulators are.¹⁴

Fidelity

Fidelity refers to realism. Often misconstrued, “high fidelity” is not synonymous with “hi-tech”. It is more useful to consider types of fidelity – physical, functional, and psychological. Complex simulations need to avoid falling into the “uncanny valley” (a term borrowed from robotic engineering) where there is enough artefact to interfere with the suspension of disbelief (Figure 2). In other words, “better a good cartoon than a bad oil painting.” Generally, it is advisable to use the least complexity necessary to achieve the required fidelity. For example, in a simulated operating

room crisis for surgeons, a poster of an anaesthetic machine may suffice, but simulated blood or bile in the field may be required, since it will be a focus of attention.¹⁵

Feedback and debrief

It is believed that most of the learning from simulation is achieved through feedback or debrief. Indeed, Dieckmann et al. maintain it is unethical to provide simulation without careful feedback and/or debrief, as it could be damaging rather than beneficial.¹⁶

Whereas feedback comprises relatively quick and efficient comments (usually from an expert to a novice, often about practical skills and safety issues) debrief is a longer discussion (usually in groups and following complex activities) in which learner(s) and facilitator develop shared understanding or cognitive skills.

Many tools or frameworks exist for feedback and debrief.¹¹ Figure 3 demonstrates an example of the framework used by our group. It allows the participant(s) to react freely and safely, before setting an agenda, analysing the observed behaviours and exploring the assumptions and frameworks behind them, before introducing “micro-teaches” where appropriate (or drawing these from the group), and together agreeing take-home messages. To explore learners’ frames and assumptions, a useful technique is “advocacy-enquiry”, e.g. “I noticed you chose x, often we choose y, could you tell me more about that?” The aim is always to build knowledge, skills, attitudes, and confidence in the learner, and therefore care should be taken over psychological safety.¹⁰ In this way, learning will have the power of being self-directed or seemingly self-discovered, and will include unexpected as well as stated Learning Outcomes.

Deliberate Practice

It would be bizarre if a professional musician or athlete practised only during concerts or competitive games respectively. However, it remains surprisingly uncommon for surgeons to practise outside of their clinical settings. Herein lies the basis of the pedagogical concept of Deliberate Practice (DP).

Distinction should be made between simulation for (a) instruction, (b) DP, or (c) assessment. One definition of DP is the intentional repetition of a skill (either technical or cognitive) with intermittent feedback provided to correct errors and improve performance.¹⁸ DP can also be a teacher-led, goal-directed instruction whereby trainees are provided with structured training tasks. Using the latter definition, a recent review concluded that simulation-based educational interventions underpinned by DP were effective in developing surgical skill and 30-day skill retention amongst trainee surgeons.¹⁹ Evidence for skill retention beyond 30-days is limited by availability of good studies, but there is little dispute about the role of DP in skill acquisition.

Furthermore, we have long understood the phases of skill acquisition: (i) cognitive (the starting phase, where the novice's motor skills demand their full attention), (ii) associative (where neural connections are becoming established through DP), and (iii) automated (where, as proficiency is attained, the learner's attention is freed up for the higher cognitive functions of the operation or procedure).^(19,20) In simulation, these stages can even be manipulated to best advantage. For example, in a wet lab bowel anastomosis model, the trainee can be taken back to a cognitive stage to allow revision of technique, by placing the task in a more difficult setting, such as deep in a simulated pelvis.⁴

The BBASS (Black Belt Academy of Surgical Skills) programme (bbass.org), Skills Clubs (www.scotlanddeanery.nhs.scot/media/399291/whats-in-the-sim-strategy-v42e.pdf), and the Incentivised Laparoscopy Practice (ILPs) programme (see below) are examples of initiatives driving DP in early years surgical training.

Mastery Learning

The "mastery learning" approach to technical skills training, developed in Chicago, emphasises very standardised stepwise methods, with comprehensive checklists and rigorously defined acceptable standards to attain, and a need to repeat cycles of practice until these are attained.¹⁵ This approach was initially developed for Internal Medicine and Critical Care procedures like central venous cannulation or lumbar puncture, and more recently adapted to surgical procedures including exploration of the common bile duct. It has been evaluated to the extent even of clinical outcomes (Kirkpatrick level 4) and financial cost-effectiveness, which is a notable achievement, but has yet to be widely adopted into simulation-based medical and surgical training.

Curricular integration

Though Issenberg's 10 features that lead to effective simulation-based healthcare education (Table 1) are well established,¹³ simulation remains less well integrated into early years training than in other high reliability industries such as civil and military aviation or the oil and nuclear power industries. It is interesting to consider why this may be. When the Scottish Surgical Simulation Collaborative (SSSC) (of the Royal College of Surgeons of Edinburgh, the Royal College of Physicians and Surgeons of Glasgow and NHS Education for Scotland) undertook a report in 2013, they found there was no lack of evidence base. Indeed, as Ker wrote in 2010, "There is no other high reliability profession which has waited for such evidence before adopting simulation into training programmes because the cost of failure is simply too high."²¹ Nor did there appear to be a lack of facilities or of trained faculty around the country. The SSSC did, however, find a lack of co-ordinated strategy and funding and chose to address those perceived deficiencies.

THE SCOTTISH CORE SURGICAL SIMULATION STRATEGY

How then, in the early years of surgical training, can a training programme strategically provide integrated simulation? And how can trainees best engage with it? In 2012, the SSSC was formed as a bicollegiate working group from the Edinburgh and Glasgow Surgical Royal Colleges. In 2015-16 this group drafted a simulation strategy for the Scottish Core Surgical Training (CST) programmes (equivalent to surgical residency years 1 and 2), mapped to the UK Core Surgical curriculum [2016 CST curriculum available from

https://www.iscp.ac.uk/curriculum/surgical/specialty_year_syllabus.aspx?enc=UaniGe0oHRsdKwk8+V2yRQ==] [2021 CST curriculum available from https://www.gmc-uk.org/-/media/documents/core-surgical-training-curriculum-aug-2021-approved-oct-20v2_pdf-84480134.pdf]. Some key principles in the design of the simulation strategy were:

- It should adopt Issenberg's 10 essential features,
- It should include technical skills training (part tasks and whole operations/procedures) and non-technical skills training (immersive scenario-based simulation),
- It should include both instructional courses and DP,
- Delivery should be distributed across the multiple training sites,
- It should play to the strengths of existing centres, but expertise should be shared, and faculty developed across the locations.

Figure 4 shows a summary infographic of this strategy.

(www.scotlanddeanery.nhs.scot/media/399291/whats-in-the-sim-strategy-v42e.pdf) The cost of delivery was £2,100 per trainee per annum, which was noted to be less than the estimated cost savings in (a) workplace training time and (b) potential patient harm and subsequent litigation. Scotland's CST programmes formally adopted the strategy, and backed by Scottish Government funding, it was implemented from August 2018 as part of a wider reform, the Improving Surgical Training (IST) pilot (<https://www.scotlanddeanery.nhs.scot/trainee-information/improving-surgical-training-programme-ist/>).

Annually, approximately 50 trainees enrol onto the two CST programmes in Scotland. Each trainee has benefitted from the fully funded simulation strategy (in addition to some pre-existing study leave budget for other courses) since 2018, albeit with disruptions and adaptations in 2020-21 due to the COVID pandemic.

In each of the 2 years, there are 3 courses, a series of monthly training events, and a take-home DP programme. Additionally, the majority of the 18 CST sites across Scotland have local “skills clubs”, supported by the IST simulation strategy.

Boot Camp

The first of the courses is the Scottish Surgical Boot Camp. (www.surgicalbootcamps.com; Walker, 2020) This mandatory 4-day holistic induction course takes place in the Inverness Clinical Skills Centre. The course is designed to take trainees through technical skills and non-technical skills in parallel series of instruction and related simulations, where there is the opportunity for practice with individual or group feedback and debrief, followed by repetition of same skills but in varied settings of increasing difficulty (Figure 5). For example, there is a progression in operative skills in wet labs from porcine skin flaps, through porcine bowel anastomosis, to vascular anastomosis or patch graft using 3D-printed aquagel models. Similarly, in non-technical skills, after a classroom session based on the RCSEd Non-Technical Skills for Surgeons (NoTSS) taxonomy (Yule, 2012), trainees progress through a prioritisation and phone calls exercise, a simulated ward round, a simulated Morbidity and Mortality meeting, and some complex communication skills challenges. Other sessions include writing operation notes, “How to get the Most from your Trainer” and “Memorable Cases”. The programme is described in more detail elsewhere.²²

The boot camp features a social programme that provides trainees with a networking opportunity. A qualitative study of this course describes how all these features together form a whole “activity system” that provides induction to a community of practice, including hitherto hidden curriculum.²³

The themes of boot camp are carried into the programme of monthly training days.

Other courses in the first year

Other courses delivered in the first year teach fundamentals of critical care (either the Intercollegiate CCrISP course (Care of the Critically Ill Surgical Patient) or the RCSEd’s new RAPID course (Recognition and Prevention of Injury and Deterioration) and fundamentals of minimally invasive surgery (an RCPSG one-day “Core Laparoscopy Skills” course).

Courses in the second year

The first course of the 2nd year is the 2-day “BaSiCS” course, undertaken at Glasgow’s Clinical Anatomy Skills Centre. (www.rcpsg.ac.uk/events/casbasics) This human cadaveric course puts together component surgical skills into whole general surgical operations. (There are alternatives for certain subspecialty-destined Core trainees.)

“Managing Surgical Crises”, the second course, is a one-day event delivered in Glasgow, Edinburgh and Dundee, whose primary aim is to teach trainees skills in recognising and responding to things going wrong in the operating room. Animal models are used to perform a series of 8 short simulations where trainees respond to unexpected events (eg. a leak of bile or a bleeding spleen) using an algorithm.

Thirdly, CoSMoS (Consultation Skills that Matter for Surgeons) is a new RCSEd training programme for 2022, covering consultation skills, Shared Decision Making and informed consent. It includes some theory and tools, opportunity for practice with actors, and the facility to subsequently video-record a consultation with a real patient and use this for debrief with faculty.

Monthly training days

A blended learning approach is used to deliver the monthly training days, which run on a 2-year cycle. Pre-course videos and webinar classrooms are mixed with face-to-face sessions involving simulations in various skills centres. Monthly training days are used to deliver introductory knowledge and skills relevant to subspecialties (e.g. vascular or plastic surgery), while other training days are geared towards specific skills training (e.g. a stoma training day including porcine models). Trainees are expected to attend at least 7 per year.

Take-home deliberate practice programmes

The Incentivised Laparoscopy Practice (ILPs) programme is available for all first-year trainees. Its design was informed by an extensive multicentre study undertaken to understand the barriers and facilitators to engagement with previous examples of such a programme.²⁰ At boot camp, trainees are each loaned a laparoscopic simulator (eoSim, EOSurgical, Edinburgh) and instructed on its use. There is a programme of 6 tasks, with online video instruction, and trainees are required to submit 6 videos during the following 6 months for scoring using a modified OSATS (Objective Structured Assessment of Technical Skill).

In the second year “VASim” DP programme, 3D-printed aquagel models of blood vessels (OrganLike, Glasgow) and the instrument-containing kit are posted to each trainee. The programme was designed for trainees to allow practice and develop skills in open vascular surgery. Feedback is delivered on video uploads of vascular anastomoses.

Skills clubs

Finally, the strategy has supported local Skills Clubs in hospitals, where trainees at various stages meet to practise a range of technical skills. This was an aspirational rather than a mandatory part of the strategy, but interestingly the COVID pandemic saw a rise in the number and activity of skills

clubs, which have now been running in majority of the 18 hospitals associated with the Scottish CST programmes.

It is interesting to note key features of other surgical simulation strategies that this pilot did not adopt. Although we have already discussed the role of assessment in constructive alignment and driving learning, it has not been a big feature of this pilot, largely because of the difficulty in introducing perceived or actual hurdles to progress in one deanery but not in other parts of the UK.

Evaluations of the Scottish CST and IST simulation strategy

In 2014-15, the first cohort of core surgical trainees in Scotland took part in version 1 of the ILP programme.²⁴ A framework of continuous improvement allowed us to test our procedures, assess engagement/recruitment and retention, and determine what had worked or not worked in the initial 2014-15 feasibility study. In 2017, a second, multi-centre study explored the barriers and facilitators to engagement with ILP.¹⁴ We have learned that a programmatic approach to implementing any educational innovation is required. Simply handing out kit, no matter how good, is not enough.

The first year of the strategy has been piloted as planned in 2018-2019, but the second year has not yet been trialled as initially planned due to COVID pandemic disruption. It is interesting to note that the initial phase of the pandemic had a deleterious effect on engagement even with the take-home ILPs programme, though that has recovered to near 100% engagement since. However, it appeared to have a boosting effect on skills clubs, with 10 new clubs requesting supplies of kit during the second half of 2020.

A comprehensive, mixed methods evaluation of the Scottish IST pilot is under way and will report soon, including quantitative outcome data (albeit with historical controls) and rich qualitative data from thematic analysis of structured interviews.

OTHER EXAMPLES OF CURRICULAR INTEGRATION

Table 2 outlines other good examples of surgical training programmes integrating simulation into their curriculum. While this is by no means a comprehensive list of global programmes: it gives stakeholders in surgical education a differing perspective of each programme.

It is rare to see a comprehensive integrated simulation strategy for technical and non-technical skills that incorporates instruction, DP, and assessment, distributed across a whole region or country. A possible exception is the innovative orthopaedic residency programme in Toronto.²⁵ This programme

is exemplary in the way it has embedded simulation into its' competency-based curriculum to shorten the duration of the programme. It comes with an expense (15 times that of traditional training) but the majority of that was not related to the simulation features.

Surgical simulation may have different utility in later years of training, with more specialty-specific procedural training and perhaps more advanced team training. That could be described as an adjuvant modality rather than the more neo-adjuvant approach in early years.

WHAT NEXT?

The evidence suggests that successful simulation-based surgical education will depend on provision of facility, of trained faculty, and of curricular institutionalisation,¹³ with constructive alignment. From our experience and data, we would add that all stakeholders of the training system need to value this modality that is so much more embedded in other high-risk / high-reliability industries.

The advancement in surgical technologies and the widespread uptake of robotic surgery across surgical specialties presents a déjà vu for the generation of surgeons who were tasked with mastering laparoscopic surgery three decades ago. Although home-made cardboard cut-outs have been replaced by sophisticated hardware and software, the principles of deliberate practice, mastery learning, feedback and reflection remain the same.

The pandemic-related global disruption to surgical education and training has resulted in a large body of case studies describing innovations and adaptations involving simulation for surgical skills. The sharing of stories and practices is one step forward in appraising the unintended consequences of the pandemic.²⁶ The pandemic may have helped make the case for simulation in a post-pandemic era of surgical training.

Practice Points

- Simulation is a tool; however, it is not the tool that should be our main object of interest, but the task for which it is used.
- In the absence of a constructively aligned and purposeful programme that is valued by trainees, trainers, and the training system, it is not enough to issue the kit, no matter how good the simulators are.
- We should use the least complexity necessary to achieve the required fidelity.

- The principles of deliberate practice, mastery learning, feedback and reflection remain unchanged since novice surgeons began to learn laparoscopic skills three decades ago.
- Much of the learning will occur during debrief, which should be done with care and psychological safety, exploring frames and assumptions.

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Figure 1. Constructive alignment.

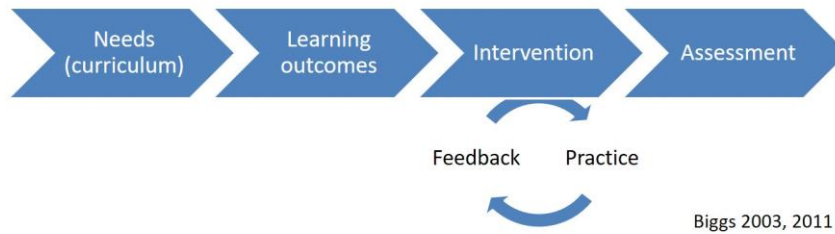


Table 1. Issenberg's 10 features of high-fidelity simulation that lead to successful simulation-based healthcare education.

1. FEEDBACK should be provided during the learning experience
2. Learners should engage in REPETITIVE PRACTICE
3. Simulation should be INTEGRATED into the overall curriculum
4. Learners should practise with INCREASING LEVELS of difficulty
5. MULTIPLE learning STRATEGIES should be employed
6. Simulations should represent CLINICAL VARIATION
7. The simulation environment should be CONTROLLED
8. Simulations should foster INDIVIDUALISED LEARNING
9. OUTCOMES must be clearly DEFINED and measured
10. The SIMULATOR should be VALID as a representation of a human or situation

Figure 2. The “uncanny valley” (adapted from Mori)(Available from: <https://spectrum.ieee.org/the-uncanny-valley>)

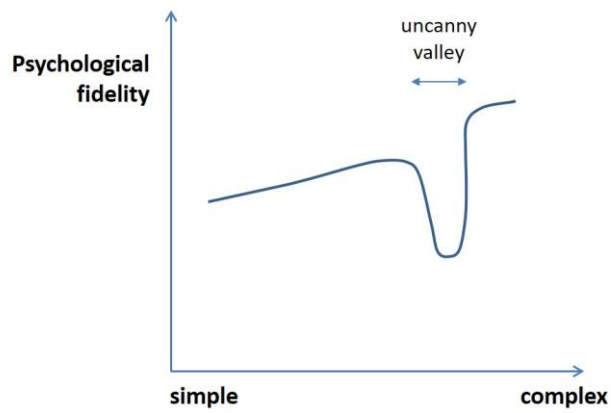


Figure 3. A structured approach to a debrief conversation (May A *et al*, Scottish Centre for Simulation and Clinical Human Factors, unpublished).

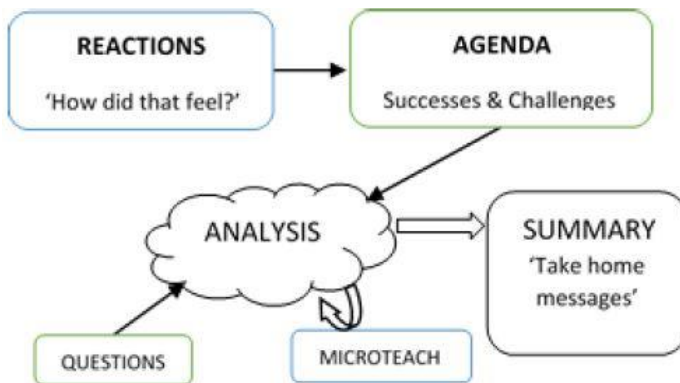


Figure 4. Overview of the Scottish IST simulation strategy.

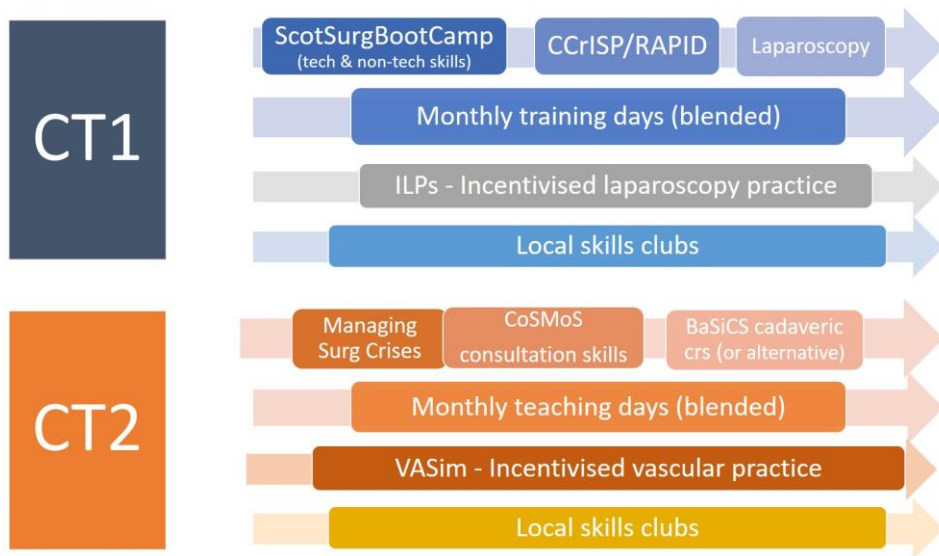


Figure 5. Scottish Surgical Boot Camp: parallel progressions in technical and non-technical skills.

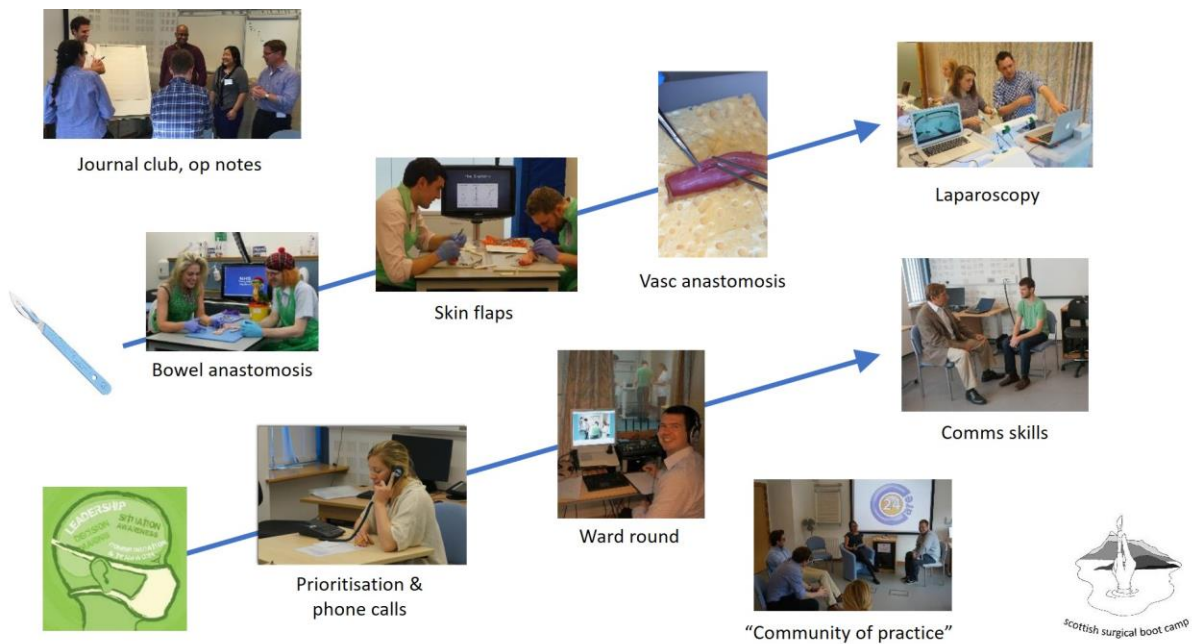


Table 2. Other published examples of integrated simulation strategies.

Programme name/Site, Country	Specialty	Trainee level	Weblink
Urology Simulation Bootcamp, Leeds, UK	Urology	Year 1	https://www.baus.org.uk/professionals/events/3827/6th_urology_simulation_boot_camp/ doi.org/10.1007/s12262-021-03016-5
Introduction to Phacoemulsification Surgery, Royal College of Ophthalmologists, UK	Ophthalmology	ST1 (year 1)	www.rcophth.ac.uk/training/ost-information/simulation/
Nice Medical School Simulation centre, Nice, France	General, thoracic, paediatric, urology	Year 1-4	doi.org/10.1016/j.jviscsurg.2011.12.007
Division of Orthopaedic surgery, University of Toronto, Canada	Orthopaedics	PGY1	https://uoftorthopaedics.ca/education/residency/training-content/ 10.1016/j.surg.2010.11.011 https://doi.org/10.1080/0142159X.2017.1421751
Washington University Institute for Surgical Education (WISE), Washington, USA	General, plastic, urology, vascular, cardiothoracic	PGY1	https://simulation.wustl.edu/centers/surgical-skills-lab/
Surgery for Abdomino-thoracic Violence (SAVE), Washington, USA	General, vascular, urology, plastic	PGY1-2	https://surgery.wustl.edu/wise-surgery-simulation-education-training-stl/ https://doi.org/10.1016/j.jsurg.2018.12.003 https://doi.org/10.1097/TA.0000000000003037
Hospital of the University of Pennsylvania, USA	Trauma and surgical critical care	PGY1	https://doi.org/10.1016/j.jsurg.2015.03.001