Royal Australasian College of Surgeons

E-learning for non-technical skills in surgery

A rapid literature review

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ABBREVIATIONS

ANTS	Anaesthetists' Non-Technical Skills
DVD	digital video disc
NOTECHS	Non-Technical Skills Scale
NOTSS	Non-Technical Skills for Surgeons
NTS	non-technical skills
PICO	participants, interventions, comparators, outcomes
RACS	Royal Australasian College of Surgeons
RCT	randomised controlled trial
RUFUS	rural-focused urban surgeon
UK	United Kingdom
USA	United States of America
VR	virtual reality
WHO	World Health Organization

INTRODUCTION

E-learning is an increasingly popular method for training in healthcare (including surgery), primarily due to its accessibility and flexibility. This approach encompasses an array of tools, spanning from online textbooks to cognitive simulators, enabling learning regardless of the learner's geographic location, time constraints or availability of teaching resources.[1-3] However, developing effective e-learning teaching resources can be resource-intensive, and it is crucial to determine whether e-learning is effective in influencing changes in clinical behaviour and improving patient outcomes.[4]

Two prevalent e-learning formats have been recognised: distance e-learning and computer-assisted instruction. Distance e-learning uses information technologies to deliver instruction to learners located remotely from a central site. Computer-assisted instruction (also called computer-based learning and computer-based training) uses computers to aid in the delivery of stand-alone multimedia packages for learning and teaching. These two formats are encompassed within the broader field of e-learning as the internet becomes the integrating technology.[5] However, the distinction between the two is important from a research perspective because most e-learning research is based on learning in situ rather than remote distance e-learning.

E-learning can be synchronous—connecting learners with instructors and other students in real-time—or asynchronous—enabling learners to study at a time and place of their choosing.[6] Synchronous e-learning through virtual lectures and other meetings is becoming more common, supported by a variety of common videoconference technologies.[7] [8] However, asynchronous e-learning offers several advantages compared with traditional pedagogic or synchronous learning. It provides flexibility for learning that can adapt to various work patterns, and it eliminates the challenges associated with coordinating synchronous educational activities for all learners.[9] Rural surgical trainees and those in low-resource settings particularly benefit from internet-based asynchronous e-learning, as they may not have the same educational opportunities as their metropolitan counterparts.[10] [11] E-learning technologies empower learners by providing control over content, the order of learning, the pace of study, and when and how they access learning materials. This flexibility enables individuals to customise their learning experiences to align with their unique educational goals.[5] Therefore, asynchronous internet-based e-learning provides a practical solution for those who contend with the constraints of remote locations and demanding work schedules.

Although resource-intensive, e-learning has been shown to enhance accessibility to education and to provide efficacious, cost-effective, flexible and interactive learning compared to in-person training.[12] [13] Recent years have seen a proliferation of internet and software-based platforms, with more advanced and complex user interfaces being developed.[14] [15]

Most e-learning to date has focused on providing information and improving surgeons' technical skills (e.g. laparoscopy, knot-tying, suturing).[13] [16] More recently, non-technical skills (NTS) have gained awareness in healthcare, specifically surgery, as adverse events have been shown to originate from behavioural failures rather than a lack of technical expertise.[17] As many as 10% to 15% of patients admitted to hospital experience an adverse event not directly related to their underlying condition, around 50% of which are classified as avoidable.[17] Research into medical errors and adverse events indicates that up to 80% can be attributed to a breakdown of NTS, including poor situational awareness, poor interactions and communication with team members, inadequate monitoring, or failure to follow procedures and routines.[18] Within the aviation industry—another high-hazard industry—non-technical performance is recognised as being crucial to safety. There is a growing body of evidence that the same is true in surgical practice.[19] [20] While the specific definition of NTS can vary, it generally includes social skills (communication, teamwork, leadership) and cognitive competencies (situational awareness, decision-making). Although technical skills are necessary for safe and effective surgery, surgeons also need to be skilled in NTS to ensure optimum outcomes for patients.[17]

The Royal Australasian College of Surgeons (RACS) recently completed a project to discover the professional skills specifically relevant to rural surgeons and individuals involved in rural outreach.[21] The greatest difference encompassed the non-technical skills of judgment and clinical decision-making,

specifically an understanding of the rural context, rural contextual decision-making and rural-focused urban surgical skills (RUFUS). RUFUS surgeons care for non-metropolitan patients through in-reach, outreach, telehealth and design of surgical systems, and they provide peer support to rural surgeons. Due to the time constraints of supervisors in rural practice, it has been suggested that these rural skills be taught via a curriculum provided through a voluntary e-learning module.[22] This rapid literature review investigates the evidence on e-learning for NTS for surgeons.

As part of this project, RACS also undertook a survey of rural surgeons and trainees to further inform the next steps of developing an e-learning curriculum for rural professional skills. The survey results are provided as a separate report.

Research question

What is the effectiveness of internet-based e-learning programs for improving the NTS of surgeons and surgical trainees?

METHODS

Inclusion and exclusion criteria

Eligible participants, interventions, comparators and outcomes (PICO), and study types are described in Table 1. As the focus is on NTS, any e-learning tool that focuses on a specific surgical procedure or technical skill was excluded.

Table 1 PICO and study selection criteria

Population	Surgeons or surgical trainees of any specialty
Intervention	Internet-based e-learning programs defined as any asynchronous educational intervention that is mediated electronically via the internet
Comparator	Nil or traditional face-to-face teaching methodologies
Outcome	Primary: Impact on surgeons' non-technical skills using objectively administered evaluation criteria Secondary: Impact of patient outcomes using objective outcomes measures Surgeons' perceptions of e-learning programs using subjective and objective outcome measures
Types of studies	Systematic reviews, RCTs, observational studies
Limits	English language

Abbreviations: RCT: Randomised controlled trial

Definitions

NTS are defined in accordance with the Non-Technical Skills for Surgeons (NOTSS) framework, encompassing situational awareness, decision-making, task management, communication, and teamwork and leadership.[23] E-learning is defined as the use of electronic media, information and communication technologies, and various digital platforms to deliver education, training or instructional content without restriction by time or location. This may encompass various forms, including online modules, webinars, multimedia content and more.

Search strategy

A literature search of Ovid MEDLINE and Embase (Appendix A Table 2, Table 3) was performed from inception to 19 April 2024. Clinical trials registers (PROSPERO and Clinicaltrials.gov) were also searched and supplementary free text searches were performed in Google. Reference lists of identified reports were searched for additional studies (pearling).

Study selection and data extraction

Titles and abstracts were screened for relevance according to the pre-defined inclusion criteria (Table 1) by one reviewer. Full text reports of potentially relevant studies were selected for further inspection. Any uncertainty regarding study selection was resolved through discussion with a second reviewer. Reference lists of articles selected for full text inspection were screened for further studies.

A standardised data extraction template was used to extract data from the individual studies.

Evidence analysis

A narrative synthesis was undertaken. Quality assessment was not planned for this rapid review.

RESULTS

The systematic literature search identified 694 studies. Following the removal of 55 duplicates, 119 studies were investigated in full text; 6 trials (8 publications) met the PICO criteria and were included.

The included studies are summarised in Appendix A Table 4. Studies varied in design, including 1 randomised controlled trial (RCT),[24] 2 cohort studies providing before and after results,[25-28] and 3 pilot, single-arm feasibility studies providing a description of the module.[29-31] The searches also identified a number of systematic reviews on the topic of NTS in surgery, some of which discussed an aspect of e-learning as part of a broader review of theoretical learning and technical skills. The bibliographies of these systematic reviews were searched for relevant primary studies relating to NTS.[13 16 32-35]

The included studies covered a range of surgical specialties, including general surgery, colorectal surgery, plastic surgery, urology and ophthalmology.

One RCT investigated the use of an instructional video with written information, compared with written information alone (non-video) on the NTS of plastic surgery residents in simulated burns patient management.[24] Compared to the non-video group, the video group achieved significantly higher scores in the decision-making NTS ($p = 0.035$) and total NOTSS score ($p < 0.005$), as well as improvements in technical skills.

An Australian trial provided revised Non-Technical Skills Scale (NOTECHS) scores before and after a 1-hour digital video disc (DVD) training program on teamwork in the operating theatre for cardiac, hepatobiliary, upper gastrointestinal and vascular surgical procedures.[25 26] The intervention improved NTS scores ($p < 0.001$).

One case series reported the use of presentations, including videos, provided to ophthalmology surgeons for self-directed learning.[27 28] When the intervention was tested using simulation-based training for the management of posterior capsule rupture there were significant improvements in all reported NOTSS outcomes.

Three pilot studies described the development and initial use of e-learning modules as part of a feasibility exercise.[29-31] Although it is impossible to determine the effectiveness of these tools, each intervention (where reported) was well-liked and feedback was positive in terms of its educational value. Two of the pilot studies described the development of clinical scenarios relevant to that specialty, including virtual reality (VR) modelling and interactive elements, as well as videos.[29 31] The scenarios were identified with expert input to create storyboards, which were tested. The third pilot study included a range of questions and matching tasks, together with images and videos, to identify safety hazards.[30] While no formal NTS assessment was reported for this trial, the cognitive training was considered by the authors to be an NTS.

DISCUSSION

This rapid review identified a small number of publications directly reporting on e-learning modules for NTS in certain aspects of surgery. The limited evidence comprised various trial designs, including pilot studies, with relatively small patient numbers. While the application of these trial scenarios to real-world learning experiences and clinical outcomes, and the transferability to other surgical scenarios is uncertain, the studies show that NTS for surgery can be effectively taught using asynchronous e-learning techniques.

Although the studies varied in their design, certain themes were consistently reported. The target audience was identified; the planned training need was established; the material was developed with relevant scenarios that were storyboarded; the material was created on an appropriate platform; expert feedback (clinical and educational) was included and the material was aligned with relevant guidelines and built on existing resources where available; and the final material was tested and validated. Models often used interactive and engaging designs in their modules.

E-learning, including teaching and learning delivered through online systems, is not a new concept and reflects a wide mix of content and delivery that can be used either independently or blended with other learning styles.[33 36] The heterogeneity of platforms and interventions is vast, ranging from online communication, community discussions and journal clubs; access to electronic text, video or multimedia content; intermittent or spaced education, interactive learning and feedback; and virtual patients, VR environments, and gaming.[13 32 37 38]

E-learning for surgical education is most commonly used to provide examples of patient cases, to teach theoretical knowledge (cognitive learning) through online tutorials, or to teach surgical skills.[13 16 33] Systematic reviews report the use and outcomes of e-learning across the range of surgical specialties for students and trainees and as continuing professional development for Fellows.[13 33 37 39-44] Established e-learning examples include a national web portal provided by the Accreditation Council of Graduate Medical Education (ACGME) to deliver content on core competencies to general surgery residents (the Surgical Council on Resident Education, or SCORE, portal) and the Society of American Gastrointestinal Endoscopic Surgery (SAGES) course on the basic fundamentals of laparoscopic surgery.[32 33 45] These resources provide information and knowledge about conditions, diseases and procedures, with guideline-based content supplemented with text, videos and images.

Over recent years, virtual meetings and lectures have become more common in healthcare teaching, a phenomenon that increased substantially as a result of the COVID pandemic.[7 8 39 40] This digital education and e-learning (commonly videos on guidelines or surgical procedures and webinars on clinical cases) provides additional opportunities for medical students and trainees to access educational material, particularly when physical attendance at a training activity is problematic or when asynchronous access to the training resource is beneficial. Several recent systematic reviews provide examples of e-learning for surgical specialties. For surgical and anatomical training, online lectures were found to be beneficial by surgical students and their tutors, although limitations identified by the trainees included lack of personal contact with the tutor, poor networking opportunities and reduced student concentration.[39] Urology trainees found e-learning programs useful and interesting.[40] Plastic surgery trainees showed high levels of satisfaction and interest in e-learning delivery for teaching skills and knowledge.[41] E-learning was also shown to be associated with high satisfaction and improvements in knowledge and procedural competencies of practicing surgeons.[8 37] Limited evidence showed that video learning techniques are effective (as good as or superior to alternative methods) for teaching technical skills development, either as a standalone module or in combination with other standard teaching techniques.[46]

The importance of NTS in the operating theatre has long been recognised, with many initiatives driven by anaesthetists, such as the development of the anaesthetists' NTS (ANTS) behavioural marker system.[47 48] Although NTS in anaesthesia was not the focus of this review, published examples of e-learning compared with didactic learning for this cohort include debriefing for simulated crisis scenarios and training in simulated resuscitation.[49-51] There were no reported differences between the different

models of instruction. NTS in surgery has traditionally been taught using conventional teaching methods and formal curricula, including single- or multi-day courses, lectures, didactic teaching and practice sessions.[52 53] Training courses are generally based on existing validated NTS tools, including NOTSS and the Oxford NOTECHS II.[35] These courses include face-to-face curricula as well as blended courses with an online component.[7 54 55]

More recently, surgical curricula for NTS have included the use of simulation (high- and low-fidelity) and programs related to crisis resource management training.[56] In recent years, there has been an increase in the number of publications for simulation-based surgical training for technical skills and NTS.[57] Wet- and dry-laboratory simulation for technical skills and NTS has been reported across a range of surgical specialties.[16 58-67] Commercial immersive VR platforms offer another opportunity for simulated training in NTS for surgery.[16 34 61 68-70] Compared to box simulation training, VR simulation tools are reported as being equivalent in terms of skills score and skills completion time.[16 61] However, there is a large variety of VR platforms across a range of procedures; the evidence-base for each is often limited and quality data for this modality are still emerging.[61 68 70]

Effective NTS are particularly important for successful teamwork.[71] The program TeamSTEPPS is a common team training curriculum.[32 72] Hi-fidelity team-based simulations and other team training exercises have been developed for the acute care setting and the operating theatre.[73-78] These tools benefit NTS development and can provide improvements on patient outcomes, but published studies are small and heterogeneous in their design and reporting.[75-77]

Behavioural and neurological data have shown that making errors can significantly enhance new learning.[79] The ability to observe the consequences of cognitive decisions and actions has a significant benefit when learning NTS via simulations. Learning from mistakes, when accompanied by constructive feedback, leads to more effective learning. For this type of error-based learning to be successful, participants must grasp where the mistake occurred, what the correct solution entails, and the underlying reasons behind it.[79] E-learning provides the additional benefit of creating a safe learning environment where learning through errors avoids the need for corrective learning from peers, thus circumventing any discomfort associated with peer-reviewed assessment.

CONCLUSIONS

A limited number of studies showed that teaching NTS through asynchronous e-learning is feasible for surgical training. All studies showed improvements in some or all reported NTS outcomes, although the application of these trial scenarios to real-world learning experiences and the transferability to other surgical scenarios is uncertain. Patient-relevant outcomes were not reported. The evidence-base was impacted by small studies and by varied interventions, trial designs and outcomes reporting, so data synthesis across studies was not possible. This reflects the broader evidence-base for e-learning and alternative tools for NTS training, which includes a wide range of interventions and often limited supporting evidence of effectiveness.

While studies varied in their designs, certain themes were consistently reported. The target audience was identified; the planned training need was established; the material was developed with relevant scenarios that were storyboarded; the material was created on an appropriate platform; expert feedback was included and material aligned with relevant guidelines; and the final material was tested and validated.

E-learning as a whole, and specifically for NTS, shows promise; is well received by trainees, trainers and surgeons; and can be a valuable addition to healthcare education, particularly when the modules involve an interactive and engaging design. Increased awareness of the importance of NTS in patient safety should encourage the prioritisation of research development and implementation in this area.

APPENDIX A: SEARCH STRATEGY

Table 2 Ovid MEDLINE search results 1946 to 19 April 19 2024

#	Query	Results
1	surgeons/	15,535
2	exp Specialties, Surgical/	223,665
3	"Internship and Residency"/	62,114
4	(surg* or intern or interns or internship or internships or residen* or registrar* or trainee or trainees).mp.	4,151,273
5	1 or 2 or 3 or 4 [surgeon or trainee]	4,237,201
6	((education or educational or educate or coach$ or teaching or training or train or coach$) adj15 (non-technical or nontechnical or NTS)).mp.	1,085
7	5 and 6	577

Table 3 Ovid Embase search results 1974 to 19 April 2024

#	Query	Results
1	surgeons/	137,617
2	exp Specialties, Surgical/	6,029,260
3	"Internship and Residency"/	241,125
4	(surg* or intern or interns or internship or internships or residen* or registrar* or trainee or trainees).mp.	5,604,803
5	1 or 2 or 3 or 4 [surgeon or trainee]	7,842,440
6	((education or educational or educate or coach$ or teaching or training or train or coach$) adj15 (non-technical or nontechnical or NTS)).mp.	1,559
7	5 and 6	1,029
8	limit 7 to conference abstract status	347
9	7 not 8	682
10	limit 9 to "remove medline records"	117

APPENDIX B: SUMMARY OF INCLUDED STUDIES

Table 4 Summary of included studies

Study ID Country	Specialty Number of participants	Study design Description of study | Summary of intervention	Outcomes reported	Overall conclusion
Beyer-Berjot 2015[29] UK, France	Colorectal surgery No participants – proof of concept study	Pilot study, single-arm Scenario: enhanced recovery after surgery for colorectal surgery patients Intervention: training for enhanced recovery after surgery for online virtual patients (4 preoperative, 5 postoperative cases) Detailed scenarios were created in a specific user interface after developing the storyboard, in line with guidelines, published literature and expert advice. The module allowed a participant to observe and interact with the patient and interact with other specialties. The module was accessed via the internet.	Nil The storyboard cases are described.	Virtual patients can be used to develop technical and non-technical skills.
Gasteratos 2021[24] USA	Plastic surgery 60 final-year residents	RCT Scenario: simulation training in burns patient management Intervention: use of an instructional video demonstration (total time 7:20 minutes) in addition to written material. Seven videos provided a scenario and were watched at home. The videos covered a range of technical and non-technical themes and were in line with guidelines. Comparator: written materials only	Technical (various) and non-technical skills Non-Technical Skills for Surgeons (NOTSS) tool	Compared to the non-video group, the video group achieved significantly higher scores in the technical skills of assessment of breathing ($p = 0.015$), disability ($p = 0.023$) and exposure ($p = 0.005$), and in the non-technical skills of decision-making ($p = 0.035$) and total NOTSS score ($p < 0.005$). There was no significant difference between groups for leadership, teamwork, situational awareness or communication skills.

Study ID Country	Specialty Number of participants	Study design Description of study | Summary of intervention	Outcomes reported	Overall conclusion
				The video was considered to be a valuable tool to enhance trainee competencies
Gillespie 2017, 2021[25 26] Australia	Surgery (various specialties) 179 team procedures including a surgeon, nurse and anaesthetist	Before/after comparative study (no concurrent control) Scenarios: cardiac, hepatobiliary, upper gastrointestinal and vascular surgical procedures Intervention: 1-hour DVD team training program based on individuals and shared situational awareness in 2 clinical scenarios and including principles from the Crew Resource Management training and WHO Surgical Safety Checklist	Revised NOTECHS tool Surgeries were observed by a single trained observer before and after the intervention	Total NOTECHS scores improved after the intervention ($p < 0.001$). Barriers to the training program included the video being too long. The team training program, delivered as a DVD, improved teams NTS.
Isreb 2019[30] UK	General surgery 33 participants completed the module	Pilot study, single-arm Standalone online module for cognitive surgical training Model investigated: laparoscopic cholecystectomy Intervention: multiple-choice questions, extended matching items and single-line free-text questions. The module contained relevant sketch images and real-life hazards video clips highlighting potential mistakes to enhance safety knowledge, reducing bias, and improving self-limitation awareness. Two experts were invited to validate the prototype before testing.	Qualitative feedback, semi-structured interviews No specific NTS assessment undertaken	The overall feedback was positive. Results supported the value of this online resource in enhancing knowledge and awareness
Pears 2023[31] UK	Urology 32 trainees	Pilot study, single-arm Setting: authentic clinical scenarios (detail not provided) Intervention: development and assessment of an online teaching tool in collaboration with urology experts, medical education specialists and a human factor researcher. Development included identification of relevant scenarios, storyboarding and testing.	User feedback survey System Usability Scale (SUS) Training Evaluation Inventory (TEI)	The application was considered to be easy to use with positive effects on learning and confidence in non-technical abilities. It is unclear if the application can be provided as an online module; however, the study does not describe the need for a dedicated platform.

Study ID Country	Specialty Number of participants	Study design Description of study | Summary of intervention	Outcomes reported	Overall conclusion
		Two 15-minute virtual reality scenarios designed to enhance non-technical skills, and included videos and interactive modules		
Wood 2023, 2024[27] [28] UK	Ophthalmology 17 surgeons	Case series before/after comparative study Model: simulation-based training for management of posterior capsule rupture as an intraoperative complication (provided before and after the intervention) Intervention: 3 presentations provided remotely via Zoom, including videos. The presentation material was provided to the participants for self-directed learning.	HUman Factors in intraoperative Ophthalmic Emergencies Scoring system (HUFOES) and NOTSS for non-technical skills Objective Structured Assessment of Technical Skill (OSATS) global rating scale for technical skills Questionnaire feedback	There was a significant increase in technical and non-technical skills. Mean NOTSS scores increased from 30.1 ± 9.7 pre-training to 36.8 ± 8.8 ($p < 0.001$) post-training, with significant increases across all NOTSS domains. Survey feedback was that the teaching was extremely, very or moderately enjoyable (92.3%). Participants strongly or somewhat agreed that their non-technical skills had improved (92.3%).

Abbreviations: DVD: digital video disc; RCT: randomised controlled trial; NOTECHS: Non-Technical Skills Scale; NOTSS: Non-Technical Skills for Surgeons; NTS: non-technical skills; UK: United Kingdom; USA: United States of America; WHO: World Health Organization

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