REVIEW

Improving safety and reducing error in endoscopy: simulation training in human factors

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ABSTRACT

Patient safety incidents occur throughout healthcare and early reports have exposed how deficiencies in 'human factors' have contributed to mortality in endoscopy. Recognising this, in the UK, the Joint Advisory Group for Gastrointestinal Endoscopy have implemented a number of initiatives including the 'Improving Safety and Reducing Error in Endoscopy' (ISREE) strategy. Within this, simulation training in human factors and Endoscopic Non-Technical Skills (ENTS) is being developed. Across healthcare, simulation training has been shown to improve team skills and patient outcomes. Although the literature is sparse, integrated and in situ simulation modalities have shown promise in endoscopy. Outcomes demonstrate improved individual and team performance and development of skills that aid clinical practice. Additionally, the use of simulation training to detect latent errors in the working environment is of significant value in reducing error and preventing harm. Implementation of simulation training at local and regional levels can be successfully achieved with collaboration between organisational, educational and clinical leads. Nationally, simulation strategies are a key aspect of the ISREE strategy to improve ENTS training. These may include integration of simulation into current training or development of novel simulation-based curricula. However used, it is evident that simulation training is an important tool in developing safer endoscopy.

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INTRODUCTION

Medical error or patient safety incidents (PSIs) occur throughout all branches of medicine.[1] The 2004 'National Confidential Enquiry into Patient Outcomes and Death' (NCEPOD) report estimated a 3% inpatient 30-day mortality rate after therapeutic endoscopy.[2] The report highlighted deficiencies in non-technical skills (NTS) as contributory but the extent of their influence was unclear. The authors of a recent systematic literature review concluded that NTS are an 'essential component' of endoscopic practice.[3]

The Joint Advisory Group for Gastrointestinal Endoscopy (JAG) has developed several initiatives to promote safer endoscopy. The Global Rating Scale (GRS) rates endoscopy units in terms of clinical quality, patient experience, workforce and training,[4] in order to drive improvements in care. The implementation of safety checklists has improved the processes around endoscopy, aiming to reduce error and improve teamworking.[5] Demonstrating the impact of JAG initiatives on safety is challenging. Nevertheless, a recent literature review of 34 studies highlighted how initiatives may contribute to improved quality of care through safer sedation, improved patient comfort and lower risk of post-colonoscopy colorectal carcinoma.[6]

It is apparent that the nature of endoscopy is changing. A recent nationwide survey identified the significantly increasing demand and lack of capacity in endoscopy.[7] Together with increasingly therapeutic and complex procedures, these pressures will inevitably play a role in the quality and safety of endoscopy.[8]

Training and assessment have been crucial in improving safety. The implementation of an e-portfolio, mandated training courses and validated assessment have led to a significant improvement in endoscopic training in the UK over the last two decades. The recent introduction of the Endoscopic Non-Technical Skills (ENTS) framework into Direct Observation of Procedural Skills (DOPS) reflects the acknowledgement of the impact of ENTS on safety in endoscopy.[9]

SIMULATION GLOSSARY	
SIMULATION	An educational modality that allows participants to practice in a risk-free environment, learning through direct experience and observation.
DEBRIEF	The process of describing and analysing events during a scenario to consolidate learning and theorise ways to improve. A learner-focussed process, led by trained facilitators.
HUMAN FACTORS	The "environmental, organisational and job factors and human and individual characteristics, which influence behaviour at work in a way which can affect health and safety".
NTS	'Non-Technical Skills': cognitive and social skills integral to an encounter or task.
ENTS	'Endoscopic Non-Technical Skills': communication and teamwork, situation awareness, leadership, judgement and decision making.
CRM	'Crew Resource Management': a set of principles developed in aviation for team training of non-technical skills (NTS). When applied in healthcare, can be conducted through a combination of didactic and facilitated simulation training.
FIDELITY	The degree of authenticity within a simulated scenario. Fidelity can range from low e.g. simple manikin to high e.g. computerised manikin in simulated ward environment. The level of fidelity must be appropriate to learning objectives.
INTEGRATED SIMULATION	Use of multiple simulation modalities including high-fidelity, low-fidelity, virtual reality and simulated patients to improve realism and efficacy of learning.
IN-SITU SIMULATION	Simulation in the clinical environment, involving the individuals who work there. Enables fully immersive, multidisciplinary team training.
LATENT ERROR	Hidden errors in the organisation or working environment that can be identified through simulation. Risk stratification is important to understand the severity of error. Correction of errors can prevent potential patient harm.

Figure 1 A glossary of terms relevant to simulation in endoscopy. CRM, Crew Resource Management; ENTS, Endoscopic Non-Technical Skills.

WHAT IS ISREE?

Recognising the ongoing need to understand and improve safety in endoscopy, JAG has recently developed the 'Improving Safety and Reducing Error in Endoscopy' (ISREE) implementation strategy.[10] Key strategic aims are outlined below:

- Improving training in ENTS and incident reporting.
- Promoting measures to prevent PSIs.
- Promoting PSI reporting.
- Promoting learning from incidents.
- Supporting underperforming services/endoscopists.

The JAG Quality Assurance of Training (QA-T) group acknowledges that, although no national ENTS training currently exists, certain training strategies may be of use. The group have identified simulation as an educational modality of interest in this setting. The aim of this article is to highlight the use of simulation to develop ENTS training in promoting safer endoscopy. For reference, a glossary of terms related to simulation training in endoscopy is shown in figure 1.

WHAT ARE HUMAN FACTORS?

> 'Human factors refer to environmental, organisational and job factors and human and individual characteristics, which influence behaviour at work in a way which can affect health and safety' (Health & Safety Executive,[11])

Human factors encompass a wide range of elements contributing to safety, ranging from organisation and staffing to individual and team characteristics, which include NTS. Human factors research incorporates methods to develop NTS training and the design of systems and processes.[12]

WHAT ARE ENTS?

NTS are cognitive and social skills that influence quality and safety outcomes.[13] ENTS are classified into four domains: (1) Communication & teamwork, (2) Situation awareness, (3) Leadership and (4) Judgement & decision making. JAG recently introduced the ENTS framework into DOPS for diagnostic and therapeutic endoscopy in 2016 (table 1[14]). The ENTS framework was developed from those used in anaesthetics and surgery, which have been used to drive assessment and subsequent quality assurance. Preliminary results suggest that ENTS correlate well with other assessable DOPS domains, demonstrating its construct validity.[15]

The ISREE strategy outlines the need for a focus on ENTS training. Strategies such as small group, didactic teaching,[9] didactic training within a wider, structured endoscopy curriculum[16] and e-learning (https://www.e-lfh.org.uk/programmes/endoscopy/) have been used in recent years but the optimal format of delivery remains unclear.

HOW CAN SIMULATION REDUCE ERROR AND IMPROVE PATIENT SAFETY?

Simulation allows participants to practice within a controlled, risk-free environment, followed by a period of reflective analysis or 'debrief' in order to consolidate knowledge. There can be various levels of fidelity of the simulated environment targeted towards specific learning needs.

Simulation in NTS training has been used in various healthcare settings for some time, drawing on Crew Resource Management (CRM) principles in aviation. Within healthcare, it is known that poorly functioning teams can increase the risk of error and patient harm.[17] CRM is designed to reduce error and improve safety through team training in NTS, developing and reinforcing 'effective teamwork behaviours'.[18] In healthcare, simulated team training can lead to increased confidence and better team working.[19] It has been demonstrated to improve patient outcomes in critical care[20] and reduce surgical mortality.[21] Additionally, simulation may lead to improved patient outcomes over other forms of NTS training.[22] Alongside individual studies, a systematic review of the healthcare literature identified that team processes significantly impact on clinical performance and that CRM training can reduce complication rates, morbidity and mortality.[23] It has been suggested that systematic team training in NTS is integral in change to safer practice.[24 25]

Nationally, there appears to be a call for implementation of simulation-based education with both the

Table 1 ENTS framework[14]

Category	Element
Communication and teamwork	Maintains clear communication
	Gives and receives knowledge and information in a clear and timely fashion
	Ensures team and endoscopist working together
	Ensures patient is centre of procedure, ensures safety and comfort
	Clear communication of results and management plan with patient/carers
Situation awareness	Procedure carried out with respect and dignity
	Continuous evaluation of patient condition
	Ensures lack of distractions and maintains concentration, particularly during difficult situations
	Intraprocedural changes to scope setup monitored and rechecked
Leadership	Provides emotional and cognitive support to team members by tailoring leadership and teaching style appropriately
	Supports safety and quality by adhering to current protocols and codes of clinical practice
	Adopts a calm and controlled demeanour when under pressure, using all resources to maintain control of situation and taking responsibility for patient outcome
Judgement and decision making	Considers options and possible courses of action to solve an issue or problem, including assessment of risk or benefit
	Communicates decisions and actions to team members prior to implementation
	Reviews outcomes of procedure or options for dealing with problems
	Reflects on issues and institutes changes to improve practice

ENTS, Endoscopic Non-Technical Skills.

Chief Medical Officer,[26] and Department for Health recognising the potential benefits to patient safety.[27]

WHAT ABOUT SIMULATION IN ENDOSCOPY?

Simulation is not new to endoscopy training. Over the past two decades, there has been widely documented use of simulation to develop technical proficiency through animal, mechanical and screen-based virtual reality (VR) simulators.[28–30] The development of ENTS simulation training however, is relatively new. There have only been a handful of interventions developed, largely published in abstract format. In their review of the literature, Hitchins *et al*[3] found only seven studies relating to NTS training in endoscopy, six of these used simulation. There have been no studies of endoscopy simulation looking directly at patient outcomes. In the following sections, the simulation modalities that have been used in ENTS training are described.

WHAT IS INTEGRATED SIMULATION?

The concept of integrated simulation was pioneered by Kneebone and Darzi's group in the early 2000s. The group studied nurse endoscopists 'performing' flexible sigmoidoscopy on simulated patients using VR simulators.[31] Alongside demonstrating technical ability, participants had to interact and engage with their 'patients' in, as the authors described, a 'quasi-clinical' environment. Authenticating the task of endoscopy, through addition of an actor, added an additional level of realism with participants finding this 'integration' of technical and communication skills useful. Subsequently, several simulation programmes have developed 'CRM-style' scenarios using a combination of VR simulation, high-fidelity manikins and simulated patients to recreate emergency situations during endoscopy.[32–34]

El Menabawey *et al*[32] recently described a 5-year experience of the 'HiFIVE' (Human Factors in Virtual Endoscopy) course. Designed around rare but serious incidents arising within endoscopy, it focuses on a wide range of human factors and has been recently refined to incorporate the different elements of the ENTS framework. A combination of VR simulation and simulated patients is used. Scenarios reflect emergencies in endoscopy or focus on specific skills away from the endoscopy theatre such as breaking bad news. Over 8 courses involving 44 participants (doctors, nurses and healthcare assistants), there was a significant improvement in participants' confidence in several ENTS domains. Additionally, strategies for improving future practice and improved patient centeredness were identified as positive outcomes by learners. Several authors describe the use of integrated scenarios in response to clinical incidents or gaps in knowledge. Examples included management of respiratory complications following sedation[33] and major haemorrhage during endoscopic haemostasis.[34]

One disadvantage of integrated simulation is the relative cost associated with its delivery. A combination of simulation equipment, actors, facilities and support staff is necessary for effective training. Funding streams may need to be sought, for example through educational grants. The notion that the beneficial impact of training may outweigh costs in the long term is attractive but difficult to demonstrate in real world analyses.[35] Additionally, the need for trained faculty and a simulation environment are two factors that may prevent successful delivery of integrated simulation. As simulation becomes more prevalent, these may begin to be addressed.

Table 2 Endoscopy in situ simulation in the UK

Study	Description	Feedback	Duration	Participants	Results
Webster *et al*,[39] (abstract)	Endoscopy team training Integrated simulation (simulated patient and VR simulator). Video feedback used	Participant feedback pre-session and post-session	Four individual courses	Endoscopy team (nurses, healthcare assistants, endoscopists) 47 participants	Improved self-reported confidence in managing emergency scenarios (85% participants) Development of shared learning
Ravindran *et al*,[40] (abstract)	Endoscopy nurse training Low fidelity manikin, mobile simulation equipment, role playing	Participant feedback immediately post session	15 sessions (over 1 year)	Endoscopy nurses, healthcare assistants 99 responses	Improved self-reported communication and leadership skills 97% agreed training improved clinical practice
Jackson *et al*,[41] (abstract)	Gastroenterology ward MDT team training GI-related clinical scenarios including post-endoscopycare	Unclear	Five sessions (over 6 months)	MDT ward members 24 participants	Increased sense of preparation for clinical incidents Led to development of further targeted training sessions

VR, virtual reality.

WHAT IS IN SITU SIMULATION?

In situ simulation involves the delivery of simulated scenarios in the clinical environment, involving participants undertaking normal duties.[36] The concept is to promote fully immersive, multidisciplinary team training within the workplace making learning directly transferable to the real world. Scenarios can involve high or low fidelity manikins and mobile simulation equipment that can be setup within a bed space or clinical area.

In situ simulation has been shown to benefit team training, with perceived improvements in teamwork, and eventually patient outcome.[37] It is an emerging simulation modality in endoscopy with an estimated prevalence of 2% worldwide.[36] Where it is used, endoscopy staff find it to be a 'useful' and 'realistic training experience'.[38] Within the UK, only three sites have shared results of their endoscopy in situ programmes.[39–41] These studies are summarised in table 2.

In situ simulation can be versatile and reactive to the pressures of the working environment. Delivering sessions regularly allows training to quickly respond to clinical incidents. In addition, new guidelines or policies can be incorporated into the training to keep staff updated so important learning is disseminated. Minimal preparation is required, with lower costs compared with conventional simulation.[42] As training is delivered directly in the working environment, staff do not require time away from their workplace or the need to rearrange commitments.

A significant challenge of in situ simulation is effective delivery, which may be challenging on a busy endoscopy unit. Solutions including careful planning and protected training are conceivable but feasibility of regular training may be impacted. Other drawbacks also include the use of medical equipment in training, infection control risks and intensity of labour for the team delivering simulation.[43] Furthermore, the interruption of clinical duties may be perceived as a negative feature of in-situ simulation. There is some evidence to suggest that the introduction of training may overcome this short-term impact with long-term organisational gains.[43] Similarly, patient advocacy groups acknowledge 'brief delays in care' as a result of in situ simulation being 'outweighed by the value' of team training.[44]

WHAT ARE LATENT ERRORS AND WHY ARE THEY IMPORTANT?

A further benefit of practising in the low-risk, in situ environment is the detection of latent errors. These are failures in organisation or environment that can impact on patient safety. Discovery of errors can prompt interventions that ultimately improve patient safety, reflecting system 'resilience'.[12] Several examples have been documented within endoscopy, including the lack of Sengstaken-Blakemore tubes on the unit and malfunctioning emergency bells.[40 41] This reflects a development in patient safety culture whereby training is reactive, responding to clinical incidents, and also proactive, preventing potential harm before it occurs.

Risk matrices can be used to quantify the impact of errors, and these are based on risk consequence and likelihood. 'Consequence' describes the effect on the patient and 'likelihood' outlines how common these events occur. These are combined to create a score. Within simulation training, latent error reporting includes the type of error (medication, equipment, environment, staffing or training) alongside risk assessment.[45]

Combining system evaluation and teamwork training synchronously is an effective improvement strategy for a healthcare organisation. However, it is imperative that robust reporting tools are in place so that identified latent errors are acted on and managed appropriately. Identified latent errors should be reported using local incident reporting tools. Representation of the simulation team on local patient safety committees allows clinical incidents to be assimilated into training scenarios, identified

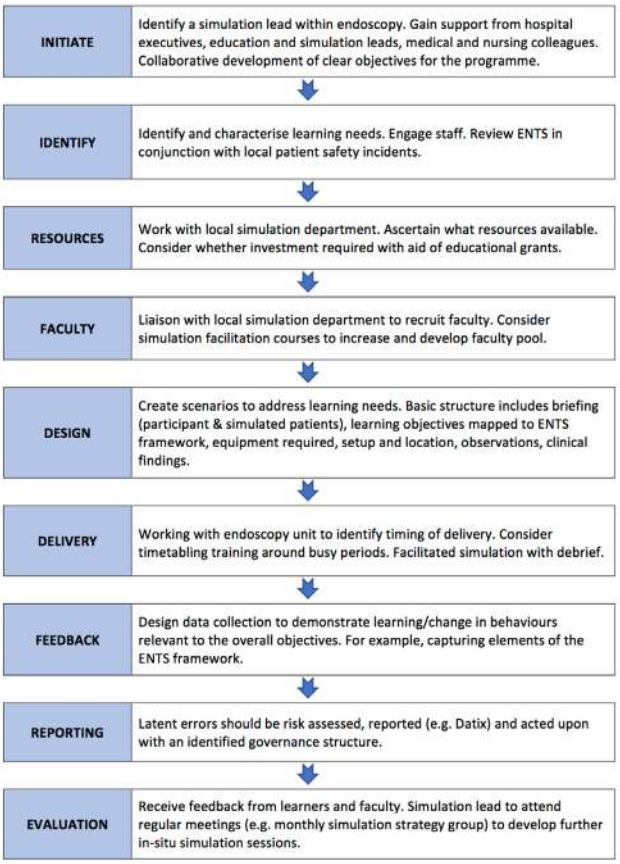

Figure 2 How to implement in situ simulation in a local endoscopy unit.[27 36 43 46] ENTS, Endoscopic Non-Technical Skills.

latent errors discussed and any necessary actions undertaken with efficiency and transparency.

CAN I IMPLEMENT SIMULATION IN MY DEPARTMENT?

Implementation of simulation training requires input from multiple stakeholders. There are many factors to consider and the Association for Simulated Practice in Healthcare (ASPiH) provide a set of standards for introducing simulation at various levels.[46]

In situ simulation

At the most basic level, low fidelity manikins and simple monitoring equipment are enough to create an in situ simulated scenario. However, there are numerous factors to consider before arranging sessions. As a summary, a basic 'How to' guide (see figure 2) describes the steps required to implement in situ simulation at a local level, based on the published guidance, ASPiH standards and the authors' experiences.

Integrated simulation

The development of integrated simulation training through local courses requires significant amounts of planning and a dedicated simulation department and faculty. These could be developed as part of a regional strategy, but require investment and ongoing evaluation to achieve sustainability.[47] Part of the ISREE strategy is to understand how regional centres can provide ENTS training in this manner including centrally run courses or visiting faculty. The JAG QA-T group are in the process of developing pilot programmes in line with this approach.

WHAT DOES THE FUTURE HOLD?

A national simulation strategy incorporating the ENTS framework is the next step to improving training in human factors. Flin stated that NTS training is unlikely to change professional behaviours unless it is properly incorporated into educational and safety management systems.[25] Integrated simulation courses and in situ simulation programmes could be developed for teams alongside existing training opportunities. This would vary across regions dependent on simulation availability. A standardised approach to team training has been shown to improve patient outcomes. Initiatives such as TeamSTEPPS,[48] and the TRANSFORM Patient Safety Project,[49] use a multilevel approach incorporating simulation. The high implementation costs of such strategies may be a limitation of their use in endoscopy; however, elements of these programmes may be replicable and a worthwhile consideration. On a smaller scale, one group has demonstrated that implementation of an NTS curriculum (didactic teaching combined with integrated simulation) was superior to simulation alone in a randomised trial.[50] Thus, development of a novel curriculum may be one strategy worth pursuing.

An example of how simulation implementation may look in the UK is proposed in figure 3.

CONCLUSION

There is amassing evidence to demonstrate the benefit of simulation training in developing NTS and improving patient outcomes across healthcare. Although the literature base is small, we have seen promising results in endoscopy through integrated and in situ simulation programmes which have a focus on human factors and

Figure 3 National, regional and local responsibilities for implementing ENTS simulation training. ENTS, Endoscopic Non-Technical Skills; ISREE, Improving Safetyand Reducing Error in Endoscopy.

ENTS. Added benefits such as latent error detection provide a further justification for their use.

Development of ENTS simulation training should be in line with the ISREE strategy, guided by the ASPiH standards. Individual departments should be encouraged to begin developing their own simulation practice, in situ being a good starting point. Nationally, there will need to be a focus on how simulation can be incorporated alongside existing training. A further focus of ISREE is to monitor outcomes, measuring the effectiveness of simulation thus improving the quality of evidence available. Future areas of investigation may also include exploring current use of simulation within UK endoscopy and accessibility of resources.

Evidently, there is much to consider in the coming years; however, it is clear that use of simulation training is another key step towards improving safety and reducing error in endoscopy.

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REFERENCES

1 Vincent C, Neale G, Woloshynowych M. Adverse events in British hospitals: preliminary retrospective record review. *BMJ* 2001;322:517–9.
2 Cullinane M. Scoping our practice: the 2004 report of the National Confidential Enquiry into Patient Outcome and Death. 2004 https://www.ncepod.org.uk/2004report/index.htm
3 Hitchins CR, Metzner M, Edworthy J, *et al*. Non-technical skills and gastrointestinal endoscopy: a review of the literature. *Frontline Gastroenterol* 2018;9:129–34.
4 Joint Advisory Group for Gastrointestinal Endoscopy. The JAG Standards. 2018 https://www.thejag.org.uk/CMS/Page.aspx?PageId=53
5 Matharoo M, Thomas-Gibson S, Haycock A, *et al*. Implementation of an endoscopy safety checklist. *Frontline Gastroenterol* 2014;5:260–5.
6 Siau K, Green JT, Hawkes ND, *et al*. Impact of the Joint Advisory Group on Gastrointestinal Endoscopy (JAG) on endoscopy services in the UK and beyond. *Frontline Gastroenterol* 2019;10:93–106.
7 Shenbagaraj L, Thomas-Gibson S, Stebbing J, *et al*. Endoscopy in 2017: a national survey of practice in the UK. *Frontline Gastroenterology* 2019;10:7–15.
8 Matharoo M, Thomas-Gibson S. Safe endoscopy. *Frontline Gastroenterol* 2017;8:86–9.
9 Matharoo M, Haycock A, Sevdalis N, *et al*. Endoscopic non-technical skills team training: the next step in quality assurance of endoscopy training. *World J Gastroenterol* 2014;20:17507–15.
10 Joint Advisory Group for Gastrointestinal Endoscopy. Improving Safety and Reducing Error in Endoscopy (ISREE) implementation strategy. 2018 https://www.thejag.org.uk/Downloads/General/180801-Improving Safety and Reducing Error in Endoscopy (ISREE) Implementation strategy v1.0.pdf
11 Health & Safety Executive. Reducing Error and influencing behaviour. 1999 http://www.hse.gov.uk/pUbns/priced/hsg48.pdf
12 Russ AL, Fairbanks RJ, Karsh BT, *et al*. The science of human factors: separating fact from fiction. *BMJ Qual Saf* 2013;22:802–8.
13 Flin R, Maran N. Identifying and training non-technical skills for teams in acute medicine. *Qual Saf Health Care* 2004;13(suppl 1):i80–4.
14 Joint Advisory Group for Gastrointestinal Endoscopy. Download Centre: Formative DOPS Colonoscopy & Flexible sigmoidoscopy. 2016 http://www.thejag.org.uk/downloads/DOPS Forms For International and reference use only/Formative DOPS_Colonoscopy and Flexible sigmoidoscopy.pdf
15 Siau K, *et al*. PTU-009 Competency of endoscopic non-technical skills (ents) during endoscopy training. *Gut* 2017;66(Suppl 2):A54.
16 Hawkes N, Turner J, Hurley J. Accelerated training in upper GI endoscopy - an analysis of sprint programme outcomes [abstract]. *United Eur Gastroenterol J* 2015;3(Suppl 1):A368–9.
17 Kohn L, Corrigan J, Donaldson M. *To Err is Human: building a safer health system*. Washington DC: Institute of Medicine National Academies Press, 1999.
18 Weaver SJ, Dy SM, Rosen MA. Team-training in healthcare: a narrative synthesis of the literature. *BMJ Qual Saf* 2014;23:359–72.
19 Higham H, Baxendale B. To err is human: use of simulation to enhance training and patient safety in anaesthesia. *Br J Anaesth* 2017;119:i106–14.
20 Wheelan SA, Burchill CN, Tilin F. The link between teamwork and patients' outcomes in intensive care units. Am. *J Crit Care* 2014;12:527–34.
21 Neily J, Mills PD, Young-Xu Y, *et al*. Association between implementation of a medical team training program and surgical mortality. *JAMA* 2010;304:1693–700.
22 Riley W, Davis S, Miller K, *et al*. Didactic and simulation nontechnical skills team training to improve perinatal patient outcomes in a community hospital. *Jt Comm J Qual Patient Saf* 2011;37:357–64.
23 Schmutz J, Manser T. Do team processes really have an effect on clinical performance? A systematic literature review. *Br J Anaesth* 2013;110:529–44.
24 Sevdalis N, Hull L, Birnbach DJ. Improving patient safety in the operating theatre and perioperative care: obstacles, interventions, and priorities for accelerating progress. *Br J Anaesth* 2012;109 Suppl 1:i3–i16.
25 Flin R, Patey R. Improving patient safety through training in non-technical skills. *BMJ* 2009;339:b3595.
26 Donaldson L. *Safer medical practice: machines, manikins and polo mints, in 150 Years of the Annual Report of the Chief Medical Officer: On the State of the Public Health 2008*. London, UK: Department of Health, 2009:49–55.
27 Department of Health. A framework for technology enhanced learning. 2011 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/215316/dh_131061.pdf
28 Walsh CM, Sherlock ME, Ling SC, *et al*. Virtual reality simulation training for health professions trainees in gastrointestinal endoscopy. *Cochrane Database Syst Rev* 2012;6:CD008237.
29 Haycock AV, Youd P, Bassett P, *et al*. Simulator training improves practical skills in therapeutic GI endoscopy: results from a randomized, blinded, controlled study. *Gastrointest Endosc* 2009;70:835–45.
30 Haycock A, Koch AD, Familiari P, *et al*. Training and transfer of colonoscopy skills: a multinational, randomized,

blinded, controlled trial of simulator versus bedside training. *Gastrointest Endosc* 2010;71:298–307.
31 Kneebone RL, Nestel D, Moorthy K, *et al*. Learning the skills of flexible sigmoidoscopy - the wider perspective. *Med Educ* 2003;37(s1):50–8.
32 El Menabawey T, *et al*. PTH-133 Five years of HIFIVE (human factors in virtual endoscopy): an endoscopic non-technical skills simulation programme. *Gut* 2018;67(Suppl 1):A272.
33 Lightdale JR, Weinstock P. Simulation and training of procedural sedation. *Techniques in Gastrointestinal Endoscopy* 2011;13:167–73.
34 Goel A, Geraghty J, Pimblett M, *et al*. PWE-423 Human factors training (hft) through simulation based scenarios in endoscopic haemostasis improves teamworking. *Gut* 2015;64(Suppl 1):A395.
35 Maloney S, Haines T. Issues of cost-benefit and cost-effectiveness for simulation in health professions education. *Adv Simul* 2016;1:13.
36 Rosen MA, Hunt EA, Pronovost PJ, *et al*. In situ simulation in continuing education for the health care professions: a systematic review. *J Contin Educ Health Prof* 2012;32:243–54.
37 Riley W, Lownik E, Parrotta C, *et al*. Creating high reliability teams in healthcare through in situ simulation training. *Adm Sci* 2011;1:14–31.
38 Heard LA, Fredette ME, Atmadja ML, *et al*. Perceptions of simulation-based training in crisis resource management in the endoscopy unit. *Gastroenterol Nurs* 2011;34:42–8.
39 Webster S, Howson W, McKay A, *et al*. PTU-013 Simulation-based human factors training in endoscopy – putting the team in the spotlight. *Gut* 2014;63:A42–3.
40 Ravindran S. OC-034 Endoscopy in-situ simulation – improving nurse education and enhancing patient safety. *Gut* 2017;66(Suppl 2):A17.
41 Jackson L. PTH-135 Gastroenterology in situ simulation: the ASPIH guidance in practice. *Gut* 2018;67(Suppl 1):A273.
42 Walker ST, Sevdalis N, McKay A, *et al*. Unannounced in situ simulations: integrating training and clinical practice. *BMJ Qual Saf* 2013;22:453–8.
43 Patterson M, Blike G, Nadkarni V. *In Situ simulation: challenges and results, in advances in patient safety: new directions and alternative approaches (Vol. 3: Performance and Tools)*. Rockville (MD): Agency for Healthcare Research and Quality (US) CTI - Advances in Patient Safety, 2008.
44 Lighthall GK, Poon T, Harrison TK. Using in situ simulation to improve in-hospital cardiopulmonary resuscitation. *Jt Comm J Qual Patient Saf* 2010;36:209–16.
45 Lok A, *et al*. A proactive approach to harm prevention: identifying latent risks through in situ simulation training. *Infant* 2015;11:160–3.
46 Association for Simulated Practice in Healthcare. The ASPiH Standards Framework and Guidance, Association for Simulated Practice in Healthcare (ASPiH) standards for simulation-based education. 2016 http://ebsltd.wpengine.com/wp-content/uploads/2017/07/standards-framework.pdf
47 Gadhok R, Murray S, Wood E. PTH-126 Virtual reality and beyond: integrating simulation into the gastroenterology training curriculum. *Gut* 2016;65(Suppl 1):A281–2.
48 King H, Henrikson K. *TeamSTEPPS: team strategies and tools to enhance performance and patient safety, in advances in patient safety: new directions and alternative approaches (Vol. 3: Performance and Tools)*. Rockville (MD): Agency for Healthcare Research and Quality (US) CTI - Advances in Patient Safety, 2008.
49 Braddock CH, Szaflarski N, Forsey L, *et al*. The TRANSFORM Patient safety project: a microsystem approach to improving outcomes on inpatient units. *J Gen Intern Med* 2015;30:425–33.
50 Grover SC, Scaffidi MA, Khan R, *et al*. Sa1075 A Virtual reality curriculum in non-technical skills improves colonoscopic performance: a randomized trial. *Gastrointest Endosc* 2017;85:AB181.