

Development of a robotic training curriculum for visceral and gastrointestinal surgical trainees: an international Delphi study

Michael G. Fadel^{1,*}, Josephine Walshaw² , Marina Yiasemidou³ , Matthew Boal⁴ , Francesca Pecchini⁵, Muhammed Elhadi^{6,7} , Lisa H. Massey⁸, Francesco M. Carrano⁹, Matyas Fehervari¹⁰ , Caoimhe M. Walsh¹, Piers R. Boshier¹, Jennifer Eckhoff¹¹, Peter Buckle¹, the European Robotic Surgery Consensus (ERSC) Study Group, Suzanne S. Gisbertz^{12,13}, Nicole Bouvy¹⁴, Alberto Arezzo¹⁵, Silvana Perretta^{16,17}, Felix Nickel¹⁸, Jim Khan¹⁹, George B. Hanna¹, Barbara Seeliger^{16,17,20,21} , Stavros A. Antoniou²² , Hans F. Fuchs¹¹ , Nader K. Francis⁴  and Christos Kontovounisios^{1,23,24,25,26} 

¹Department of Surgery and Cancer, Imperial College London, London, UK

²Leeds Institute of Medical Research, St James's University Hospital, University of Leeds, Leeds, UK

³Department of Colorectal Surgery, The Royal London Hospital, Barts Health NHS Trust, London, UK

⁴The Griffin Institute, Northwick Park and St Mark's Hospital, London, UK

⁵Division of General Surgery, Emergency and New Technologies, Baggiovara General Hospital, Modena, Italy

⁶Tripoli University Hospital, Tripoli, Libya

⁷College of Medicine, Korea University, Seoul, Republic of Korea (South Korea)

⁸Department of Colorectal Surgery, Nottingham University Hospitals NHS Trust, Nottingham, UK

⁹Department of Medical and Surgical Sciences and Translational Medicine, Faculty of Medicine and Psychology, St Andrea Hospital, Sapienza University, Rome, Italy

¹⁰Department of Bariatric Surgery, Maidstone and Tunbridge Wells NHS Trust, Kent, UK

¹¹Department of General, Visceral, Cancer, and Transplantation Surgery, University Hospital Cologne, Cologne, Germany

¹²Department of Surgery, Amsterdam UMC location University of Amsterdam, Amsterdam, The Netherlands

¹³Cancer Centre Amsterdam, Amsterdam, The Netherlands

¹⁴Department of Surgery, Leiden University Medical Centre, Leiden, The Netherlands

¹⁵Department of Surgical Sciences, University of Turin, Turin, Italy

¹⁶Institute of Image-Guided Surgery, IHU-Strasbourg, Strasbourg, France

¹⁷Department of Digestive and Endocrine Surgery, University Hospitals of Strasbourg, Strasbourg, France

¹⁸Department of General, Visceral, and Thoracic Surgery, University Medical Centre Hamburg-Eppendorf, Hamburg, Germany

¹⁹Department of Colorectal Surgery, Portsmouth Hospitals University NHS Trust, Portsmouth, UK

²⁰ICube, UMR 7357, CNRS, INSERM U1328 RODIN, University of Strasbourg, Strasbourg, France

²¹Research Institute Against Digestive Cancer (IRCAD), Strasbourg, France

²²Department of Surgery, Papageorgiou General Hospital, Thessaloniki, Greece

²³2nd Surgical Department, HYGEIA Hospital, Athens, Greece

²⁴Department of Surgery, NYU Grossman School of Medicine, New York, New York, USA

²⁵School of Medicine, National and Kapodistrian University of Athens, Athens, Greece

²⁶Department of Colorectal Surgery, Chelsea and Westminster Hospital and Royal Marsden NHS Foundation Trust, London, UK

Abstract

Background: The rapid adoption of robotic surgical systems globally has created a critical gap in training, assessment, and certification for visceral and gastrointestinal (GI) surgical trainees. This study, led by the European Association for Endoscopic Surgery (EAES), aimed to achieve an international consensus on a structured, platform-agnostic robotic training curriculum for GI surgery trainees.

Methods: A 106-item Delphi questionnaire was developed with an international committee of surgical experts, trainees, methodologists, and patient representatives. It was disseminated to a multidisciplinary panel of 83 GI robotic surgeons, trainees, human factor experts, robotic theatre team members, and industry providers. Two Delphi survey rounds were conducted, with a priori consensus standard set at 70% or higher for agreement. A consensus meeting was subsequently held to discuss and finalise the items needed for a robotic training curriculum for GI surgery trainees.

Results: Seventy-one (86%) participants from 15 countries completed round one. A total of 82 items (77%) reached consensus and 32 new items were generated from free-text comments. Seventy of these participants (99%) completed the 56-item round two questionnaire, with 36 items (64%) reaching consensus and 5 new items generated. All 143 statements were discussed in the meeting and consensus was reached in the following areas: (i) key knowledge requirements of the bedside assistant and console surgeon; (ii) training components; (iii) performance assessment; and (iv) certification and supervision.

Conclusion: International surgical experts, trainees, and other key stakeholders reached consensus on the critical components of a platform-agnostic robotic training curriculum for GI surgical trainees. This will help shape the future of robotic surgical education and certification, promote standardised training practices, and ultimately benefit patient safety and outcomes.

*Correspondence to: Michael G. Fadel, The Commonwealth Building, The Hammersmith Hospital, Du Cane Road, London W12 0NN, UK (e-mail: m.fadel@imperial.ac.uk)

†Joint senior authors

Members of the European Robotic Surgery Consensus (ERSC) Study Group are co-authors of this study and are listed under the heading Collaborators.

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Introduction

Robotic surgery has rapidly expanded within the field of visceral and gastrointestinal (GI) surgery, which comprises disciplines including general, upper and lower GI, hepato-pancreato-biliary (HPB), endocrine, and bariatric surgery. The adoption of robotics has reshaped surgical practice, team dynamics, and the educational needs of trainees^{1–3}, driven by improvements in ergonomics, enhanced visualisation, and refined dexterity that facilitate complex minimally invasive procedures^{4–6}. These advantages may potentially improve surgical quality and oncological outcomes for certain procedures^{6–10}. Robotic systems are established in elective surgical practice globally, and are also progressively being introduced within the emergency setting^{11–14}.

However, the integration of robotic surgery has not been accompanied by the development of standardised surgical training programmes. Current approaches to robotic training remain variable across GI surgery, with a lack of standardisation in bedside-to-console progression, case-volume expectations, and assessment methods^{2,15}. In many hospitals, access to robotic platforms can be restricted by cost, system availability, or limited faculty expertise, who themselves are required to complete their proficiency-gain curve. Furthermore, training often relies on industry-led programmes for specialties and sporadic courses and individual fellowships for residents rather than structured proficiency-based pathways and accreditation^{16,17}. As a result, GI surgical residents often report fragmented or insufficient exposure to robotic procedures, leading to differences in experience and progression to independent practice^{18,19}.

A standardised, competency-based approach to robotic training in GI surgery is essential. Structured training curricula have been shown to enhance skill acquisition, facilitate progression along the learning curve, and provide a robust evidence base for credentialing and independent practice^{20–22}. Despite growing international experience, there is currently no consensus among surgical specialty boards and professional societies on the training, assessment, and certification of GI trainees in robotic surgery.

To address these critical gaps, the authors established the European Robotic Surgery Consensus (ERSC) group to develop an evidence- and consensus-based curriculum for robotic training in GI surgery under the auspices of the European Association of Endoscopic Surgery (EAES) society in collaboration with its affiliated member, the United European Gastroenterology (UEG) society. Herein the authors present the consensus process used to establish essential elements of a robotic curriculum for GI surgical trainees, including learning requisites, training components, assessment, and certification requirements to progress to independent and safe practice.

Methods

Project management and statement generation

An international project management committee (PMC) and an advisory executive committee (EC) established a study protocol

outlining a structured, multi-stage consensus process²³ (Fig. 1). The PMC (M.G.F., J.W., M.Y., M.B., S.A.A., H.F.F., N.F.K., C.K.) was responsible for the day-to-day management and the EC (F.P., M.E., L.H.M., F.M.C., M.F., S.P., F.N., J.K., G.B.H., B.S.) provided strategic oversight of the project. The committee members are a multidisciplinary group of general, upper GI, HPB, and lower GI surgical experts and trainees, educational experts, and methodologists (Supplementary file 1).

Members of the PMC and EC held regular meetings to discuss and draft statements for the Delphi process using findings from the authors' pan-European survey¹⁷ and systematic review of multi-specialty robotic training curricula²⁰, as well as existing evidence^{24–29}. The full search strategy of the systematic review is detailed in Walshaw *et al.*²⁰. The drafted statements for the Delphi process were reviewed and finalised by the entire committee and two patient representatives. The statements were entered onto the Qualtrics XM software platform³⁰ and tested by the committee to check usability and technical functionality.

The first-round questionnaire contained 106 items, which were divided into four sections to help compose the GI robotic training curriculum: knowledge requirements of the bedside assistant and console surgeon (43 items); training components (35 items); performance assessment (15 items); and requirements for certification and supervision (13 items).

Participant selection

The appropriate selection of a group of experts with a high and concordant skill level is critical to promote robustness and data validity in Delphi studies^{31,32}. Key stakeholder groups for the Delphi panel were agreed upon by the committee and patient representatives. Participants were carefully selected on account of their expertise within these groups, along with their experience and interest in training and education: (i) independent, experienced GI surgeons (including general, HPB, and upper and lower GI surgeons practising minimally invasive and/or robotic surgery); (ii) GI surgical trainees/residents; (iii) the extended robotic theatre team (including anaesthetists, scrub nurses, and robotic practitioners); (iv) experts in technical skill competency assessment, Non-Technical Skills for Surgeons (NOTSS) experts, and psychologists; and (v) robotic industry representatives.

Based on observations from previous Delphi studies in the literature, the authors targeted a minimum total sample size of 60 expert participants to take part in the Delphi process^{31,33–36}. This sample size has been shown to have high replicability of results compared with those of larger sample sizes in Delphi studies³⁷. After the publication of the protocol²³, the decision was made to involve robotic industry representatives in the Delphi panel due to their experience in leading robotic training programmes and courses. Panel members were invited from European countries as well as global industry robotic providers. The committee recorded conflicts of interests and endeavoured to ensure a broad representation across the

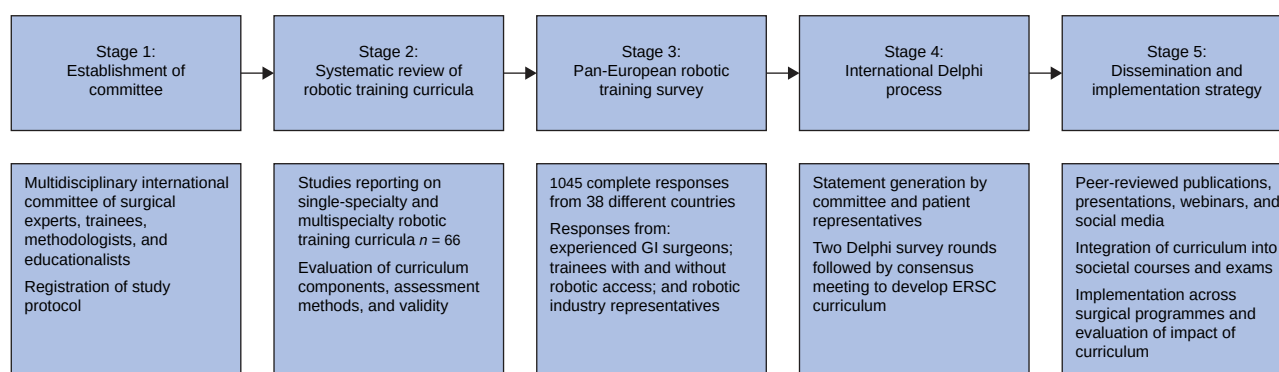


Fig. 1 Five key stages for developing the ERSC robotic training curriculum for GI and visceral surgery trainees

ERSC, European Robotic Surgery Consensus; GI, gastrointestinal.

stakeholder groups, based on robotic experience and skills, demographics, and geographical location. The authors aimed to have representation from at least ten European countries and a minimum of six representatives within each stakeholder group. To ensure equal opportunities for each industry company, the authors aimed for a minimum of four industry providers with up to three representatives from the same company participating in the voting process. This was to mitigate any potential conflicts and reinforce the platform-agnostic nature of the curriculum, particularly given the current number of robotic platforms emerging on the market.

Delphi survey rounds

The Delphi methodology is a structured, iterative process to acquire knowledge and opinions from experts on a selected topic^{38,39}. It has been widely adopted for establishing guidelines and recommendations in the medical and surgical field^{40–42}. While a virtual Delphi approach provides participant anonymity, which may allow for more open expression of views^{43,44}, it also has the potential disadvantage of lacking group interaction for consensus building³³. For this reason, the authors arranged two online questionnaire rounds followed by a hybrid consensus meeting enabling members to provide further clarification on specific issues and present arguments to justify their viewpoints.

The two rounds of the Delphi survey were conducted using the Qualtrics XM software, with a demographics questionnaire in round one. Participants were e-mailed a website link prompting them to complete the Delphi survey. Members of the Delphi panel provided their responses to each item using a Likert scale following the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) 9-point scale^{34–36,45}: 1–3 = of limited importance (item should not be included in the robotic training curriculum); 4–6 = important but not critical (item should be discussed in the consensus meeting); and 7–9 = important and critical (item should be included in the robotic training curriculum). A ‘do not know’ option was included for participants who did not feel qualified to rank any specific item. The panel had the opportunity to suggest additional statements or modifications to the statements in free-text fields.

Each round was open for approximately 4 weeks. Responses were analysed and summarized by the PMC between each round, and the following consensus definitions^{36,45} were used: consensus for inclusion: $\geq 70\%$ participants scoring 7–9 and $< 15\%$ participants scoring 1–3; consensus for exclusion: $\geq 70\%$ participants scoring 1–3 and $< 15\%$ participants scoring 7–9; and no consensus for inclusion or exclusion: failure to achieve either of the above.

Consensus meeting

The overall aim of the hybrid consensus meeting was to discuss and agree on the final statements needed for a robotic training curriculum for GI trainees. The meeting was held over one full day at the Hammersmith Hospital Campus, Imperial College London (London, UK). Committee members and stakeholder group representatives were invited to participate in the consensus meeting, with a maximum target of 30 participants in total, as larger meetings can limit interaction among participants⁴⁶. The committee selected participants for the meeting from those who registered their interest based on: their ability to attend the meeting on proposed dates and times; and the requirement to have an international multidisciplinary group of stakeholders.

Before the consensus meeting, all participants were sent the meeting agenda, participant list, summary of the survey and systematic review findings, and the results of the Delphi survey rounds via e-mail. The consensus meeting itself intended to: (i) ratify inclusion of all items that reached consensus in the Delphi survey; (ii) discuss and anonymously vote (on Qualtrics XM) for inclusion ($\geq 70\%$ voting to include or exclude) of items that had not reached consensus; and (iii) discuss merging and wording of all items in the final curriculum^{45–47}. The meeting was facilitated by an independent chair (P.B., a Professor in Human Factors) and a co-chair (M.G.F., a GI surgical trainee). The chair provided a structured interaction among participants to ensure all members had equal opportunities to contribute throughout the meeting. The importance of developing an international, feasible, platform-agnostic curriculum that included only critical statements were emphasised to participants during the meeting. Items that were platform-specific but considered critical were discussed for inclusion. Discussion of items during the meeting was audio recorded (with participant verbal consent) to facilitate comprehensive minutes and maintain a record of decisions made. Dissemination and implementation strategies, along with future evaluation of developed outputs, were also discussed. After the Delphi process, the curriculum phases and key components were finalised by the committee and members of the study group.

Statistical analysis

Only fully completed responses from round one and two of the survey were included in the analysis. Descriptive statistics were applied to summarize participant demographics and responses

across each round. The percentage of participants that rated an item with a score of 1–9 using the GRADE 9-point scale was calculated. All analyses were performed using SPSS® (IBM, Armonk, NY, USA; version 28.0).

Ethical approval

This Delphi consensus study was conducted in accordance with the guidelines of the authors' institutional research ethics committee. For this type of study, ethical approval is not required (waiver letter obtained). Informed consent was obtained from all participants of the Delphi process.

Results

Demographics of participants

Eighty-three participants were invited to take part in round one of the Delphi process, with 71 participants (86%) completing all components (Table 1). Respondents were from 15 countries, with the top 6 contributing countries being the UK (n = 25, 35%), Italy (n = 16, 23%), Spain (n = 8, 11%), the Netherlands (n = 4, 6%), Germany (n = 3, 4%), and Greece (n = 3, 4%). Five industry providers participated: Asensus Surgical (Durham, NC, USA); CMR Surgical (Cambridge, UK); Intuitive Surgical (Sunnyvale, CA, USA); Medtronic (Minneapolis, MN, USA); and Surgical Science (Gothenburg, Sweden). The full Delphi participant list is shown in [Supplementary file 2](#). A total of 28 participants attended the consensus meeting. This comprised 8 committee members, who were all experienced GI surgeons; and 20 stakeholders from the ERSC Study Group, including experienced GI surgeons (n = 3), trainees (n = 6), theatre team staff (n = 4), NOTSS experts and psychologists (n = 2), robotic industry providers (n = 4), and a patient representative.

Overview of Delphi process

In round one, 82 items (77%) from 106 items reached consensus, with 32 new items generated (Fig. 2). Seventy of the 71 respondents (99%) subsequently completed all components of the second round. In this round, 56 items (24 items that did not reach consensus and 32 new items in round 1) were presented with 36 items (64%) achieving consensus and five new statements were generated. All 143 items (106 initial items and 37 new items from rounds 1 and 2) were discussed and voted on during the consensus meeting. After the Delphi process, the committee and panel finalized the curriculum components, comprising 57 statements spanning key domains based on knowledge requirements, training components, performance assessment, and certification standards.

Knowledge requirements of the bedside assistant and console surgeon trainee

Delphi panellists agreed that preoperative knowledge of the theatre room set-up and patient positioning (94%, round 1), and draping the robotic system (70%, round 2) were essential core skills for both the bedside assistant and console surgeon trainee (Table 2). The intraoperative key skills of the bedside assistant and console surgeon should include safe entry, docking, troubleshooting, inserting and changing robotic instruments, tissue handling, emergency undocking, and conversion. Additional core skills were identified for the console surgeon, including demonstrating control use of the foot pedals and hand clutches (99%, round 1), multi-arm control of the robotic instruments (96%, round 1), and tissue dissection (97%,

Table 1 Demographics of participants who completed round one of the Delphi process (n = 71)

Characteristics	Values
Age (years)	
21–30	1 (1.4)
31–40	22 (31)
41–50	30 (42)
51–60	12 (17)
≥61	6 (9)
Sex	
Male	43 (61)
Female	28 (39)
Country (n = 15)	
Austria	1 (1.4)
Cyprus	1 (1.4)
Denmark	1 (1.4)
France	2 (3)
Germany	3 (4)
Greece	3 (4)
Ireland	1 (1.4)
Italy	16 (23)
Lithuania	1 (1.4)
Netherlands	4 (6)
Romania	1 (1.4)
Spain	8 (11)
Sweden	2 (3)
UK	25 (35)
USA	2 (3)
Stakeholder group	
General surgeons	16 (23)
Upper GI and HPB surgeons	15 (21)
Lower GI surgeons	15 (21)
GI surgical trainees/residents	10 (14)
Theatre team members, NOTSS experts, and psychologists	7 (10)
Robotic industry representatives	8 (11)
Surgical subspecialty	
Bariatric	2 (3)
Emergency and trauma	1 (1.4)
General	16 (23)
HPB	4 (6)
Hernia/abdominal wall	2 (3)
Lower GI	20 (28)
Surgical oncology	1 (1.4)
Upper GI	12 (17)
Other	5 (7)
Hospital type	
Public university (teaching)	53 (75)
Public non-university (non-teaching)	3 (4)
Private	3 (4)
Other	4 (6)
Not applicable	8 (11)
Robotic platform	
Da Vinci	54 (76)
Hugo	4 (6)
Versius	4 (6)
Senhance	1 (1.4)
Other	3 (4)
Surgeon operative experience	
Bedside assisted more than 50 cases	33 (72)
Performed more than 50 cases independently	31 (67)
Performed more than 200 cases independently	19 (41)

Values are n (%). NOTSS, Non-Technical Skills for Surgeons; HPB, hepato-pancreato-biliary; GI, gastrointestinal.

round 1). Demonstrating suture handling and knot tying was also deemed critical for the console surgeon (97%, round 1). Non-technical skills, such as situational awareness and team communication, were deemed essential for both the bedside assistant and console surgeon trainee, with leadership skills (96%, round 1), ergonomic awareness (80%, round 2) and time

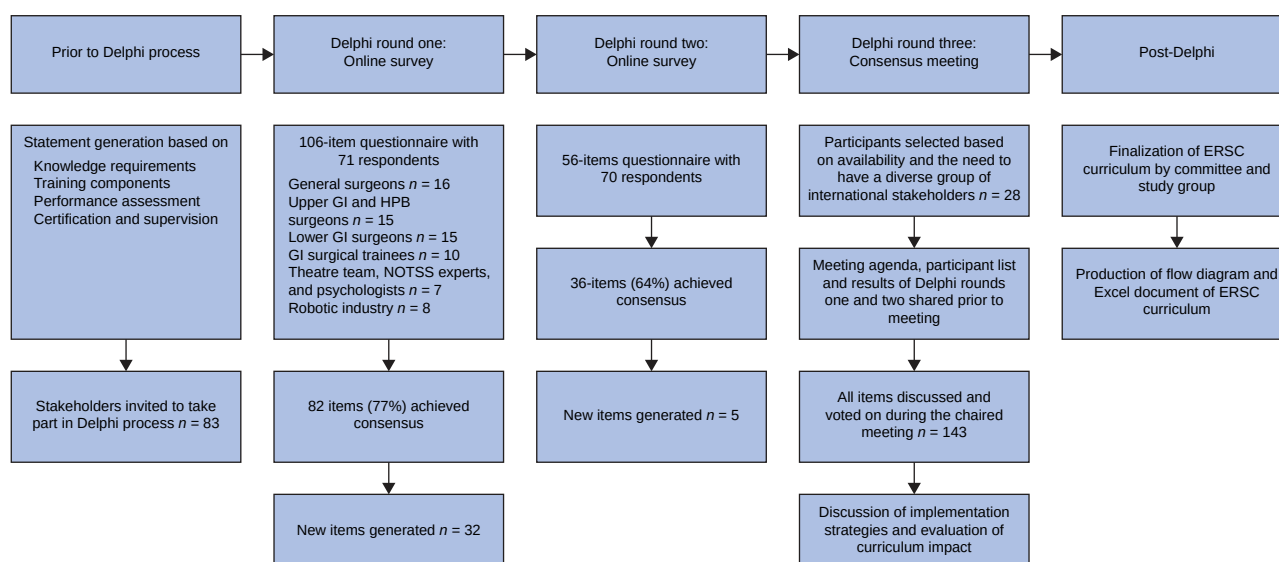


Fig. 2 Delphi methodology to reach consensus on the fundamentals of the ERSC robotic training curriculum for GI and visceral surgical trainees
ERSC, European Robotic Surgery Consensus; GI, gastrointestinal; HPB, hepatopancreatobiliary; NOTSS, Non-Technical Skills for Surgeons.

management (80%, round 2) believed to be specific skills essential for the console surgeon. The voting scores of the items that reached consensus, as well as those that did not, are shown in [Supplementary file 3](#).

Training components

E-learning modules were considered critical (82%, round 1) in providing theoretical knowledge on robotic consoles set-up and troubleshooting (100%, round 1), patient selection and preparation (92%, round 1), port placement (97%, round 1), and docking (99%, round 1) ([Table 3](#)). Demonstrations of common robotic procedures (for example gastrectomy, hemicolectomy), emergency management, and non-technical skills were also deemed essential modules. Non-technical skills may also be covered during e-learning through theoretical knowledge learning (for example types of leadership styles, safety checklists), case studies, and videos of simulated scenarios, followed by reflective learning exercises. It was agreed that there should be a pass/fail knowledge assessment at the end of the e-learning, and that, over time, robotic curricula should be detailed and integrated into these modules. Core skills/device training on port positioning, docking, emergency conversion, and non-technical skills, through team-based scenarios, were deemed critical (97%, round 1), along with proficiency-based, rather than time-based, virtual reality simulation (83%, round 1).

Dry-lab simulation, ideally using high-fidelity three-dimensional (3D) anatomical models (96%, round 2) if available, is essential for becoming familiar with robotic instruments and energy use for enhancing advanced dissection skills. Wet-lab simulation, with either animal or cadaveric models, was introduced into the curriculum to develop real-tissue handling skills (70%, round 2); however, it was acknowledged that trainees may not necessarily be exposed to this due to legal restrictions in their country and other ethical and practical considerations, such as cost and availability. Dry and wet-lab simulation metrics deemed critical included completion of tasks (90%, round 1) with associated scores (96%, round 1), error rate (87%, round 1), camera control (90%, round 1), economy of movement in tissue dissection and suturing

(86%, round 1), and safe energy application (93%, round 1). Time spent on a given task (58%, round 1 and 57%, round 2) and the number of attempts (63%, round 1 and 61%, round 2) were believed to be less important. Although currently platform-specific, dual console training was deemed important for trainee learning and mentoring (83%, round 1). However, it was also acknowledged that access to dual consoles for trainees, whether on site or remotely in a telesurgery set-up, may be limited by institutional costs and theatre space requirements. Alongside simulation training, trainees should be able to progress to bedside assisting (89%, round 1) and live case observation (94%, round 1).

Performance assessment

When operating on the console, GI surgical trainees should capture the number of cases performed for each procedure (83%, round 1) and routine clinical outcome data (89%, round 1), such as intraoperative⁴⁸ or postoperative⁴⁹ complications, unplanned conversion rate, and return to theatre ([Table 4](#)). Recording the number of hours operating on the console and the number of key steps of the procedure completed were deemed less critical. The technical skills of GI trainees should be assessed using a combination of case logs (73%, round 1), global rating scales such as Global Evaluative Assessment of Robotic Skills (GEARS)^{50,51} (80%, round 1), procedure-specific tools such as Competency Assessment Tools (CATs)⁵² (83%, round 1), and video assessment (87%, round 1). In terms of video assessment, the Delphi panel agreed that the key steps of an operative video should be assessed (73%, round 2), rather than the full length of the video, to ensure feasibility. The video assessment should ideally be performed by a minimum of two experts including the proctor and a blinded expert (73%, round 2). Another blinded expert may be required if there is significant disagreement between the two initial experts.

Requirements for certification and supervision

The Delphi panel reached consensus that a trainee should be primarily signed off as practically safe and independent by the trainer/proctor (93%, round 1). Trainees should demonstrate

Table 2 Curriculum knowledge requirements of the bedside assistant and console surgeon trainee with consensus scores of critically important (7–9) in rounds one and two

Item	Section 1: Knowledge requirements of the bedside assistant and console surgeon	Round one (score 7–9), %	Round two (score 7–9), %
Key skills of the bedside assistant and console surgeon should include:			
Preoperative:			
1	Knowledge of the theatre room set-up and patient position	94	–
2	Knowledge of the console and its functions	97	–
3	Knowledge of how to drape the robotic system	69	70
4	Knowledge of the physiology of pneumoperitoneum	89	–
Intraoperative:			
5	Be able to perform safe entry of trocars, port placement, and closure	93	–
6	Be able to dock the robotic system safely	90	–
7	Be able to troubleshoot and re-dock the robotic system	90	–
8	Be able to insert, change, and remove robotic instruments	90	–
9	Be able to appropriately use assistant port and maintain a clear image	85	–
10	Be able to demonstrate correct techniques for tissue handling	97	–
11	Be able to manage intraoperative complications (for example bleeding)	97	–
12	Be able to convert to laparoscopic/open surgery	97	–
13	Be able to perform planned and emergency undocking	97	–
14	Be able to manage collisions/arm clashes	–	96
Non-technical skills:			
15	Be able to demonstrate situational awareness	99	–
16	Be able to demonstrate effective communication skills with the team	99	–
Additional key skills of the console surgeon should include:			
Preoperative:			
17	Knowledge of procedure-specific port placement	97	–
Intraoperative:			
18	Be able to demonstrate master manipulator control use of the foot pedal and hand clutches (including camera control)	99	–
19	Be able to demonstrate multi-arm control of the robotic instruments	96	–
20	Be able to demonstrate correct techniques for tissue dissection	97	–
21	Be able to demonstrate suture handling and knot tying	97	–
Non-technical skills:			
22	Be able to demonstrate leadership skills	96	–
23	Be able to demonstrate ergonomic awareness and fatigue management	–	80
24	Be able to demonstrate time management and pacing	–	80

Table 3 Curriculum components of the GI surgery robotic training programme with consensus scores of critically important (7–9) in rounds one and two

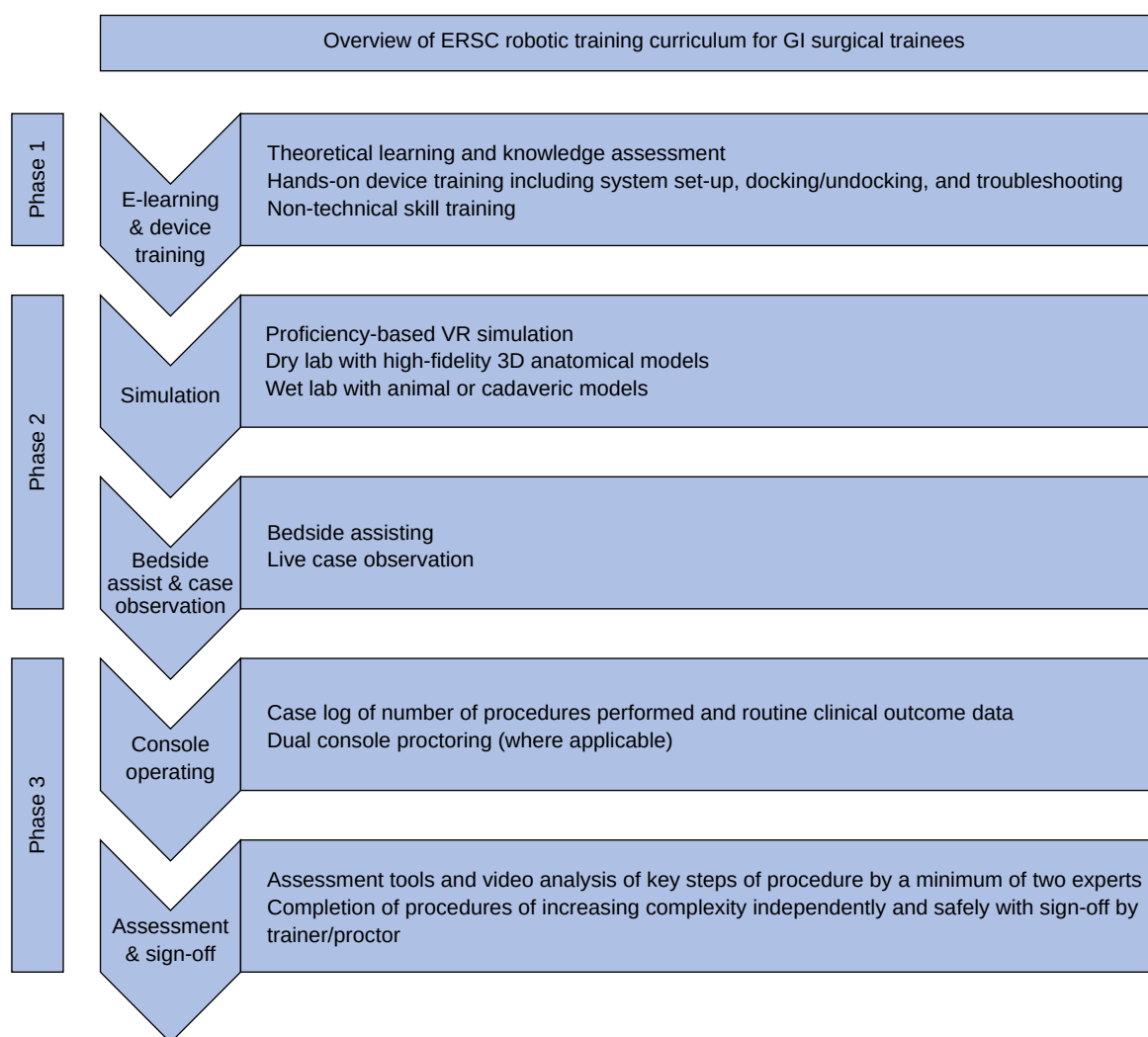
Item	Section 2: Training components	Round one (score 7–9), %	Round two (score 7–9), %
Key components of a robotic training curriculum for GI surgical trainees should include:			
25	E-learning modules	82	–
26	Core skills/device training (patient and port positioning, docking, non-technical skills, emergency undocking, and conversion)	97	–
27	Virtual reality simulation training (proficiency-based training including endowrist manipulation, camera control, and tissue dissection)	83	–
28	Dual console training (where applicable)	83	–
29	Dry-lab simulation (high-fidelity models), for example familiarisation with robotic instruments, use of energy and haemostasis, advanced dissection skills	96	–
30	Wet-lab simulation (animal or cadaveric)	66	70
31	Bedside assisting	89	–
32	Live case observation (observation of robotic operations performed by an expert robotic surgeon)	94	–
Robotic e-learning modules for GI surgical trainees should include:			
33	Introduction to robotic systems and principles of ergonomics	–	93
34	How to set up robotic console and troubleshooting	100	–
35	Patient selection and preparation	92	–
36	Port placement	97	–
37	Docking	99	–
38	Demonstration of common procedures	–	93
939	Emergency management/conversion to open or laparoscopy	96	–
40	Knowledge assessment	75	–
Dry and wet lab robotic simulation metrics for GI surgical trainees should capture:			
41	Completion of tasks	90	–
42	Task scores	96	–
43	Error rate (for example instrument clash, loss of instrument view)	87	–
44	Proficient camera control	90	–
45	Appropriate use of the third arm	83	–
46	Use of hand and foot controllers at the console	94	–
47	Economy of movement in tissue dissection and suturing	86	–
48	Safe energy application	93	–
49	Hand-eye coordination efficiency	–	90
GI, gastrointestinal.			

stepwise progression in acquiring skills during this training process and do so in cases of increasing complexity (85%, round 1). The completion of a robotic fellowship programme was

Table 4 Performance assessment, certification and supervision requirements of the GI surgery robotic training curriculum with consensus scores of critically important (7–9) in rounds one and two

Item	Section 3: Performance assessment	Round one (score 7–9), %	Round two (score 7–9), %
When robotic console operating, clinical metrics for GI surgical trainees should capture:			
50	Number of procedures performed	83	–
51	Routine clinical outcome data recorded for cases, for example intraoperative and postoperative complication rates, return to theatre, readmissions, unplanned conversion rate to open or laparoscopy, histopathological outcomes (if applicable)	89	–
Technical skill assessment for GI surgical trainees to progress to independent practice should include:			
52	Case logs	73	–
53	Validated objective assessments (for example GEARS)	80	–
54	Procedure-specific objective assessment tools (for example CATs)	83	–
55	Video assessment using objective tools—key steps of operative video assessed by a minimum of two experts (for example by proctor and a blinded expert)	87	–
Item	Section 4: Recommended requirements for certification and supervision	Round one (score 7–9), %	Round two (score 7–9), %
The following are required for robotic platform sign-off for GI surgical trainees:			
56	Completion of robotic procedures independently—trainer/proctor should deem the trainee as being able to practice independently and safely (for example through the use of objective assessment metrics/video assessment and clinical outcome metrics)	93	–
57	Stepwise progression on acquiring skills and demonstrate this in cases of increasing complexity	85	–

GI, gastrointestinal; CATs, Competency Assessment Tools; GEARS, Global Evaluative Assessment of Robotic Skills.

**Fig. 3 Overview of the key phases and steps of the proposed ERSC robotic training curriculum for gastrointestinal and visceral surgical trainees**

ERSC, European Robotic Surgery Consensus; GI, gastrointestinal; VR, virtual reality; 3D, three-dimensional.

deemed desirable but not mandatory in this curriculum (63%, round 1 and 66%, round 2), especially due to a lack of available robotic fellowships even at an international level.

The long-term impact of the robotic training curriculum can be primarily assessed by the number of procedures performed per year by a given trainee (80%, round 1) and their related clinical outcomes (for example complication rates per year) (86%, round 1). Overall, the curriculum should lead to a trainee demonstrating a gradual reduction in the percentage of assisted cases, coinciding with an increase in the percentage of performed and trained cases in cases of growing complexity. A flow diagram (Fig. 3) and a copy of the phased ERSC robotic training curriculum is available on Microsoft Excel (Supplementary file 4).

Discussion

This Delphi study proposes an evidence-based, comprehensive international framework for a platform-agnostic robotic training curriculum for GI surgical trainees, ultimately aiming to produce robotic surgeons who can practice independently and safely. The proposed ERSC curriculum is unique as it spans all stages of training, from novice to bedside assistant and console surgeon, and encompasses both technical and non-technical skills. Training is delivered through a structured approach, incorporating: e-learning for theoretical understanding; simulation (virtual, dry, and wet labs) for hands-on practice; bedside assisting and live case observation; and supervised console operation until expert-assessed sign-off and certification. There should be a shift from the subjective assessment of trainees to the use of standardised, validated objective assessment tools to measure surgical performance. Certification can be undertaken by a qualified proctor if the trainee demonstrates safe and independent operation.

The Delphi panel agreed on core competencies for the bedside assistant and console surgeon, reflecting the complementary roles in robotic procedures, with additional competencies needed for console surgeons. For example, bedside assistant trainees must be proficient in robot set-up, safe docking, instrument exchange, troubleshooting, and emergency undocking, ensuring patient safety and efficient teamwork. Console surgeons are expected to also master advanced technical skills including multi-arm instrument control, precise tissue handling, and dissection, alongside non-technical skills such as leadership and time management. The Delphi process affirmed that these role-specific competencies should be explicitly addressed in training.

Panellists strongly supported didactic e-learning modules on practical topics to ground trainees in the fundamentals of robotics. There was also consensus on the need for simulation training as a progressive preparatory step before bedside assisting and console operating, aligning with prior structured curricula²² such as the Fundamentals of Robotic Surgery curriculum⁵³ and the European Urology Programme⁵⁴, both of which emphasise proficiency-based progression. The Delphi panel agreed on important dry and wet-lab simulation metrics; however, it should be acknowledged that further work is required to define these metrics and ensure they provide discriminatory value in training. Dual console training was highlighted by the Delphi panel as an important enabler of effective real-time training^{55–57}. However, it should be taken into account that dual console training is currently platform-specific and can be limited by theatre space and associated costs, and is

therefore unlikely to be universally accessible for trainees across Europe.

A major focus of the consensus was establishing objective performance and clinical metrics on patient outcomes for assessment and certification. The panel agreed that trainee progression should be evaluated using a combination of global objective assessment tools and procedure-specific metrics. Summative assessments at the end of a defined interval were deemed more practical and feasible, rather than continuous assessments during training. Structured rating scales, such as GEARS⁵⁰ and procedure-specific CATs^{52,58}, were endorsed to provide measures of technical proficiency, complemented by the monitoring of clinical metrics, including complications and unplanned conversion rates. This mirrors the competency-based credentialing models advocated in other specialties, where a combination of simulation benchmarks and intraoperative performance data is used to sign-off trainees⁵⁴.

The panel did not reach a consensus on routine full-length video assessments by external raters, reflecting an ongoing debate about the feasibility of examiner agreement in video-based evaluations. Instead, a more focused approach assessing key video segments of an operation with input from both a blinded expert reviewer and the trainee's proctor was considered more practical and feasible^{59,60}. It has also been shown that there is minimal difference in operative assessment when raters used shorter, condensed videos compared with full-length videos⁶¹. Expert consensus of procedures^{61,62} can be used to define the critical steps of a procedure for video assessment. The adoption of artificial intelligence (AI)-based video assessment may also be considered in the future, once concerns regarding technical robustness, safety, and ethical challenges have been addressed. For example, EndoDigest, an AI platform, has recently been developed and validated to trim full-length videos down to key steps to reliably speed up video-based assessments^{63,64}.

Validity and reliability considerations underpinning this Delphi process merit discussion. Content validity was built by deriving statements from a prior systematic review²⁰ and stakeholder survey work¹⁷, ensuring grounding in evidence and real-world training gaps. The high consensus rates (consensus agreed on 77% of items in round 1 and 64% of remaining items in round 2) suggest face validity among a broad group of key stakeholders and experts. However, institutional and legal differences across regions may limit transferability. Training requirements and credentialing vary internationally; some countries or hospitals mandate formal certification or a minimum number of cases, while others rely on less structured sign-offs. The consensus aims to reflect a primarily European context and platform-agnostic curriculum, assuming the feasibility of elements such as wet lab training, standardized assessments, and dedicated proctoring, which may not be uniformly available. Thus, while the consensus provides a strong template, local adaptation will be necessary.

For further development of the proposed ERSC curriculum, the authors are following Kern's framework to implement and evaluate the effectiveness of the curriculum. The curriculum will be integrated within societal courses, international exams, and surgical training programmes, following the Laparoscopic Colorectal Surgery Training Programme (LAPCO) model²¹, in collaboration with surgical societies, such as EAES and UEG, and industry. Competency level scores will be developed and added to the curriculum, and knowledge and skill acquisition of participants will be assessed using pre- and post-curriculum

performance. Long-term participant performance after curriculum completion can be tracked using operative case numbers and outcomes over time. Feedback obtained from learners and trainers will also allow for further fine-tuning and pedagogical alignment of the curriculum, and the curriculum can be updated as necessary.

The successful implementation of the ERSC curriculum will require coordinated efforts from training institutions, professional bodies, and industry partners. The curriculum's modular nature will lend itself to flexible adoption; training centres could integrate the e-learning component into existing didactic teaching, utilize available simulators for the recommended dry and virtual lab sessions, and collaborate with regional labs or industry courses to provide a wet-lab experience. Incorporating bedside assisting and, where feasible, dual console cases as important components will require scheduling trainees in those roles, which may impact operative workflow. Institutions could address this by establishing formal robotic mentorship programmes where an experienced robotic surgeon (or a team of mentors) is accountable for guiding trainees through the bedside-to-console progression. Train-the-trainer programmes may be necessary to familiarize mentors with curriculum expectations and assessment tools, ensuring evaluations remain calibrated and fair across different sites⁶⁵. Moreover, incorporating the curriculum into existing surgical training timelines will necessitate acknowledging that robotic training is now an integral part of GI surgery education, warranting dedicated time and resources. Future implementation should involve the wider multidisciplinary team, with surgical assistants, scrub nurses, and anaesthetists included in training to strengthen teamwork, safety, and efficiency.

Despite the robust methodological process adopted, several limitations must be acknowledged. A relatively large proportion of the Delphi panel was from the UK (35%), Italy (23%), and Spain (11%), with limited representation from Eastern and Northern Europe. This could reduce the generalizability to settings with different case volumes, infrastructure, or access to robotic platforms. Limited participation from low- and middle-income countries may mean that perspectives on implementing training in resource-limited settings have been under-represented. In addition, there is potential response and selection bias, as the panel largely consisted of early adopters and robotic enthusiasts, many of whom had performed more than 50 independent robotic cases. This may have introduced bias towards more intensive training requirements and optimistic assumptions about resource availability. The authors attempted to mitigate this by including a range of stakeholder roles and by allowing open discussion and justification during the consensus meeting. Furthermore, Delphi studies often rely purely on expert opinion to generate findings and in some cases specific statements may be best addressed through other approaches, such as a systematic review of research evidence.

The authors have set out to develop a robotic training curriculum for GI surgical trainees broadly, without stratification by subspecialty. This broad applicability is a strength but may obscure nuanced subspecialty differences. For example, the new European coloproctology guideline for robotic training emphasizes steps specific to colorectal resections, such as total mesorectal excision, as key competencies for certification²⁷. The authors present a foundational framework that can be augmented by specialty or national boards with

procedure-specific requirements as needed. Overall, the consensus aligns with the direction of recent multi-specialty frameworks, such as the Orsi Consensus Meeting on European Robotic Training⁶⁶, which identified common training needs, while adding curriculum content specific to GI surgery. In particular, the panel emphasized that non-technical skill training, team-based aspects, and stepwise certification requirements adds an important dimension to curricula, complementing the technical skill focus of earlier programmes.

In summary, this Delphi-based consensus provides the foundational framework for an international, platform-agnostic curriculum for GI surgical trainees in robotic surgery. It specifies the skills to be learned, the methods of acquisition, and the approaches to competency assessment and certification, providing a framework to standardize training and improve the quality of robotic surgical education. A rigorous, evidence-informed consensus process supports the validity of the authors' recommendations. By addressing both technical and non-technical competencies, and outlining a structured yet flexible learning pathway, the proposed curriculum components can help synchronize robotic training across diverse training programmes, and can be further adapted for dedicated subspecialty training. Future efforts should focus on piloting this curriculum framework in real-world settings, evaluating its impact on trainee performance and confidence, and patient outcomes, with further refinement based on those insights. With continual updates as technology and techniques evolve, and potential expansion to other regions, the curriculum can serve as a foundation for credentialing models, ensuring that the next generation of GI surgeons is safely and proficiently prepared to operate with robotic technology, ultimately improving patient outcomes.

Collaborators

General surgeons: Nicola de Angelis, Paolo Bianchi, Alexander Bloemendaal, Diego Cuccurullo, Sofia Esposito, Gianmaria Casoni Patticini, Micaela Piccoli, Mauro Podda, Elisa Reitano, María Rita Rodríguez Luna, Ernesto Tartaglia, Victor Tomulescu, and Martin Wagner. **Upper GI/HPB surgeons:** Altaf Awan, Mark van Berge Henegouwen, Imran Bhatti, David Chan, Sonia Fernández-Ananin, Giovanni Maria Garbarino, Peter Grimmering, Benedetto Ielpo, Magnus Nilsson, Bijendra Patel, Alice Tsai, Christoph Tschuor, Gemma Vellalta, and Ramon Villalonga. **Colorectal surgeons:** Manish Chand, Audrius Dulskas, Antonio D'Urso, Nicola Eardley, Eloy Espin-Basany, Giampaolo Formisano, Nikolaos Gouvas, Rosa Maria Jiménez-Rodríguez, Michail Klimovskij, Gianluca Pellino, Thalia Petropoulou, Wanda Petz, Kapil Sahnan and Theodosopoulos Theodosios. **GI trainees:** Ademola Adeyeye, Asma Afzal, Daniel Campioni-Norman, Bibek Das, Michael Devine, Lachlan Dick, Dolores Krauss, Gita Lingam, Pietro Mascagni, Tamsin Morrison, and Munir Tarazi. **Robotic theatre team and human factor experts:** Alexandra Aye Ivanuta, Peter A Brennan, Michael Eichlseder, Samantha Evans, Neli Harvey, Ronalyn Hosena, Hannah Kettley-Linsell, Stella Mavroveli, Freideriki Sifaki, Tayana Soukup, and Madeleine Wells. **Industry representatives:** Lakshmi Balasubramanian (Intuitive Surgical), Niall Fahy (Medtronic), Harald Ginterstorfer (Intuitive Surgical), Elizabeth Jones (Medtronic), Sara Lazzaretti (Asensus Surgical), David Marante (Intuitive Surgical), Gregory De Martino (Intuitive Surgical), Anders Melander (Surgical Science), Shelley Petersen (Intuitive Surgical), James Scott (Intuitive Surgical), Mark Slack (CMR Surgical), and Katherine

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Author contributions

Michael G. Fadel (Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing—original draft), Josephine Walshaw (Conceptualization, Data curation, Formal analysis, Funding acquisition, Writing—original draft), Marina Yiasemidou (Methodology, Writing—review & editing), Matthew Boal (Methodology, Writing—review & editing), Francesca Pecchini (Data curation, Formal analysis, Funding acquisition, Methodology, Writing—review & editing), Muhammed Elhadi (Data curation, Formal analysis, Funding acquisition, Methodology, Writing—review & editing), Lisa H. Massey (Methodology, Project administration, Writing—review & editing), Francesco M. Carrano (Methodology, Project administration, Writing—review & editing), Matyas Fehervari (Writing—review & editing), Caoimhe M. Walsh (Writing—review & editing), Piers R. Boshier (Writing—review & editing), Jennifer Eckhoff (Writing—review & editing), Peter Buckle (Methodology, Project administration, Writing—review & editing), Suzanne S. Gisbertz (Writing—review & editing), Nicole Bouvy (Writing—reviewing & editing), Alberto Arezzo (Writing—review & editing), the European Robotic Surgery Consensus (ERSC) Study Group (Methodology, Writing—reviewing & editing), Silvana Perretta (Methodology, Project administration, Writing—review & editing), Felix Nickel (Methodology, Project administration, Writing—review & editing), Jim Khan (Methodology, Project administration, Writing—review & editing), George B. Hanna (Methodology, Project administration, Supervision, Writing—reviewing & editing), Barbara Seeliger (Methodology, Project administration, Validation, Writing—review & editing), Stavros A. Antoniou (Methodology, Project administration, Validation, Writing—review & editing), Hans F. Fuchs (Methodology, Project administration, Supervision, Validation, Writing—review & editing), Nader K. Francis (Conceptualization, Methodology, Project administration, Supervision, Validation, Writing—review & editing), and Christos Kontovounisios (Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Validation, Visualization, Writing—review & editing).

Disclosure

H.F.F. is a member of the advisory board of Medtronic, Stryker Corporation, and DistalMotion, and holds an educational grant (ESOMAP trial) and teaching courses through EAES with Intuitive Surgical. N.B. is a member of the global technology advisory board of Medtronic. S.S.G. is a consultant for Medcaroid, Johnson & Johnson, and Olympus. B.S. is the recipient of a grant from the French National Agency for Research (Agence Nationale de la Recherche (ANR)) within the framework of the project AI-DIAL (ANR-22-CE17-0019-01, ANR-23-IACL-0004) and

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Supplementary material

Supplementary material is available at [BJS](https://www.bjs.com) online.

Data availability

The relevant data has been included in the article or uploaded as supplementary information. Any additional data is available upon reasonable request.

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