Thieme

Modified Delphi Procedure to Achieve Consensus for the Concept of a National Curriculum for Minimally Invasive and Robot-assisted Surgery in Germany (GeRMIQ)

Modifiziertes Delphi-Verfahren zur Konsensfindung für die Konzeption eines bundesweiten Curriculums für minimalinvasive und roboterassistierte Chirurgie in Deutschland (GeRMIQ)

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minimally invasive surgery, robot-assisted surgery, curriculum, Delphi process, consensus

Schlüsselwörter

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ABSTRACT

Background

The rapid development of minimally invasive surgery (MIS) and robot-assisted surgery (RAS) requires standardized training to ensure high-quality patient care. In Germany, there is currently a lack of a standardized curriculum that

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teaches these specialized skills. The aim of this study is to find a consensus for the development of a nationwide curriculum for MIS and RAS with the subsequent implementation of the consented content.

Methods
A modified Delphi process was used to reach consensus among national experts in MIS and RAS. The process included a literature review, an online survey and an expert conference.

Results
All 12 invited experts participated in the survey. They primarily achieved consensus on 73 % and secondarily within the expert conference on 95 out of 122 questions (77.9 %). The preference for a basic curriculum as a foundation on which specialized modules can build on was particularly clear. The results support the development of an integrated curriculum for MIS and RAS that includes step-by-step training from theoretical knowledge via e-learning modules to practical skills in dry lab simulations and in the OR. Emphasis was placed on the need to promote clinical judgment and decision making through targeted assessment during the learning curve to ensure effective application of learned skills in clinical practice. There was also a consensus that training content must be aligned with learners' skill acquisition using objective performance assessments in line with the principle of proficiency-based progression (PBP). The continuous updating of the curriculum to keep it up to date with the latest technology was considered essential.

Conclusion
The study underlines the urgent need for a standardized training curriculum for MIS and RAS in Germany in order to increase patient safety and improve the quality of surgical care. There is broad expert consensus for the implementation of such a curriculum. It aims to ensure a contemporary and internationally competitive uniform quality of training and to increase the attractiveness of surgical training.

ZUSAMMENFASSUNG

Hintergrund
Die rasante Entwicklung der minimalinvasiven Chirurgie (MIS) und der roboterassistierten Chirurgie (RAS) erfordert eine standardisierte Weiterbildung, um eine qualitativ hochwertige Patientenversorgung sicherzustellen. In Deutschland mangelt es bislang an einem einheitlichen Curriculum, das diese spezialisierten Fähigkeiten vermittelt. Ziel dieser Arbeit ist eine Konsensfindung für die Entwicklung eines bundesweiten Curriculums für MIS und RAS mit der anschließenden Umsetzung der konsentierten Inhalte.

Methoden
Ein modifiziertes Delphi-Verfahren wurde angewandt, um einen Konsens unter nationalen Expert*innen für MIS und RAS zu erzielen. Der Prozess umfasste eine Literaturrecherche, eine Onlineumfrage und eine Expertenkonferenz.

Ergebnisse
Alle 12 eingeladenen Expert*innen nahmen an der Umfrage teil, erreichten primär in 73 % und sekundär im Rahmen der Expertenkonferenz bei 95 von 122 Fragen (77,9 %) einen Konsens. Die Präferenz für ein Basiscurriculum als Fundament, auf dem spezialisierte Module aufbauen können, wurde besonders deutlich. Die Ergebnisse unterstützen die Entwicklung eines integrierten Curriculums für MIS und RAS, das eine schrittweise Ausbildung vom theoretischen Wissen über E-Learning-Module bis hin zu praktischen Fertigkeiten in Dry-Lab-Simulationen und im OP beinhaltet. Betont wurde die Notwendigkeit, das klinische Urteilsvermögen und die Entscheidungsfindung durch gezieltes Assessment während der Lernkurve zu fördern, um eine effektive Anwendung der erlernten Fähigkeiten in der klinischen Praxis sicherzustellen. Einigkeit bestand auch darüber, dass die Ausbildungsinhalte anhand objektiver Leistungsbewertungen gemäß dem Prinzip der Proficiency-based Progression (PBP) auf den Kompetenzerwerb der Lernenden abgestimmt werden müssen. Die kontinuierliche Aktualisierung des Curriculums, um es an den neuesten technologischen Stand anzupassen, wurde als wesentlich erachtet.

Schlussfolgerung
Die Studie unterstreicht die dringende Notwendigkeit eines standardisierten Weiterbildungscurriculums für MIS und RAS in Deutschland, um die Patientensicherheit zu erhöhen und die Qualität der chirurgischen Versorgung zu verbessern. Für die Implementierung eines solchen Curriculums besteht ein breiter Expertenkonsens. Ein solches Curriculum zielt darauf ab, eine zeitgemäße und international konkurrenzfähige einheitliche Qualität der Ausbildung zu gewährleisten und die Attraktivität der chirurgischen Ausbildung zu steigern.

Introduction

The rapid progress of technological developments in minimally invasive surgery (MIS) and robot-assisted surgery (RAS) is creating many more options for more precise and more effective patient care [1]. The positive impact of these innovative procedures, especially in terms of fewer postoperative complications and faster convalescence times, is well proven [2, 3]. In addition, integrating AI applications (AI: artificial intelligence) into MIS and RAS will significantly support surgical practice and develop it further [4, 5].

Given the rapid changes in technology, the challenge for surgical teams is to keep pace with rapidly developing new technologies and provide comprehensive training [6]. In Germany, standardized national structures to teach these specialized skills are lacking. At present, there are only a few regionally limited initiatives which are attempting to confront this problem [7, 8]. The existing training regulations continue to rely on target figures and do not sufficiently focus on improving competencies when they define further training, especially with regards to integrating simulator-based and specialized training [9].

Given these circumstances, the necessity of a national training curriculum for MIS and RAS is becoming increasingly urgent. Such a curriculum would not just offer the opportunity to increase patient safety using targeted training based on the principle of PBP (PBP: proficiency-based progression) but would also contribute to the active shaping of technological advances in surgery. It would permit comparability in an era of technological change and thereby ensure a better quality of care. Moreover, such a curriculum would increase the attractivity of a surgical career for young doctors by offering innovation and better structured advanced training, which is a basic part of attracting and retaining new entrants to the field of surgery [10, 11].

With the support of the Germany Society for General and Visceral Surgery (Deutsche Gesellschaft für Allgemein- und Viszeralchirurgie, DGAV), a Delphi process was initiated to create the structural conditions to develop and implement such a curriculum. National experts were included to ensure that the curriculum would be practice-oriented, comprehensive and state-of-the-art in science and technology. The Delphi process provided an opportunity to gather opinions, define a consensus, and draft a future-oriented curriculum by forming a working group within the specialist medical association. The cross-location cooperation aimed to create a structured and broadly accepted national curriculum for Germany which would best meet the requirements for this medical specialty and ensure high-quality patient care.

Method

Working group and approach

The Delphi process to create a national curriculum for minimally invasive and robot-assisted surgery (GeRMIQ = German Robotic and Minimally Invasive Surgery Qualification) was initiated by a specialist panel of experts. The working group (AG) was set up by specialists for visceral surgery working at different universities (TH, FN, HM) who stood out based on their professional expertise, scientific activities and many years of experience in the field of minimally invasive and robot-assisted surgery and its training.

A deliberate choice was made not to have an ethics vote as the study did not involve any patients and the study design did not require it.

The approach was divided into 4 steps:

1. Analysis of the status quo and literature search An independent search of the literature was carried out to analyze the existing training curricula for MIS/RAS in Germany and internationally. This systematic examination used sources such as PubMed, Google Scholar and the DNB-OPAC catalog of the German National Library. A detailed list of questions was developed in kick-off meetings by the initiators of the project.

2. Choice of experts and online survey The choice of national experts was based on their scientific activity and expertise in MIS/RAS. Particular care was taken to include the broadest range of experts with different levels of seniority to ensure a wide range of experience. The questions were prepared in advance and sent out via the SoSci Survey platform and were available for evaluation from 27 September 2023 to 8 October 2023. The questions/statements were structured to elicit either a dichotomous response or be answered using a Likert scale. This was done to create a more differentiated weighting of specific topics. The concept of the questions allowed the experts to give their responses based on their clinical experience and personal judgment. The Comments function of the survey also allowed respondents to freely express their opinions. Anonymization of all participants was maintained to ensure the necessary integrity and objective expressions of opinion. A reminder email was sent to non-responders to maximize participation.

3. Conference of experts to build a consensus The results of the online survey were processed statistically and presented visually in PowerPoint. The presentation of the results of the online survey aimed to identify those areas where no consensus was achieved during personal discussions and to discuss them, taking the scientific evidence into account. The conference of experts was held in the Bonn Surgical Technology Center (BOSTER). Finally, the 3rd iteration took the form of an online conference. Participants had the option to revise or double-down on their positions. Ambiguous cases were discussed and second vote was carried out where necessary.

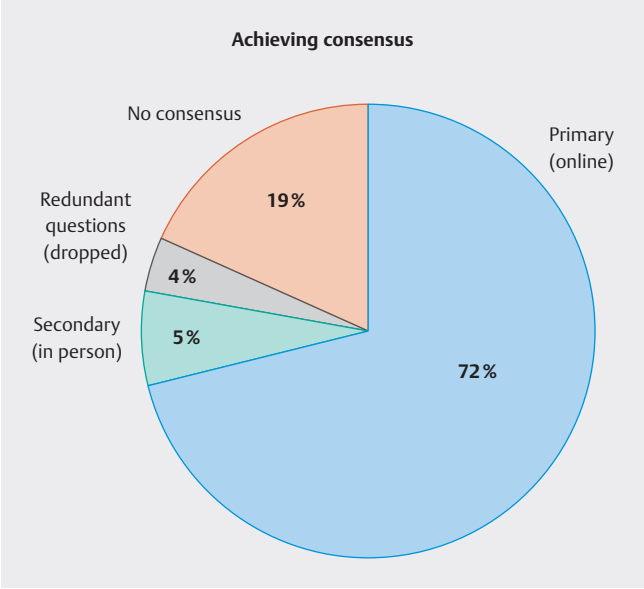
4. Implementation of the consensus content The development and practical implementation of the consented contents as the basis of a nationally applicable curriculum is currently in its developmental stage. The aim is to create high-quality standards which will be continuously optimized while including more surgical interest groups.

Delphi process and definition of consensus

A 2-step modified Delphi process was used to achieve consensus. This approach is used to arrive at a consistent result when numerous high-level scientific perspectives are under consideration. The a priori definition of consensus was an agreement of ≥ 80 %, based on the standards for leading scientific publications [12].

Results

All 12 experts invited to participate in the online round of questions responded (response rate: 100 %). The group of participants consisted of 10 senior physicians, one medical specialist and one junior doctor. A total of 122 questions/statements were sent out in the form of an electronic questionnaire, of which 78 questions had binary response options and 44 questions required ranking on a Likert scale. There was a primary consensus on 89 of the 122 questions (72 %). During the meeting of experts, a secondary consensus was achieved for 6 further questions, meaning that there was consensus regarding 77 % of the questions (n = 95). Four



▶ **Fig. 1** Percentage of questions for which a consensus was reached.

questions/statements (4%) were dropped because they were redundant. No consensus was achieved for 23 questions (19%), even after discussion (▶ **Fig. 1**). For the sake of clarity the focus here will mainly be on the statements for which a consensus could be achieved during the process.

Basic concept and target group

Position Overall, everyone agreed about the benefits of having a standardized curriculum (▶ **Table 1**). All of the medical specialists agreed with the statement that such a curriculum should be developed and evaluated quickly. There was also a clear agreement (100%) about the need for comprehensive improvements in the quality of training and of the need to ensure that medical staff had the requisite knowledge and skills and the option to carry out extensive scientific studies. All of the experts unanimously agreed (100%) that patient safety and outcomes should be improved. There was also an unanimous consensus that the GeRMIQ curriculum would make the national surgical community more competitive on the global stage and would encourage an independent evaluation and introduction of innovative technologies. Finally, all of the experts agreed that continuous updates of the GeRMIQ would provide sustainable support for further training and lead to more innovation in the field of surgery.

Basic concept The overwhelming majority (90.9%) finally voted for the creation of a combined curriculum for MIS and RAS and almost unanimously rejected the idea of developing a curriculum exclusively for RAS which would not include standard laparoscopy. There was a general consensus with regards to the possible use of the GeRMIQ as the basis for other medical specialties (urology/gynecology), with a primary agreement in the 1st round of 83.3% and a subsequent secondary consensus of 100%. There was full agreement that the "basic training" of the GeRMIQ should be designed as a minimum target to allow for future specialization (▶ **Table 2**).

▶**Table 1** Position.

	1st round: e-survey yes/no (in %)	**2nd round:** yes/no (in %)	**Consensus**
A national curriculum for minimally invasive and robot-assisted surgery (BCMR) is beneficial because …			
… overall, it would offer more benefits than disadvantages, and it should be developed and evaluated quickly.	91.7/8.3	100/0	Yes
… the quality of training can be improved nationwide.	100/0	100/0	Yes
… it will ensure that medical staff have the requisite knowledge and skills.	100/0	100/0	Yes
… it can improve patient safety and therefore patient outcomes.	100/0	100/0	Yes
… comprehensive scientific studies will be possible (e.g., didactic studies, studies on simulation technology, etc.).	91.7/8.3	100/0	Yes
… the national surgical community can become more competitive on the global market in some areas.	91.7/8.3	100/0	Yes
"… the increasing numbers of innovative technologies entering the market (e.g., new robot-assisted systems) can be evaluated and introduced independently of industry."	83.3/16.7	100/0	Yes
… it could increase the trust of patients in innovative surgical techniques.	66.7/33.3	9.1/90.9	No
"… continuous updates (e.g., annually) will sustainably support further training and a more innovative orientation in the field of surgery."	83.3/16.7	100/0	Yes

▶**Table 2** Basic concept.

	1st round: e-survey yes/no (in %)	**2nd round:** yes/no (in %)	**Consensus**
A combined BCMR should be created for MIS and RAS.	91.7/8.3	90.9/9.1	Yes
A BCMR should only be created for RAS and not include conventional laparoscopy.	0/100	0/100	No
A BCMR could also serve as the basis for other medical specialties (urology/gynecology).	83.3/16.7	100/0	Yes
In parallel to a "basic" BCMR, a "specialized" BCMR should also be devised (HPB/UGI/COLO etc.).	50/50	0/100	No
The minimum goal should be to first design a "basic" BCMR which can serve as a basis for a future "specialized" BCMR (HPB/OGI/COLO, etc.).	91.7/8.3	100/0	Yes

BCMR: national curriculum for minimally invasive and robot-assisted surgery; HPB: Hepato-pancreaticobiliary, UGI: Upper gastrointestinal tract, COLO: Colorectal

▶**Table 3** Target group.

	1st round: e-survey yes/no in %	**2nd round:** yes/no in %	**Consensus**
A BCMR should be initially available for:			
▪ medical practitioners in advanced and further training (main target group: junior doctors prior to their specialist examinations)	91.7/0	100/0	Yes
▪ medical practitioners who have at least qualified as specialist in a surgical field	33.3/66.7	0/100	No
▪ surgeons with no experience of working with robots (e.g., senior surgeons)	75/25	18.2/81.8	No
▪ surgical staff	75/25	–	No consensus
▪ the extended surgical team	58.3/41.7	–	No consensus
▪ medical students	25/75	–	No consensus
Basic training in MIS/RAS already in the first years of surgical training is an advantage.	83.3/16.7	100/0	Yes
Successful completion of the curriculum should be obligatory for admission to specialist examinations (e.g., for visceral surgery) of the MC.	83.3/16.7	81.8/18.2	Yes

BCMR: national curriculum for minimally invasive and robot-assisted surgery; MC: German Medical Council

Target group Clear tendencies were identified with regards to target groups but there were also differences of opinion (▶**Table 3**). A consensus was achieved regarding the proposal that the curriculum should be available to doctors in advanced training (especially before they have completed their specialist qualification). The idea that the curriculum should only be available to medical specialists or preferably to senior physicians with no experience of working with medical robots (which is currently the case in many places) was rejected. The majority of the experts (1st round: 83.3%; after the meeting of experts: 100%) supported the integration of basic training in MIS and RAS already in the first years of surgical training. Likewise, it was noted with an agreement of 81.8% that successful completion of the GeRMIQ curriculum should be an obligatory part of admission to the final specialist examination, for example in visceral surgery.

Components and organization

There was unanimous consensus that the curriculum should consist of a number of consecutive stages (▶**Table 4**, ▶**Table 5**, ▶**Table 6**; ▶**Fig. 2**) and should include objective criteria to evaluate progression, including online tests and benchmarks for practical exercises. The group also agreed that the curriculum demonstrate highlight proficiency-based progression (PBP) to identify the progress of individual learners during the different stages. Benchmarking the performance of learners was also agreed upon, with 90.9% of the experts voting in favor.

▶**Table 4** Components and organization (Part 1).

	1st round: e-survey yes/no (in %)	**2nd round:** yes/no (in %)	**Consensus**
The BCMR should consist of different consecutive stages (e.g., e-learning, learning to use equipment, dry lab exercises, first surgical procedures with video-based assessment [VBA]).	91.7/0	100/0	Yes
The BCMR should include objective criteria to evaluate progression during different stages (e.g., online tests, benchmarks for practical exercises, etc.).	83.3/8.3	100/0	Yes
The BCMR should be able to show proficiency-based progression (PBP).	83.3/8.3	100/0	Yes
As part of the BCMR, a performance level for persons doing the training should be defined as part of benchmarking.	75/16–7	90.9/9.1	Yes

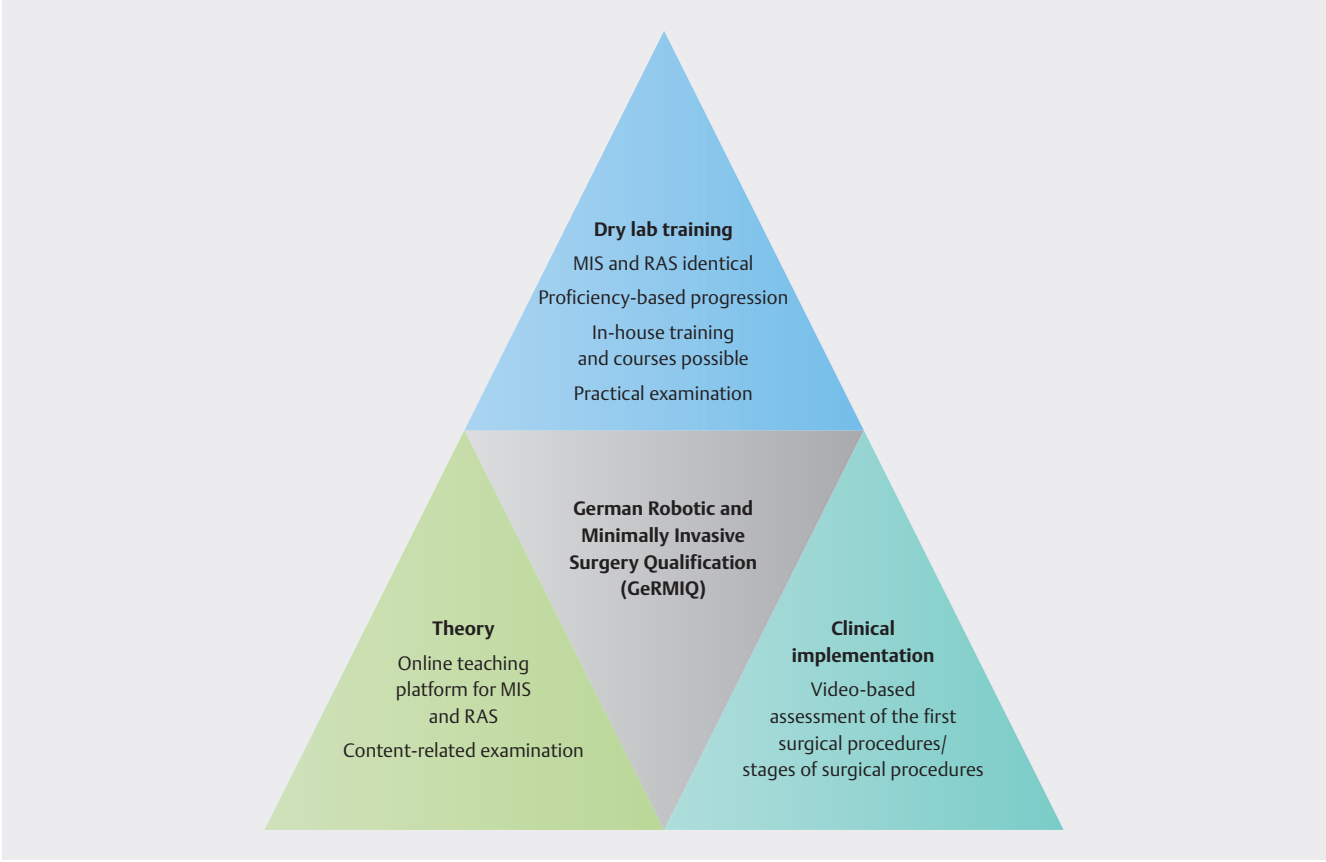
▶**Table 5** Components and organization (Part 2).

	1st round: e-survey no/rather no/neutral/ rather yes/absolutely (in %)	**2nd round:** yes/no (in %)	**Consensus**
The BCMR must include the following obligatory basic components (which are not part of any surgical procedures):			
▪ E-learning (including virtual contents)	0/0/0/25/75	100/0	Yes
▪ Examination of e-learning contents	0/8.3/16.7/25/50	100/0	Yes
▪ Learning to use equipment (e.g., training provided by various RAS companies)	0/0/0/8.3/91.7	100/0	Yes
▪ Examination of understanding of the equipment	0/8.3/8.3/16.7/66.7	81.8/18.2	Yes
▪ Dry lab training (e.g., toolbox, digital simulator)	0/0/8.3/8.3/83.3	100/0	Yes
▪ Assessment of dry lab skills	8.3/8.3/8.3/25/50	90.9/9.1	Yes
▪ Wet lab training (e.g., body donation, large animal)	25/16.7/25/0/33.3	–	No consensus
▪ Assessment of wet lab skills	41.7/8.3/16.7/8.3/25	–	No consensus

▶**Table 6** Components and organization (Part 3).

	1st round: e-survey no/rather no/neutral/ rather yes/absolutely (in %)	**2nd round:** yes/no (in %)	**Consensus**
The BCMR must include the following basic components (steps of surgical procedures on real patients):			
▪ Sitting-in on live operations (VR or in person)	16.7/8.3/25/16.7/33.3	18.2/81.8	No
▪ Assisting in a certain number of MIS/RAS index operations (e.g., 5 laparoscopic cholecystectomies)	0/0/0/16.7/83.3	100/0	Yes
▪ Carrying out the surgical procedure or substeps of a certain number of MIS/RAS index operations	8.3/8.3/0/16.7/66.7	81.8/18.2	Yes

VR: virtual reality



▶ **Fig. 2** Components of the curriculum.

The obligatory integration of e-learning contents including virtual contents and their assessment (100 % agreement) as well as learning to use equipment, e.g., through training provided by the respective RAS companies (100 % agreement), and the assessment of what has been learned (81.8 % agreement) were considered essential elements of the curriculum.

Dry lab training (100 % agreement) and the assessment of dry lab skills (90.9 % agreement) were considered important components of the GeRMIQ. It was not possible to arrive at a general agreement with regards to wet lab training and the assessment of wet lab skills.

However, there was a consensus (81.8 %) that sitting-in on live operations, whether virtually or in person, should not be viewed as an obligatory basic component of the curriculum. In contrast, assisting in a specified number of MIS/RAS index operations (100 % agreement) and carrying out surgical procedures or substeps of a specified number of MIS/RAS index operations oneself (81.8 % agreement) was considered an obligatory basic component.

The consensus was unanimous (100 %) with regards to implementing a system of continuous monitoring and updating of the curriculum and the qualification requirements to ensure that they comply with current standards and technologies (▶ **Table 7**). The experts were unanimously in favor of setting up a GeRMIQ expert committee which would be responsible for organizing the curriculum and continually adapting it. Likewise, the value and importance of having an examination board to review applications for accreditation and to issue certificates was unanimously accepted by the experts (100 %). A unanimous consensus was achieved with regards to the teaching format, whereby the theoretical part would be largely carried out online and completed prior to the practical part, which would be carried out locally in hospitals. All of the experts voted in favor of graduates of the GerMIQ receiving a certificate. A co-operation with hospitals, medical facilities and other relevant organizations to promote the availability of training options was unanimously endorsed. The professional medical organization DGAV (Germany Society for General and Visceral Surgery) was unanimously considered to be the most suitable organization to provide sufficient staffing, financial and other resources to implement the curriculum and to serve as a communication platform, especially with the German Medical Council.

▶**Table 7** Other organizational aspects.

	1st round: e-survey yes/no (in %)	2nd round: yes/no (in %)	Consensus
Any system of continuous monitoring and updating the curriculum and qualification requirements must ensure that they conform to current standards and technologies.	91.7/8.3	100/0	Yes
Such an update should be carried out annually.	33.3/66.7	–	No consensus
Such an update should be carried out every 2 years.	41.7/58.3	–	No consensus
Such an update should be carried out every 3 years.	16.7/83.3	–	No consensus
A points system can be used to facilitate the accreditation of parts of the BCMR and would be generally sensible.	91.7/8.3	100/0	Yes
Setting up a BCMR expert committee is useful for the organization and continuous adaptation of the curriculum in future.	100/0	100/0	Yes
It would be useful to set up an examination board which would review applications for accreditation and decide on the issuing of certificates.	83.3/16.7	100/0	Yes
In principle, the theoretical part should be largely done online and completed prior to starting practical training, which would be carried out locally in hospitals.	83.3/16.7	100/0	Yes
After completing the BCMR, graduates should receive a certificate (e.g., "DGAV basic certificate for conventional minimally invasive and robot-assisted surgery")	83.3/15.7	100/0	Yes
A collaboration with hospitals, medical facilities and other relevant organizations will be required to promote the availability of training options in robotic surgery.	100/0	100/0	Yes
As a professional assocation, the DGAV could ensure the availability of staff, financial and other resources, monitor certification and serve as a communication platform including to the German Medical Council.	100/0	100/0	Yes

Theory

Theory: contents There was an unanimous consensus (100%) with regards to integrating legal aspects (e.g., information, responsibility) and ethical questions in the context of artificial intelligence (AI) which should be included in e-learning. Similarly, the panel agreed that the curriculum would also need to provide an overview of the current level of e-learning technology. A consensus (100%) was also achieved with regards to the inclusion of recommendations on the clinical implementation of new systems (including team training) and that e-learning modules would also need to include information about the selection and preparation of patients, trocar placement and docking, as well as approaches for index operations (e.g., laparoscopic cholecystectomy [CHE] and robotic hemicolectomy). The group of experts agreed that the basic characteristics of different systems and the pitfalls associated with controlling them would need to be shown and taught as part of e-learning modules (▶**Table 8**).

Theory: Organization, examination, accreditation The results for certain organizational aspects of e-learning in the context of the proposed curriculum showed that the experts were clearly in agreement (▶**Table 9**) with a unanimous consensus that e-learning should be available free of charge and be financed by hospitals. There was also a clear preference for new e-learning modules to be integrated into an existing learning platform (81.8% agreement). There was unanimous consensus (100%) with regards to the (partial) accreditation of already established courses for MIS and RAS. It was suggested that a points system to evaluate existing courses/curricula would be useful for parts of the GeRMIQ. This approach was explicitly supported to ensure that not all courses will have to be completely re-oriented.

Practical training without patients

Practical training without patients: contents The experts unanimously agreed (100%) that practical elements such as tissue dissection, tying of sutures, suturing, and the use of instruments by assisting medical staff should be included in the practical training (▶**Table 10**, ▶**Table 11**). There was 100% consensus for carrying out simulations of specialty-relevant index operations such as laparoscopic cholecystectomy, which shows the importance of practical training as a good preparation for successful surgery. The integration of surgery-relevant non-technical skills (NOTSS) and the need to review benchmarks (local/regional or central, e.g., at conferences) after accreditation was unanimously approved. There was a general consensus (100%) that a review of benchmarks should be consistent with other national/international accreditation processes, for example with those of the UEMS (European Union of Medical Specialists).

▶**Table 8** Theory: contents.

	1st round: e-survey no/rather no/neutral/ rather yes/absolutely (in %)	**2nd round:** yes/no (in %)	**Consensus**
E-learning should include:			
▪ History of MIS/RAS	0/33.3/41.7/8.3/16.7	–	No consensus
▪ Legal aspects (e.g., information, responsibility) and ethics (esp. for the future with regards to AI)	0/0/8.3/41.7/41.7	100/0	Yes
▪ Overview of the current level of technology	0/0/16.7/16.7/66.7	100/0	Yes
▪ Overview of innovative areas (e.g., VR, AI decision support, etc.)	0/0/41.7/16.7/41.7	0/100	No
▪ Recommendations on the clinical implementation of new systems (incl. team training)	0/0/8.3/33.3/58.3	100/0	Yes
▪ Composition and training of surgical teams	0/0/8.3/16.7/25	100/0	Yes
▪ Information on the selection and preparation of patients	0/0/0/25/75	100/0	Yes
▪ Information on the procedure for index surgeries (e.g., laparoscopisc CHE, robotic hemicolectomy)	0/0/0/8.3/91.66	100/0	Yes
▪ Information on trocar placement and docking	0/0/0/16.7/83.3	100/0	Yes
▪ Perioperative management	0/8.3/16.7/16.7/58.3	0/100	No
▪ Non-technical skills (such as NOTSS)	0/16.7/41.7/16.7/16.7	0/100	No
▪ Basic features of different systems	0/0/16.7/33.3/50	100/0	Yes
▪ Pitfalls in controlling systems	0/0/0/16.7/83.3	100/0	Yes

▶**Table 9** Theory: Organization, examination, accreditation.

	1st round: e-survey yes/no (in %)	**2nd round:** yes/no (in %)	**Consensus**
E-learning should be available free of charge (e.g., financed by hospitals).	100/0	100/0	Yes
It would make sense to affiliate e-learning to an existing learning platform.	66.7/33.3	81,8/18,2	Yes
The (partial) accreditation via already existing courses on minimally invasive and robot-assisted surgery appears to be useful and is explicitly supported, meaning that not all courses will have to be completely re-oriented.	91.7/8.3	100/0	Yes

▶**Table 10** Practical training without patients: contents (Part 1).

	1st round: e-survey no/rather no/neutral/ rather yes/absolutely (in %)	**2nd round:** yes/no (in %)	**Consensus**
Practical training without patients should include:			
▪ Two-handed movements	0/0/0/0/100	100/0	Yes
▪ Guiding the camera	0/0/8,3/8,3/83,3	100/0	Yes
▪ Tissue dissection	0/0/0/16,7/83,3	100/0	Yes
▪ Tying of sutures	0/0/0/0/100	100/0	Yes
▪ Suturing	0/0/0/0/100	100/0	Yes
▪ Safe application of diathermy	0/0/8,3/0/91,7	100/0	Yes
▪ Potential use of instruments by assisting staff	0/0/8,3/25/66,7	100/0	Yes
▪ Emergency conversions	0/0/0/0/100	100/0	Yes

▶**Table 11** Practical training without patients: contents (Part 2).

	1st round: e-survey yes/no (in %)	2nd round: yes/no (in %)	Consensus
Specialty-relevant index operations (e.g., laparoscopic cholecystectomy) should be first performed using a simulator prior to the first real surgery.	91.7/8.3	100/0	Yes
The curriculum should include surgery-relevant non-technical skills (NOTSS).	N/A*	100/0	Yes
Local and regional benchmark reviews should be possible (after accreditation).	66.7/33.3	–	No consensus
Benchmark reviews should be done centrally (e.g., at conferences /surgical courses).	41.7/58.3	–	No consensus
Benchmark reviews should carried out locally or regionally (after accreditation) but central reviews (e.g., at conferences /surgical courses) should also be possible.	N/A*	100/0	Yes
Benchmark reviews should be compatible with other national/international accreditation processes (e.g., UEMS).	83,3/16,7	100/0	Yes

▶**Table 12** Practical training without patients: organization, practical examination, accreditation.

	1st round: e-survey yes/no (in %)	2nd round: yes/no (in %)	Consensus
If practical training in MIS/RAS with all the accessories is not available in all hospitals, a regional structure could be created to ensure that everyone has access to BCMR practical training and BCMR examinations.	100/0	100/0	Yes
If training for robot-assisted surgery is available in a hospital, a regional training structure could be created to optimize access to training.	75/25	–	No consensus
Regional centers should be monitored by persons who offer training in MIS/RAS.	75/25	–	No consensus
The individual providing practical training in MIS/RAS should be accredited (e.g., by the DGAV).	83.3/16.7	81.8/18.2	Yes
Practical training centers and teaching hospitals should be evaluated and accredited (e.g., by the DGAV).	75/25	–	No consensus
There should be separate accreditations for MIS and for RAS.	83.3/8.3	100/0	Yes

Practical training without patients: organization, practical examination, accreditation

Access to practical training When the panel considered the organization of practical training and practical examinations, the experts unanimously supported the introduction of regional structures (100%), while the consensus about the corresponding monitoring of regional centers was more mixed. There was a consensus (81.8%) that, in general, the persons providing practical training in MIS/RAS should be accredited and that there should be separate accreditations for MIS and RAS (100%) to do justice to the specific demands and features of the respective areas. This again shows how important a differentiated evaluation of MIS and RAS will be when developing the curriculum (▶**Table 12**).

The opinions with regards to the ideal distance to the next regional center and the time frame (flexible/according to a fixed schedule during working hours or during approved educational leave; part-time, full-time, several days) varied (▶**Table 13**). There was a clear consensus (100%) that the costs of dry lab training (for example, artificial organs) should be borne by the teaching hospital and not by the trainees. The experts were unanimously in favor of co-operation agreements with medical professional societies to provide easier access to dry lab training for hospitals and trainees.

Practical training with patients: contents, videos, NOTSS, etc.

Evaluation of practical competence There was a general consensus (100%) that, in the medium term, the first real surgical procedure after successfully completing training outside of the operating room should be evaluated by video-based assessment (VBA; ▶**Table 14** and ▶**Table 15**). There was also a general consensus (100%) that evaluation of a representative operation of an index procedure should be carried out at the time of performance and after completing the learning curve. The experts unanimously supported a points system which would reflect the level of difficulty, an evaluation of defined surgical steps, and mistakes which must be avoided. There was a consensus that there should be an oppor-

▶**Table 13** Access to practical training.

	1st round: e-survey yes/no (in %)	2nd round: yes/no (in %)	Consensus
What is the appropriate time frame to carry out practical training?			
According to a fixed schedule during working hours	58.3/33.3	–	No consensus
During approved educational leave	91.7/8.3	–	No consensus
In the trainee's free time	25/58.3	–	No consensus
Flexibly during working hours	58.3/33.3	–	No consensus
If regional centers existed, what would be the preferred time frame?			
Full-time	58.3/25	–	No consensus
Part-time	8.3/66.7	–	No consensus
Over several days	66.7/25	–	No consensus
A reasonable distance to a regional center is:			
< 20 km	25/58.3	–	No consensus
< 50 km	41.7/50	–	No consensus
< 100 km	75/8.3	–	No consensus
The teaching hospital should bear the costs of dry lab training (e.g. artificial organs).	83.3/16.7	100/0	Yes
Co-operation agreements (DGAV) should be concluded for dry lab training to provide easier access to dry lab training for hospitals and trainees.	100/0	100/0	Yes

▶**Table 14** Practical training with patients: contents, videos, NOTSS, etc.

	1st round: e-survey no/rather no/neutral/ rather yes/absolutely (in %)	2nd round: yes/no (in %)	Consensus
In the medium term, the first real surgical procedures after successful completion of training outside the operating room should, in future, also be evaluated by video-based assessment (VBA) in Germany in accordance with international models, to increase patient safety.	8.3/8.3/25/16.7/41.7	100/0	Yes

tunity for experts to provide constructive feedback to the surgeons in training, and that established scores (e.g., GEARS, OSATS, OPSA, ABS, Operative Performance Assessment) could be used for this. Initially used standardized evaluations by experts could be useful for future AI-based evaluations.

Non-technical skills for surgeons (NOTSS) There was a clear consensus (100 %) about the need to integrate emergency scenarios in the curriculum. The consensus on training decision-making was 81.8 %. There was also general support (90.9 % respectively) for training situational awareness and training the surgical team (▶ **Table 16**).

Discussion

In contrast to several international initiatives [13, 14, 15], the Federal Republic of Germany currently lacks a comprehensive standardized curriculum for the advanced training of MIS and RAS. Although these advanced technologies are becoming increasingly important in medical practice [16], structured training and advanced training in these areas is not yet properly established in Germany.

Traditionally, surgical skills were acquired in accordance with the model proposed by Halsted: "See one, do one, teach one", which was based on observation, followed by the gradual acquisition of competencies by emulating role models, in accordance with social cognitive theory [17]. The problems with this approach are well known, including misgivings that if the acquired understanding is purely based on clinical experience, this will result in trainee surgeons having heterogeneous skills. Moreover, the current expectation is that physicians providing surgical training will both educate the new generation of surgeons and learn to master the new technologies themselves [18].

▶**Table 15** Evaluation of practical competencies.

	1st round: e-survey yes/no (in %)	**2nd round:** yes/no (in %)	**Consensus**
Evaluation of practical competencies and skills in the operating room (also using video analysis) should include the following:			
▪ Evaluation of the first 5 operations of an index procedure (laparoscopic cholecystectomy)	50/50	–	No consensus
▪ Evaluation of the first 10–20 operations of an index procedure (laparoscopic cholecystectomy)	8.3/83.3	9.1/90.9	No
▪ Evaluation of > 20 operations of an index procedure (laparoscopic cholecystectomy)	8.3/91.7	9.1/90.9	No
▪ Evaluation of a representative operation of an index procedure at the time of performance and after completing the learning curve	91.7/8.3	100/0	Yes
▪ A points system for easier analysis and representation and to allow comparisons	100/0	100/0	Yes
▪ The level of difficulty of the individual surgical procedure	100/0	100/0	Yes
▪ An objective evaluation of defined surgical steps (e.g. clipping of the cystic artery in laparoscopic cholecystectomy) and of mistakes which must be avoided (e.g., clipping of the cystic duct centrally at the CHD)	83.3/16.7	100/0	Yes
▪ An opportunity for experts to provide constructive feedback to the surgeons in training	91.7/0	100/0	Yes
▪ Established scores could be used such as GEARS, OSATS etc.	91.7/8.3	100/0	Yes
▪ The evaluation/feedback should be provided by an accredited evaluator.	58.3/41.7	100/0	Yes
▪ The evaluation/feedback should be provided by 2 or more independent evaluators.	33.3/66.7	0/100	No
▪ In the context of machine learning, standardized evaluations by experts could serve as the basis for future AI-based evaluations.	100/0	100/0	Yes
▪ Video evaluations should be double-blinded.	75/25	100/0	Yes

GEARS: Global Evaluative Assessment of Robotic Skills; OSATS: Objective Structured Assessment of Technical Skills

▶**Table 16** Non-technical skills for surgeons (NOTSS).

	1st round: e-survey no/rather no/neutral/ rather yes/absolutely (in %)	**2nd round:** yes/no (in %)	**Consensus**
The following non-technical skills should be integrated in the BCMR:			
▪ Communication	8.3/0/16.7/16.7/58.3	–	No consensus
▪ Emergency scenarios	8.3/0/0/0/91.7	100/0	Yes
▪ Decision making	16.7/0/8.3/25/50	81.8/ 18.2	Yes
▪ Leadership qualities	16.7/8.3/33.3/25/16.7	0/100	No
▪ Training cognitive skills	16.7/16.7/16.7/25/25	0/100	No
▪ Efficiency training of the surgical team	16.7/0/16.7/25/41.7	0/100	No
Non-technical skills should include:			
▪ Training situational awareness	8.3/8.3/16.7/16.7/50	90.9/9.1	Yes
▪ Training the surgical team	0/16.7/16.7/16.7/50	90.9/9.1	Yes

To prevent heterogeneous and inadequate training, some of the different surgical subspecialties have come up with a number of approaches to improve training by amending the curricula, but the scope of the proposed changes has often been limited and inconsistent. The Surgical Clinic of the UKSH Campus Lübeck developed a "Robotic Surgery Training Curriculum – RoSTraC," a 3-stage training program which ranges from basic and simulation training to training in the lab using institutional robotic systems to structured training on patients in the operating room [8]. The "Robotic Curriculum for young Surgeons" (RoCS), which was developed by the Surgical Department of Magdeburg University Hospital, also includes theoretical and simulation training but it focuses on the clinical implementation of practical robotic training. With the RoCS concept, surgeons should gradually acquire basic competencies in the use of robotic systems until they sit their final medical specialist examinations [7].

The advanced training initiatives described above are promising. But the lack of national training standards despite the continuous advances of MIS and RAS technologies in Germany means there is a risk that the clinical implementation and application will be suboptimal [19] which would be a barrier to technological progress in the field of surgery. There is also the risk that the lack of advanced training programs will limit surgeons' ability to cope with the latest technological developments and and integrate them into clinical practice, potentially preventing them from developing these technologies further in co-operation with the medical industry. The consequences would not just limit technological progress but also reduce the willingness to carry out innovative procedures. One example of this is the limited use of minimally invasive surgery to treat colorectal carcinoma in Germany compared to other countries internationally; in 2015, around 55 % of procedures to treat colorectal cancer in the United Kingdom were minimally invasive interventions as opposed to just 28.5 % in Germany [20, 21]. Setting up a structured curriculum is therefore not just important for patient safety and the quality of medical care but also for the promotion and continued development of MIS and RAS and for integrating innovative technologies into clinical practice.

The results of the Delphi consensus presented here reveal the current challenges and deficits of existing training programs and the need to amend them sooner rather than later. Although the new competencies-based structure of the regulations on specialist training has increased reference numbers, minimally invasive techniques and robotic procedures are still not sufficiently integrated into the curriculum [22]. A survey of the members of the DGAV carried out by the Young Surgeons Working Group in 2023 showed that they felt that MIS and RAS had not been adequately incorporated into the new specialist training regulations. More than half of the persons surveyed would have liked minimally invasive surgery to play a greater role and around 30 % demanded the integration of RAS. A majority of the respondents considered training using simulators to be an important part of surgical training [23]. In addition to the lack of specifications in the specialist training regulations, incorporating a comprehensive training program into the clinical routines of surgical departments will be an organizational challenge [7]. Critics point to the still limited prevalence of robot-assisted systems (and digital simulators) and the corresponding lack of progress in the use of minimally invasive technologies [20]. The evaluation of the results of the Delphi process shows that the experts largely agreed with this assessment. The introduction of such a curriculum would be an important contribution to improving the quality of training and ensuring that medical staff have the necessary knowledge and skills. The unanimously positive attitude towards improving patient safety is an indication of the overarching objective, which is to advance the quality of surgical care. The clear support for creating a joint basic training program as a basis for future specialization corresponds to the general international trend. The creation of such a curriculum would have the advantage that its implementation would be less dependent on industry and that it would be regularly evaluated, although such a curriculum cannot completely replace manufacturer-specific training. Similar to international proposals, the evaluation by various target groups showed how important it is to make training available in different stages of a surgical career [24]. There should be a special focus on providing training for physicians working towards their specialist qualification and training in MIS should start early. In the USA, learning the fundamentals of laparoscopic surgery (FLS) is obligatory to pass the Board Examination of the American College of Surgeons [25]. The Delphi process revealed a consensus that the curriculum should be an obligatory part of advanced specialist training. The evaluation of components of the GeRMIQ demonstrated the multifaceted nature of surgical training. The unanimous support of a curriculum which would consist of different stages and include objective assessment criteria at different stages underlines the importance of a structured transparent assessment of learners' progress by evaluating their acquired competencies. The current global trend towards integrating digital teaching methods into medical training focuses on including e-learning an an obligatory basic component of training. In view of the current discussion about flexible working times, the compatibility of family and a career, parental leave, and the problems of combining a scientific carer with clinical surgical training, e-learning and non-patient-based simulations offer distinct advantages. The experts supported continuous monitoring and updating of the curriculum, indicating an awareness of the rapid progress of technological developments. The unanimous consensus with regards to the introduction of a points-based system for accreditation corresponded to international recommendations on establishing transparent assessment systems. It was generally agreed that a panel of experts and an examination board should be set up to ensure the continued quality and topicality of the curriculum. The assessment of the proposed theoretical contents of the curriculum clearly showed the multidimensional nature of MIS and RAS. The general consensus was that theoretical training should include legal aspects, basic ethical principles, and information on current technologies. When the experts turned their attention to the organization of e-learning, they were agreed about the need to ensure that these programs would be accessible and have adequate financing. The unanimous consensus that e-learning should be available free of charge and that e-learning should be integrated in existing teaching platforms corresponds to international attempts to facilitate access to medical education [26]. This would permit the seamless integration of digital teaching methods into established educational environments. When the ex-

perts were asked about practical aspects of training, the central importance of hands-on training and the need for a structured assessment of this training was evident. The consensus was that training should include two-handed movements, guiding the camera, and other practical aspects, in line with international recommendations on the simulation of surgical procedures [27].

Digital assessment methods including VBA (video-based assessment) are becoming increasingly important in surgical training [28], and this was evident by the clear position and final unanimous consensus of the experts. The issues associated with assessing practical skills and integrating non-technical skills reflect the comprehensive nature of surgical competencies. The consensus on video-based assessments and the focus on the need to perform representative surgical procedures was in line with international trends for the digital assessment of surgical skills.

The study on the development of a national curriculum for minimally invasive and robot-assisted surgery in Germany using a Delphi process has some methodological limitations which could limit its informative value. Firstly, the choice and limited number of participating national experts could have limited the range of perspectives and led to bias, which would potentially limit the transferability of the results to other countries or other medical specialties. Secondly, despite the comprehensive list of questions, relevant external factors such as the need to adapt to hospital reforms and the fact that the healthcare system is running close to full capacity due to the rise in the number of inner-European conflicts could not be taken fully into consideration. These potential gaps indicate the necessity of regularly review and adapting the curriculum to ensure that it remains relevant and effective. Another important limitation is that the practical implementation of the curriculum was not addressed, which leaves such issues as the availability of resources, the acceptance of the changes by the larger surgical community, and the long-term impacts on surgical training and patient care open. These limitations demonstrate the need for continued research and regular amendments of the curriculum to ensure that it remains relevant and effective in a dynamic medical field.

Conclusion

Given the upcoming far-reaching changes in the healthcare sector, especially those caused by digitalization, demographic change, structural change and limited financial resources, the results of this Delphi process highlight the need for a clearly structured organization of advanced surgical training in MIS and RAS. The survey clearly demonstrates the urgent need for a national curriculum which will not only facilitate further training but also establish clear structures for such training. Consensus-based standardized training guidelines have many advantages with regards to patient safety, technological progress, and the comparability and quality of training. An established curriculum based on theory, dry lab training, and clinical assessment (▶ **Fig. 2**) will make the effective implementation of established procedures possible and promote the use of modern technologies which can improve the safety and effectiveness of surgical procedures. The Delphi process also highlighted the importance of a structured curriculum as a highly attractive factor for surgical trainees. This will be essential to attract qualified young talent in the field of surgery and guarantee the long-term quality and sustainability of surgical care.

Conflict of Interest

The authors declare that they have no conflict of interest.

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