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Training and qualification in gynecological minimal access surgery: A systematic review



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A B S T R A C T

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Minimally invasive surgery demands specific endoscopic psychomotor skills that are usually acquired outside the operating theatre. We present the results of a systematic analysis to identify how simulation is used during training and qualification in minimal access surgery to improve gynecologist's surgical skills. We found that despite the availability of simulation tools along with methods for training and testing specific endoscopic psychomotor and technical skills, there is no clear evidence of the superiority of one tool or method over the others in skill acquisition. However, prospective studies show that well-guided training courses

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combined with different trainers and methods improve significantly surgeon's laparoscopic skills and suturing ability, which are unforgettable over time. However, this proficiency could deteriorate over time when it is solely learned and executed on simulation trainers. Structured curricula including theory, simulation, and live-surgery seem to be the best option for trainees. More research in this field is needed.

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Introduction

Minimally invasive surgery (MIS) demands specific endoscopic psychomotor skills that are usually acquired during a critical training phase outside the operating theatre [1]. Simulation allows surgeons to improve their skills and proficiency in endoscopic surgery, which is later reflected in more sophisticated surgical performance, patient safety, and surgical outcomes [2,3]. Worldwide, continuous medical education, professional development, and simulation centers are available that offer programs in different degrees of surgical competence including subspecialty training and fellowships for advanced laparoscopic procedures. Furthermore, hospitals, health insurance companies, national health systems, and health care authorities demand certified surgeons to avoid medico-legal litigations and the waste of resources when not properly trained surgeons perform endoscopic procedures [2]. Proficiency-based training is aimed to offer trainees a standardized experience in a safe environment for practice, error, assessment, and feedback [2,4,5].

Despite the availability of simulation tools along with methods for training and testing specific endoscopic psychomotor and technical skills, there is no clear evidence of the superiority of one tool or method over the others in skill acquisition [1,5,6]. Furthermore, there is some controversy about how much time in a simulation environment is required to gain most benefits out of a proficiency-based training program, whether mandatory or protected practice, distributed or deliberate training [2,5,6]. Therefore, we conducted this systematic qualitative analysis of studies to identify how simulation is used during training and qualification in minimal access surgery to improve gynecologist's surgical skills. Questions addressed were as follows: which training methods are used, duration of fellowships, which skills should be reached, which evaluation methods are used and criteria to certify gynecological surgeons as laparoscopist?

Method

This review followed the PRISMA Statement for Systematic Reviews and Meta-analyses [7]. Full electronic search was performed in PubMed for studies published from June 2008 to June 2018, in German and English. Additional milestone articles were included if they were older than 10 years and were cited more than 5 times in different meta-analyses or review articles. The literature search was performed in July 2018 by topic combining Medical Subject Headings (MeSH) "education; gynecology, laparoscopy, fellowships and scholarships; teaching." MIS training was used as non-MeSH term.

Articles were screened by two of the authors independently. A third author made an independent decision, when the authors could not agree whether to include an article. During the first round, articles were excluded based on their title and duplicates were removed. During the second round, the remaining articles were excluded based on their abstract. Articles were included based on the following criteria: articles should be no older than 10 years or "Milestone Articles"; should be focused on laparoscopic gynecology; programs should include steps, modules, levels or have some sort of succession; programs should include simulation, e-learning, on animal- or cadaver training, or on-hands training; and programs should have specific endpoints. Exclusion criteria were as follows: workshops with duration below 3 days, disciplines other than gynecology, languages other than

English or German, programs without outlined structure or minimally invasive endpoint, and robotic surgery. No medical ethical committee approval was needed.

In the second phase, the identified articles were categorized according to study design as showed in the abstract into: prospective, retrospective, comparative, single-cohort, cross-sectional study, as well review and meta-analysis. In the third phase, a critical qualitative analysis of screened full-texts articles was performed according to addressed questions. The following information was extracted from all articles: study design, duration of intervention, training methods, primary outcomes, secondary outcomes, and conclusion.

Results

A total of 451 records were identified through database searching; five additional records were identified through other sources. After screening, 25 full-text articles were included in the present review (Fig. 1). Fourteen were prospective, single-cohort or case-control studies, four of them were randomized, six were retrospective studies, three were reviews, and two were surveys. The study populations ranged from 28 to 135 participants.

Duration of programs

The duration of fellowship and training programs varied from six days to one year. Seven of the included studies did not describe the exact duration of their training program. The methods used for skill training included theoretical lectures, training on low-fidelity (box trainers) and high-fidelity trainers (virtual reality (VR) laparoscopic simulators, VR), animal model training, mentor feedback, and live surgery [8–12].

Two training programs had a complete duration of one year [13,14]. Janssens et al. [13] reported a 12 months lasting laparoscopic training curriculum that included four hours training per fortnight, from which two hours were directly supervised, while Connor [14] described unlimited access to the VR simulator for one year. Another study from Burden et al. [15] also described 24-h access to the VR simulator, but the total duration of the training program lasted half of the time.

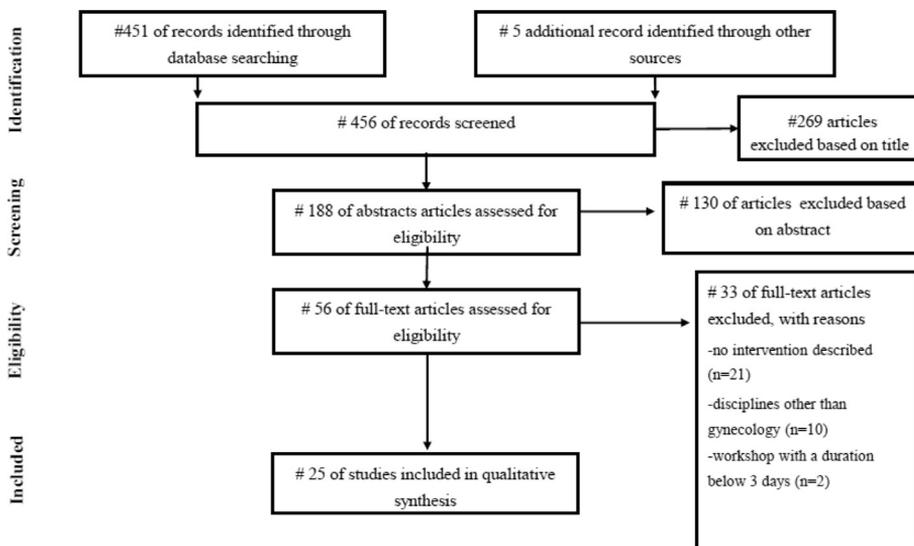


Fig. 1. Identification and selection of studies according to PRISMA [7].

Free access to a surgical skills laboratory was possible in a seven-week curriculum, conducted by Shore et al. [16]. The curriculum was completed with one hour theoretical lectures weekly and two hours per week practical sessions. Kirby et al. [17] evaluated a simulator-based laparoscopic training program with duration of three months and a requested practice time of four hours per month, but the access was also free. Two studies described durations of about four and two weeks, but there was no additional information about practice time within this period [18,19]. Molinas et al. [20] reported a program with 60 residents/specialists in gynecology without previous experience in laparoscopic surgery. The duration of the program lasted four weeks, with one-two hours daily training sessions, two-three times a week. A prospective study with randomized trainees lasted one week, and the time for training sessions was not described [21]. The shortest training program was about six days but separated into two-to three-day modules conducted two months apart. Theoretical sessions had a complete duration of 18 h, and practical training was conducted for 35 h [22].

Skills and training methods

Seven of the 25 included studies used high-fidelity VR laparoscopic simulators such as LapSim[®] VR simulator (Surgical Science, Gothenburg, Sweden) [10,15,21], LAP Mentor[®] VR simulator (Simbionix, Israel) [13,14] or MIST-VR (Minimally Invasive Surgical Trainer-Virtual Reality; Mentice AB, Gothenburg, Sweden) [8]. The skill training by low-fidelity trainers, such as video-or box-trainers, was implemented in six of the included studies [9,12,17,18,22]. Two studies used both box-trainer and VR laparoscopic simulator for skill training [13,16]. The following basic skills were frequently taught on low-fidelity trainers: peg transfer, cutting and grasping, curved lines, circle cutting, extracorporeal and intracorporeal knots, and laparoscopic suturing. High-fidelity trainers were able to teach specific gynecological skills such as salpingectomy or tubal occlusion.

Moore et al. [8] conducted a study to evaluate whether performance on the MIST-VR simulation trainer reflects laparoscopic experience among medical students, gynecology residents, and attending physicians. MIST-VR simulation trainer is based on abstracted graphics, and the 26 participants had to perform and repeat a “manipulative diathermy” task. The primary outcome measure was the number of task repetitions to reach the minimal proficiency level. Here, simulator training scores of attending physicians with operating room experience were worse than those of medical students ($p < 0.01$).

A prospective randomized trial [21] with 28 residents in obstetrics and gynecology compared a control group with standard training, a second group with training in the LapSimGyn[®] VR simulator and a third group with VR simulator training plus structured mentorship during subsequent laparoscopies. The simulator training tasks contained the basic skills “cutting,” “clip applying,” “lifting and grasping,” as well as the specific skills “tubal occlusion” and “salpingectomy.” The participants were tested for nontechnical skills, such as visuospatial abilities, self-efficacy, and flow. Subsequent to simulator training, all groups had to perform three laparoscopic tubal occlusions, which were video-recorded. The surgical performance was measured as the duration of operation. The laparoscopic performance was improved after proficiency-based training, not only measured by duration of surgery but also by self-efficacy scores and flow scores.

Basic skills and specific gynecological skills with a salpingectomy at the end of practice were also included in a retrospective study by Vedel et al. [10]; here, the residents were instructed by either student facilitators or a resident facilitator. The final examination consisted of performing an upgraded salpingectomy module. The student-facilitated group required significantly fewer attempts than the resident-facilitated group (median 12 vs. 28 attempts, $p < 0.003$), suggesting that students can act as facilitators for trainers practice on a laparoscopic VR simulators.

Burden et al. [15] and Shore et al. [16] reported the final performance of gynecology trainees from postgraduation year 1 and 2 (PGY1/2) by using the laparoscopic VR simulation (LapSim[®] VR trainer). Burden conducted a study with nine gynecology trainees, who were scheduled to perform a pre-validated structured program on a laparoscopic VR simulator and had to answer two semistructured interviews. The program had ten modules, from which nine were basic skills and one was a salpingectomy as a specific skill. The trainees had 24-h access to the VR simulator for six months and the possibility to request one-to-one supervision <https://paperpile.com/c/pXG9aT/jkit>. No participant

completed the self-directed laparoscopic training program, but reasons were not elucidated; however, subjective surgical skills improvement was reported by trainees.

In the study from Shore, 27 gynecology residents received either conventional training or an evidence-based laparoscopy curriculum, which took place three-hour sessions weekly over a period of seven weeks. Next to VR simulation training, the participants received cognitive training (lectures, self-directed readings, and video-based learning), box-trainer technical skills and non-technical skills. The VR simulator curriculum was proficiency-based and contained the basic tasks “camera navigation,” “instrument navigation,” “coordination,” “grasping,” “lifting and grasping,” and “cutting.” At the end of the curriculum, the participants performed a video-recorded laparoscopic right salpingectomy and intracorporeal knot tying of the left round ligament or proximal end of fallopian tube on a human patient. The residents who followed the evidence-based laparoscopy curriculum showed higher levels of technical proficiency during laparoscopic salpingectomy ($p = 0.043$), better procedure-specific knowledge ($p = 0.001$), and better nontechnical aspects of performance ($p = 0.019$).

Luursema et al. [23] reported another high-fidelity laparoscopic simulator based evaluation program with the LapSim[®] VR for gynecology and surgery residents from PGY-0 to PGY-5, but no specific gynecological skills were practiced. The one-on-one supervised and 50-min lasting trainings consisted of a briefing, a pre- and post-test, a main-practice part and a debriefing.

Both low- and high-fidelity trainers were also used in another training program for residents that included a one-year curriculum and a survey about the curriculum at the end [13]. The training was part-time supervised by consultants and included cognitive procedures, such as skills and procedure videos, and psychomotor basic skills, as well as specific gynecological skills on the LapMentor[®] VR simulator. The authors reported that training improved their simulated performance, reduced operative time by 12% ($p = 0.01$), with a total path length of left instruments ($p = 0.04$). Participants were satisfied with their achievements and quality of the program.

A randomized controlled study by Kroft et al. [11] determined whether preoperative practice is helpful to PGY 2 to 6 gynecology residents for following surgery. The participants did a baseline surgical proficiency testing on study entry. They were stratified into groups of skill levels and had either preoperative practice with feedback, preoperative practice alone, or feedback alone. The practice before surgery consisted of 15 min of preparation, doing a salpingectomy on the LapSim[®] VR simulator, before performing a laparoscopic salpingectomy supervised by a staff surgeon in the operation room. This study showed that surgical preoperative practice combined with instructor feedback did not improve the operative performance compared to either preoperative practice alone or feedback alone.

One study by Connor et al. [14] tested the effect of repetition in a basic high-fidelity laparoscopic training exercise. Thirty-three gynecology residents repeated the performance of a standardized peg transfer basic exercise during a 12-month period (mean 16.2 times per resident in a year) and time for each exercise was measured. The results observed a significant correlation with the number of completed exercises and decreased time for each repetition (mean 2.28 s, $p < 0.001$), especially in the first nine completed exercises.

Two studies used pelvic box trainers. Participants in the study of Modaffari et al. [19] practiced basic skills and showed a significant improvement in knowledge of electrosurgery and safe laparoscopic setup. Molinas et al. [20] evaluated the effect of pre-training in hand-eye coordination upon the learning curve of laparoscopic intra-corporeal knot tying, based on the Laparoscopic Skills Training and Testing (LASTT) model, developed by The European Academy of Gynecological Surgery. They observed a wide range of differences in the evaluated skills at the beginning of the course that disappeared after 30 repetitions of the tasks.

Training with animal models was reported in two studies. Botchorishvili et al. [22] performed a laparoscopic nephrectomy in a live porcine model for evaluation. The participants from Botchorishvili observed a significant improvement in time and technical scores for laparoscopic suturing and porcine nephrectomy ($p < 0.0001$), but after two months, there was no improvement in suturing time and technical scores anymore. Moreover, Corona et al. [24] used a laparoscopic mouse model to evaluate the impact of surgeon training on adhesion formation. Each of the five trainees performed 80 interventions to induce adhesion formations through bipolar lesions. A significant difference was observed in experienced and non-experienced surgeons ($p < 0.05$) in regard to duration of surgery and adhesion formation from the beginning to the end of the training, with better scores at the end of the

training for both groups. Further, experienced surgeons required ten procedures to reach the plateau and the gap between groups was shorter at the end.

Residents in PGY 2 to 4 from a study by Urwitz-Lane et al. [9] practiced four basic skills according to the objective structured assessment of technical skills (OSATS) for obstetrics and gynecology [25], a validated objective assessment tool of surgical skills, which consists of an operation-specific checklist and a global rating scale [9,12,16,21,22]. The global rating scale is a method of evaluation, which includes the following seven evaluation items scored on a 5-point Likert scale: respect for tissue, time and motion, instrument handling, knowledge of instruments, flow of operation, use of assistants, and knowledge of specific procedures. The more experienced residents performed significantly faster the peg transfer drill ($p < 0.01$) than those with less experience, but there were no differences between experience and performance time on other basic skills.

Participants in a study by Rindos et al. [18] were randomized to receive a standard curriculum or a standard curriculum plus weekly coaching meetings with an expert in laparoscopic surgery. The trainees were either junior (PGY1/2) - or senior (PGY 3/4) residents and were video-recorded performing a laparoscopic suturing task with an extracorporeal knot in a vaginal cuff model. Residents from both control group and intervention group showed improvement in their simulation laparoscopic suturing, but the improvement was especially in junior residents when compared to senior residents. The coached junior residents had a significant improvement ($p < 0.005$) between weeks 1 and 2 when compared to not-coached junior residents.

A randomized trial by Gala et al. [12] evaluated the performance of a laparoscopic bilateral salpingectomy by residents who either had traditional teaching without simulation or faculty-directed sessions in a simulation laboratory. The proficiency-based training sessions included basic skills according to the fundamentals of laparoscopic surgery (FLS), which are based on McGill Inanimate System for Training and Evaluation of Laparoscopic Skills (MISTELS) program [26,27]. Training tasks included 56 residents who received simulation training. They had the greatest levels of improvement, measured by higher OSATS scores in the operating room (27.5 vs. 30.0, $p < 0.03$), in competence on the simulated tasks (96.2% vs. 61.1%, $p < 0.01$), and in higher normalized simulation scores (378 ± 54 vs. 264 ± 86 , $p < 0.01$).

Kirby et al. [17] conducted a study with box trainer laparoscopic training using Simulab Lap-Trainer[®] and used additionally didactic lectures, self-paced learning modules and three pig laboratory sessions. The curriculum included basic skills such as suturing, peg transfer, or intracorporeal and extracorporeal knots. When compared to baseline evaluation, the evaluation after three months showed significant improvement in average summary time for all tasks (64 min at baseline compared to 36 min at three-month evaluation, $p < 0.001$).

Evaluation methods

Regarding the evaluation methods and criteria to certify gynecological surgeons, five studies used OSATS. Three of these studies [11,16,21] used modified OSATS scores for gynecology, the objective structured assessment of laparoscopic salpingectomy (OSA-LS) to evaluate the trainees during performance of a live surgery [28]. Participants from Shore et al. were additionally evaluated for perioperative intracorporeal knot tying by means of the FLS score. During this evaluation, the learned tasks are assessed in terms of cut-off times (efficiency and precision). Rindos [18] used the Global Operative Assessment of Laparoscopic Skills (GOALS) score to assess proficiency in depth perception, bimanual dexterity, efficiency, tissue handling, and autonomy [29]. Additional proficiency metrics of needle handling, knot tying, and vaginal mucosa incorporation were assessed by means of the GOALS + vaginal cuff metrics. The European Academy of Gynaecological Surgery used the efficiency of suturing training and testing (SUTT) model by laparoscopy to evaluate the suturing skill acquisition at the beginning and at the end of a teaching course with 25 trainee gynecologists, which had three different experience levels in laparoscopy (minor, intermediate, and major) [30]. SUTT included four skills: both hands stitching and continuous suturing; right hand stitching and intracorporeal knotting; left-hand stitching and intracorporeal knotting; dominant hand stitching, tissue approximation and intracorporeal knotting. The time needed to perform the exercises was recorded for each trainee, and group and statistical analysis was used to note the differences. Authors reported that all trainees achieved significant improvement in suturing time ($p < 0.005$) as measured before and after completion of the training. Similar significantly improved

suturing time differences ($p < 0.005$) were noted among the groups of trainees with different laparoscopic experience. All aforementioned evaluation methods report that well-guided training courses improve significantly surgeon's laparoscopic suturing ability.

VR laparoscopic trainers are also used to capture simple motion analysis parameters for assessment, such as path length, left- and right-hand motion, and time to complete tasks. Almost all of the programs that used VR laparoscopic trainers reported time to task completion as a main outcome [10,13,14,17,23]. In contrast, Moore [8] used the number of task repetitions to reach minimal proficiency for evaluation. Luursema [23] scored next to time to completion, left- and right-hand motion, as well as damage control in basic skills. In this study, the proficiency of basic skills was evaluated by means of Heinrich et al. [31] and van Dongen et al. [32] expert performance scoring methods for VR simulator training. The group using the Heinrichs expert values graduated on an average of 1.5 fewer sessions than the group using the van Dongen.

In the study by Janssens [13], trainees performed a simulated bilateral salpingo-oophorectomy to assess their time to task completion, total path length for left and right instruments, injuries to blood vessels or vital structures, bleeding incidents, and unsafe use of electrosurgical devices. Additionally, operating time for a live adnexal surgery after simulation training was measured. There was no significant difference in time to complete the procedure before simulator training vs. after simulator training in live-surgery (mean difference 11 min, $p = 0.28$).

Discussion

Specific psychomotor skills for MIS-like camera navigation, hand-eye coordination, and bi-manual coordination enable surgeons to visually focus on a 2D screen while performing counterintuitive movements for manipulating instruments during surgery. Additional technical skills required by modern surgeons are the introduction of MIS instruments into the abdomen or organs, organ manipulation, tissue dissection, use of MIS instruments with 30 or 45 degree optics, suturing, and the administration of diagnostic or therapeutic substances into abdomen or organs.

Available evidence shows that laparoscopic skills could be acquired through practice in animals, cadavers, box trainers and VR simulators, as well as hands-on courses, irrespectively of the initial level of trainee's experience. To reach this goal, each program should be designed specifically for its audience, such as medical students [33], residents, and surgeons. Five prospective controlled studies report that these lab-acquired skills have a positive effect on the MIS learning curve and transfer favorably to regular practice in the clinical setting, mainly after proficiency-based training [13,15,16,19,21]. Proficiency-based training has also demonstrated that learned basic skills, such as hand-eye coordination and laparoscopic intracorporeal knot tying, could be retained over time even if surgeons do not perform laparoscopic surgery up to two years [1]. In contrast, Botchorishvili reported that right-hand coordination could deteriorate after a short period of time [22]. Curricula that include theory, mentoring, preoperative basic, and advanced skills tasks on low- and high-fidelity trainers show significant improvement of the operative performance. However, there is a lack of evidence of a superiority of a specific training program or evaluation method due to the diversity of training programs in terms of duration, tasks, facilities, mentoring, and availability.

The importance of the experienced training benefits has been also evaluated in several surveys between residents of general surgery, gynecology, and urology in both Canada and Europa [5,6]. Results show that attending a laparoscopic simulation course in a dedicated skills lab had a beneficial impact on the surgical performance of most responders. Additionally, more than half of those surveyed agreed that proficiency-based training should be mandatory before facing the operating room [15,19,34,35]. Despite this, almost all of the participants reported to be unsatisfied with the training workshops because the courses were poorly designed, were offered infrequently (only once a year), were not organized in a manner that facilitated retention of skills learned (with training sessions lasting more than four hours making it difficult to effectively retain course material), or were lacking a structured or an objective evaluation of the acquired psychomotor skills [5]. Beside these difficulties, training resources are used much less frequently when participants have continuous access but no structured sessions, as clinical duties seem to overcome the motivation of trainees [15]. Respondents also

suggested that more structured laparoscopic training programs should be offered to reach the skills required for high-complexity laparoscopic surgery [35].

In an attempt to counteract the mentioned problems, the Gynaecological Endoscopic Surgical Education and Assessment (GESEA) program offers a structured approach and implements two separated stages in its learning strategy [36]. In the first stage, a skill certificate on theoretical knowledge and specific practical psychomotor skills is acquired through a high-stake examination without restriction in time to accomplish the various tasks; in the second stage, a clinical program is completed to achieve surgical competence and receive the corresponding diploma. Three diplomas can be awarded: (a) the Bachelor in Endoscopy, (b) the Minimally Invasive Gynecological Surgery (MIGS), and (c) the Master level. The Master level is sub-divided into two separate diplomas: the Master in Laparoscopic Pelvic Surgery and the Master in Hysteroscopy. Through these diplomas, the GESEA program is aimed to help institutions to have certified surgeons to maximize patients safety and operation time and avoid potential malpractice suits [2].

Practice points

- On simulation trainers, laparoscopic handling and adoption of specific tasks have a positive influence on the learning curve of required skills for MIS, independently of the previous level of experience in laparoscopic surgery.
- Incorporation of simulation trainers and minimally invasive training in a specialist registrar should be done in a structured curriculum where training sessions are part of the work schedule.
- Training should be designed specifically for its audience and should be conducted under constant objective evaluation of the acquired skills in combination with independent feedback from experienced laparoscopic surgeons.

Research agenda

More research about how simulator-based training improves laparoscopic skills in gynecological surgeons and the transferability between acquisition of simulated laparoscopic tasks and general laparoscopic proficiency is necessary, as it is postulated in many studies without a conclusive proof.

Conclusion

There is no conclusive evidence reporting how simulation is used to improve gynecologist's surgical skills in MIS and how much the adoption of specific laparoscopic tasks leads to greater general laparoscopic proficiency. Prospective studies show that even a short well-guided training course model improves significantly surgeon's laparoscopic suturing ability, but this proficiency could deteriorate over time when is solely learned and executed on simulation trainers. Therefore, a combination of structured time on simulation trainers together with immediate feedback from experienced laparoscopic surgeons can counter deterioration of acquired skills. Structured curricula including theory, simulation, and live-surgery seem to be the best option for trainees, but more research in this field is needed.

Conflicts of interest

The authors have no conflicts of interest. No external funding was involved during this analysis.

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