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REVIEW ARTICLE

A review of robotic surgical training: establishing a curriculum and credentialing process in ophthalmology

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Abstract

Ophthalmic surgery requires a highly dexterous and precise surgical approach to work within the small confines of the eye, and the use of robotics offers numerous potential advantages to current surgical techniques. However, there is a lag in the development of a comprehensive training and credentialing system for robotic eye surgery, and certification of robotic skills proficiency relies heavily on industry leadership. We conducted a literature review on the curricular elements of established robotics training programs as well as privileging guidelines from various institutions to outline key components in training and credentialing robotic surgeons for ophthalmic surgeries. Based on our literature review and informal discussions between the authors and other robotic ophthalmic experts, we recommend that the overall training framework for robotic ophthalmic trainees proceeds in a stepwise, competency-based manner from didactic learning, to simulation exercises, to finally operative experiences. Nontechnical skills such as device troubleshooting and interprofessional teamwork should also be formally taught and evaluated. In addition, we have developed an assessment tool based on validated global rating scales for surgical skills that may be used to monitor the progress of trainees. Finally, we propose a graduating model for granting privileges to robotic surgeons. Further work will need to be undertaken to assess the feasibility, efficacy and integrity of the training curriculum and credentialing practices for robotic ophthalmic surgery.

Introduction

Ophthalmic microsurgery requires a highly dexterous, steady, and precise surgical approach to work within the small confines of the eye [1]. Ocular tissues such as the retina do not regenerate, making it imperative for surgeons to avoid preventable injuries [2]. The use of robotics in eye surgery offers numerous potential advantages to current surgical techniques, including increased precision and maneuverability, tremor reduction, better ergonomics, and simultaneous utilization of multiple surgical instruments and cameras [3, 4]. Robotic eye surgery was first described in 1989 [5], and since then, multiple ophthalmic robotic procedures have been developed and performed either experimentally or in humans, including corneal transplantation [6], penetrating keratoplasty [7, 8], cataract extraction [9, 10], and pars plana vitrectomy [11, 12].

Surgical subspecialties such as gynecology, urology, and general surgery have already integrated robotics into their surgical approach, and formal training programs to support this have been developed [13–23]. In contrast, robotic ophthalmic surgery still remains in its infancy with extremely limited implementation and no formal training curricula—despite the fact that robotic eye surgery has distinctly different technical and nontechnical elements compared to manual ophthalmic surgery [24, 25]. A competency-based robotics training pathway is needed to ensure the safe and appropriate use of this new technology: reducing the risks of preventable complications, responding to instrument or system malfunctions, assisting with hospital credentialing, and generally mitigating the medico-legal aspects of inadequate surgical training [26].

The goals of this paper are to (1) review the curricular elements of established training programs in robotic surgery, (2) outline a training and credentialing framework for robotic eye surgery based on the experiences and suggested guidelines in existing robotic surgical training programs,

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and (3) identify commonalities and distinctive features of robotic ophthalmic surgery as they relate to training and credentialing.

Methods

An extensive literature search using MEDLINE, EMBASE, Web of Science, and Cumulative Index to Nursing and Allied Health Literature databases, as well as a focused internet search, was performed for all articles relevant to the training curriculum and credentialing process of robotic surgery. All articles from inception to March 2020 were included and no language restrictions were applied. Specific search strategies were used for each database and were tested by an academic librarian. The keywords and MeSH terms used to identify the articles were as follows: “robotic surgery training”, “curriculum,” “medical education”, “competency”, “credentialing”, and “privileging.” Since this study did not involve human subjects, institutional review board approval was not required.

A total of 2807 articles were retrieved from the literature search, and after removing the duplicates (1267), there were 1540 unique citations. Screening of the titles and abstracts to identify eligible studies based on a set of pre-determined inclusion criteria was conducted by one author (BH) and resulted in the exclusion of 1402 articles. Studies were excluded if they were not published in English, if they were not a journal publication, or if they did not have a focus on education, training, curriculum, or credentialing aspects of robotic surgery. The remaining 138 studies underwent a full text screening by two authors (BH and MS). This second round of screening excluded studies that utilized surveys, or if they only focused on a specific surgical procedure or technique. After the exclusion of 94 full text articles, a final total of 44 studies were included and categorized into three main subjects: (1) curriculum framework, (2) training modalities (dry, virtual and wet lab simulations) and assessment, and (3) credentialing processes. Discrepancies were resolved by discussion with a third reviewer (ME). A flow diagram outlining the process of this literature search is shown in Fig. 1.

Results

In total, there were 10 papers on curriculum framework, 26 papers on training modalities and assessment, and 8 papers on credentialing processes. The studies on the overall curricular framework reported performance outcomes following implementation of a robotics surgical training program and included multiple surgical disciplines across

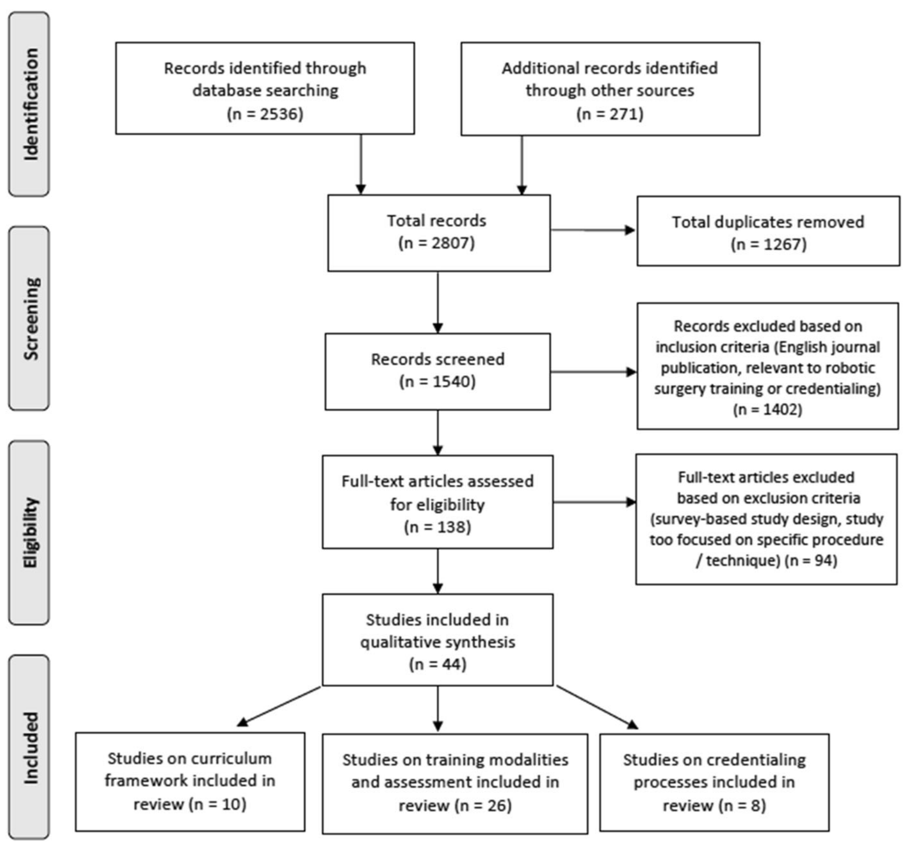

Fig. 1 PRISMA flow chart. Flow diagram of studies from the literature search that were included in this review.

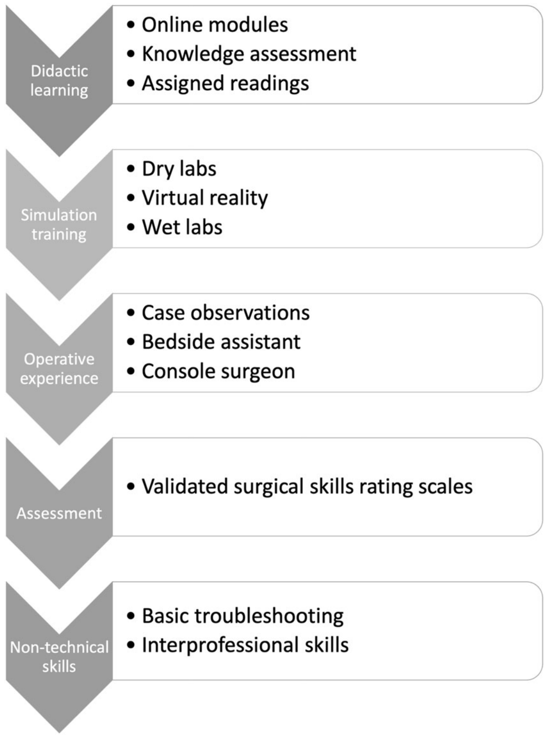

Fig. 2 Proposed curricular framework. The principle training framework should proceed in a stepwise, proficiency-based manner from didactic online lectures, to hands-on lab training, to gradual involvement in the operating room.

different academic training centers in Europe, Canada and the United States. [13–20, 22, 27] The principle training framework remained consistent in all ten of these papers, proceeding in a stepwise proficiency-based manner from didactic online lectures, to hands-on lab training, to finally gradual involvement in the operating room (Fig. 2). Of the eight papers that reported guidelines on their credentialing process, three of them were multidisciplinary and the other five were from general surgery, otolaryngology, gynecology, and thoracic surgery [28–35].

Training curriculum

Didactic learning

Based on our literature review, the da Vinci system (Intuitive Surgical Inc., Sunnyvale, CA, USA) is the most commonly studied robotics platform in the literature. Learning this system typically begins with building the foundational knowledge of robot technology, device functions, and system limitations [26]. Intuitive surgical provides free, interactive online modules to introduce the various components of its robotics platform [36], and each module has questions to assess learning and retention. Upon successful completion of all modules and an online knowledge assessment, a certificate of completion is provided. In addition to industry-provided online training modules, several training programs assign peer-reviewed articles that are to be discussed with the attending staff [13, 37].

Simulation training modalities

The next step in training typically incorporates knowledge application of robotic technology into a practical laboratory setting. Trainees usually participate in brief, in-person training sessions with industry representatives to familiarize themselves with the operation of the robotic consoles and to ensure proper and safe application of techniques [17]. There are three primary training environments that are most frequently used in robotic surgery: dry labs, virtual reality (VR) simulators and wet labs. In dry lab settings, individuals use inanimate models to acquaint themselves with the instruments and to develop dissecting and suturing techniques in a less immersive environment. The major limitation of this approach is the lack of an authentic environment and media that are representative of live or human tissue. VR simulators enable surgeons to practice techniques in a digital environment that more completely recreates entire surgical procedures. Compared to dry lab training, this is a more immersive experience and requires the trainee to practice surgical decision making, however, it still cannot replicate the feel and response of human tissue. Lastly, wet labs allow trainees to develop surgical skills on cadavers or live animal models, although the high costs associated with this training approach can be a limitation.

Studies have shown that individuals who train in a wet lab setting have higher minimal proficiency scores compared to those who train with VR or dry lab simulators [38]. In addition, the total training time for wet lab trainees to reach minimum proficiency was also significantly lower than dry lab training (116 min versus 561 min) [39]. For all three modalities, the most effective training approach was one that included numerous repetitions of a specified task that were independent to the training program duration) [40].

Operative experience

Most programs have trainees start with observing surgical cases in the operating theater and then progressing to a bedside assistant role, where procedural steps such as patient positioning and port placement, as well as physical and mechanical limitations of the robotic system are taught in the later stage [13, 19, 26, 41]. Once trainees advance to using the console, involvement is gradual, with the surgical case divided into achievable steps. Trainees are then allowed to perform increasingly more complex parts of the procedure at the discretion of the supervising surgeon as competency levels of more simple procedures are successfully attained [13, 19]. As dual console systems become more common, training will likely be enhanced as both the supervising surgeon and trainee are able to operate and interact collaboratively at the same time [42].

Assessment

In order to monitor trainee progress, competency benchmarks and a system for regular formal evaluation of proficiency need to be established. It is important to recognize that different individuals have different learning curves (i.e., the number of cases that need to be performed before there is an acceptable plateau of surgical performance parameters such as operating time, facility of tissue manipulation, complication rate, and conversion to manual techniques) [26]. As such, continuous bidirectional feedback during training is essential to help trainees identify their strengths and weaknesses, while also assisting trainers maintain an effective and supportive coaching and mentoring environment.

One clinical tool for assessing robotic surgical skills is the Global Evaluative Assessment of Robotic Skills (GEARS), which consists of six domains (depth perception, bimanual dexterity, efficiency, force sensitivity, autonomy, and robotic control) scored on a five-point Likert scale [43]. GEARS was created upon consultation with an expert panel of robotic surgeons and has been shown to be valid, reliable, and versatile in providing formative feedback to trainees in various training environments [44]. Alternatively, two other global rating scales that have also been validated for evaluating the skills of surgical trainees are the Global Operative Assessment of Laparoscopic Skills (GOALS) [45] and Objective Structured Assessment of Technical Skills (OSATS) [46]. Given the absence of any assessment tools specific for ophthalmic surgery, it is likely that one will need to be generated. One of our co-authors (MdS) has developed a modified grading scale (Table 1) based on GOALS and OSATS that can be used to evaluate ophthalmic robotic surgical skills and is currently analyzing its reliability and validity in assessing longitudinal performance in a clinical study.

Nontechnical skills

Although the training phases described above focus primarily on technical skills, nontechnical skills such as device troubleshooting, teamwork, and communication are equally as important in robotic surgery. In fact, one study has found 86% of adverse surgical events being unrelated to a

Table 1 Modified rating scale for assessment of operative performance.

Rating of operative performance (based on Reznick and Vassiliou)			
Assessed skill	Grading		
	1	2	3
Time and motion	Unnecessary moves	Efficient time and/or motion, with some unnecessary moves	Clear economy of movement with maximum efficiency
Instrument/robot handling	Repeated, tentative and/or awkward moves	Competent use of instruments but occasional stiffness and/or awkward moves	Fluid movement with instruments and no awkwardness
Knowledge of instrument/robotic procedure	Incorrect use of instruments; uncontrolled and/or unsafe movement with robot	Knows how to use instruments appropriately; some familiarity with robotics procedure	Confident use of instruments and knowledge of robotics procedure
Flow of procedure	Frequently pauses while operating and/or unsure of next steps	Demonstrates some forward planning with reasonable progression of procedure	Obvious advanced planning with effortless flow from one step to the next
Use of assistant/alternate steps	Consistently makes inappropriate use of assistant and/or alternate modules	Appropriate use of assistance and/or alternate modules most of the time	Strategic use of assistance/alternate steps to best advantage all the time
Risk mitigation	Inappropriate anticipation and/or unable to respond to simulated emergencies	Appropriate recognition of a simulated emergency but has some hesitancy in response	Appropriate recognition of a simulated emergency and use of appropriate modules
Autonomy	Unable to complete entire task, even with verbal guidance	Completes tasks safely with moderate guidance	Completes task independently without prompting
Force sensitivity	Aggressive movements, tears tissue, and/or injures structures	Occasional uncontrolled movements, but able to recognize and respond accordingly	Applies appropriate tension, no injury to tissues/structures

surgeon's technical ability [47], while another study suggests that 75% of negative surgical outcomes or delays from robotic surgeries are due to nontechnical complications such as electrical, system, or software failures [48]. Therefore, it is necessary that a robotics training curriculum include strategies for basic equipment troubleshooting and contingency planning (i.e., when to convert to an open approach) in the event that surgical devices become nonoperational.

As support staff and nursing personnel are key players in good surgical outcomes, team simulations to practice interprofessional teamwork and communication skills should be incorporated in the robotics surgical program. An aviation-style teamwork training program that emphasizes cooperation, problem-solving and situation awareness can help reduce technical errors and misunderstandings in the surgical theater [49]. In addition, the Non-Technical Skills for Surgeons and Oxford Nontechnical Skills Training Tools for the Surgical Team have been found to be effective for evaluating the nontechnical skills of the individual surgeon and the team, respectively [50]. All individuals assigned to robotic surgery should receive training and be assessed for their understanding of the robotic system and troubleshooting options. A pre and post-operative robotic checklist should be developed and adhered to so that device and site-specific operations are standardized and consistently performed [51]. A post-operative team debriefing to evaluate whether the robotic systemic performed as expected, and if there were deviations or modifications, should also be undertaken.

Credentialing structure

Surgical complications due to insufficient training and negligent credentialing can increase the risk of medicolegal consequences, and hospitals need to ensure an ethical and transparent model for privileging surgeons [52, 53]. Multiple institutions have developed their own training and credentialing parameters for robotic surgery, however there is no consensus yet on any standardized guidelines. Based on our review of different institutional policies (Table 2) [28–35], we propose the following stepwise algorithm of graduating privileges with continuous evaluation and monitoring of competency at each stage (Fig. 3). The highest minimum number of cases from the suggested guidelines was used in our model, although the minimum number of cases for progression of privileges may differ for ocular surgeries compared to non-eye procedures. It may also differ based on the complexity of the task or the level of automation in hybrid cases of robotic combined with nonrobotic surgeries.

The first level of surgical privileges is provisional: surgeons can perform robotic procedures under the direct supervision of a proctor. In order to be granted provisional privileges, surgeons need to have board certification, hold clinical privileges, and perform an appropriate annual volume of the non-robotic approach to the same procedure. For trainees who have completed a residency program with robotics training, a robotics case list with a minimum of 20 robotic cases, and the program director's attestation of competency are required. Non-residency-trained surgeons (i.e., those who are already practicing and who wish to obtain robotic privileges) are also required to complete an approved robotic surgery course that includes online modules and hands-on exposure, although the course can be abbreviated for a more streamlined approach.

Both residency-trained and non-residency-trained robotic surgeons should complete initial cases within the first 2 months after training to avoid degradation of surgical skills [30]. Those who have completed at least ten proctored cases and who have received a formal recommendation by the division or department chair would then be able to proceed to the independent privileges level, which allow surgeons to perform robotic procedures without proctor supervision [29, 32, 35]. Most programs require at least 20 cases per year with no absence of cases longer than two months and review of the first ten robotic cases to maintain independent privileges [30, 33–35]. A departmental quality assessment (QA)/quality improvement (QI) steering committee should be formed to review case logs and outcomes for the annual renewal of the independent privilege position.

Surgeons who have independent robotic privileges and who have completed an annual minimum of 50 robotic procedures with good outcomes may be considered for proctorship privilege and be responsible for proctoring other trainees. Hospitals should publish standards for surgical outcomes and trends should be followed to identify deviations from the normal [33, 34]. If a surgeon wishes to attempt more complex cases, at least 15 basic cases without complications should be performed and the first two advanced cases should be assisted by another surgeon with privileges to conduct advanced procedures [30]. It is also recommended that surgeons submit a request to the robotic steering committee (similar to an ethics committee review) prior to undertaking more challenging procedures or when contemplating a novel procedure [33]. In the latter scenario, it would be also reasonable to include an assessment from the manufacturer regarding the technical ability of the system to carry out the novel procedure as proposed.

As forms of automated surgery become incorporated into the mainstream, guidelines to support robotic ophthalmic surgery will need to be created and these minimal standards would need to be re-evaluated.

Table 2 Guidelines for credentialing from 8 institutions.

Authors	Year	Participants	Method	Surgical subspecialty	Residency requirements	Provisional privileges	Independent privileges	Proctorship
Erickson et al.	2012	15 hospitals	Survey	Gynecology	Industry-sponsored training Program director attestation letter Robotic case list Minimum number of 5 console cases during residency	Proctored cases after residency (number not specified)	Not specified	Not specified
Ballantyne et al.	2002	2 hospitals	Review of hospital instituted processes derived from SAGES guidelines	General surgery	Board certification Open privileges for same robotic procedure Completion of an accredited residency or FDA mandated training course	Proctoring of first 4–10 cases	Ongoing monitoring of robotic surgery outcomes	Not specified
Bhora et al.	2016	Institutional experience, informal discussion between robotic experts	Literature review	Thoracic surgery	Medical degree or equivalent Open/MIS for same robotic procedure Program director attestation letter Robotic case list Minimum number of 20 console cases during residency Completion of an accredited residency or FDA mandated training course Documentation of suitable number of open/MIS cases for same robotic procedure	Minimum 10 proctored cases	Minimum 10 non-proctored cases per year with good outcomes Ongoing monitoring by dept. QA/QI committee	Minimum 25 non-proctored robotic cases with good outcomes
Green et al.	2020	Application of principles and structure "Surgical Privileging and Credentialing: A Report of a Discussion and Study Group of the American Surgical Association"	Descriptive study	General surgery, gynecological oncology	Completion of an accredited residency or FDA mandated training course	Minimum 3 proctored cases	Minimum 20 cases over 12–24 months with no absence cases longer than 4 months Review of case outcomes by robotic steering committee in first 12 months or sooner if there are adverse events	Not specified
Estes et al.	2017	1 academic university medical center	Descriptive study of institution experience and processes on development and implementation of a robotics program	OBGYN, ENT, General Surgery, Thoracic surgery	Residency/ fellowship attestation letter Robotics case list Board certification Open privileges for same robotic procedure Robotic case list Minimum number of 20 console cases during residency	Minimum 2 proctored cases	Minimum 6 cases per year First 5 robotic cases should be reviewed Ongoing monitoring of competency and case volume requirements by dept. chair for renewing robotic privileges	Not specified
Lenihan et al.	2011	Multidisciplinary committee at 1 hospital	Report of credential program based on aviation model and	OBGYN, Urology, General surgery,	Completion of an accredited residency or	Minimum 3 proctored cases	Minimum 20–24 cases per year with at least 1 case	

Table 2 (continued)

Authors	Year	Participants	Method	Surgical subspecialty	Residency requirements	Provisional privileges	Independent privileges	Proctorship
			guidelines from survey and experienced robotic surgeons	Cardiology, Anesthesia, medical staff	FDA mandated training course	Initial cases should be done within 60 days after training	every 8 weeks First 5 cases should be reviewed 12–15 simple cases should be done before attempting advanced cases	Minimum of 40 non-proctored robotic cases
AAGL	2014	Advancing minimally invasive gynecology worldwide	Guidelines from current clinical evidence, expert opinion, and institutional experience	Gynecology	Board certification Open privileges for same robotic procedure Completion of an accredited residency or FDA mandated training course	Minimum 2 proctored cases Initial cases should be done within 2 months after training	Minimum 20 cases per year First 5 cases should be reviewed Minimum 15 successful basic cases without complications before attempting advanced cases	Minimum 50 non-proctored robotic cases Approved by robotics review committee and/or hospital board
Gross et al.	2016	14 training centers	Proposal of standardized guidelines, or "best practices, for ENT robotic surgeons	ENT	Completion of an accredited residency or FDA mandated training course	Minimum 2–10 proctored cases	Minimum 20 cases per year First 5–10 cases should be reviewed Minimum 15 successful basic cases without complications before attempting advanced cases Ongoing monitoring and minimum case volume	Minimum 20–40 non-proctored robotic cases

Fig. 3 Proposed credentialing model. A stepwise model for graduating privileges with continuous evaluation and monitoring of competency at each stage.

Ophthalmological considerations

Robotic ophthalmic training

Given that robotic eye surgeries impose particular surgical and engineering challenges that are different from other robotic procedures, the development of training curricula and credentialing structures should take into account the unique intricacies of ophthalmic procedures. Currently, the robotic ophthalmic devices that are most frequently employed are assistive devices for controlling intraocular instruments in vitreoretinal surgeries. Since non-robotic eye surgery still requires microscopes and digital imaging systems for surgical visualization, the transition to ophthalmic robotic surgery will require gaining facility with controlling a single intraocular instrument that is telemanipulated via a handpiece while sitting at the traditional surgical position at the head of the bed. As bimanual robotic systems are currently not available, the surgeon's other hand functions as it would in traditional surgery—typically holding a light pipe or a second instrument such as a pick or forceps. Under intraocular chandelier lighting, micromovements of the eye created by the instrument in the surgeon's hand are eliminated, the eye becomes more stable, and the surgeon can focus their entire attention on the task that requires the robotic system.

To date, the only approved surgical robotic system for ophthalmology is the CE Mark licensed Preceyes Surgical System (BV, Eindhoven, Netherlands), with which clinical intraocular surgical trials are already underway [54]. This device was designed to approximate the functionality and operational movements required of traditional intraocular forceps, pick, scissors, or sub-retinal needle. However, motion-scaling, a larger handpiece, activation buttons, and suspension of the controller above and adjacent to the surgical field are significant modifications from traditional instrument use—requiring new learning and adjustment of pre-existing techniques. In contrast to the da Vinci system, the Preceyes system has a remote center of motion that allows for robotic programming of tasks to perform. This necessitates the surgeon to master a series of sequential subroutines as each subroutine interaction will be specific to the task and to the level of scaling in relation to the required task. Proficient understanding of the robot will be crucial to comprehend the subroutines and mitigations.

Despite these differences, however, the similarities of the Preceyes Surgical System to traditional vitreoretinal instrument manipulation seem to make learning this robot efficiently achievable. In fact, one of the areas in vitreoretinal surgery where robotics has gained considerable traction alongside conventional manual techniques is macular membrane peeling [55]. There is evidence to suggest that retinal surgeons are able to learn internal limiting membrane peeling within the Eyesi (VRmagic, Mannheim, Germany) simulated vitreoretinal surgical environment after a very short period of training on the Preceyes robot [56]. Based on early simulator data from this study, an appropriately focused course with measurable technical performance endpoints would confirm that attending retinal surgeons have acquired a sufficient degree of proficiency and safety on a device prior to in-human use.

Training with the Preceyes Surgical System can occur using many different simulation options, including a plastic eye model for learning basic movements and cellophane mock-ups for practicing sub-retinal injections and membrane peeling [57]. Moreover, the Preceyes system is compatible with the Eyesi (VRmagic) surgical simulator and can also be easily used in formal wet lab training environments with pig eyes. In contrast to existing non-ocular surgical wet labs, a pig's eye model is both relatively inexpensive and somewhat representative of a human eye. At the time of writing, the Eyesi (VRmagic) robotics simulation module is not yet commercially available. As a result, one would expect training curricula in the absence of a simulated VR environment to follow the progression as discussed earlier in the paper from didactic to dry lab to wet lab. However, a VR simulation device would allow for the development and assessment of objective surgical metrics. In addition, because early cases with a robotics platform will likely involve a minority of the current retinal surgical workload, a simulator-based skills refresher course would need to be made available for surgeons who experience significant time intervals between robotic cases.

One of the challenges to integrating robotics into ophthalmology is ensuring an appropriate balance of benefits and costs. Specifically, robotics for ophthalmology need to demonstrate versatility in applicability for different surgeries, ability to enable novel therapies, and elimination of redundant personnel. At present, the increased precision of robotics for ophthalmic surgeries comes at the cost of increased surgical time [58]. With increasing surgical experience ideally enhanced by the use of simulators such as the Eyesi, improved surgical skills would lead to greater efficiencies. Similarly, as systems become more widely used in ophthalmic surgery, nursing and support staff will also become more proficient in the set-up and perioperative management of these cases.

Credentialing and privileging of robotic ophthalmic surgeons

Credentialing is the process of appointing a surgeon to medical staff at a healthcare facility and involves reviewing medical staff licensure, insurance, education, training, skills and experience. Privileging is the process of allowing surgeons to undertake specific procedures at certain facilities. Given the preliminary state of robotic ophthalmic surgery, few proficient surgeons, and the availability of only a single CE marked device, credentialing and privileging of new surgeons will likely be a challenge for administrators over the next number of years. As well, the Preceyes Surgical System and any new robotics platform for ophthalmic surgery will require significant training of not only the surgeon, but also support staff, nursing, biomedical engineers, and surgical assistants. It is our hope that documents such as this may give hospitals some understanding of what types of education and experience may be needed of surgeons and other team members prior to implementing a new surgical robotics ophthalmic program.

Conclusions

With its potential to enhance microsurgery, robotics will likely revolutionize ophthalmic surgery in the future. We have highlighted here an evidence-based roadmap of the essential components needed to build a robotics surgical skills curriculum and proposed a graduating model for granting robotic privileges. Several unique features to the training and credentialing of robotic surgeons for ophthalmic surgeries have also been identified. Further work will need to be undertaken to assess the feasibility, efficacy and integrity of training curriculum and credentialing practices for robotic ophthalmic surgery.

Author contributions DM: conceptualization, methodology, validation, writing—original draft, writing—review & editing, visualization, project administration, supervision. ME: methodology, project administration. MS: methodology, investigation, writing - review & editing. MdS: conceptualization, writing—review & editing. BH: conceptualization, methodology, validation, investigation, data curation, writing—original draft, writing—review & editing, visualization, project administration.

Compliance with ethical standards

Conflict of interest MdS is a co-founder, employee and patent holder of Preceyes BV. The author has no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript apart from those disclosed. None of the other authors report a conflict of interest.

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