35 Robotic Surgical Training: Imparting Necessary Skills to Future Urologic Surgeons

Tyler Luthringer, Kevin C. Zorn, and David M. Albala

35.1 Introduction

Over the last decade, training opportunities for aspiring surgeons have become increasingly limited. Advances in healthcare technology, the development of day-case surgery, and the setting of quality-assurance targets for informed patients have lowered resident exposure to patient-based surgery and created a new demand for alternative methods of surgical training [1]. Furthermore, restraints on the lengths of residency workweeks and the emphasis on operating room efficiency have mutually curtailed teaching time for surgeons-in-training [2]. Robotic surgery currently presents the greatest challenge for training programs and aspiring surgeons alike, for reasons of instrument cost and a lack of training alternatives outside of the operating suite. The field of urology has been a long-time leader in the application of robotic surgery, largely for the great advantages the interface offers within the tight confines of the human pelvis. Robotic-assisted radical prostatectomy (RARP) continues to be the most prevalently executed robotic procedure worldwide, with advantages offered to both surgeons and patients favoring rapid adoption. This multitude of advantages robotic-assisted (RA) surgery offers to patients—accelerated return to preoperative activity, shorter periods of hospitalization, decreased postoperative pain and dependence on analgesics, etc.—has fueled the rising popularity of minimally invasive procedures compared to alternatives [3–5]. Additionally, improvements of visual field, operative precision, and toll on fatigue have brought many surgeons to favor the RA approach. In 2011, it is estimated that over 80 % of all radical prostatectomies will be performed robotically. Despite this, the high expenditure and upkeep requirements make many hospitals and surgical urology practices reluctant to train inexperienced surgeons in the procedure due to a lengthy learning curve and the high surgical volume necessary to offset the cost of the technology [6]. As such, new and effective training modalities are dually necessary for patients and medical institutions alike.

In order to progress the surgical standard of care and meet today's rising expectations for improved patient outcomes, the technology for robotic surgical training must advance and simultaneously be made affordable for establishments of academic medicine. Although numerous training simulators for laparoscopic surgery are now used in medical

T. Luthringer • D.M. Albala, M.D. (✉)
Division of Urological Surgery, Associated Medical Professionals, Syracuse, NY, USA
e-mail: dalbala@ampofny.com

K.C. Zorn
University of Montreal Hospital Center (CHUM), 235 Rene Levesque East, Suite 301, Montreal, Quebec H2X1N8, Canada

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school electives and residency programs, the high cost of such devices limit the universal availability at training institutions. Of greater issue is that, despite growing interest, a well-accepted, validated robotic simulator has yet to make significant headway into the marketplace. By generating a more effective and efficient means of training robotic surgeons before their introduction into the operating room, the incurred costs associated with the large learning curve of the robotic surgery can be reduced, and resident training can become more affordable for teaching institutions. In addition, improvements in robotic training will promote trainee familiarization with both the device and surgical procedure prior to any patient-based instruction, promoting safety and improved outcomes. Innovative measures, however, must be taken by medical technology organizations and teaching hospitals to ensure that the next generation of surgeons has the means to uphold elevating healthcare standards. In addition, there is a great need for the establishment of a centralized credentialing agency, specific curricula for teaching robotic procedures to naïve students, and a means of competency evaluation prior to granting surgical privileges. The goal of this chapter is to present the need for, the current state of, and the future of robotic surgical training; while RARP and urologic residency will be emphasized, this discussion is extremely pertinent to all surgical disciplines.

35.2 Evolution of Robotic Surgical Training

While practice makes perfect, there is bound to be error during any surgeon's initial cases. Surgical residency programs have allowed for this over the course of a 5–6-year program to institute slow, supervised clinical training. Over time, the Halstedian model of "see one, do one, teach one" has been applied to progress trainee exposure in a stepwise manner, as well as implement new surgical technology into practice, allowing such innovation to continuously offer increasing patient and surgeon benefits. This teaching methodology will be valuable to aspiring urologists in the upcoming 5–10 years as a large volume of experienced robotic surgeons become available as mentors; however, there is an immediate need for an effective means to educate postgraduate urologists who lack formal robotic training. Currently, the majority of the United States' surgical robots (>1,200) are being used by low-volume, nonacademic urologists who lack fellowship training. In order to properly train the next generation of surgeons under the Halstedian model, it is important that future mentors themselves are skilled, experienced, and trained in robotic surgery. Nevertheless, the training of physicians does pose unique challenges, and the foremost among these pertain to ensuring the safety of the patient. Multiple training methods have been proposed including the use of mini-fellowships, simulators, and proctoring and preceptoring. Outside of urological training centers, the expansive application of robotic surgery has created the need for adequate education programs for aspiring and practicing surgeons across a number of medical fields. During the 4 years after the induction of robotic surgery into one medium-sized city's healthcare system, the number of RARP performed increased by a monthly factor of five while the number of open prostatectomies became nominal. This rapid expansion of the RARP was attributed to the numerous benefits the robotic system offers to both patients and surgeons, as well as a concerted effort to properly train the surgeons in the area [7]. Although the RARP was one of the first procedures to widely make use of this new technology, robotic surgery is not limited to the urologist. The far-reaching nature of this breakthrough device has proven applicable to many surgical fields, and the number of surgical subspecialties that are currently taking advantage of this technology has grown substantially in the last 5 years. The robot has implemented itself in the surgical practices of cardiothoracic, colorectal, and general surgery, as well as otolaryngology, nephrology, gynecology, and pediatrics [8–10]. As a young innovation, however, robotic surgery is very much in the developmental period and is still expanding into the healthcare market.

As the world of surgical technology continues to advance, measures must be taken to ensure that education keeps pace. As mentioned previously, surgical education for robotic surgeons is a crucial aspect of the progression of robotic surgery and its safe implementation in the operating room. In 2006, despite many residents being exposed to robotics, only 38 % were satisfied with their laparoscopic training, and 31 % found it inadequate [11]. Clinical exposure to robotics has since improved with dedicated American Urological Association (AUA) robotic guidelines being implemented into the curriculum (see AUA website, http://www.auanet.org/content/homepage/homepage.cfm). However, robotic technology has yet to become standard in pertinent surgical training at all academic venues. Innovative practice tools to help prepare residents and fellows for robotic-assisted procedures are only in the production stages, and just a few have been introduced into the current curricula of select institutions. While there is increased awareness and effort, it is important that these training tools are quickly validated and globally incorporated into existing programs so that education programs have established universal objectives for adequate robotic competency [12].

35.3 The Learning Curve and Surgical Experience

Counterproductively during robotic apprenticeship, as humans, we are naturally flawed to forget over time (Hermann Ebbinghaus, German psychologist, 1850–1909). As such, evaluation methods are not only important and necessary for up-and-coming robotic trainees, but they are imperative for periodic and repetitious assessment of practicing surgeons' skills, especially for those with a smaller case load to attain a level of automation of the procedure.

Current training programs and residencies have shown the promising benefits that a formal education in robotic surgery can have for physicians; such benefits are not only important for patients and surgeons to consider but for investing healthcare institutions as well. Kwon et al. have shown that formally trained robotic surgeons have shorter operative times, which permit for a greater case volume over a given period [13]. In turn, a high surgical volume has been directly linked to improve patient outcomes and lower levels of complication [14]. In a 6 year, 2,666 patient study both complication and blood transfusion rates were inversely correlated with surgical experience (volume) during minimally invasive (MI) robotic prostatectomy [15]. As a larger surgical volume is naturally associated with a greater sense of procedure familiarity, instrumentation expertise, and motor memory of the surgical process, one should attain a great deal of experience prior to beginning robotic surgery on his/her own.

To date, even without the use of the dual console da Vinci® Si model (discussed below), the inclusion of robotics trainees has not generally been linked to poor patient outcomes or a decrease in program efficiency when a stepwise introduction to the surgical procedure is used. In a training assessment, Schroeck et al. determined that trainee presence did not impact a surgeon's own learning curve and further concluded that trainees' outcomes were comparable to those of their mentors [16]. In another study, Davis et al. showed that trainee introduction in the operating room had no negative impact on patient outcomes and necessitated no major or minor corrections by senior instructors [17]. They additionally illustrated that initial exposure to 40 RARP cases provided trainees with quality basic skills, although trainees did have significantly longer procedure times than instructing surgeons. Operative times have, however, been shown to continually decrease in mature surgeons even after hundreds of performed surgeries [16], which is likely attributed to improved surgical efficiency by both the surgeon and the robotic team.

Budäus et al. determined surgical expertise to be a primary factor in patient hospitalization period following minimally invasive (MI) prostatectomy [18]. Consistently, in another study, surgeon experience—measured by annual robotic prostatectomy caseload—was inversely related to associated hospital costs [19]. Such considerations may be crucial to institutions when initially trying to launch a robotics program in a cost-effective manner. Furthermore, a comparative evaluation of hospital charges based on surgical caseload for open versus MI prostatectomy showed a greater caseload effect for the MI approach. That is, a given increase in surgical experience reduced hospital costs by more for surgeons who utilized MI rather than open technique [20]; this further demonstrates the potential value of widespread, adequate robotic training.

Organized mentor-guided instruction, as opposed to informal individual practice, has proven beneficial for robotic naïve students in terms of technical skill achievement, especially for more advanced robotic skills such as suture placement and knot tying [21]. This study attests to the fact that some formal education is necessary to impart indispensible skills to surgeons-in-training prior to their introduction to actual patient surgery. In addition to more efficient operative times, formally trained surgeons boast better patient outcomes. Kwon et al. showed that RARP-trained surgeons had a better surgical margin rate and shorter procedure time than surgeons with no formal training [13]. With regard to formally trained surgeons adapting to a robotic platform, Tewari et al. reported no compromise of oncological safety in a study of over a 1,000 patients [22]. The data collected included positive surgical margin rate and video recordings of procedures. The study reasoned that the enhanced visual feedback offered by the robotic platform compensated for the lack of tactile feedback afforded during laparoscopic and open procedures. Published literature also suggests that a formally trained surgeon in robotics will benefit both the patient and the efficiency of a robotics program, while having no adverse influence on patient safety or operative time during the training process.

35.4 Unique Needs and Responsibilities of the Surgeon During Robotic Surgery

The youthful and unique nature of the robotic surgical platform further necessitates adequate surgical training. Perhaps the most frequently reported disadvantage of the robot is the lack of tactile feedback. Although the enhanced visual field has been said to make up for the deficiency in haptic control, the dissimilarity between the robotic instrumentation and previous technology sufficiently illustrates the need to accustom surgeons to the new interface through training and education [22]. In an international multicenter study that investigated the learning curve properties for RARP, prior open surgical experience had no reducing effect on positive margin rate during one's learning curve (200–250 cases in this study). Secin et al. concluded that surgical margin outcome was primarily a function of laparoscopic-specific training and experience [23]. Future robotic platforms (Titan Medical, Toronto, Canada) as well as adjuncts to the da Vinci® platform (Vibrosense, David Lee, U Penn) may soon help provide force feedback to the console surgeon. The most immediate advances in robotics will most likely come through incremental changes in the currently available systems. However, there are still many areas in which the current systems can be improved.

The physical parameters of the standard robotic operating suite layout also contribute to the challenge of these procedures. Robotic surgery is unique in that the surgeon console is physically removed and distant from the patient during the operation, presenting an additional element of challenge to bedside instruction of assistants. The separation that is forced between the surgeon and bedside trainee by the robotic console necessitates additional verbal coordination for the instruction of naïve students. Due to the surgeon's inability to see outside of the camera field of vision, clear and coherent communication between the console surgeon and bedside assistant is imperative. Bedside placement of clips, suture cutting, and other medical acts are also not performed by the surgeon, rather the assistant. Furthermore, because whoever is at the surgeon console has absolute control of the robot at that point in the procedure, simulation must be used to safely acquaint residents and fellows with the robotic approach prior to their exposure in the operating room.

On top of the physical differences imposed by the robotic interface, urologic robotic training faces another unique challenge. Some surgical fields have been able to use animal models to train residents on the robotic interface prior to further instruction via live-patient procedures—the pig heart, for example, is commonly practiced on in cardiology training and has proven to be an effective representation of the human model for trainees. Adding to the difficulties of training for RARP and other urologic surgical procedures is the lack of an adequate animal model that has human semblance in the pelvic and prostate region. Although porcine models are more readily available, the paucity of perirenal fat and lack of overlying intestine make these models very different from live human cases.

Cadaver labs, on the other hand, still present a variety of issues, most notably that of high cost. To run successful cadaver-based robotic training requires a physical lab space, a complete da Vinci® robotic system, that is, unlikely to be used to for any income-generating surgical cases, and an ongoing supply of nonrenewable, expensive cadavers. For all these reasons, cadaver-based training has thus far been financially and logistically unsound for robotic urologic surgery. To surpass these inadequacies of animal and cadaver models for surgical training in many specialties, the demand for surgical simulators and training alternatives has been and will continue to be on the rise. Robotic-assisted surgery has proven beneficial to patients on numerous levels; expanding the capacity to train surgeons in robotic procedures will extend these benefits to a greater patient population.

35.5 Present Robotic Training Modalities

As stated above, in recent years, a number of existing training programs have been greatly successful in their efforts to educate young robotic surgeons, which ought to provide encouragement, reassurance, and a model of action for new academic programs. Additionally, recent breakthroughs in training technology have begun to show promise for the future of preoperative robotic education.

35.5.1 Residency

Although residency exposure to robotic surgery is still generally considered inadequate, it has improved markedly, and the feasibility of implementing the means to higher levels of resident training has been demonstrated. High surgical volume is a key aspect of a robotics training program—it mutually serves to offset the cost of the capital investment of the robot, and it increases the number of teaching opportunities. Common patient features such as obesity, previous hormone therapy, and high-risk pathology may increase procedure complexity, and thereby significantly reduce the number of cases suitable for training in a small pool of patients [17]. Madeb et al. reported a parallel between growing robotic surgical volume and the incorporation of robotic-assisted surgery into a urologic residency program. In order to raise their rate of residency exposure while maintaining standards of patient safety, significant modifications of their training technique were made [7].

Robotic trainees are generally progressed from the bedside to the robotic console, where they are introduced to surgical tasks of increasing complexity [16, 17]. A three-part training model for educating urology residents in RARP has proven effective by the comparison of estimated blood loss measurements and positive surgical margin rates between mentors and trainees [16]. Shroeck et al. characterized three parts of RARP as follows: Part 1—bladder dissection, incision of the endopelvic fascia, and control of the dorsal venous plexus; Part 2—bladder neck incision, posterior dissection of the prostate, nerve sparing, transaction of the dorsal venous complex and urethra, and pelvic lymphadenectomy; and Part 3—suturing and testing the vesicourethral anastomosis [16]. Under the teaching program described, trainees were initially introduced to the robotic procedure by lecture, video, and literature review prior to receiving basic functional instruction with the robot from an Intuitive Surgical, Inc. (Sunnyvale, CA) representative. For roughly ten cases each, trainees would assist mentors at the bedside, followed by assisting with Parts 1, 3, and then 2 of RARP at the robotic console, in said order. Only after achieving proficiency in all discrete procedure sections would trainees begin to perform two or all three parts of the surgery. Throughout their study no implications of significantly different outcomes between mentors and trainees were seen, and trainees did experience a dramatic decrease in operative time throughout their instruction period, achieving comparable procedure times to their mentors by the end of the study [16]. This teaching model for RARP very well may prove safe, effective, and financially feasible for other institutions in their attempts to increase resident and fellow training in urologic robotic surgery. While a number of current training programs now offer sufficient robotic exposure to resident trainees, this offers no solution to practicing urologists in the community who wish to learn the robotic approach.

35.5.2 Fellowship and Mini-Fellowship

While exposure to robotics has increased in some residency programs, robotic "fellowship" is the common approach for practiced and naïve surgeons who seek additional training in robotic surgery. Currently available in many forms, "fellowships" in robotics may range from short 5-day courses to 2-year programs. Even the short courses have shown a positive impact on implementation of robotic assistance into surgical practice; the lengthier opportunities, however, are not feasible for the majority of practicing urologists. Altunrende et al. demonstrated that a 2-day robotic kidney course consisting of lecture and skills practice had an immediate impact on the number of robotic procedures performed by participating surgeons [24]. A 5-day robotic fellowship has also shown to have positive short- and long-term impacts on the incorporation robotic prostatectomy in surgeon practice [25]. Likewise, a 5-day postgraduate mini-fellowship on laparoscopic renal surgery reportedly allowed participating urologists to introduce and expand upon their practice of minimally invasive renal surgery [26]. Following such short periods of training, however, novice surgeons must immediately and frequently continue to use their newly acquired robotic skills—which is challenging in regions of low case volume—further attesting to the need for a validated simulation trainer for robotics. Current training programs and instruction models for the introduction of robotic procedures show promise for the future of the robotic surgical education. Expanding the number of institutions that offer training in robotics and developing stepwise teaching models for more procedures are a necessary progression to advance the education and application of the RA surgical approach.

35.5.3 Proctoring and Preceptorship

Proctorship, the current training approach implemented by Intuitive Surgical for all new users, has been widely criticized by urologic academia. Following a day-long hands-on porcine lab to familiarize one with the robotic platform and layout, the surgeon is proctored for a minimum of two surgical cases before becoming credentialed by their hospital institution. In robotic urologic surgery, a proctor functions to report his/her findings on a trainee's competency level to the department head or medical staff of the surgeon-learner's institution. The institution may then act on the proctor's recommendation autonomously, and either grant surgical privileges or require additional training for the aspiring surgeon. Frequently, the proctor is a different surgeon from around the country for each case; as such, this method leaves novice surgeons without a role model or mentor figure who is able to evaluate and aid in their progression. Furthermore, in proctorship, the expert surgeon is unable to scrub in to actively coach the trainee through difficult parts of the case or to relieve them in an emergency.

Preceptorship is an alternative that allows the experienced surgeon to help at the console and attempt to transfer his/her skills to the trainee through an active "hands-on" approach. This method provides more direct feedback for the surgeon-learner and permits for a safer training environment during the steep part of the learning curve. While proctoring generally occurs at the trainee's home institution, preceptorship may occur at the location of either the surgeon-learner or expert, as well as within a mini-fellowship or mini-residency program [27].

While proctoring plays a crucial role in observing and certifying competency for robotic urologic surgeons, a common criticism of the system is the means by which surgeons currently earn proctor or preceptor status, as well as the inherently inconsistent skill and experience level between various "experts." Furthermore, proctoring presents practical difficulties for both the aspiring and instructing surgeon; either requires the proctor to take time out of his/her schedule to travel to the learner's institution or involves the surgeon-in-training to bring his/her patient to the proctor's location. To circumvent these difficulties, modern telemedicine technology has recently been put to use to allow an expert surgeon to observe, oversee, and actively supervise a surgical procedure being conducted by a trainee from a remote location. With the expansion of robotic facilities worldwide, the application of remote proctoring for robotic urologic surgery will enable the most expert surgeons to easily proctor and ultimately optimize patient outcomes and improve safety.

35.5.4 Virtual Reality and Laparoscopic Training Modules

Virtual reality (VR) simulation has been integrated into surgical curricula as an intuitive method to enhance preclinical training. According to *Lewis* et al., VR simulators may be the solution to the reduction of training opportunities faced by current surgical trainees [28]. They report that new VR technology allows aspiring surgeons to practice full-length, realistic procedures on electronic models where mistakes can be used as learning points and pose no risk to patients. Another study evaluated whether or not common laparoscopic simulators could be effectively adapted for training on a robotic platform. Feifer et al. illustrated that the joint use of a ProMIS® hybrid and the LapSim® VR simulator can improve robotic console performance in medical students; such an approach may offer a cost-effective alternative to early robotic training until a pure robotic simulator has been widely validated [29]. As robotic surgery continues to gain popularity among patients, surgeons, and residents, the need for an affordable and accepted robotic training device will persist. While popular laparoscopic simulators have proven effective for improving robotic console performance in naïve students, these training tools are far from inexpensive. The two commonly used laparoscopic training devices, the LapSim® and ProMIS®, average at a cost of $25,000 and $50,000, respectively [29]. Standard laparoscopic simulator technology is currently being remolded to better emulate the robotic surgical experience.

35.5.5 Robotic Surgery Simulation

Simulation training for the robotic surgical interface is likely the most feasible and effective means of providing trainees with a basis of tactile skill prior to introducing them to the actual robotic device. Through simulation, academic institutions may help surgeons-in-training overcome a portion of the learning curve without taking up valuable and expensive time in the operating suite, which will further promote patient safety and quality outcomes. To our knowledge, Mimic®'s dV-Trainer™ is currently the most widely accessible simulator model for the da Vinci® interface and is utilized at over 30 training sites. In collaboration with Intuitive Surgical Inc. (Sunnyvale, CA), Mimic Technologies used product development insight to incorporate accurate robot modeling kinetics, as well as realistic icons and instruments into the training modules. Exercises on the simulation program include instruction on EndoWrist® manipulation, camera and clutching, energy management, and needle driving. Mimic's MScore™ software also provides a comprehensive trainee evaluation and score reports for credentialing and privileging. In a recent comparison study on the effectiveness of simulation training on the dV-Trainer versus repeated exercises on the actual da Vinci® system, Lerner et al. found that each practice approach yielded similar improvements in the timing and accuracy of some drills [30]. They further concluded that the dV-Trainer may help bridge the gap between the acquisition of surgical skill and its live implementation on the operating table.

Virtual reality robotic simulators such as Mimic®'s dV-Trainer can now be leased by institutions to help immature robotic surgeons overcome the steep learning curve of the RA approach. Even though the lease option allows traditionally nonteaching hospitals and other academic programs to avoid permanent investment in an evolving piece of technology, it is by no means a cheap solution. In a Mimic® dV-Trainer presentation from May 2011, 3- to 4-year lease arrangements for the device ranged from roughly $110,000–$140,000, depending on the chosen plan of service. Another up-and-coming collaboration project is the Robotic Surgical Simulator (RoSS), codeveloped by Roswell Park Cancer Institute and the University of Buffalo's School of Engineering and Applied Sciences. This piece of equipment is said to transmit real-time feel and a highly realistic simulation to the surgeon-in-training and has been described as a "flight simulator" for robotic surgery.

In December of 2011, Intuitive Surgical Inc. (Sunnyvale, CA) released the da Vinci® Si Skills Simulator software. This technology allows residents and surgeons to learn and practice the use of the robotic device in a nonoperative fashion, as well as track their acquired proficiency. With a focus on the basic use of the system and its features, the Skills Simulator lets trainees accustom themselves to the interface through manipulation of the actual surgeon console controls. Compatible with any da Vinci® Si model, this additional software employs three-dimensional simulation visuals to provide the user with numerous skills exercises in virtual environments and task-specific metrics of varying difficulty—as described in Intuitive Surgical Inc.'s 2010 Annual Report. Having the option to undergo console-based simulation would provide trainees with unparalleled hands-on practice and allow them to gain an unmatchable level of comfort with the robotic platform prior to participating on any patient-based surgery. In addition to promoting safe training practice, having both the operative and training modules combined into a single device would prevent institutions from having to make separate expensive purchases. Surgeons-in-training would be able to observe procedures completed by their mentors, and then practice with the simulating software between cases and whenever the operating room is vacant.

Simulator cost, in concert with lack of validation for the simulators that are young on the market, still makes the investment difficult to justify for many institutions. Until further development of a well-accepted robotic training interface, laparoscopic VR simulators may be effective in helping trainees overcome an early portion of the learning curve of the robotic platform. As the technology for robotic surgical simulation improves and competing models are released to the market, hopefully these educational simulators become more affordable and accessible to aspiring robotic surgeons.

35.5.6 Da Vinci® Si Dual Console Model

In 2009, Intuitive Surgical Inc. (Sunnyvale, CA) began offering a dual-console da Vinci® Si model—envisioned both as a tool of operative assistance for the primary surgeon and to permit active instruction during surgeon-student training sessions. This equipment upgrade allows an experienced surgeon and trainee to share control of the robotic arms and simultaneously operate on a patient. While both surgeons easily communicate and share an equal field of vision, the trainee can proceed through the procedure with the input and guidance of the mature instructor. At any intraoperative juncture, the instructor may override the movements of the trainee to ensure patient safety and a quality procedure outcome. Additionally, the surgeons may control virtual 3D pointers, aiding visual communication and instruction. This dual-console approach is thought to be an effective means of late-stage training in robotic surgery; however, as the training model is a relatively new addition to the da Vinci® lineup, there has yet to be any validating study that shows it to be a cost-effective and efficient educational approach. The additional cost of the dual-console robot, $2.2 million compared to the $1.75 million of the standard device, may deter a number of academic institutions from the investment, thus limiting accessibility of the dual device to surgeons-in-training. The need for supporting literature regarding the value of the da Vinci® Si dual-console training model is needed to encourage its acquisition in more teaching hospitals.

35.5.7 What May Come in the Future

With the growing demand for robotic-assisted procedures in all specialties, the need to continually progress robotic training equipment and simulation technology is clear. In recent years many suggestions have been made to better the trainee experience and to make robotic surgery education less expensive; those proposals have included the modification of laparoscopic training devices, upgrades or add-ons to the current robotic platform, and the generation of a full-on robotic surgery simulator (the responses to which have just been described). In their study, Davis et al. also noted equipment upgrades of potential value during live surgical instruction, including enhanced visual technology for the bedside surgeon and two-way microphones for improved communication between the bedside and the robotic console [17]. Recent developments have certainly advanced the quality and depth of robotic surgical training; however, many of these new tools remain pricey and are not yet supported by published literature.

There is still ample room for technological innovation within the realm of robotic surgical training beyond the recent efforts. Advances in this area will hopefully enhance the convenience and quality of education for students of robotics and further promote the safe integration of patient surgery into the experiences of the novice surgeon. While the currently available training options should become more affordable and accessible to trainees over time, the need to parallel the pace of innovation for both surgical and training equipment will persist. As advances in operative technology are continuously being made, representative training models should follow to promote the greatest quality of surgical education. For instance, a near-infrared imaging system has recently been incorporated into the da Vinci® Si and utilized for indocyanine green-fluorescent imaging during robotic-assisted laparoscopic nephrectomy [31]. And, what may be the next generation of the robotic surgical platform, Titan Medical Inc.'s Amadeus®, is being designed to allow a surgeon force feedback for the first time. How well and how soon will training simulators come to emulate these groundbreaking technologies?

35.6 Concerns

From a technological standpoint, one must wonder whether the development of robotic surgical training devices will proceed fast enough to prepare the next generation of surgeons. With the application of robotic surgery still on the rise, academic medicine must provide an increasing supply of apt surgeons to meet the patient demand for the robotic approach. Supporting evidence of the effectiveness of currently available robotic simulators and training devices may serve to encourage investments by hospitals and educational institutions. However, for the most part, only a series of small studies with a lack of consistency have been performed, and further efforts are needed to validate a specific training tool. Whether or not the efficacy of these training devices is authenticated by literature, we must hope that the technology becomes available to more teaching institutions by ways of decreased cost. In addition, as patient demand and expectations continue to rise, is it imperative that not only the accessibility of but the quality of robotic surgical training be amplified by new equipment and inventiveness. The discrepant growth rates of robotic surgery's popularity and the advancement of its training approach over the past decade are becoming cause for concern. While RA surgical technology has undergone a rapid evolutionary expansion since the turn of the century, only recently has training technology mirrored this level of innovation. When planning for the future, healthcare industries must consider how to offer higher-quality robotic training to a greater number of aspiring surgeons, under a financially feasible and safe model of implementation.

Training programs for robotic surgery are also presented with a variety of limitations and concerns. Of utmost consideration in any hospital is the focus on patient safety, which complicates the dilemma on how to best educate and train aspiring surgeons. While many would argue that the best way to learn is by "doing," the need to gradually introduce residents to operating room participation is readily apparent. Rising expectations of patient outcomes have paralleled the evolution of robotic surgical technology. As a consequence, some institutions may feel reluctant to instruct naïve students in robotic surgery out of concern that expectations may not be met. Prematurely training surgeons on patients are considered unacceptable in any surgical field, making this concern equally pertinent across today's healthcare world. This challenge, in conjunction with the elevating expectations of patient outcomes, has served to decrease the operative exposure of many trainees. The laparoscopic nature of robotic-assisted surgery and the removed surgeon console have diminished the efficacy of bedside assistance for residents. While the new da Vinci® Si model does offer a second teaching console and an extra telestration monitor as training enhancements, these tools are not yet widely utilized or validated. While there are many hopes that training models for the robotic platform become more affordable as the technology does [32, 33], the current cost of the robot, as well as optional trainee console, leaves many institutions without a device to safely introduce patient surgery to residents and fellows.

Frequently it is this high cost of the operating room and educational training technology that presents the greatest obstacle for institutions in their willingness to train residents in patient-based robotic surgery. As the robotic surgical interface is a substantial capital investment, any hospital or university faces a great opportunity cost for all extra time the device is used for educational purposes rather than for additional surgical cases. As a solution, some academic programs have introduced students to only portions of a procedure at a time. The implementation of stepwise training curricula has effectively increased trainee exposure, while posing very limited inference to work flow, operative time, and surgical volume in a number of program models [16, 34]. The establishment of teaching approaches for specific procedures within robotic-surgical specialties would greatly benefit the effectiveness of residency and fellowship training in those fields. Furthermore, such procedural organization may make educational endeavors financially feasible for more teaching hospitals.

Another ongoing concern is the lack of consensus on robotic credentialing for the field of urology despite the numerous attempts to address these issues [35]. The American Urology Association (AUA) published Standard Operating Practice's (SOP's) for Urology Robotic Surgery intended for those seeking certification in 2010 [36]. These SOP's, however, do not include specific guidelines for granting privileges for individual surgical procedures; they rather describe the responsibilities of credentialing parties and outline the minimum experience requirements for the practice of urological robotic surgery. The AUA maintains that credentialing physicians for operative procedures are the responsibility of each teaching institution and that qualified committees or individuals at each site may formulate their own requirements for approving a surgeon's practice of robotic surgery. In addition to the completion of an ACGME-accredited urology residency program and American Board of Urology certification, one must have robotic surgical training in their residency and/or fellowship—indicating at least 20 completed robotic procedures. The AUA has deemed a structured training program appropriate for active urologists who wish implement robotic-assisted surgery into their practice, as well as for residents who received inadequate robotic exposure during their residency training. The requirements for the attaining privileges in robotic surgery for those in either of these scenarios include the following: completion of an online training module, certification in the open approach of the given procedure, hands-on experience and instruction with the robotic surgical interface, successful completion of the proctored procedure, procedure assistance by a certified robotic urologist until competency has been verified, the initial presence of adequate biomedical support in early performed cases, and a review of surgical outcomes.

Despite these experience requirements set forth by the AUA, the lack of any validated surgical training curricula and means of effectively evaluating skill and surgical competency leave the criteria for robotic certification ambiguous at many institutions. Furthermore, with the associated learning curve of the da Vinci® platform, 20 cases are not deemed an acceptable case volume to achieve surgical proficiency. The Society of Urologic Robotic Surgeons (SURS) maintains that proctoring is a critical component of the training process and should, therefore, be a prerequisite for all credentialed surgeons and robotic practice [37]. At the same time, the minimal criterion for becoming a proctor, which is currently set by the robotic industry, is also thought to be inadequate. SURS believes that the establishment of a centralized certification authority is crucial to establish and uphold the integrity of certification standards for robotic surgery and to further promote the safe implementation of RARP for patients, surgeons, and institutions alike. It is recommended that such an authority assumes responsibility for granting permission to proctor and for the development of a standardized means of evaluating surgeons-in-training. Also, SURS believes that the medicolegal implications of proctoring and preceptoring need to be minimized and better defined. A full series of recommendations put forth by the Society of Urologic Robotic Surgeons is listed in the Appendix.

Lastly, the use of more technology and instrumentation presents surgeons with additional venues for complication. While malfunction of the da Vinci® platform is quite uncommon, it has been noted in the literature. As part of the robotic training process, a surgeon must be taught how to deal with technical complications, especially those that may occur intraoperatively. According to a recent international survey, 56.8 % of responding surgeons performing RARP had encountered a technical problem that could not be resolved during the procedure [38]. In the event of a platform malfunction, a surgeon has the choice to proceed with a laparoscopic or open approach. The survey further illustrated that fellowship-trained surgeons were more likely to use laparoscopy, while there was no correlate to surgical volume [38]. Laparoscopic proficiency during robotic surgery is indispensable. As it has also been shown to complement the acquisition of robotic skill, laparoscopic training should be a part of, or a prerequisite to, a fellowship in robotic surgery.

35.7 Recommendations

Educating surgeons to achieve proficiency with the robotic platform is a multiple-step process. In order to ensure cost efficiency and patient safety, familiarization with the robotic interface must begin outside of the operating room. Lectures or online tutorials ought to be the first means for aspiring surgeons to attain knowledge about the new technology. Steps of video learning, observation, virtual reality simulation, and practice on cadavers or animal models should follow. Ideally, a surgeon's first surgical attempts will utilize a dual-console robot, during which a mature surgeon may regain control of the operation at any time. It is also advisable that a proctor remains present during a surgeon's initial individually executed procedures [39]. In the event of a complication, if a subspecialist is not available, assistance from an experienced robotic surgeon in a remote location may be transferred via teleproctoring [40]. Until residency programs begin to produce a larger supply of proficient robotic surgeons, it is recommended that more "mini-residency" training programs and regional preceptoring centers are established [37].

Conclusion

Despite the recent rise of surgical simulation and educational technology, the need for a structured and validated system to train and verify the competency of new users persists. As simulation can be utilized to both build and evaluate the skill set of aspiring physicians, it is likely the future not only of robotic surgery but of all medical training.

Consider the comparison of medicine and aviation, a field in which simulation has had an integral role in both training and skill maintenance for considerable time. A plane model cannot be sold without an accompanying simulator that has been established and validated. In contrast, the surgical robot was built and distributed without any pathway for patient-safety education models. If pilots and surgeons share a common responsibility for the safety of others, why has such discrepancy been tolerated? Should medical technology companies be permitted to release new products without a training simulator as its counterpart?

Beyond simulation, the development of proper and effective guidelines in robotic surgery is of utmost importance. The Society of Urologic Robotic Surgeons has recently published a consensus report on training, credentialing, and proctoring. In addition, the American Urological Association has distributed and approved standard operating practices for urologic robotic surgery. Together, these organizations have tried to outline safe practices for surgeons to follow in order to safely perform robotic urologic procedures.

Appendix

Suggested Recommendations for the Safe Implementation and Credentialing of RARP at an Institution: Society of Urologic Robotic Surgeons

1. The establishment of a national/international, centralized, certification authority which would institute and uphold standards for safe introduction of RARP in an institutional credentialing committee setup.
2. Credentialing of institutions and individuals to be based on these standard guidelines. The guidelines need to cover basic requirements with regard to training, certification courses, departmental staffing, and infrastructure.
3. Until residency programs provide an abundance of skilled robotic urologists (5–10 years), we recommend an increased number of regional centers to assist with preceptoring through mini-residency programs.
4. The central certification authority, rather than the robotic industry, should assume responsibility for identifying and promoting expert robotic surgeons. Only such designated experts, based on peer-support, submitted videos, and case logs, should be permitted to serve as a proctor.
5. The central certification authority will need to develop a standardized report for proctors to complete for each RARP, which will need to be submitted to the institutional robotic committee for review.
6. The first few (3–5) cases of the novice urologist will need to be proctored by an approved proctor, preferrably by the same proctor for all cases. Individualized requirements may be necessary for those with laparoscopic versus open radical prostatectomy experience and background. The proctor's report will then collectively be reviewed by the institutional departmental staff/credentialing committee prior to granting unrestricted robotic privileges.
7. Legal liability of the proctor/preceptor to be minimized by including the institutional legal counsel in the credentialing committee of the institution. He/she should be actively involved in the formulation of guidelines and their implementation.
8. The institution should indemnify the proctor against any possible legal implications while performing proctoring services for RARP.
9. Informed consent must be obtained from the patient with regards to the role of the proctor during the surgery and thereafter.
10. The role of the proctor should be clearly defined by the institutional credentialing

committee. Whether or not the proctor is expected to intervene in case of a possible intraoperative necessity should be clearly established and documented beforehand.

11. A system of periodic review by the institutional robotic committee of the performance of the surgeon including case selection, surgical competence, management of complications, and postoperative outcomes should be set in place. Continuance of robotic privileges should be subject to consistent performance in all of these criteria. Failure to perform adequately should result in a recommendation for a refresher training or additional preceptoring prior to continuity of these privileges.

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