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Integration of Robotics in Urology Residency Programs: an Unchecked Technological Revolution

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Abstract

Purpose of Review To review the integration of robotics in urology residency programs and evaluate how it has impacted a graduates' level of surgical competence.

Recent Findings Surgical technique training has shown a dramatic shift towards robotics with the most profound occurring in oncology. However, integration of robotics is not uniform across programs nor even among residents themselves. Robotics require graduates to garner a broader skill set within the same prescribed training time. Unfortunately, in this modern era, graduates are feeling more ill-equipped to start independent practice and show an increased need to pursue fellowship training to achieve technical proficiency.

Summary The dissemination of robotics in residency programs has gone unchecked. Modulating existing training structures through (1) development of procedure- and surgical technique-specific target metrics for graduation and (2) integration of a formalized robotic curriculum may improve the overall quality and outcome of the educational experience.

Keywords Robotic surgery · Open surgery · Residency training · Surgical education · Surgical technique · Urology

Introduction

Beginning in 2000, with the development of the da Vinci robotic-assisted laparoscopic system, robotics have rapidly disseminated into all areas of surgery [1]. The utilization of robotic surgery has increased on average 2.1% per year and for some procedures has been reported as high as 5.4% per year [2•]. This rise in robotics has naturally resulted in a subsequent decline in alternative techniques such as laparoscopy and open surgery. Although from a patient perspective, this shifting of surgical technique dominance may not seem problematic, it does raise concern for the surgical educator and trainee alike.

With the wide adoption of robotics, its impact on patient factors, such as blood loss, convalescence, oncologic outcomes, and cost, has been heavily debated [3, 4]. However, there is dearth of investigation on how the robotic evolution has influenced resident procedural competency. Resident training in the era of robotics encounters two unique scenarios which were not present historically: (1) the need to learn two separate and complex skill sets, open and robotics, for the same procedure and (2) the lack of exposure to an open procedure for which robotics has been universally adopted. These unique training scenarios put into question whether residents even have the opportunity to acquire the same level of proficiency as their historic counterparts or if this technological revolution has ill equipped them to becoming independent surgeons upon graduation.

Unfortunately, there are a number of barriers to exploring the implications of robotic dissemination within training and a graduate's level of competence in surgical technique. For example, the American College of Graduate Medical Education (ACGME), the governing body for residency education, has used achievement of a minimum number of index cases by graduation as a marker of surgical proficiency. Competency in surgical technique has only been addressed by requiring a minimum number of laparoscopic/robotic cases performed in any surgical area. Interestingly, the original minimum set by the ACGME of 50 laparoscopic/robotic cases was easily achievable by 2015 [5••]. As a result of this trend and the continued diffusion of robotics in urology, the minimum number of laparoscopic/robotic cases has recently

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been raised to 80. However, there remains no accountability as to the breadth of procedures or the range of complexity needed to fulfill this surgical technique case minimum.

Starting in 2011, the ACGME began requiring residents to identify the surgical technique utilized (robotic vs. open) when performing major index cases [5••]. Although this tracking method exists, there remains no specification as to the balance in surgical technique needed to achieve competency at graduation. Unfortunately, the urology community is unable to capitalize on this national databank, as resident case logs, on a granular level, are restricted by the ACGME for research purposes. This has impeded efforts to understand what impact robotic dissemination has had on resident training.

In light of these challenges, we aim, through this review, to expose what we do know regarding the evolution of robotics in urologic training programs and its impact on resident proficiency. We will then compare these few self-evaluations in urology with the more plentiful examinations performed in the field of general surgery. Finally, we will explore what factors may be modifiable in this changed landscape of residency training to understand how we can best maximize residency education in current times.

The Evolution of Robotics in Urology Residency Training

In 2018, Merrill et al. [5••] provided the first objective evaluation of the trends of robotic vs. open surgery utilized in residency training. Capitalizing on the new robotic tracking mechanism in resident case logs starting in 2011 and the voluntarily participation of 11 US accredited Urology programs, the authors were able to finally decipher granular trends in surgical technique training and explore inter- and intra-institutional variation. Not surprisingly, the authors found that robotic surgery increased significantly during this period, rising from a median proportion of 21.8% of cases in 2011 to 44.8% in 2017. Although increases in robotics were appreciated in all major case categories, the largest occurred in the field of oncology with the median proportion of robotic cases rising to 54.2% by 2017. Interestingly, this increase in utilization of robotics in training occurred despite a slight decrease in the total major case performed by residents [5••].

Among the major case categories examined, robotic cases lagged behind that of open cases most notably in the areas of reconstruction and pediatrics (Fig. 1) [5••]. Only in the area of kidney reconstruction did robotic surgery surpass open procedures, and continue to rise, beginning in 2012. Pediatrics, on the other hand, showed a consistent dominance of using open surgery for all major cases over time. Juxtaposed to these trends is that of oncology, where use of robotics in training became more frequent than that of open surgery beginning in 2016. For some oncologic procedures, such as radical prostatectomy, the heavy utilization of robotics over open surgery occurred as early as 2012 [5••].

In addition to differences among major case category, Merrill et al. [5••] also found significant differences existed in the balance of robotic and open surgical training between residency programs (Fig. 2). This inter-institutional variation was most notably appreciated when comparing resident experiences in pediatrics. For example, depending on the institution, graduating residents in 2017 ranged from performing a median of 1 robotic and 34 open major pediatric cases to 15 robotic and 17 open major pediatric cases (Fig. 2C). Less inter-institutional variation appeared to be occurring in the areas of reconstruction and oncology. This variation in surgical technique exposure was also appreciated among residents of the same institution. Merrill et al. [5••] gave an example of one institution who graduated 4 residents in 2017 whom had an overall balance of robotic vs. open case exposure as follows, "graduate A—278 vs. 307; graduate B—180 vs. 169; graduate C—207 vs. 262; graduate D—380 vs. 347." Although data was not provided to help us understand the reasons for or impact of this variation, the suggestion that training experiences by residents of the same program may not be equitable is concerning and something we should not easily dismiss without further investigation.

In this landmark study, Merrill et al. [5••] give us our first, and only to date, understanding of the current training trends in surgical technique in urology and reveal that there are real differences occurring in oncology, reconstruction, and pediatrics, between residency programs and among residents of the same institution. These findings raise questions as to if such imbalances in surgical technique training translate to true education inequities and lack of preparedness for independent practice. More of these self-evaluations are needed in the field of urology in order to better appreciate the nationwide scope of this issue and whether this is an area which mandates more regulation to ensure training quality control.

A Comparative Examination of Robotic Dissemination in General Surgery Training Programs

The field of general surgery has been more proactive in performing self-evaluations of the shifts occurring in surgical technique education over time. In a large analyses spanning over two decades (1993–2012), Richards et al. [6] assessed the trends of minimally invasive surgery (MIS) versus open procedures performed by general surgery residents. Through using Current Procedural Terminology (CPT) codes, the group was able to separate ACGME resident logged cases performed in a minimally invasive fashion

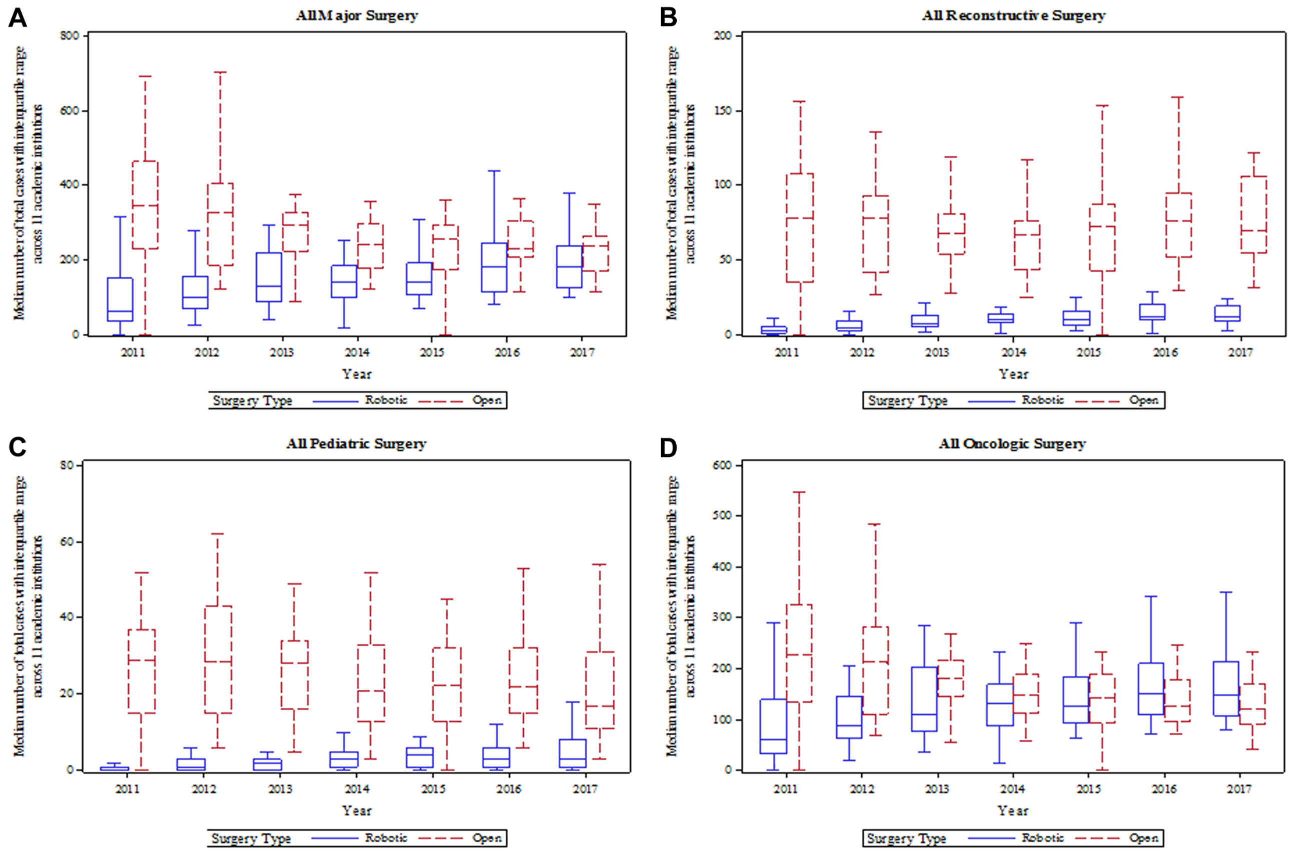

Fig. 1 Distribution of surgical technique across procedural category by residency graduates from 2011 to 2017. **A** All major surgeries. **B** Reconstructive surgery. **C** Pediatric surgery. **D** Oncologic surgery. Taken by permission from Merrill SB et al. The balance between open and robotic training among graduating urology residents: does surgical technique need monitoring? J Urol. 2020 May;203(5):996–1002. https://doi.org/10.1097/01.JU.0000555938.43866.33

(robotic + laparoscopic) from open. In doing so, they learned there was a noteworthy overall increase of 10.7% in utilizing MIS as compared to the open technique when training residents. Some procedures, such as appendectomy, antireflux, thoracic wedge, and partial gastric resection, were even found to have predominantly shifted from originally being open to now an MIS dominated approach [6]. Unfortunately, Richards et al. [6] were not able to delineate how much of this MIS shift was accountable to robotics. CPT codes, even to this day, in many cases, lack the specificity to define a procedure as being purely laparoscopic vs. robotically assisted, further impeding our understanding of the evolution of robotics into surgery.

Although Richards et al. [6] analysis only went up to 2012, incorporation of MIS into general surgery training undoubtedly has further expanded, even into more common procedures, as evidenced by the recent 2020 report from Sheetz et al. [2•]. Here, using the Michigan Surgical Quality Collaborative (MSQC), the group examined a total of 169,404 cases performed by multiple providers at 73 different Michigan hospitals and reported a 13.3% increase in robotic case volume, a 1.9% decrease in laparoscopic cases and a 10% decrease in open surgeries from 2012 to 2018. The largest increases in utilizing robotics occurred in inguinal (27.1% increase) and ventral (21.9% increase) hernia repairs as well as anti-reflux (13.8% increase) and colectomy (20.6% increase) procedures [2•]. The authors' comment that these large shifts towards using the robotic technique, especially for minor procedures, have many implications and potentially reflect an overuse, and even misuse, of this technology as a whole. Just because a procedure can be performed robotically does not indicate that it should be performed this way as other factors need to be accounted for such as cost and resource use [2•]. This valuable point of being sound stewards of medical resources and cost when determining surgical approach is a way of thinking that is just as imperative as learning the technique itself. Unfortunately, the rapid dissemination of robotics in training gives us pause as to if this thought process is even being explored with the trainee.

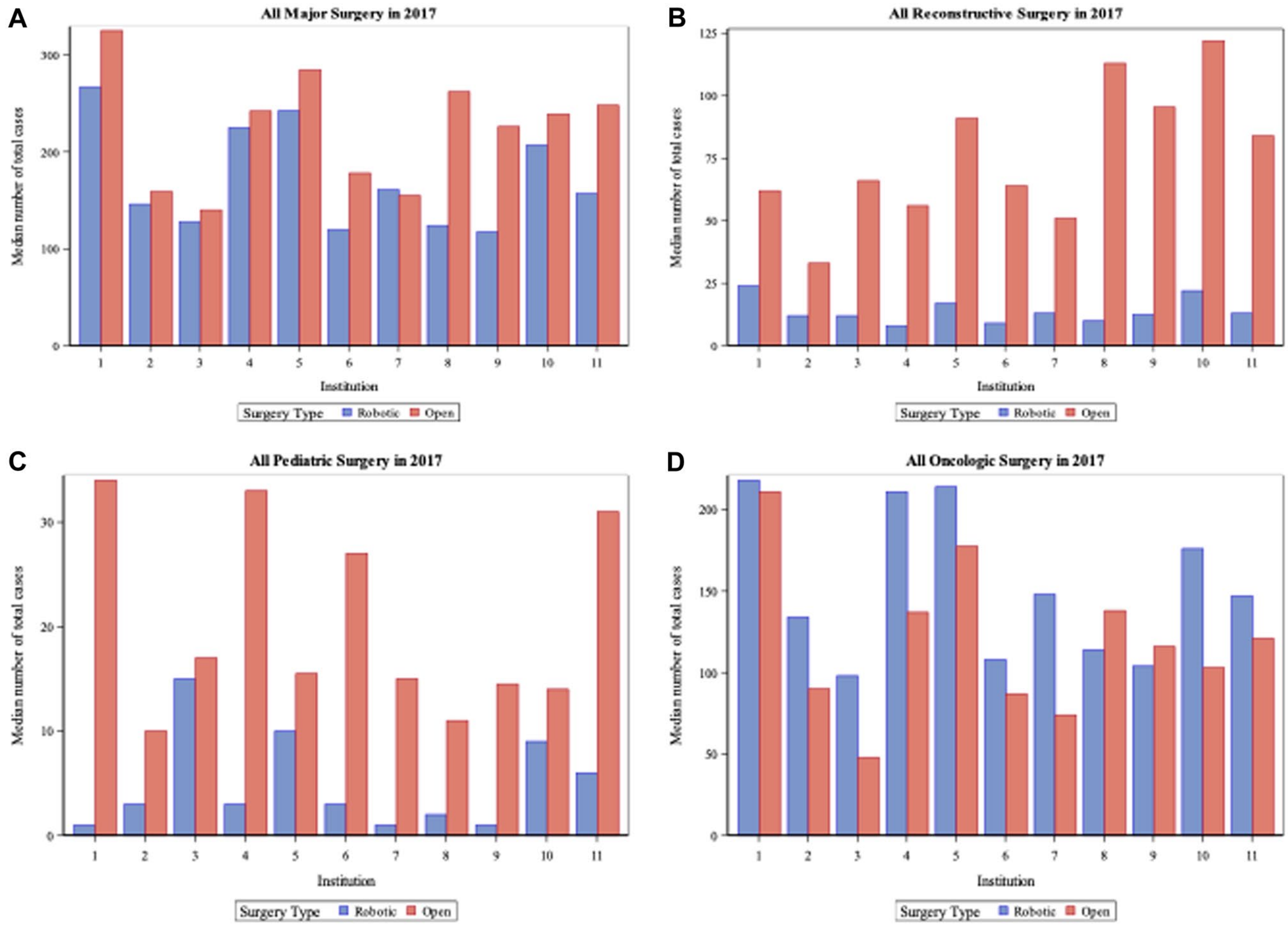

Fig. 2 Comparison of surgical technique distribution among residency graduates in 2017 across all 11 participating institutions. **A** All major surgeries. **B** Reconstructive surgery. **C** Pediatric surgery. **D** Oncologic surgery. Taken by permission from Merrill SB et al. The balance between open and robotic training among graduating urology residents: does surgical technique need monitoring? J Urol. 2020 May;203(5):996–1002. https://doi.org/10.1097/01.JU.0000555938.43866.33

Implications of Integrating Robotics Into Training

Evolution in surgery is unavoidable. However, it is the integration of these novel techniques into surgical education for which we must particularly pay attention. With the integration of robotics, concern has been raised regarding the appropriateness of graduates' level of independence and need for further fellowship training to achieve competence. In 2019, Okhunov et al. [7•] examined this very issue by surveying US urology chief residents and recent graduates. The authors found that, unfortunately, 59–88% of residents perceived themselves as "not at all" proficient in robotics by the end of their training. Only 27% and 35% of chief residents felt competent with common robotic procedures such as prostatectomy and nephrectomy, respectively. Overall, proficiency was sensed to be higher for a procedure when it was done in an open fashion [7•]. With Merrill et al.'s [5••] work showing a rising trend in utilizing robotics in training and an overall decrease in total major case load, it is not surprising that residents are feeling incompetent with their skills upon graduation. Importantly, Okhunov et al.'s [7•] findings speak to the degree of technical challenges imposed when integrating robotics into surgical education. Thus, even in the current environment where there may be less open procedures performed, residents appear better adept to developing open skill sets than robotics. This raises the question as to if more robotic exposure (i.e., robotic cases) is what is needed to feel competent by graduation? Okhunov et al. [7•] allude to this possibility with the finding that 72% of chief residents decided to continue their training by transitioning to fellowship and the majority (61%) did so on account of needing to further advance their skills.

A similar need for further education beyond residency has been felt by graduates in general surgery. In a survey sent to 5512 US general surgery residency graduates from 2009 to 2013, Klingensmith et al. [8] found that 35% decided to do additional fellowship training in order to improve skills, confidence, and experience. Although learning subspecialty specifics was a dominating factor, a large fraction of general surgery graduates still felt that they had received inadequate training during residency to achieve independence [8]. Another survey analysis implicated that the 5-year training program may no longer be sufficient to adequately prepare general surgery residents for the broader skill set now needed for independent practice [9].

Where do these feelings of inadequacy come from? One survey performed by Khalafallah et al. [10•] suggest that the integration of robotics into surgical education may be in part the source. Although a majority (58%) of the general surgery residents surveyed felt an overall educational benefit from robotic integration, 38% actually found it to be a detriment. For these residents, learning robotics was detracting from their abilities to sufficiently learn open and pure laparoscopic techniques. Additionally, when given the chance to learn robotics, it was not as primary surgeon at the console, thus making the opportunity less valuable for achieving proficiency [10•]. Certainly, if residents are having to divide their time even further, to learn a greater variety of skill sets, and are not receiving the necessary training to develop such skill sets, it is no surprise they would feel ill-equipped for independence.

These sentiments of unpreparedness by graduates appear to also be shared by fellowship directors. In 2012, using a survey to all US general surgery subspecialty fellowship directors, Mattar et al. [11] found that 66% of directors felt new fellows were unable to complete even 30 min of an operation unsupervised. Only 21% of fellowship directors felt that fellows were actually prepared for operating room independence. In regard to their laparoscopic/robotic skills, these directors believed that simulation training during residency did not adequately prepare them for how to use this application in actual practice. From their perspective, general surgery training programs were not malleable and adaptive enough to keep pace with the rapid dissemination of technology [11].

Although not yet reported on, one can extrapolate that these perceptions of training inadequacy by the trainee may in part be due to lack of sufficient robotic volume and/or lack of autonomy given to the resident on the console. The steep, variable learning curve required in robotics has been well reported [12–14]. This is likely no different for the resident learner even though a lower level of competence/skill would be acceptable here compared to the established surgeon. Knowing that there is a rough number of cases for which robotic procedural proficiency is estimated when in practice, a similar number, modified to the resident learner, should be used as a target metric for robotic training competency. However, as Merrill et al**.** [5••] point out, the ACGME has yet to establish any regulation on the balance of surgical technique utilized when achieving minimum case numbers. Currently, for urology residents, only a minimum of 80 laparoscopic/robotic cases, non-specified in terms of procedure type or complexity, is required for graduation. Without transparency by the ACGME and granularity in surgical technique reporting, it is hard to decipher how much of this sense by residents of "unpreparedness" is attributable to the volume of robotic exposure during training.

Certainly intertwined to this concern regarding appropriate volume is that of the quality of robotic training and the degree to which residents are allowed to act in the role of "primary surgeon." As shown by Mehaffey et al. [15], in a survey of general surgery residents at University of Virginia from 2011 to 2015, residents felt that they spent significantly less time acting as "surgeon" for robotic compared to laparoscopic cases. Historically, it was noted that during the integration of laparoscopy, 59% of residents participated as the "surgeon." However, in the era of robotics, only 21.5% of residents reported sitting at the robotic console, thereby, acting as "surgeon," and only 18.3% of residents reported spending over 50% of the case at the console [15].

Although giving residents' autonomy during surgery is not a challenge unique to robotics, it may be more complex to navigate. For example, in general, robotic surgery has translated into longer operative times [3, 16]. If surgical educators are in need of completing multiple robotic cases a day, time constraints are likely to trickle down to the resident experiencing less opportunity on the console and acting as "surgeon" for the case. Additionally, unless the residency institution has sufficient resources, in terms of surgical technicians or additional able-bodied residents as well as robotic training consoles (dual console), the environment may be disadvantageous for providing learner autonomy. For example, an optimal learning environment in robotics consists of an able-bodied bedside assistant plus a dual console that can host both the educator and resident learner. This environment affords the learner to be at the dual console, thereby better visualizing what the surgeon is seeing and to quickly move back and forth from the position of "acting surgeon" to "watchful learner." This environment also allows the surgical educator to have a greater sense of security when providing independence to the resident, knowing that at any time, surgical control can be easily transitioned back. Although crucial to the quality of training and the degree of autonomy provided, the robotic surgical environment is not standardized or regulated.

Modifiable Factors to Maximize Residency Competency

Teaching residents how to become competent and technically sound surgeons is a formidable mission. Thus, when trying to achieve these objectives amidst a prescribed amount of training time and advancing technological landscape, we are bound to encounter challenges which appear impossible to navigate. Robotic education can be seen as one of these challenges. However, it is clear that robotics is here to stay and its applications are only going to penetrate more deeply in the future. Thus, it is prudent to determine how best to modulate this learning environment in order to provide the resident the opportunity to gain the most applicable skills to be competent and independent urologists.

To this end, we appreciate two modifiable factors that can help achieve an appropriate balance with surgical technique training and an equitable resident experience. First, similar to the index case numbers recommended by the ACGME for residency graduation, surgical technique-specific target metrics need to be created. Having target case numbers that are both procedure- and surgical technique-specific would certainly put forward a more standardized curriculum and reduce training deficiencies in surgical technique that are due to volume. Defining surgical technique-specific target metrics which are appropriate for training the "general" urologist require both an understanding of what is currently taking place both in residency programs and in independent practice. Greater transparency by the ACGME of national resident case logs would help to define more precisely the current case numbers, by surgical technique, which appears to be resulting in this generalized sense of resident unpreparedness. Currently, the only procedure- and surgical technique-specific case numbers we have in urology are those from the 11 institutions voluntarily solicited by Merrill et al. [5••]. Since at present we have 142 US accredited urology residency programs, a more comprehensive evaluation of the current balance in surgical technique training is needed. Luckily, this data has been recorded and archived by the ACGME since 2012. But unfortunately, access and use of this wealth of information for research purposes have been restricted.

In addition to knowing residency case numbers, it is just as valuable to understand the procedure- and surgical technique-specific case number graduates are performing when in independent practice. Having a better appreciation of the types of cases being carried out by the "general" urologist would certainly help us define a case mix balance which more appropriately mirrors what is needed to be competent in actual practice. We are currently underway to define these numbers in a representative way by using the American Board of Urology case logs which are submitted for final board certification status. We hope that this analysis will bring us closer to defining procedure- and surgical technique-specific target metrics for urology residency programs and affording residents an improved sense of preparedness upon graduation.

Another modifiable factor is the quality of the robotic training experience in residency programs. Currently, the environment in which this novel technology is learned is not standardized or regulated. Traditionally, when only the open approach was required to be learned, the variation in experience was limited to only the teacher and patient pathology. Now with the introduction of advanced technology such as robotics, there are a lot more environmental variables influencing the learner, such as whether or not there is a bedside assistant, dual console, robotic simulators available to even a dedicated robotic curriculum. All these factors can influence the degree to which the resident has the opportunity to act as "primary surgeon" and thereby develop the competence needed for independent practice. Unfortunately, many of these factors are unable to be regulated by educational governing bodies as they are dictated by individual hospital resources. However, one element in this training environment which may be modifiable is the institution of a robotic curriculum.

To date, there is no standardized or even recommended robotic training curricula by the ACGME. The majority of residency programs utilize an amalgam of on-line instructional material combined with a gradual advancement of bedside assisting to finally robotic console work. However, this learning structure is typically inconsistent from one resident to the next and in general has not fostered an overwhelming sense of technical proficiency upon graduation. The age of robotics has made the traditional teaching method: "see one, do one, teach one" archaic, necessitating the development of a more modern curriculum [17•].

Realizing a different education curriculum is needed, there has been great effort, across disciplines, in determining key components which may be more effective for both teaching and learning this novel technology. In gynecology, a successful robotic curriculum has been determined to comprise, at a minimum, a structure which begins with online learning and virtual training to understand the mechanisms behind robotics and then which progresses to simulations, both virtual and three dimensional, followed by bed-siding, then to finally spending time on the console [17•]. This defined methodology affords the educator both structure and concrete measures to guide how and when to progress an individual resident through training. In general surgery, utilizing an outcome-based dynamic design in robotic curricula, in which the learner progresses forward based on an objective evaluation of their performance, has been found to be a superior strategy for the learner as compared to a self-directed approach [18•]. Through such an adaptive learning environment, the resident is provided with the opportunity to garner a skill set which is more durable, comprehensive, and translatable. Lastly, incorporating objective feedback mechanisms such as the System for Improving Procedural Learning (SIMPL) or the 4-level Zwisch scale appear integral to surgical curricula, regardless of the surgical approach being applied [19, 20]. Such applications allow the resident to be provided with immediate and consistent performance evaluations, creating a real-time awareness of their perceived level of autonomy and competence for a particular case. For the educator, these tools help to promote regular and meaningful feedback as well as a consistent engagement with the resident throughout the learning process. Although more investigation is needed in developing discipline specific robotic curricula, these key components highlight what may be advantageous to achieve quality improvement and equity in a resident's robotic training experience.

Conclusion

The application of robotics has rapidly disseminated into training programs unchecked. Although a natural, and even desired, technological evolution for the discipline of surgery and patient alike, the implications on the trainee and their education do not appear to be as advantageous. In urology, the utilization of robotics in training is increasing across all major procedural domains and for the majority of oncology procedures is becoming the dominant surgical technique. Unfortunately, the integration of robotics is not uniformly occurring across all training programs nor even among residents of the same program. This variability in training is unsettling especially when realizing graduates are feeling ill-equipped for independent practice. Robotics has required residents to garner an additional and advanced skill set, but no further time, nor even educational structure, has been afforded to them to do this effectively. Thus, in order to develop competent and technically sound graduates, within a prescribed training time and amidst a technologically advancing landscape, residency programs need more regulated structure. We appreciate two modifiable factors which may improve the balance and equity of surgical technique training and overall quality of the educational experience: (1) development of procedure- and surgical technique-specific target metrics to be achieved by graduation and (2) integration of a formalized robotic curriculum into residency programs. Just as we do in surgery itself, we must adapt our educational methods to the advancement of technology and wisely integrate modifications to ensure effective outcomes as well as quality control.

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