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Research Paper

Is the robotic revolution stunting surgical skills?

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HIGHLIGHTS

- There has been widespread adoption of robotics in minimally invasive general surgery throughout the United States with a decrease in laparoscopy
- Robotic outcomes are generally equivalent or worse when compared with laparoscopy, with significantly higher healthcare costs
- Trainees are increasingly underprepared to enter independent practice
- Large-scale incorporation of robotics into training exacerbates of trainee underpreparedness to enter independent practice
- Careful consideration should be given as to how to incorporate robotics into surgical training

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ABSTRACT

This perspective piece aims to examine the impact of the growing utilization of robotic platforms in general and minimally invasive surgery on surgical trainee experience, skill level, and comfort in performing general surgical and minimally invasive procedures following completion of training. We review current literature and explore the application of robotic surgery to surgical training, where minimum case thresholds and breadth distribution are well defined, and where development of surgical technique is historically gained through delicate tissue handling with haptic feedback rather than relying on visual feedback alone. We call for careful consideration as to how best to incorporate robotics in surgical training in order to embrace technological advances without endangering the surgical proficiency of the surgeons of tomorrow.

Key message: The large-scale incorporation of robotics into general and minimally invasive surgical training is something that most, if not all, trainees must grapple with in today's world, and the proportion of robotics is increasing. This shift may significantly negatively affect trainees in terms of surgical skill upon completion of training and must be approached with an appropriate degree of concern and thoughtfulness so as to protect the surgeons of tomorrow.

Over the past two decades, robotic platforms have been widely adopted in minimally invasive general surgery, with a concurrent decrease in laparoscopy. One study examining a large sample across the U.S. from 2012 to 2018 demonstrated an increase in the use of the robotic platform from 1.8 % of surgeries to 15.1 %, with specific procedures like inguinal hernia repair seeing even greater robotic utilization, increasing from 0.7 % to 28.8 % usage over the same period [1]. Logically, the rise of robotics has been associated with a decrease in laparoscopic minimally invasive surgery [1].

Studies examining the efficacy, utility, and value of the robotic platform largely conclude that robotic surgery is non-inferior to laparoscopy in terms of patient outcomes, as demonstrated by a recent updated systematic review [2], but results in longer operative times and is more expensive, even when performed by very experienced, well established surgeons. In particular, within the field of minimally invasive general surgery–encompassing bariatric, foregut, and abdominal wall surgery–which has adopted the robotic platform to a greater degree than other general surgical subspecialties, studies have largely failed to demonstrate a clinical or economic benefit when compared with laparoscopy. Several large hernia repair trials comparing robotics with laparoscopy, including the RIVAL trial at both 1 and 2 year follow-up as well as ventral hernia repair trials [3–7] have demonstrated equivalent clinical outcomes with added healthcare costs. The findings were similar in studies examining the use of robotics in bariatric surgery [8–11], foregut surgery [12], and colorectal surgery [13–16], with one recent study demonstrating increased risk of common bile duct injury during

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robotic cholecystectomy and questioning the safety of the robotic platform in this surgery [17]–a procedure increasingly performed using the robot. And, while these studies have focused on the clinical impact of robotics, other studies have demonstrated greater CO_2 emissions and worse environmental impact of robotic surgery when compared with laparoscopy [18,19]. Even with the positive and sometimes deceptive "spin" often found in studies reporting the outcomes or impact of robotic surgery [20], many of which are funded at least in part by the robotic companies [21], current literature does not convincingly support what seems to be a large-scale conversion of laparoscopic to robotic surgery in general and minimally invasive surgery. Regardless, it is estimated that general surgery and its subspecialties will represent 87 % of the robotic surgery market by 2030, with a 10.5 % compound annual growth rate of robotic surgery in the U.S. between 2020 and 2030 [22]. With the field growing so rapidly, it is not surprising that most surgical trainees feel that robotics should be incorporated into formal training, with one study reporting that nearly three-fourths of trainees believe robotic surgery will be important for the future of their desired specialty [23]. It logically follows that careful attention should be paid to its incorporation into surgical training and its effect on surgical trainees. However, there is little discussion or focus at the national or international level regarding the impact of what is often a large-scale incorporation of robotic surgery on surgical trainees in terms of surgical trainee experience, skill level, and comfort in performing "bread and butter" procedures following completion of training.

There is already a sense of trepidation among residency and fellowship program directors, as well as senior surgeons and members of surgical leadership both nationally and internationally, that surgical autonomy among trainees is in decline; one recent study demonstrated that trainees perform cases independently less than 4 % of the time [24], which may result in incomplete readiness to enter independent practice at the end of training. Indeed, the recent inception of the American College of Surgeons' Mastery in General Surgery fellowship speaks to the fact that residency may not succeed in producing competent general surgeons by the time of graduation. Further complicate this issue by adding a third operative modality - robotics, in addition to laparoscopy and open surgery - during surgical training, and the picture becomes increasingly muddled, leaving one glaring question: How can robotic surgery be incorporated into surgical training that often already struggles to meet minimum case thresholds and produce competent surgeons while respecting work hour maximums?

In the United States, general surgery residents must complete a minimum of 850 cases - at least 175 of which must be laparoscopic - in order to be considered safe and competent surgeons and thereby graduate from a training program [25]. Without extending the length of surgical training, the addition of robotic surgery to surgical training will significantly reduce the number of laparoscopic and/or open cases completed by trainees, especially given that the number of cases required to achieve competence on the robotic platform has been estimated to be around 50 cases in the hands of already very experienced laparoscopic surgeons (though they vary widely) and may be significantly higher for trainees [26–32]. It logically follows, then, that there will be a reduction in open and laparoscopic surgical skill and/or comfort on the part of recent graduates, given their attempt to master a third operative modality during their time-limited training.

Further complicating this picture are two elements specific to robotic surgery. The first is that research has shown that most residents often do not perform meaningful portions of the operation during robotic cases, commonly serving as a bedside assistant or passive observer during much of a given case; and that when they do perform significant portions of cases, the cases are simpler in complexity than what the given trainee would likely perform laparoscopically [33]. While it may be the case that some training programs have skilled robotic surgical educators who allow residents to perform significant, graduated, and level-appropriate portions of cases, literature has demonstrated that in at least one national survey of over 240 training programs, 63 % of trainees indicated that they had participated in robotic cases and yet only 18 % reported having operated at the console, and approximately half of the trainees felt that robotic surgery at their training institution interfered with their training [34]. While the number of training programs with dedicated physician assistant bedside assistants, which have been shown to increase the amount of operating console time for trainees [35], is likely increasing, it is still far from the norm. Furthermore, a recent study evaluating residents' and fellows' active control time, defined as the amount of trainee console time spent in active system manipulations over total active time over both trainee and surgeon consoles (in a dual console system) during cases found that PGY5 trainees perform only 60 % of a given standard case and 35 % of a complex case, and that even fellows perform approximately only 74 % of a standard case, and 47 % of a complex case [36]; even according to the Robotic Surgery Education Working Group's most recent consensus recommendations for a universal structured robotic surgery curriculum, fellows and PGY5 residents performing only this portion of complex cases would not be considered to have achieved "procedural proficiency" [37]. In light of the foregoing, it seems apparent that, overall, robotic cases are not equivalent experiences to laparoscopic cases in terms of their educational value [33]. The second element specific to robotic surgery is that research examining skill-acquisition has demonstrated positive skill transference from the laparoscopic to the robotic platform, but not the reverse – primary exposure to the robotic platform, which lacks the haptic feedback critical to the development of tissue handling and integral in laparoscopy, actually hindered subjects' abilities to perform tasks laparoscopically [38].

It is worth acknowledging, however, that the robotic platform can provide unique educational opportunities and advantages over traditional laparoscopy, if leveraged appropriately. The first is the potential advantage of modular and whole case simulations that are measurable on the current robotic simulators and are now available at many training programs with increasing prevalence [39]. The second is that the dual console robotic system has several built-in safety features to prevent trainee harm to patients, such as a system which allows for single to multiple instrument guidance as appropriate, as well as a full system instrument swap or safety stop, both at the press of a button by the lead surgeon [40,41]. Additionally, dual console systems provide added training benefits, such as a 3-dimensional pointer and the ability of the lead surgeon to provide telestration to teach techniques and guide procedures without taking over the case [40,42], and these benefits may be even further enhanced when instant video replay via the robotic video capture system is widely available over the coming years. Though far from universal, if available at a given training program, these features offer certain educational advantages unique to robotic platforms.

At this point, current surgical trainees in general surgery residency programs and subspecialty fellowships face a rapidly evolving surgical landscape in which the robotic surgical platform is often featured prominently, despite significant and outstanding questions regarding clinical or economic benefits of the technology. When considering evidence indicating that trainees receive diminished educational value from robotic cases, that there is negative skill transference between robotics and laparoscopy, and that the robot is not ubiquitous and is often unavailable at smaller centers (or even after hours in centers with extensive robotics), coupled with the fact that surgical training is time-limited and that there is a significant sacrifice of open and laparoscopic cases in order to achieve robotic competence, there is reason to question the large scale incorporation of robotic surgery into surgical training. Trainees may require significantly more operative cases during training to achieve appropriate operative autonomy with the addition of robotics.

Trainees may be correct to view the robotic platform as important to their future areas of specialty. However, embracing new technology in the surgical armamentarium should not be at the expense of learning the fundamentals of surgical skills. Trainees and surgical residency and fellowship programs alike should treat robotic and laparoscopic training

as discrete entities and careful consideration should be given to how best to incorporate robotics in surgical training while still allowing for the development of overall surgical proficiency.

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Damien J. Lazar: Conceptualization, Project administration, Writing – original draft, Writing – review & editing. **George S. Ferzli:** Conceptualization, Writing – review & editing.

Declaration of competing interest

The authors have no conflicts of interest to declare.

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