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Integrating Robotic Technology Into Resident Training: Challenges and Recommendations From the Front Lines

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Data: Some of the quotations in Table 2 were elicited in response to a prompt posted on a monitored social media site. All data were anonymized.

Abstract

Purpose

To develop recommendations for improving the integration of robotic technology into today's apprentice-based resident training.

Method

During a national meeting in 2017, 24 robotic surgeons were interviewed about their experiences integrating robotic technology into resident training. Qualitative thematic analysis of interview notes and recordings revealed themes related to challenges and recommendations.

Results

Four themes emerged, each corresponding to a general recommendation for integrating robotic technology into training. The first, surgical techniques versus tools, contrasts faculty's sequential mastery—surgical techniques first, then the robotic tool—with residents' simultaneous learning. The recommendation is to create separate learning opportunities for focused skill acquisition. The second theme, timing of exposure to the robotic tool, describes trainees' initial focus on tool use for basic surgical steps. The recommendation is to increase access to basic robotic cases. The third theme covers the relationship of laparoscopic and robotic surgery. The recommendation is to emphasize similar and dissimilar features during all minimally invasive surgical cases. The fourth theme, use of the dual console (which enables two consoles to operate the robot; the primary determines the secondary's functionality), highlights the unique teaching opportunities this console creates. The recommendation is for surgeons to give verbal guidance so residents completely understand surgical techniques.

Conclusions

Surgical educators should consider technique versus tool, timing of exposure to the tool, overlapping and varying features of robotic and laparoscopic surgery, and use of the dual console as they develop curricula to ensure thorough acquisition and synthesis of all elements of robotic surgery.

The applications of robotic technology in surgical practice have grown exponentially over the last 15 years. Popularity was initially limited to certain surgical specialties, but in the last 5 years, nearly the entire spectrum of surgical practice has adopted robotic technology.[1–14] Because this expansion includes academic medical centers, surgical trainees are increasingly exposed to this technology. However, a recent review of current resident-specific curricula for robotic technology revealed minimal standardization and a lack of cognitive components.[15] As educators examine the robotic surgical environment more closely, they have begun to question how this new technology might resist integration into today's apprentice-based learning environment. For example, early studies suggest that despite increased exposure to robotic technology, residents have a negative initial impression. In a 2014 study, 46% of 192 general surgery residents responding to a national survey felt that robotic-assisted surgeries interfered with resident training. That study is also one of many that have suggested exposure to robotic-assisted surgical procedures is increasing in general surgery residencies[6,16–18]—over 96% of respondents noted the presence and ongoing use of robotic technology in their training programs.

Robotic technology appears to be increasingly popular among general surgeons working in an academic setting, so it is unclear why the popularity among residents does not align with this view. One reason for the residents' negativity may be the decreased hands-on operative experience in this new robotic environment. For example, introduction of robotic technology at a gynecology residency program resulted in significantly fewer procedures available to residents.[19] Similarly, in a study of general surgery residents, 63% reported participating in a robotic operation, but only 18% reported accessing the operative console[18] (the unit, separate from the robotic arms and the operating table, that enables the surgeon to manipulate the robotic arms.

The console includes the operative controls and a screen that displays a 3-dimensional view of the operation). Although the number of robotic-assisted general surgery cases is increasing, it appears the resident's role is often limited to exchanging instruments at the bedside or intermittently suctioning excess fluid using an assistant hand port.

The integration of robotic surgery into surgical education is often compared with the integration of laparoscopic and endovascular surgery, which occurred without significant challenges over the past 3 decades. Similar to laparoscopic and endovascular technology, robotic technology aims to assist physicians with complex surgical tasks by minimizing human error while increasing the technical ease of performing surgical interventions. However, one distinguishing feature of robotic technology is the independence it gives to a single operating surgeon. A single operating surgeon can control 4 robotic arms, including the camera and multiple instruments and electrocautery devices. This independence is undoubtedly beneficial where resources are limited, but in the training environment, serious challenges emerge. In the traditional training environment, the physical involvement of residents is essential to provide the operating surgeon adequate visualization and assistance with retracting tissues. This natural dependence on residents to create a manageable and functional surgical field decreases with robotic technology.

The purpose of this study is to understand how robotic surgeons are approaching the integration of robotic surgery into resident training at their academic medical centers and to identify challenges and make recommendations. We hypothesized our findings would reveal that today's surgeons use different approaches to integrate robotic technology into surgical training, and that regardless of diverse viewpoints and methodologies, the challenges that emerge would reflect consistent themes.

Method

Study design and participants

We conducted semi-structured interviews over 3 consecutive days (March 22–24) at the 2017 annual meeting of the Society of American Gastrointestinal and Endoscopic Surgeons in Houston, Texas. We approached conference attendees randomly at separate locations throughout the exhibition hall and surrounding conference venue. We limited participants to active practicing surgeons who used robotic technology and worked with residents or fellows in the robotic operative environment. We excluded non-surgeons, or surgeons not using robotic technology. C.A.G. and K.M.M., both surgical research fellows, conducted the interviews. They approached attendees covering a broad age spectrum with the goal of obtaining input from participants with different levels of faculty experience. There were no time restrictions.

The semi-structured interview questions were designed to solicit information about surgeon experiences with robotic technology and interactions with residents or fellows in training, challenges they have encountered, and recommendations for improving integration. The authors, who have a wide range of expertise in education and surgery, developed the interview script together (see Supplemental Digital Appendix 1 at http://links.lww.com/ACADMED/A671). (C.A.G. has a master's degree in arts and education with a focus on health professions education from the University of California, Berkeley, and led the design and implementation of the robotic curriculum for the Department of Surgery, University of California, San Francisco; K.M.M received a training grant from the National Institutes of Health [NIH] to take courses in research design; H.W.H. has received NIH funding for multiple research projects; P.S.O. has more than 10 years of experience with medical education research.) Questions were open-ended and broad to avoid presumptions about the robotic environment. Interviewers approached conference participants and asked if they were practicing surgeons using robotic technology. If they said yes, interviewers asked if they were willing to discuss their experiences. Initially, participants were asked to describe their experiences with surgical robotics and integration of these skills into resident training. To provide a degree of structure to the conversations, interviewers had a list of subtopics to use as discussion points, including the following: additional information about trainees, the operative environment, training materials, greatest challenges, comparison with other surgical approaches, and recommendations for improved integration of robotic technology into resident training. Interviews were considered complete once all subtopics had been addressed. Interactions and participant responses were documented with written notes and audio recordings. All written notes and summaries of audio recordings were anonymized.

Qualitative data analysis

To analyze our data, we used a form of qualitative analysis called progressive focusing,[20] an analytical process that includes listing concepts reflected in notes and examining relationships between them.[21] Specifically, we reviewed notes and recordings from participant responses at 3 points in time: immediately after the interview, the evening following a day of interviews (which took place on 3 consecutive days), and the week after the conference concluded. We created progressive summary documents with narrowing focus. Qualitative content analysis of the summary documents and audio recordings revealed 4 consistent themes discussed in the interviews. We summarized each theme based on the challenge it presented and then used these results to make an associated recommendation. Additionally, in response to a participant's suggestion, we posted a question on a closed forum online to gather additional data to authenticate the results from the qualitative analysis.[22]

Quotations supporting these themes were recorded both from interviews and from more than 50 responses to the prompt we posted on a monitored social media platform for robotic surgeons: "For those teaching residents…could you give pearls, perspective, safety tips?"[23] The University of California, San Francisco IRB approved this study as exempt.

Results

Over 3 days of a national surgical conference, we conducted 24 interviews with eligible attendees. Our analysis of the interview data indicated that the first and most consistently cited challenge respondents faced when integrating robotic technology into resident training was the ongoing learning curve of surgical faculty using this new technology. By using thematic analysis, via progressive focusing,[20] we identified an additional 4 themes highlighting challenges specific to robotics. Within each theme, although participant opinions and responses differed greatly, we identified a single associated recommendation (Table 1). Representative quotes supporting each theme are summarized in Table 2.

Theme 1: Technique versus tool

The first theme highlights tension between two areas of learning: surgical technique and the robot, the surgical tool. The faculty surgeons who participated in our study learned to use robotic technology *after* completing their surgical training. In other words, they had mastered the cognitive and technical skills needed as a surgeon; learning to use the robot was essentially supplemental to their foundational surgical knowledge. Today, integrating robotic technology into residency occurs at a very different stage of the surgeon's professional development. Junior residents (postgraduate years [PGYs] 1–3) are just beginning to learn or are still learning critical components of surgical technique while simultaneously being introduced to robotic technology. Simply speaking, the way in which today's teachers acquired robotic skills cannot be replicated with today's learners. Today's learners are faced with more complicated technology that is not just a supplement to core surgical technique: Tool and technique must be integrated. Our respondents acknowledged observing the degree of complexity their learners faced. Many commented that the volume of new information likely creates a state of cognitive overload[24] in the operating room, decreasing residents' acquisition of content required for the mastery of both surgical technique and the robotic tool.

Approaches to managing this challenge centered around using simulation to familiarize learners with the robotic tool in an environment outside of the live operating room. Most of the robotic surgeons we interviewed had trainees participate in dry labs or work with the da Vinci simulator (Intuitive Surgical; Sunnyvale, CA) to teach robotic-specific skills such as docking (moving the base of the robot to the operative bedside and then connecting the robotic arms to ports and positioning them), instrument exchange, clutching (using a foot pedal to adjust between robotic components), and moving between robotic arms at the console. As one interview participant said, "The simulation system is very important for resident learning so that the[y] can become familiar with the robot and its capabilities" (Social media surgeon 28). According to the robotic surgeons, familiarizing residents with these components of the tool outside of the operating room appeared to increase trainee confidence during live operations. Some participants commented that trainees could focus on more technical components of the surgery if they were able to dock the robot and exchange the instruments more smoothly.

Given the repeated emphasis on learning the surgical tool separately from surgical technique and the advantages participants observed with simulation and dry labs, the following recommendation emerged: Differentiate learning environments for focused acquisition of surgical techniques and surgical tools.

Theme 2: Variable timing of exposure

The second theme gleaned from the semi-structured interviews is the variability in timing of trainee exposure to the robot. We estimated that the educational levels of the populations our participants worked with were distributed as follows: 15% junior residents (PGYs 1–3), 55% senior residents (PGYs 4–5), and 30% fellows.

When we asked the surgeons what they thought the ideal stage of trainee would be, about three-fourths felt strongly that trainees should wait until reaching the senior resident or fellowship level before learning how to operate robotically. This sentiment is exemplified in the following comment, "A certain degree of operative skill is required to understand robotics" (Surgeon 22). These surgeons thought it was essential to thoroughly understand surgical technique and anatomy before integrating the complex technology of robotics. A smaller number of surgeons differed, thinking that specific robotic tool components should be taught at the most junior level because only minimal surgical knowledge or experience is needed to learn how the tool functions. Additionally, these surgeons claimed that basic principles of surgical technique could be taught more effectively using the robot given the magnification of the surgical field and the ability to freeze the instruments when structures are visualized.

Despite the divergent attitudes about the best time to expose trainees to robotics, all surgeons agreed that trainees should initially use the robot to complete the more basic steps of a procedure. Surgeons commented that basic steps occur in all types of procedures, even technically complex operations. Surgeons consistently emphasized that learners should initially focus on the most basic operative steps of surgical procedures regardless of the overall complexity of the case. One surgeon (Surgeon 24) observed that junior-level cases often have a larger ratio of basic to complex operative steps than more senior-level cases. Therefore, the following recommendation surfaced: Regardless of level of training at initial exposure, provide increased access to cases with basic surgical steps in an effort to smooth the integration process.

Theme 3: Relationship of robotics to laparoscopy

As with the ideal timing of exposure, opinions about the relationship of laparoscopy to robotic surgery were strong and diverse. Respondents were perplexed about why they were asked, "Is robotic surgery more like open surgery or laparoscopic surgery?" as they insisted the answer was obvious. However, participants were divided in their responses, and their opinions correlated with when they thought robotics should be integrated into the resident curriculum. Respondents who claimed that robotic surgery was more similar to laparoscopic surgery than to open surgery thought robotics should be taught after trainees have learned the basics of laparoscopic surgery, as illustrated by this quote, "Laparoscopic skills such as patient positioning and port placement are critical for robotic surgery" (Surgeon 11). These participants believed that comprehending certain features of robotic technology required laparoscopic experience. They cited as examples previous experience with, and an understanding of, concepts such as port placement and triangulation. Moreover, participants emphasized that, similar to laparoscopy, the visual field in robotic surgery is limited and requires ongoing attention to the peripheral limits on-screen to identify possible complications occurring off-screen.

Other respondents, although they agreed that robotic surgery and laparoscopy have overlapping features, felt the surgical technique using robotic technology was much more similar to open surgery than to laparoscopy. These surgeons pointed out that the hand and wrist movements used in robotic surgery are much more similar to those used in open surgery than to those used in laparoscopy where there is a fulcrum effect. One surgeon (Surgeon 16) asserted that teaching concepts of open surgery was *easier* using the robot because the operation can be paused (and the instruments kept in a static position) while the instructor explains elements of anatomy or technique. The surgeons who thought robotic surgery was more similar to open surgery than to laparoscopy thought robotic surgery should be taught in tandem with other types of surgical procedures and did not favor sequential exposure to laparoscopic and robotic technology. Despite these opposing views, all surgeons agreed that some features of laparoscopic surgery and robotic surgery overlap, leading to the third recommendation: Highlighting overlapping and varying features of laparoscopic and robotic surgery during all minimally invasive surgery cases will improve the learner's understanding of these features regardless of sequence of exposure.

Theme 4: Dual console

The fourth theme highlights the dual console (a system that enables two consoles to operate the robot; the primary console determines what functions the secondary can use) as a unique teaching tool. The dual console seems to provide a platform that allows seamless role transfer from teacher to learner. The "seamless" component, emphasized by one respondent (Surgeon 6), differs dramatically from laparoscopy because the dual console enables transfer of the controls from one surgeon to the other with minimal tissue manipulation. Unlike the situation in open or laparoscopic surgery, with the dual console, surgeons do not need to physically exchange instruments or change positions around the operative table. Participants also highlighted the teaching assistance enabled by the dual console's ability to provide graded responsibility: instructors can decide if they want to relinquish one, two, or three of the robotic arms to the resident. Additionally, the dual console displays the identical 3-dimensional image that the attending physician sees, providing excellent visualization of the surgical field and the pertinent anatomy.

Almost all surgeons mentioned the dual console was a unique teaching tool in the robotic environment. While all surgeons did not have a dual console at their institutions, all expressed interest in using this technology if it were available. However, a few highlighted some of the limitations of the dual console, including the loss of visualization of off-screen actions, the inability to mirror the actions trainees should perform, and the difficulties in verbally explaining instructions to trainees. Although the dual console displays the same intracorporeal view to the attending surgeon and to the trainee, the visualization does not capture anything outside of the camera's magnified view. Off-screen information includes the position and activity of instruments outside the camera's range, the external components of the robotic equipment, and the operating surgeon's actions (such as clutching or pressing foot pedals to exchange control of the instruments, introduce electricity, or staple tissues). Additionally, surgeons highlighted the importance of accompanying the graded autonomy innate to the robotic system with dialogue so they could guide residents' actions from a separate location (the other console). Surgeons reported that they find teaching challenging when a resident is in control of the robotic instrument because they cannot physically move the instrument to illustrate directionality or precise tissue manipulation. Instead, this operative guidance has to come from the instructor's verbal description because joint movement of the instrument (as seen in open and laparoscopic surgery) is not possible. As summarized by one respondent, “It's amazing how purposeful your communication needs to be when there are parallel tasks happening in a room” (Surgeon 16). Unaddressed, these limitations could significantly diminish residents’ skill acquisition, which is why the final recommendation is to use the dual console as a unique teaching tool to provide graded autonomy but to remember that verbal guidance is necessary to appropriately convey technique.

Discussion

Since the emergence of surgical practice, training the next generation of surgeons has challenged educators. Recent attempts to standardize the resident training process have been confounded by efforts to reduce health care costs and decrease adverse outcomes.[25] Emphasis on decreasing hospital lengths of stay and increasing clinical productivity results in faculty surgeons with less time for teaching or mentoring resident surgeons.[26]

With these evolving challenges, surgical educators must critically assess the effectiveness of educational techniques in the operating room. Efficient and effective training requires continuous evaluation and modernization to parallel the constant transformation of the operative environment (surgical classroom) and the learners within it.[27,28] Recent examples of education innovation include the use of online tools such as social media, podcasts, videos, live streaming, and other resources.[28–31] The process of introducing robotic technology into surgical training influences residents’ experiences and thus requires investigation.

The results of our study lend further support to ongoing concerns that the rapid growth in robotic technology has created new challenges for surgical educators.[25,32] The first and most frequently cited challenge for surgeons integrating residents into robot-assisted cases is the ongoing learning curve of surgical faculty. This challenge has been documented in the literature on robotics[25] and laparoscopy[33] and is often present with any new technology. However, in our study we discovered themes with challenges that were not described with earlier technology. Additionally, for each of the 4 themes, we were able to identify an associated recommendation (Table 1) that we developed after considering the varying opinions of participants. These recommendations can benefit all surgical educators.

The first theme underscores the two types of skills residents must learn: surgical and technological. The surgical faculty who participated in our study were introduced to robotic technology after completing their general surgery training. Because of this sequencing, the instruction provided by the technology industry that specifically focused on the robot as a surgical tool was a sufficient addition to the surgeons' already established surgical expertise. Our results suggest that exposing trainees to fundamental surgical technique and the specifics of robotic technology in tandem may lead to a cognitive overload and result in decreased skill acquisition overall.[34] By providing opportunities for focused acquisition of the robotic tool skills outside the operating room, trainees are prepared to use the operative environment to focus on learning surgical technique. Surgeons in other specialties than our respondents (who were mainly gastrointestinal and endoscopic surgeons), such as thoracic surgery, argue for a similar emphasis on simulation outside the operating room.[35] Additionally, the materials created by the robotics industry for instructing *fully trained surgeons* to successfully and safely use the robotic tool may not be as effective with or applicable to a group of learners who comprehend less about surgical technique.

The second theme, which highlights opinions about the best timing for exposing trainees to robotic technology, reflects the various timings currently used. Some institutions are introducing robotics during the first year of surgical training, while others have a single month of exposure offered in the fourth year of training.[15] To combat this variability and attempt to standardize expectations, some fellowships require completion of a robotic course before fellowship training starts. Further exploration is needed to determine the costs and benefits of these courses as robotic surgeries, and resident participation, continue to increase.

Variability of exposure is a challenge that has plagued surgical educators for years. Current techniques for increasing learners' access to a wide variety of clinical presentations and diverse surgical approaches, and ultimately for standardizing the content of the educational experience, include the use of elearning, online curricula, and simulation for surgical training.[27] These methods attempt to increase the opportunities for hands-on experience and accessibility to information, but they cannot replicate the robotic experience. Thus, educators must consider how to increase access to the robot in the operating room. Greater access may be feasible if surgeons expand the number and type of basic surgical procedures using robotic technology (as more basic surgical steps could translate into more learner opportunities). Of course, for every surgical operation surgeons must consider all risks and benefits, and ultimately the type of surgical approach chosen should reflect what is best for each patient.

The third theme highlights an unexpected finding from this study. Opinions regarding the similarities of robotic surgery to open or laparoscopic surgery were absolute but divided. Since robotic surgery is advertised as the most advanced minimally invasive tool, one can understand the argument that robotics is an extension of laparoscopic surgery. However, recent research suggests that a preexisting understanding of laparoscopic technique may make learning robotic skills more difficult.[36] This finding supports the argument that learning how to operate robotically and learning how to operate laparoscopically require different skill sets. By emphasizing overlapping and varying features of laparoscopic and robotic techniques, educators can begin to define these similarities *and differences* for learners. Using all minimally invasive surgeries as an opportunity to discuss both laparoscopic and robotic technique allows trainees to better understand multiple modalities of minimally invasive surgery. With the technological advances occurring throughout the surgical field, comprehension of multiple modalities appears inevitable.

The final theme highlights the dual console as a unique teaching tool that provides seamless role transfer between two surgeons. However, unlike other modalities of surgical technology, use of the dual console requires verbal instruction. The need for appropriate communication in the operating setting is hardly new, but the challenges of the surgeon being at a distance from other team members is a new feature of the environment created by robotic technology[37] that influences the importance of direct and effective communication. Without understanding off-screen components of the operating room, trainees will be unable to independently recreate the same surgical field and adequately employ the appropriate surgical technique.

Despite our findings, we recognize the study has several limitations. Using interviews allowed for exploration and analysis of robotic surgeons' perspectives. However, we were limited to interviewing surgeons who were both present at the conference and available to meet with us, and thus our interview data do not include perspectives of current trainees. Additionally, interviewing in the context of a meeting resulted in an inconsistent collection of demographic data. We do not know the age range, surgical specialties, geographic regions, or gender composition of our group of participants. Collecting data at a single event, while nationally attended, could have created an unintentional respondent bias. Additional studies are needed to explore the degree of generalizability of our findings. Finally, the format of our data collection precluded validating our participants' responses.

Conclusions

This study confirmed that integrating robotic technology into resident training is indeed challenging. Additionally, this study yielded 4 recommendations that are likely to improve the process of integration and, ultimately, trainees' ability to provide appropriate and safe patient care regardless of the ever-changing operating environment. Future studies are needed to determine if these recommendations improve the integration of robotic technology into resident training at academic medical centers.

References

1. Alimoglu O, Sagiroglu J, Atak I, et al. Robot-assisted laparoscopic (RAL) procedures in general surgery. Int J Med Robot Comput Assist Surg. 2016;12(3):427-430.
2. Baker EH, Ross SW, Seshadri R, et al. Robotic pancreaticoduodenectomy for pancreatic adenocarcinoma: Role in 2014 and beyond. J Gastrointest Oncol. 2015;6(4):396-405.
3. Cerfolio RJ, Bryant AS, Minnich DJ. Starting a robotic program in general thoracic surgery: Why, how, and lessons learned. Ann Thorac Surg. 2011;91(6):1729-1737.
4. Schommer E, Patel VR, Mouraviev V, Thomas C, Thiel DD. Diffusion of robotic technology into urologic practice has led to improved resident physician robotic skills. J Surg Educ. 2016;(904):1-6.
5. Herron DM, Marohn M, The SAGES-MIRA Robotic Surgery Consensus Group. A consensus document on robotic surgery. Surg Endosc. 2008;22(2):313-325.
6. Lim SH, Lee HM, Son T, Hyung WJ, Kim H-I. Robotic surgery for gastric tumor: Current status and new approaches. Transl Gastroenterol Hepatol. 2016;1:28-28.
7. Park SS, Kim MC, Park MS, Hyung WJ. Rapid adaptation of robotic gastrectomy for gastric cancer by experienced laparoscopic surgeons. Surg Endosc Other Interv Tech. 2012;26(1):60-67.
8. Escobar Dominguez JE, Ramos MG, Seetharamaiah R, Donkor C, Rabaza J, Gonzalez A. Feasibility of robotic inguinal hernia repair, a single-institution experience. Surg Endosc Other Interv Tech. 2016;30(9):4042-4048.
9. Bhandari M, Mathur W, Mishra AK, Chandorkar D. Robotic Roux-en-Y gastric bypass: Our centre's technique with short-term experience. J Minim Access Surg. 2017;13(2):2-6.

10. Economopoulos KP, Mylonas KS, Stamou AA, et al. Laparoscopic versus robotic adrenalectomy: A comprehensive meta-analysis. Int J Surg. 2017;38:95-104.

11. Gkegkes ID, Mamais IA, Iavazzo C. Robotics in general surgery: A systematic cost assessment. J Minim Access Surg. 2016:195565.

12. Shulman LS. Signature pedagogies in the professions. Daedalus. 2005;134(3):52-59.

13. Mi J, Kang Y, Chen X, Wang B, Wang Z. Whether robot-assisted laparoscopic fundoplication is better for gastroesophageal reflux disease in adults: A systematic review and meta-analysis. Surg Endosc Other Interv Tech. 2010;24(8):1803-1814.

14. Lee J, Kim Y-M, Woo Y, Obama K, Noh SH, Hyung WJ. Robotic distal subtotal gastrectomy with D2 lymphadenectomy for gastric cancer patients with high body mass index: Comparison with conventional laparoscopic distal subtotal gastrectomy with D2 lymphadenectomy. Surg Endosc. 2015:3251-3260.

15. Green CA, Chern H, O'Sullivan PS. Current robotic curricula for surgery residents: A need for additional cognitive and psychomotor focus. Am J Surg. 2018;215(2):277-281.

16. Ahmad A, Ahmad Z, Carleton J, Agarwala A. Robotic surgery: Current perceptions and the clinical evidence. Surg Endosc. 2017;31:255-263.

17. Köckerling F. Robotic vs. standard laparoscopic technique—What is better? Front Surg. 2014;1:15. https://doi.org/10.3389/fsurg.2015.00038

18. Farivar BS, Flannagan M, Leitman IM. General surgery residents' perception of robot-assisted procedures during surgical training. J Surg Educ. 2014;72(2):235-242.

19. Brenot K, Goyert G. Impact of robotic surgery on obstetric-gynecologic resident training. J Reprod Med. 2009;54(11-12):675-677.

20. Partlett M, Hamilton D. Evaluation as illumination: A new approach to the study of innovative programmes. https://files.eric.ed.gov/fulltext/ED167634.pdf. Accessed November 30, 2018.

21. Maxwell JA. Qualitative Research Design: An Interactive Approach (Applied Social Research Methods). Thousand Oaks, CA: SAGE Publications, Inc; 1996.

22. Becker HS. Problems of inference and proof in participant observation. American Sociological Review. 1958:23;652-660.

23. Robotic Surgery Collaboration. https://www.facebook.com/groups/1522777931338325/?multi_permalinks=2228943620721749&notif_id=1543604216629092&notif_t=group_highlights [Facebook timeline]. Accessed March 31, 2017.

.24. Sweller J, van Merrienboer JGG, Paas FGWC. Cognitive architecture and instructional design. Educ Psychol Rev. 1998;10(3):251-296.

25. Mehaffey JH, Michaels AD, Mullen MG, et al. Adoption of robotics in a general surgery residency program: At what cost? J Surg Res. 2017;213:269-273.

26. Ludmerer KM. The Development of american medical education from the turn of the century to the era of managed care. Clin Orthop Relat Res. 2004;(422):256-262.

27. Evans CH, Schenarts KD. Evolving educational techniques in surgical training. Surg Clin North Am. 2016;96(1):71-88.

28. Chauvin SW. Applying educational theory to simulation-based training and assessment in surgery. Surg Clin North Am. 2015;95(4):695-715.

29. Willis RE, Van Sickle KR. Current status of simulation-based training in graduate medical education. Surg Clin North Am. 2015;95(4):767-779.

30. Samia H, Khan S, Lawrence J, Delaney CP. Simulation and its role in training. Clin Colon Rectal Surg. 2013;26(1):47-55.

31. Stefanidis D, Sevdalis N, Paige J, et al. Simulation in surgery: What's needed next? Ann Surg. 2015;261(5):846-853.

32. Jain M, Fry BT, Hess LW, Anger, JT, Gewertz BL, Catchpole, K Barriers to efficiency in robotic surgery: The resident effect. J Surg Res. 2016;205(2):296-304.

33. Stefanidis D, Acker CE, Swiderski D, Heniford BT, Greene FL. Challenges During the implementation of a laparoscopic skills curriculum in a busy general surgery residency program. J Surg Educ. 2008;65(1):4-7.

34. Young JQ, Van Merrienboer J, Durning S, Ten Cate O. Cognitive load theory: Implications for medical education: AMEE Guide No. 86. Med Teach. 2014;36(86):371-384.

35. Linsky P, Wei B. Training in robotic thoracic surgery. J Vizualized Surg. 2018;4(1).

36. Panait L, Shetty S, Shewokis PA, Sanchez JA. Do laparoscopic skills transfer to robotic surgery? J Surg Res. 2014;187(1):53-58.

37. Cao CGL, Taylor H. Effects of new technology on the operating room team. Work with Comput Syst. 2004:309-312.

Table 1

Themes, Challenges, and Associated Recommendations for Integrating Robotic Technology Into Surgical Training[a]

Themes	Challenges	Recommendations
Technique vs tool	Residents must learn both in tandem.	Differentiate learning environments for focused acquisition of surgical technique and surgical tool.
Variable timing of exposure	Type and timing of initial exposure varies (e.g., first case could be technically complex).	Regardless of level of training at initial exposure, provide increased access to cases with basic surgical steps in an effort to smooth the integration process.
Relationship of robotics to laparoscopy	The two types of surgery have some similar features, but others that are very different.	Highlight overlapping and varying features during all minimally invasive surgery cases to improve learner's understanding of these features regardless of sequence of exposure.
Dual console[b]	Resident's required involvement as assistant is reduced in robotic surgeries.	Use the dual console as a unique teaching tool to provide graded autonomy but remember verbal guidance is necessary to appropriately convey technique.

[a]Developed from interviews of 24 surgeons at the 2017 Annual Meeting of the Society of American Gastrointestinal and Endoscopic Surgeons in Houston, Texas, March 22–24, and from responses to a prompt posted on a monitored social media platform for robotic surgeons.

[b]A system that enables two consoles to operate the robot; the primary console determines what functions the secondary can use.

Table 2

Quotations From Surgeons Supporting the Themes and Recommendations for Integrating Robotics Into Resident Training[a]

Themes	Quotations
Technique vs tool	• "The simulation system is very important for residents learning so that the[y] can become familiar with the robot and its capabilities." (Social media surgeon[b] 28) • "As we all know, competency and proficiency in knowledge is separate from technique." (Social media surgeon 21) • "[We must] make sure they are prepared to come to the console. I think assigning robot homework for prep is totally fair." (Social media surgeon 6)
Variable timing of exposure	• "[A] certain degree of operative skill is required to understand robotics." (Surgeon 22) • "[W]e are not allowed to do a case on the robot that we haven't proven we can do well laparoscopically. So, we are learning to use the tool as opposed to learning to do the case." (Social media surgeon 7)
Relationship of robotics to laparoscopy	• "[T]his [robotic] training pathway is different in some critical ways. I had to watch my attendings go through lap[araoscopic] colon learning curves, which hurt my personal curve. I'd like to do it better this time around." (Surgeon 16) • "Laparoscopic skills such as patient positioning and port placement are critical for robotic surgery." (Surgeon 11)
Dual console[c]	• "Dual console is invaluable. You will be seeing 3D as compared to 2D on screen, you can adjust their view by moving the camera, you can point on the screen what you want them to do, and you can immediately take over when they're about to screw up." (Social media surgeon 8) • "The communication gap is fascinating as well, since we are now not immediately in proximity to the bedside team…. It's amazing how purposeful your communication needs to be when there are parallel tasks happening in a room." (Surgeon 16)

[a]Quotations are taken from interviews of surgeons at the 2017 annual meeting of the Society of American Gastrointestinal and Endoscopic Surgeons in Houston, Texas, March 22–24, and from responses to a prompt posted on a monitored social media platform for robotic surgeons.

[b]Social media surgeon: Designates respondents who responded to the prompt on a monitored social media platform for robotic surgeons.

[c]A system that enables two consoles to operate the robot; the primary console determines what functions the secondary can use.