Is Robotic Surgery Highlighting Critical Gaps in Resident Training?

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Integrating robotic surgery into resident training is challenging. The robotic environment requires reconsideration of the apprenticeship model for surgical training and development of new curricula and instructional approaches to ensure skill acquisition. The surgical literature has mentioned the need to improve resident training in robotic surgery. This article highlights components of the robotic teaching environment that limit the efficacy of current training models. By targeting these components, educators can begin to develop more effective curricula and instructional strategies for surgical residents.

The robotic learning environment is complex. It incorporates a physically distant operative field, separating the trainer and the trainee; it makes the surgeon less dependent on assistance from a resident; and it necessitates acquisition of perceptual expertise without tactile information. At teaching hospitals, residents are exposed to an increasing number of robotic procedures, yet this often occurs in the context of observers, not participants. This has resulted in an emerging training gap. By considering relevant cognitive learning theories, we can guide surgical educators to new approaches to reduce this gap.

While recent literature highlighted the feasibility and safety of implementing robotic curricula in residency, few studies have evaluated their efficacy, or described curricular components in detail.[1] Surgical educators need a deep understanding of the robotic environment to appropriately evaluate the efficacy of resident integration in the operating room.

Robotic technology provides independence for surgeons. Using the robot, 1 surgeon controls 4 robotic arms and manipulates the camera independently, decreasing the need for residents as assistants. While beneficial to hospitals with limited staffing, this aspect of robotic surgery presents challenges in teaching settings. Typically, in open or laparoscopic operations, residents obtain technical skills as surgical assistants, providing retraction and tissue manipulation essential for creating a functional operative field. This experience allows learners to understand how the surgeon's movements (degree of tension or retraction) affect the operative field. Residents stand across from, or adjacent to, the attending surgeon throughout the procedure—often with arms entangled in an effort to create adequate visualization. Residents directly observe the attending physician's physical movements, including minute details of individual digit placement,[2] while performing each operative step.

DOI: http://dx.doi.org/10.4300/JGME-D-17-00802.1

Robotic surgery technology is entirely different. It creates a physical distance between the operating surgeon, the operative field, and any assistants or learners. Residents are positioned at the bedside assisting with instrument exchange, or seated at a console distant from the sterile operative field. They cannot see the attending's physical movements, and cannot appreciate when the attending surgeon "clutches," repositioning the hands, maximizing economy of motion. Residents also are unaware when the attending reaches for the foot pedal to swap robotic arms or activate electrocautery. Residents are limited to observing the movements of the robotic arms, either extracorporeally from the bedside or intracorporeally from a console or monitor.

To learn to perform the movements as they appear on the screen, the resident must recreate the movements of the surgeon seated at the console. In contrast, in open and laparoscopic surgery, the operating surgeon's movements are open and visible. In the robotic environment, the operating surgeon's movements cannot be fully appreciated. How will residents understand what physical movements on the console are needed to translate into the same observed actions seen on the screen?

The frequent experiential instruction that occurs in surgical training becomes complicated by a physically separated operative field (described by Zemel and Koschmann[2] as the combination of instructional demonstration, creation of referential practices, and embodied procedures).

Residents typically gain operative experience in robotic cases by watching the intracorporeal images on the screen and listening to the attending surgeon explain what he or she is doing. The image on the screen rarely portrays the entire operative field, limiting what the resident can see and learn. Increased magnification from robotic technology frequently results in 1 or 2 of the robotic arms no longer being visible on the screen. An observing resident may not have access to all the information necessary to understand critical principles of robotic surgical technique.

Today's robotic technology lacks haptic feedback, requiring robotic surgeons to rely entirely on visual processing to interpret what is happening in the operative field, and many expert robotic surgeons report that, despite a lack of tactile feedback, they can still "feel what they see."[3] Nonrobotic surgeons can relate. Consider this scenario: without touching instruments, the attending surgeon calls out to the resident, "Careful! You're pulling too much." Right then, the tissue tears, and the resident relaxes retraction to avoid further injury. How could the attending know this? How did the attending *feel* too much tension? By watching the changes in the tissue response as the resident's instrument pulls, expert surgeons can *feel* simply by observing images on the screen. But how is this process translated to residents? Once educators have a common language to describe the components of this skill, additional efforts can focus on the best teaching methods to ensure efficient and effective acquisition.

To address this challenge, we draw from relevant cognitive science theories. Perceptual learning describes experience-induced modifications in the way we extract perceived information. Using a continuous perception-action cycle, learners develop goal-driven behavior known as *perception for action*.[4] Professional vision describes practices that help novices build disciplined ways of seeing events and understanding their implications for practice.[5] Using perception for action and professional vision, learners gain perceptual expertise, often seen as a logical endpoint of the normal trajectory of learning (perceptual learning) in a domain-specific environment. Studies support the notion that perceptual expertise is gained with surgical experience and correlates with skill mastery.[6,7] Given the lack of haptic feedback and dependence on visual information guiding operative decisions in robotic surgery, understanding how to develop perception for action is essential for robotic skills mastery.

Perceptual learning is common in surgical training—residents develop technical and cognitive skills reciprocally and in situated context. Licensure, as regulated by the American Board of Surgery, requires completion of a defined number of surgical cases (or situated contexts). Although perceptual learning is widely accepted in surgical education, focused instruction using this framework has been absent. How can robotic surgeons articulate their perceptual expertise?

Researchers such as Koschmann et al[15,16] and Cope et al[17] have improved our understanding of how surgeons express what they are seeing during operative procedures. To advance their work, we need to probe surgeons' perceptual expertise. Language and gestures are essential for instruction, and develop within context. We believe through study of the robotic context, language, and associated gestures, components of this skill can be elicited from surgeons. Ensuring development of perceptual expertise will prepare future surgeons for open, laparoscopic, endoscopic, or robotic approaches to surgery. Recommended next steps for the medical education community are shown in the BOX.

To investigate expert surgeons' verbal and nonverbal language of perceptual expertise in robotics, we plan to use microanalysis, a qualitative approach in education research that identifies patterns and themes within the actions taking place in an environment.[18] In prior microanalysis of intracorporeal robotic video,

BOX Next Steps for the Medical Education Community

Surgical Residents
- Be actively involved in robotic cases—even if role is at bedside[8]
- Complete criteria recommended (as outlined by faculty/department) prior to case involvement[9,10]
- Ask targeted questions—why port placement was chosen, what instruments are being used, what important features are off-screen, what would be different if done open/laparoscopically

Surgical Faculty
- Track self-robotic experiences[11,12]: what cases were performed, how often residents are involved, how often residents are operating on console, what key points came up, what challenges arose, what to do differently in the future
- Identify case complexities and match resident appropriate level[10]
- Determine criteria residents must achieve to increase participation (stepwise, graduated process)[9,13]

Surgical Educators (Residency Program)
- Establish expectations for residents, faculty, and surgical staff for robotic cases[12–14]
- Provide faculty development opportunities to assist with robotic-specific teaching skills
- Track resident participation in robotic cases

we revealed features of the robotic environment not previously appreciated.[19] Combining microanalysis of robotic experts describing on-screen activities with semiotics (the investigation into how meaning is created and communicated), we anticipate this will generate a verbal and nonverbal language to describe specific on-screen perceptions for action by expert robotic surgeons. Revealing foundational components of perceptual expertise in surgical practice will allow for investigation and development of instructional approaches using this framework.

Surgical residents must learn surgical techniques necessary to perform safe operations using a range of tools and technologies. Revealing how robotic surgery experts use words, gestures, and vocalizations to communicate what they can only see and how elements of their perceptual expertise guide intraoperative decision-making will allow educators to develop methods to cultivate perceptual expertise. Addressing perceptual expertise in surgical training will contribute to ensuring trainees acquire the fundamental skills to successfully navigate a rapidly evolving surgical environment.

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