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Authors

Green, Courtney A
O’Sullivan, Patricia S
Sarin, Ankit
et al.

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ORIGINAL ARTICLE

Microanalysis of video from a robotic surgical procedure: implications for observational learning in the robotic environment

Courtney A. Green[1] · **Patricia S. O'Sullivan**[1,2] · **Ankit Sarin**[1] · **Hueylan Chern**[1]

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Abstract

Without haptic feedback, robotic surgeons rely on visual processing to interpret the operative field. To provide guidance for teaching in this environment, we analyzed intracorporeal actions and behaviors of a robotic surgeon. Six hours of video were captured by the intracorporeal camera during a robot-assisted lower anterior resection. After complete review, authors reduced the video to a consecutive 35 min of highly focused robotic activity and finally, a 2-min clip was subjected to microanalysis. The clip was replayed multiple times (capturing 1, 2, 10, 60 and 120 s intervals) and activities were identified, such as right and left hand motion, tissue handling and camera adjustments recorded using a software program. Activity patterns were categorized into two main themes: change in operative focus occurs when there is an inability to obtain adequate tension, and observation of robot-assisted surgery is based on an incomplete visual framework. The surgeon manipulated tissue predominantly using blunt adjustments and rarely grasped it, likely as a way to avoid tissue trauma. A magnified operative field required precise dissection, which occurs robotically with movement of a single instrument against a static field (motionless second robotic arm). This meticulous technique is unlike the bimodal manipulation often used for laparoscopic dissection. Since residents have limited active participation in robotic cases, and therefore, rely heavily on the captured image for skill acquisition, we recommend surgeons to use focus shifts as an opportunity to describe their operative decision-making and highlight instrument manipulations specific to operating with robotic technology.

Keywords Robotic surgery · Surgical education · Surgical teaching

Introduction

The exponential growth of robotic surgery over the past 15 years has resulted in the emergence of a new curriculum for surgical trainees [1–8]. Although this curriculum is not standardized, integrating robotics into resident training at most experienced centers occurs in a consistent sequence of exposure to online modules, simulation practice, observation and/or participation as bedside assistant, and finally, participation on the console [9]. Unfortunately, early studies suggest resident exposure to robotic technology may come with some costly consequences [10] and leave negative impressions amongst surgical trainees [11, 12]. A national survey conducted in 2014 revealed 46% of general surgery residents felt robot-assisted surgeries interfered with their training [12]. The reasons for these negative impressions are unclear, but one possibility is that the greater number of robotic procedures being done translates into fewer hands-on operative experiences for residents [11]. This is likely due to "on the job" training felt necessary by many current general surgeons which leaves minimal operative time for resident participation during the initial attending learning curve. A study of general surgery residents found that although 63% reported participating in a robotic operation, just 18% accessed the operative console [12]. Another study reported 100% resident participation in laparoscopic cases and 70% participation in robotic cases, but only 21% of the time were the residents actually sitting at the operative console [10].

As robotic cases continue to evolve in academic settings, educators must ensure resident skill acquisition persists uncompromised. Yet little is known about how residents

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✉ Courtney A. Green
Courtney.Green@ucsf.edu

[1] Department of Surgery, University of California, San Francisco, 513 Parnassus Avenue, S-321, San Francisco, CA 94143-0470, USA

[2] Department of Medicine, University of California, San Francisco, 505 Parnassus Avenue, Room M994, San Francisco, CA 94122, USA

acquire surgical skills in a robotic environment. One early study illustrated that structured graded exposure to robotic technology can lead to improved robotic surgical performance [13]. However, to our knowledge, no studies have investigated the process of resident skill acquisition in the current (often mostly observational) robotic environment.

To determine how residents can best acquire skills in a robotic environment requires investigation into what resources competent robotic surgeons use to operate successfully. Without haptic feedback, robotic surgeons rely on visual processing to interpret the operative field. The surgeon's visual interpretation becomes the driving force for intraoperative decision-making. The resident's exposure to robotic technology in most general surgery training programs includes a period of observation and participation in robotic cases as the bedside assistant [14]. In this role, they observe the operation via the intracorporeal footage displayed on monitors. Accordingly, we decided to analyze this same visual information.

Formal review of intraoperative video footage has been used to identify miscommunications between operative staff that could jeopardize patient safety [15]. This approach, termed microanalysis, is a qualitative method used in education research to identify patterns and themes within the actions taking place on screen. Essentially, microanalysis consists of reviewing and re-reviewing video multiple times using various intervals of focus. A recent study illustrating the strengths of this approach states, "Microanalysis… is unique in that it operates on a 'microscopic' level, highlighting human actions involved in clinical events and illuminating the ways in which they are interwoven, taking full advantage of the fine detail offered by the video record" [15].

The purpose of this study was to determine what educational surgical themes can be identified from the images portrayed on screen through a microanalysis of intracorporeal robotic footage from a robot-assisted surgical procedure.

Methods

The study was conducted using a single surgical procedure performed entirely by one faculty surgeon at the University of California San Francisco. At the patient's bedsides stood a sterile nurse serving the role of scrub technician and a sterile third year surgical resident serving the role of surgical assistant. The University approved this study as exempt.

An intracorporeal camera captured over 6 h of video during a robot-assisted lower anterior resection. An audio recording device documented the operating surgeon's verbal dialogue and was synchronized with the video record after the procedure concluded. The video was edited down to 35 min of intraoperative, robot assisted, surgical activity. This 35-min clip was reviewed repeatedly to create qualitative memos about each segment. Memos highlighted occurrence, content and subjects of verbal discourse, robot-assisted activity, hand-assisted activity and off-screen activity. On the basis of these memos, we selected a 2-min segment with diverse robotic activity and subjected it to microanalysis. The clip was replayed multiple times (capturing 1, 10, 30, 60 and 120 s intervals) to identify various on-screen activities, including right and left robotic arm motion, tissue handling, camera adjustments and verbal dialog. Documentation of on-screen activities was recorded by hand on graph paper and subsequently inputted into an electronic form (using Microsoft PowerPoint). Activities were then categorized into themes, which formed the basis for recommendations for educators and learners.

Results

Two major themes emerged from the microanalysis: change in operative focus occurs when there is an inability to obtain adequate tension, and observation of robot-assisted surgery is based on an incomplete visual framework. As shown in Fig. 1 (a portion of one of the micro-analyzed segments, which represents 1 min of video footage with various activities illustrated), changes in operative focus can be seen to have occurred immediately after increased activity of camera adjustment and tissue manipulation. Figure 1 also captures the left and right robotic arm activity; here it appears that dissection occurs with movement of *either* the right or left robotic instrument against a static second field (motionless second arm). In other words, it appears that the left arm is motionless as the right arm dissects or vice versa.

Microanalysis from a 15-min segment of 30-s intervals recorded additional activities not captured in Fig. 1. One activity recorded was third-party participation, defined as presence of either the third robotic arm on screen or the bedside assistant's tool on screen. In the entire 15-min segment, there was less than 1 min of identified third-party activity. This led us to question if there was ongoing activity with the assistant port or the additional robotic arms that was not captured on screen. When we re-reviewed this 15-min segment, we identified either one or two of the four robotic arms on screen. However, when the camera zoomed out several minutes later, the third robotic arm could be seen retracting tissue. Thus, one can presume that this third arm was functioning and intimately involved in the resulting on-screen actions we observed in Fig. 1, even though its presence or its role in the on-screen actions could not be visualized.

The lack of third-party activity observed in our review of the 15-min segment led us to consider additional off-screen activities that could be potentially occurring. Figure 2 illustrates one suggested arrangement (modified from Intuitive Surgical INC's marketing materials) of the robotic tools used

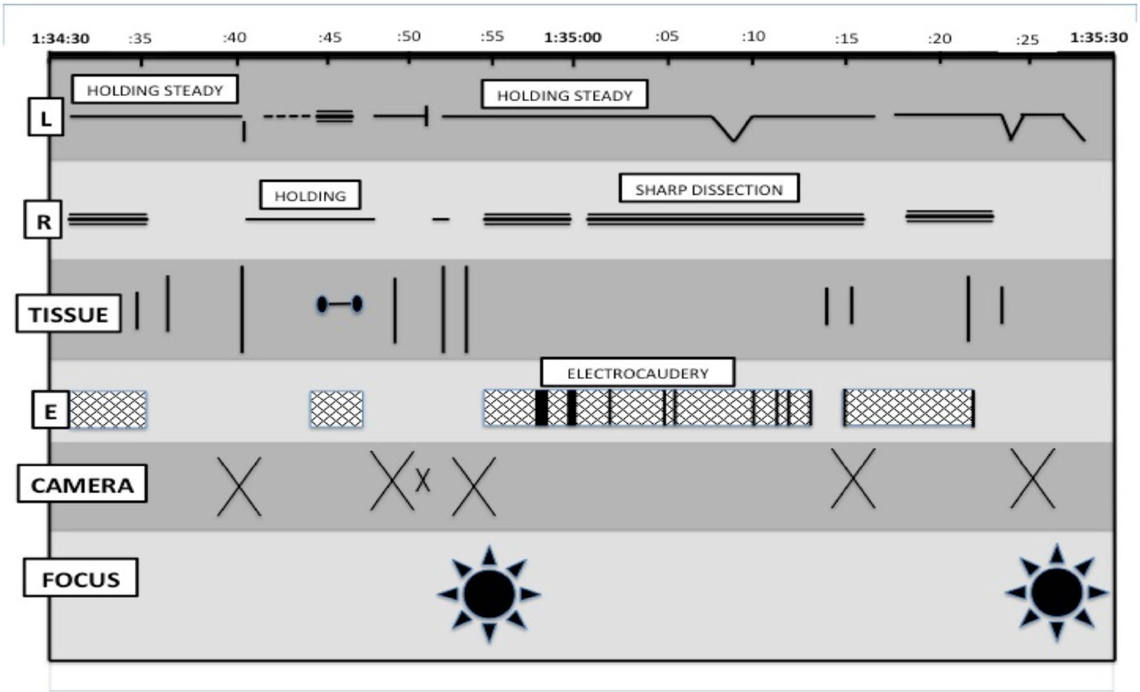
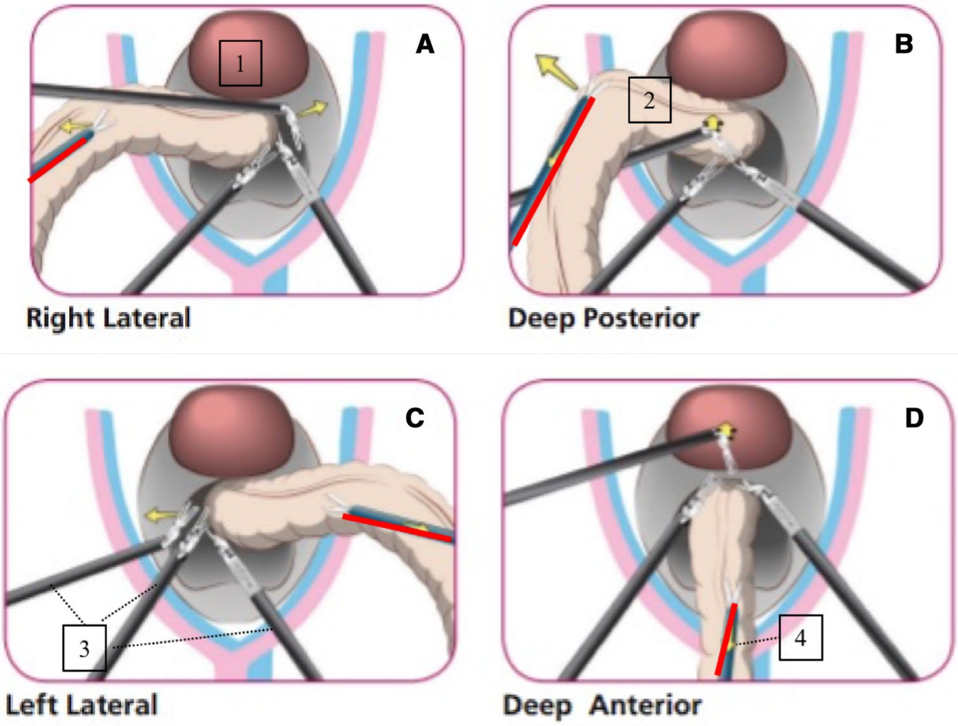


Fig. 1 Schematic diagram showing 1 min of microanalysis of on-screen activities during a robotic lower anterior resection. The analysis took place over 1-s intervals. The numbers along the top indicate 5 s has elapsed. Different activities are represented in each row. Descriptions of each row include: *L* left robotic arm activity; *R* right robotic arm activity; thickened line indicates sharp dissection. Dotted line indicates rapid short bursts of sharp dissection. Dip in line indicates arm movement. *Tissue* type of tissue manipulation (vertical lines indicate sweeping motions and circles represent grasping tissue) (longer lines indicate larger movements); *E* electrocautery activated (lack of segments indicates deactivation of electrocautery); *Camera* camera activity (large "X" indicates zooming in and small "x" indicates zooming out); *Focus* change in region of focus

Fig. 2 Recommended robotic set up for low anterior resection. (1) Bladder; (2) colon; (3) robotic instruments (black); (4) assistant port instrument (red)



to most successfully complete the mesorectal dissection of the LAR procedure [16].

If the robotic camera is located below and/or in front of any of the other instruments, the on-screen image will not display the additional instruments for the majority of the dissection. Without the complete picture, we must consider how this might change observer assumptions. One might presume that a magnified operative field requires increased precision of instrument manipulation during dissection. Perhaps that could explain the single-arm dissection observed in Fig. 1. If robotic surgery utilized single-arm dissection, robotic technique would vary greatly from the bimodal manipulation that occurs both in laparoscopic and open dissection. Surgeons know that maintaining constant tension requires providing *ongoing force* during dissection, so what is happening in Fig. 1 when one arm appears static? Is one arm frozen while the other dissects (as depicted in Fig. 1 based on the on-screen observations)? Or are both hands working in tandem as established in all other surgical techniques? Further investigation into the surgeon's physical movements during dissection suggested that bimodal manipulation is occurring in robotic surgery, but the action is at the console (where the surgeon is physically located) and thus not captured on screen. However, due to the magnification and limited field of vision offered by the intracorporeal camera, constant force (and actual hand movement) appears motionless on the screen.

Discussion

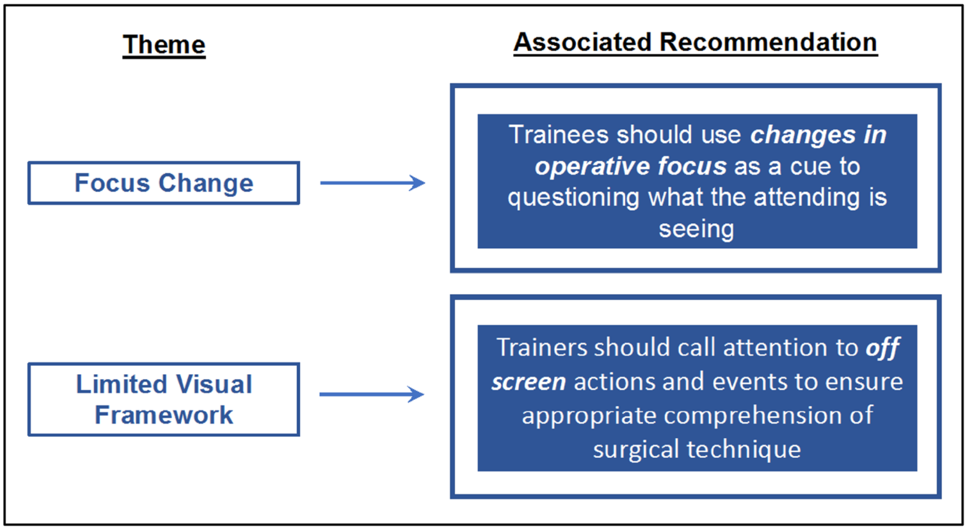
The surgical literature includes several examples of educators using intraoperative video footage to improve various components of surgical performance. Specifically, studies show analysis of surgical video can assist with pattern recognition [17], anatomic identification [18] and technical instruction [19]. Additionally, emerging professional development strategies include options for surgical coaching through video documentation [20]. Using microanalysis of intracorporeal video from a robotic-assisted surgical procedure, we identified two critical themes of robot-assisted surgery. The first theme suggests change in operative focus occurs when there is an inability to obtain adequate tension. The second theme highlights an important limitation of robot-assisted surgery: observation of robot-assisted surgery is based on an incomplete visual framework as the magnified field limits the view to only the micro-dissection rather than the broader exposure and retraction (which may have been setup earlier in the operative process). These themes suggest that observational learning in the robotic environment may require different approaches than in traditional open surgery.

The finding that change in operative focus occurs when there is an inability to obtain adequate tension emerged from understanding basic principles of surgical technique. Obtaining appropriate tension–counter tension to allow for clean dissection is key to forward progress in a surgical procedure. Repeated tissue manipulation and readjustment of the surgical view without making progress with the dissection, which occurred immediately preceding operative focus changes, suggests that the ideal tension–counter tension situation was unobtainable.

What about other events during an operation that bring about a change in the location of the surgeon's focus? For example, identifying an anatomical landmark (such as the pelvic floor muscles or the rectal tube) suggests the surgeon has completed one step of an operation and can continue on to the next (in the case of a low anterior resection identification of the pelvic floor muscularature and the complete rectal tube signals the distal dissection is complete). Another culprit of operative focus change is the presence of unexpected findings. For example, if a surgeon is performing a cancer operation and encounters an abnormal lesion at a site other than expected, the surgical focus will move to the region of the new lesion to determine its underlying pathology: is it a benign variant? Is there evidence of metastatic disease? Determining the underlying pathophysiology proves critical before continuing the operation. Similarly, if a surgeon is dissecting in between two planes and encounters unexpected bleeding or extensive adhesions, he or she may change the operative focus to an alternative location more suitable to a safe, clean dissection.

All of these examples reflect critical moments of intraoperative decision-making by the attending surgeon. Residents could use this visual cue—observing a change in operative focus—to question what the attending is seeing or why the attending is changing focus (Fig. 3). A summary of the themes and resulting recommendations that emerged from this study are illustrated in Fig. 3. Understanding what is happening at critical operative moments is essential for independent practice and would provide valuable information for the observing learner.

The importance of our second major theme emerged when we re-reviewed the video footage to understand how, with a limited view of the surgical field, trainees can learn to recreate the observed actions on screen. Our finding of a seemingly static arm in Fig. 1 contradicts a key principle of physics and of surgical technique: maintaining constant tension requires providing ongoing force during dissection. This concept, which may be innately understood by fully competent surgeons, could be completely missed by trainees if they only observe the image on screen. Additional activities occur off screen as well. For example, the intracorporeal camera (and the resulting image on screen) does not capture the position and activity of any instruments located outside of the camera's magnified view, the external components of the robotic equipment and the physical actions of the operating



Trainees should use ***changes in operative focus*** as a cue to questioning what the attending is seeing

Trainers should call attention to ***off screen*** actions and events to ensure appropriate comprehension of surgical technique

Fig. 3 Themes about robotic surgery identified in microanalysis of video footage and associated recommendations to improve observer skill acquisition

surgeon (such as clutching or pressing any of the foot petals to exchange control of the instruments or introduce electricity or stapling through specific devices). This physical barrier emerges in the robotic environment through separation of the operative field. Important actions are occurring simultaneously at various locations in the operating room. Thus, direct observation of all of the simultaneous actions is prohibited. Without understanding these additional components, trainees will be unable to independently recreate the same surgical field and adequately employ the appropriate surgical technique.

This study reflects an in-depth microanalysis of a single robotic operation—an important limitation since it is only one type of robotic operation being performed by one surgeon on one patient. The general applicability of the results would, therefore, appear to be unclear. However, the two themes that emerged relate to limitations that affect all robotic surgeries. After all, every operation that uses robotic technology depends heavily on visual interpretations to guide intraoperative decision-making (given the current lack of haptic feedback), and every robotic operation fails to capture the entire surgical field in a single space. While our in-depth analysis reflects one single case, our results may nevertheless be applicable and universal to all robotic operations.

Conclusions

This study suggests acquisition of robotic surgical skills requires more than passive observation. Using microanalysis of intracorporeal video from a robot-assisted surgery, we uncovered two major themes: change in operative focus occurs when there is an inability to obtain adequate tension, and observation of robot-assisted surgery is based on an incomplete visual framework. These themes provided the basis for our recommendation for surgeons to use focus shifts as an opportunity to describe their operative decision-making and highlight instrument manipulations specific to operating with robotic technology.

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Compliance with ethical standards

Conflict of interest All authors (Courtney A. Green, Patricia S. O'Sullivan, Ankit Sarin and Hueylan Chern) declare that they have no conflict of interest.

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