Learning to See the Body: Supporting Instructional Practices in Laparoscopic Surgical Procedures

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ABSTRACT
Learning the performance of physically manipulating instruments in minimally invasive surgeries is an impetus for the development of surgical training simulators. However, an often-overlooked aspect of surgical training is learning how to see the body through various imaging mechanisms. With this study, we address the ways in which surgeons demonstrate and instruct residents in seeing the body during minimally invasive surgical procedures. Drawing on observations and analysis of video recordings of minimally invasive surgical operations, we examine how particular anatomy and movement within the body to see and conceptualize that anatomy are made visible by the instructive practices of the surgeon. We use these findings to discuss further directions for minimally invasive surgical training through mechanisms for making the body visible during situated surgical training and surgical training simulation systems.

Author Keywords
Surgery; training; movement; vision; gestures

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
In modern day surgical interventions, medical imaging has come to play an increasingly important role, particularly with it enabling minimally invasive procedures. These are procedures that enter the body through small incisions or existing body orifices. Although the procedure itself may be longer than an open-procedure, the patient benefits of performing a minimally invasive surgery include the reduced risk of hemorrhaging, reduced pain, shortened recovery time, and reduced exposure to infections.

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In order to conduct these surgeries, alternatives to 'direct vision' of the anatomy are required – these could include fluoroscopic X-rays or, as in this paper, a laparoscope. This method of visualizing the body is referred to as 'indirect vision'. New 'indirect' digital visualization technologies in minimally invasive surgery alter what it means to see the body [7] in that they present information that could not have otherwise been seen, information in a different manner or representation than had been seen before, or new ways for the surgical team to see the body together.

Moreover, these digital representations require further work in perceiving and acting upon the information presented. Many studies of medical image use discuss the negotiations around and interpretation of images in clinical and surgical work [1, 24, 29, 30, 44] and that vision is situated and interactional (see [15, 16, 18, 23, 41, 46, 52]); that the information one must glean from an image is not self-evident and work must be done (alone with the image or in conjunction with others) in order to use the images in practice. Seeing the body during surgery is a complex process of resolving the digital body as it is represented on the screen with what one knows from prior study and what one learns through interaction and explorations of the body. Surgeons bring their past experiences into alignment with their sensory stimuli in order to interpret what is before them and address contingencies of the surgical work [43] [38]. Learning the practice of surgery is reliant on the ability of the trainer to teach a resident to resolve the body before them with the abstract representations of anatomy they have learned from books and diagrams.

One mechanism of achieving this is through dissection –the process through which the internal body is made visible and identifiable in relation to abstract representations [24]. This method of viewing the body is a part of the training and visual learning of human anatomy that a surgeon must undergo – to see the body as parts that are separable from the whole body [44]. However, in order to perform a dissection, one must be able to identify anatomy through the representation before them. It is an iterative process of seeing and acting; one that requires an effective medical gaze.

As we argue in this paper, simply viewing an image does not directly translate to a surgeon acquiring an effective medical gaze in minimally invasive surgery. Much guidance is needed in interpreting and working with that image towards the particular goals of the surgery. Koschmann has particularly been integral in showing the importance of the interpretive nature of seeing in surgery and the effect it has over action [32, 33]. However, the general attention around training programs and the development of simulations for training residents in the conduct of minimally invasive surgery has focused on the learning of skill in manipulating instruments and manipulating objects with those instruments. Much less discussion has been on the trainee's ability to make useful images and, more importantly, how to see into the body through this constrained view. For instance, learning how to identify where to look next, what one is seeing before them, and where the object they want is located in reference to where they are now are just a few of the visual abilities a new surgeon must acquire before being deemed proficient in this new method of surgery. This missing concern for how one learns to view and work with and within these images reflects, ironically, a cultural habit of the Western sciences to privilege vision as the most important perceptual sense [25]. The assumption is that what is seen in the video is self-evident – that it is what one would see if they were looking directly into the body and thus, their knowledge from one form of visual representation to the other is easily transferable.

With this paper, we want to show the considerable work surgeons engage in in order to use the images effectively in practice and consider the ways in which surgical training is accomplished, specifically in how surgeons instruct trainees in how to see the body through indirect vision. Examining these occasions when instruction is provided exposes not only how a trainee's knowledge and skills are manifest, but also how practitioners 'situate' learning in their own practice. We aim to expose the techno-mediated practices of surgical instruction and learning in using endoscopic video. This is important due to the increasing use of images in minimally invasive surgery and opportunities for design of mechanisms for interaction around those videos, but also more broadly for our understanding of how image and video seeing practices (in any domain) are not without work and require learning, experience, and training as well.

We pull from the field observations and video recordings of twelve 'naturally occurring' surgical operations for our analysis. From our findings, we aim to address the question of the future directions for minimally invasive surgical training systems as well as consider referencing mechanisms to enable trainees and trainers to observe and perceive together in situ in order to attain technical mastery.

The Challenges of Seeing in Minimally Invasive Surgery

There are a number of barriers and artifacts of use that must be overcome in order to make the leap from open surgery to closed surgery utilizing 'indirect vision' – more than simply learning how to use a new set of instruments to manipulate the body [49, 50].

For instance, there may be a difference in orientation between one's relationship to the body and the direction the imaging device is oriented. As opposed to an open abdominal operation where the surgeon looks down at their hands, instruments, and the workspace, in a laparoscopic operation the camera's line-of-sight is usually different from the surgeon's natural line-of-sight. The surgeon must compensate for artifacts such as a rotated view of the scene or the instrument tips moving in a different direction. Typically this entails a form of mental rotation of the scene by the surgeons in order to compensate [17, 6].

In addition, the scale of the visual may be well beyond that which would normally be encountered in an open surgery [54]. Due to these visual differences, there can be an unnatural linkage between movement of, for instance, instruments and its visual consequence. Surgeons must learn to see and manipulate the objects together through repeated trials to adapt the scale of their movements to match the scale of the objects on the display [11, 12]. Although magnifying the view scale of an operation can enhance fine movement control by making objects easier to see and actions more precise [34, 11], it has also been shown that the discrepancy in the visual and physical speed of movement may interfere with the user's normal visual control of action [53].

These are simply a few issues that begin to require training for surgical trainees. Beyond these issues of magnification and orientation of movement, trainees need to learn to interpret the information that is before them in order to identify anatomy. The difference in the ability to interpret what is being seen in an image quickly and accurately can be seen in the difference in attention between experts and novices. Studies of pilots [31], chess players [8], and computer programmers [3] have all shown the difference in expert attention of the scene due to their skilled experience, including shorter fixation durations due to ease in information processing [3] and limited fixations on less relevant information [8]. More relevant for our purposes, Eivazi et al [10] showed that expert surgeons' gaze would focus on the point of anatomy of importance, would not frequently change, and, once focused, would exhibit longer fixations than novices. In addition, they employ fewer fixations on the instruments being used in a procedure indicating the focus of attention should be on the anatomy being worked on, not the instruments doing the work.

Specifically with regards to minimally invasive surgery and laparoscopic images, this paper's domain and representation of interest, Law et al [36] showed that novices tend to look at the instrument tip rather than at the target and Tien et al [51] showed that experts were able to split their attention between the laparoscopic display and other vitals monitors. Thus, novices, through repeated practice as well as through guided instruction, must learn to, on the one hand, be able to attend to multiple sources of information and, on the other hand, be able to attend to the most important aspects of the field of view by filtering out the unimportant aspects.

These are the challenges and opportunities for training resident surgeons to see – to teach them to overcome the barriers of using images that may distort the field of observation and to teach them what to fixate on and what is meaningless for the work at hand.

Training the Surgeon to See

What we can ascertain from these findings is that trainees need to be provided with the resources to be able to learn how to see the representations of the bodies before them. It is not simply self-evident what is and is not important to perceive and interpret. Our question then is how surgeons provide 'tacit guidance' [45] and how 'professional vision' is gained within the surgical environment [15] in order to understand the practice of 'situated learning' [35].

A number of sociological studies have discussed how learning is integrated into surgical practice. For instance, Bosk [5] described how surgeons carve out the room for situated learning experiences while at the same time ensuring the patient's risk is minimal. In addition, Mondada [40] showed that surgeons consciously display their actions towards other surgeons and residents in the use of the endoscopic video. More recently, Svensson, Heath, & Luff [47] investigated the training of residents during surgery and identified the skilled practices of a surgeon in identifying and crafting moments for sharing insights. However, these findings do not specifically address learning to see the body in digital representations or implications for designing situated instructional learning systems. How does a surgeon provide the resources to residents to perceive and act on the images that are part of complex medical procedures?

With this study, we intend to contribute to the burgeoning corpus of HCI research concerned with the interplay of embodied movement, talk, and the use of instruments at hand [37, 21] by elucidating how surgeons instruct trainees in how to see the body. Our findings can benefit the field of minimally invasive surgery in design implications for making the body visible during situated surgical training and training simulations. But they can also more broadly contribute to the growing number of studies that address how image and video seeing practices (in any domain) are not without work. Previous work in HCI and CSCW literature such as [1], [27], [38], [39], and [42] have highlighted the interest in studies of video and imaging interaction in surgical environments as well as the long history of interest in video studies by Heath and Luff [19, 20] and John Tang [26, 48]. Our work aims to contribute to this corpus of HCI research by addressing the training practices that can guide a novice in how to perceive the images as an expert.

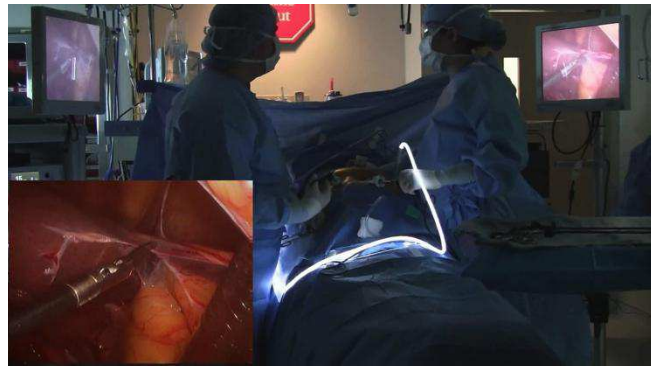

Figure 1. External Surgery Video Overlaid with Internal Laparoscopic Video

LAPAROSCOPIC SURGERY FIELDWORK

This study was conducted within the context of residency training in minimally invasive laparoscopic surgeries in the sub-specialty of general surgery. In the United States, after a student has graduated from a medical school, they continue on with their training through residencies. A residency is under the supervision of fully licensed physicians in a particular sub-specialty of medicine. This is the stage of career training where a student gains in-depth experiential practice of their chosen branch of medicine. In order to practice as a surgeon after they complete their residency, they must pass a board certification test indicating their mastery of basic knowledge and skills. Since 2009, the American Board of Surgery (ABS) required that all general surgery residents successfully complete the Fundamentals of Laparoscopic Surgery exam to be eligible to take the ABS Qualifying Exam in Surgery for certification.

One of the more significant aspects of the surgical residency is the opportunity to observe and assist senior surgeons in the operating room. In teaching hospitals, senior members of the surgical team have the responsibility to enable trainees to learn from the case. This may involve showing how to perform particular procedures to a resident or providing the resident with the opportunity to perform an incision or suture under the supervision of the surgeon.

Data Collection and Analysis

The examples presented in this paper are from fieldwork in the surgery department of a teaching hospital in the Northeast US. At that site, we employed observations and open-ended interviews – both of which we video recorded for further analysis in addition to our field notes. During the observations, we were in the surgical theatre with freedom of movement to observe the operations and the use of the images. We also had the opportunity to ask questions of the surgeons at appropriate moments during the surgery regarding image use.

A total of twelve (12) laparoscopic cholecystectomies (gallbladder removal) were observed for a total of approximately 33 hours. (The removal of the gallbladder

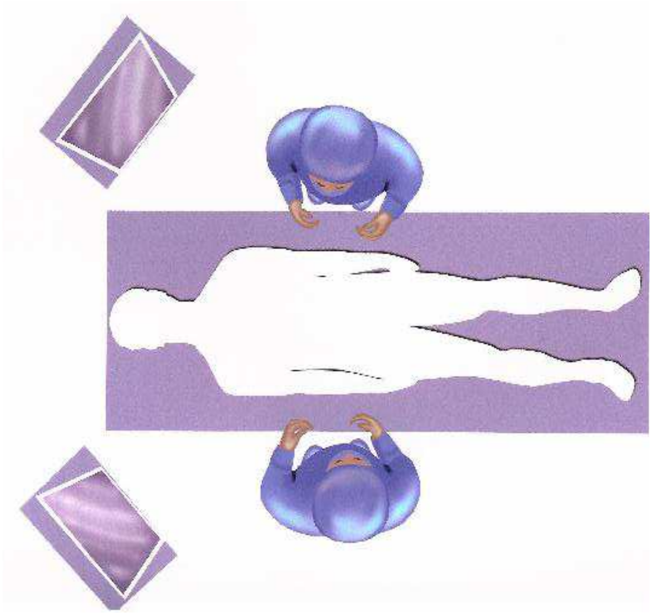

Figure 2. Example Orientation of Surgeons and Laparoscope Displays around Patient Table

during a typical laparoscopic cholecystectomy procedure is described in Jones et al. [28].) The observed cases included three different surgeons (four surgeries of each surgeon) and six different fourth year residents in different combinations of the two groups. The video collected included both the external video captured on a handheld video camera and the internal video captured by the laparoscopic recorder. For data analysis purposes, we combined the two video windows into a synced picture-in-picture format, which allowed us to simultaneously review the surgeons' actions both in and out of the body (Figure 1). As a further step in data collection and validation, the surgeons were presented with findings and given opportunities for comment during interviews.

The focus of the analysis presented here is on how the attending surgeon instructed the surgery resident to successfully view the body through the use of instruments, talk, and the laparoscope. An inductive bottom-up data analysis approach was used in which the authors examined their field notes and then the videos for themes around moments of instruction. The resulting themes led to the findings presented here and subsequent literature informing the discussion of those findings.

Laparoscopic Surgery

Laparoscopic surgery is a minimally invasive surgery that uses small incisions in the abdomen to insert instruments and cameras in order to perform procedures such as a cholecystectomy. In order to perform these procedures, the surgeon must be able to see the operative field. In most cases, a laparoscope is used for this purpose. A laparoscope is a rigid tube that houses optical components such as prisms and lenses aligned to form a lens system. There is also a separate channel made of glass fibers for transmitting light. A cable then connects the tube to a monitor providing high-resolution images to the surgeons. A laparoscope may have a 0°, 30°, or 45° lens angle to allow for viewing around objects. The view angle is steered by the light cord post and the direction of view is opposite the scope post - to look down, the light cord is steered up and to look up, the light cord is steered down.

Typically, there will first be multiple incisions and ports inserted into the abdomen: at least two for instruments and one for the laparoscope. This means that at least three hands are actively holding and manipulating instruments at the same time. Consequently, laparoscopic procedures require coordination between at least two surgeons. These surgeons may stand on opposite sides of the table, facing one another, which yields equal access to the manipulation of the instruments and camera (see Figure 2). In order to facilitate this physical arrangement, two monitors are used to display the laparoscopic video; one is placed on each side of the head of the bed, angled towards one of the surgeons. Thus, each surgeon has a different orientation to the video in relation to their orientation to the body as well as their orientation to the instrument and camera movements. In particular, the surgeon not manipulating the camera has an inverted view of the field of work. This means additional mental rotation, which could be significant if the novice is in this position.

General surgery residents in their fourth or fifth (and final) year typically perform the surgery with the senior surgeon assisting. Thus, they are also the one to hold and maneuver the laparoscope. This means that they can control what they are looking at and if the senior surgeon wants to change that view, they must take control of the laparoscope.

FINDINGS

For the following, we will discuss three ways that a surgeon helps the fourth year resident to see the body and, more importantly, how this training is integrated into surgical practice. The situations described are indicative of these training moments, but are by no means the only occurrences witnessed.

Revealing Anatomy

The laparoscope is used in minimally invasive surgery in order to see the anatomy within the body. However, 'seeing' the body through the laparoscopic video is not a matter of simply looking at the video monitor. Many of the training moments engaged in by the surgeon and the residents were in identifying anatomy in the view. The process of guiding trainees to begin to determine where and in what orientation their camera and instruments were in the body with relation to what they see was a crucial first step.

> *After inserting the laparoscope into the first port, the attending surgeon turns to the two residents and begins to question them on what they see.*
>
> *"Where are we?" [a short pause] "I know where we are, where do you think we are?"*

There is no response. They are both looking intently at the monitor as the attending moves around the camera.

"Where are we?" He asks again. "Laparoscopy is about recognizing what you see."

The resident points to the screen. "I don't understand what…"

The attending begins to explain, "We are below [posterior] to the omentum. When you see the bowel and not the peritoneum you know you are below and you need to recognize that so you don't mess your patient up."

As the surgeon points out, laparoscopy is about seeing the anatomy within the view. It first requires one to know where in the body they are. But in order to do that a surgeon needs to sometimes make a determination based on what he sees. In this example, the surgeon reveals where they have entered the internal body by pointing out the crucial wayfinding structures. He is explaining how seeing and orienting is sometimes about the context of the view.

Being able to identify various anatomy and orientation is also crucial for the first step of a laparoscopic surgery: the insertion of ports in the abdomen. A port for the camera is the first to be created. This port is used for insulfation of the abdomen and then the camera is inserted in order to guide the placement of the other ports. Thus, the camera port is inserted through direct vision while the other ports are guided by the camera through indirect vision.

After the first port is inserted into the belly button, the laparoscopic camera is inserted and maneuvered around by the attending surgeon as the resident looks on.

The resident points to the screen behind him. "It could go here."

The surgeon nods, says, "Yep. Let's go a little bit lower than usual only because the liver is coming down further", and points the camera at the liver.

The surgeon then palpates with his free finger the abdomen at the proposed insertion point and moves the camera internally up to that point. As he takes his finger away, the resident replaces it with his own finger and begins to palpate the abdomen so he can see with the camera where the insertion point would be on the internal abdominal wall.

The surgeon nods on seeing this method of identification and says, "Yes right there."

This process of palpating in order to see the resulting movement of tissue is a mechanism of connecting one's orientation and movement on the outside of the body to the resulting location on the inside of the body (Figure 3). The first step sets the stage not only with the ideal location of ports for conducting the surgery, but also with a working

Figure 3. Palpating and Orienting

map between what the surgeons know about the mapping of the body and what they now see on the video screen.

Throughout a surgery, the process of explanation, deictic referencing, and dissection makes anatomy emerge from the chaos of tissue; not in actual physical presence – there is often no change in the view as it were – but rather in how the visual information begins to take on new meaning.

The attending takes his dissector and begins to probe at the connective tissue covering. "If this is the common bile duct that means the window [space between the cystic duct and common duct] goes this way." He begins to probe with the dissector where he indicated the window would be and a space opens quite easily to reveal the window.

The resident nods during the explanation and then, when the window appears, utters, "Oh yeah. Yeah."

The attending continues with the dissection, "And this might be the artery." He uses the dissector to hook and hold up the elongated tissue.

The resident again nods with a "yeah".

"You know, what she really has is a tiny gallbladder stuck right onto the common bile duct."

This final comment completed the reveal of the anatomy as he was explaining the reason why this particular patient's anatomy looked different from what the resident had seen before. Prior experience was, in this case, interfering with the resident's vision of the tissue before her. Through the surgeon's explanation and guidance, he slowly showed her what she could not see before.

As we said before, in order to identify anatomy, there is the need sometimes to see the context. Oftentimes we saw a resident pull back the camera to see again where they were or, in this example, explain to the surgeon that they needed context, *"Can I just pull it away to get some perspective for a second?"* Context is necessary and if it can not be determined from the current view, surgeons show the residents that changing the view can help with identification, *"Let's see what we've got. Come back for a second and let's see where we think we are."*

Anatomy needs to be continually revealed to the trainee throughout the surgery as the body moves around considerably due to dissection. In the following two examples, the resident does not see what the surgeon sees, which results in surgical errors. What is evident is that the surgeon thought that the resident had the same understanding of where structures were in relation to where the work was being conducted.

> *As the resident is burning through connective tissue to dissect the cystic duct from the common duct, he lingers on the electrosurgical instrument's energy switch for a few seconds. The surgeon begins to scold, "Watch it, watch it – you have to learn to pulse electrocautery so it doesn't burn everything." He pulls the tissue a bit and then points out, "You see that? You see how close you are here?" He pulls the tissue more taught and then points to the blood indicating the artery was nicked.*
>
> …
>
> *The resident is using the electrosurgery instrument to remove tissue and expose the ducts. The surgeon sees the side of his instrument get too close to the artery and tries to stop the resident. "Don't don't don't!" But he was not effective and the back of the instrument hits the artery and bleeding begins. "I was just going to say that's the artery." Later he explains, "Use the hook to tease it off. This is the one place you can't back into because you are two close to it."*

In the first example, even though the resident had already identified the artery, he 'lost sight' of it in his focus on removing tissue from over the cystic duct. In the second example, the resident is not aware of the closeness of his instruments to other structures – structures which moments before he had demonstrated seeing.

As you can also see in the first illustration, the use of pulling tissue into focus is a technique often employed by the surgeons. A surgeon may not have control of the laparoscope, but he does have readily at his disposal the instruments currently in his hand being used for traction.

> *As a resident uses the electrosurgery instrument to remove tissue, he exposes a node. He moves in to remove more tissue and the surgeon interrupts him saying, "Stay a little bit higher." The resident moves the instrument up slightly and hovers, "Here?" The surgeon continues by explaining, "See you are off of the … [pulls the tissue taught to display the node better] if you stay on top of the nodes … see it?" The resident affirms and continues with removing tissue above the node. When he is done the surgeon starts to move the tissue around so the other side is visible and holds the tissue taut. "Come back around the other way now."*

In all of the examples, the surgeon is revealing anatomy to the trainee in order for the resident to see what the surgeon sees in the images. These situated learning moments do not take much time from the task at hand, but they do require the ability of the surgeon to demarcate where attention should be. Surgeons do this through the use of the instruments at their disposal, the video screen strategically placed behind them within reach to point to, or, as in the next section, by moving the camera itself.

Figure 4. Guiding the Hand.

Guiding the Hand to Train the Eye

There are many examples of when the surgeon finds a need to control the camera view in order to reveal anatomy. As we can see in the next two examples, oftentimes he or she grabs the hand of the resident so the resident continues to have proprioceptive awareness of the instrument's movements (Figure 4).

The surgeon tells the resident, "You need to move your post so you can see." He turns to the medical student next to him to ask her to take the retractor he is holding in his right hand. He then reaches across the table and begins to slowly turn the post all the way to the left and then he puts his hand over the residents and moves the camera view to the right in order to center the area of work again. He then proceeds to explain, "OK, so we need to open up down here."

> *The attending reaches across and grabs the hand of the resident that is guiding the electrosurgical instrument. She then moves his hand to point to a particular part of the anatomy while she explains, "So if you select the line over here…".*

Guiding the hand, however, does not always mean 'hands-on' guidance. Much guidance is through verbal explanation or even pointing at the video screen behind them (Figure 5). Either way, guidance of the hand needs to be coupled with an explanation of why the eye should be looking at the images in that manner.

> *The surgeon explains to the resident, "Open up this some more up here [points to the video screen behind him]. Just get underneath this and go up both sides of it so you don't burn it." Shortly after this instruction the resident's instrument gets too close to the gallbladder and burns it, resulting in bile seeping out. The surgeon tsks, sighs, and then says, "So what I*

Figure 5. Guiding the Eye.

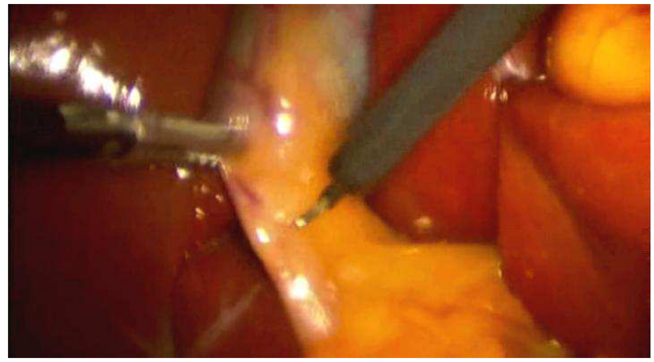

Figure 6. Demarcating a Line with the Instrument Tip.

meant was go underneath it so you don't burn the gallbladder."

This 'why' was a crucial part in understanding the instruction the resident was receiving. The 'why' encompassed what the surgeon saw as a potential collision point. But the resident did not see the 'why', but only the instruction received.

Finally, residents often learn from the surgeons that they can visually guide their instruments to a point in the body. It is the method that surgeons first use to help residents get their bearing and to ensure they do not veer off course and nick something unintentionally. Until a resident feels comfortable moving inside the body without seeing where they are going they will continue to do this when they are in control of the laparoscope. They will move the camera out to see the instrument entering and then follow the instrument to the site of work. This is not something that they will always need to do as is evidenced by a young resident doing this for a surgeon and him finally explaining, *"You don't have to come in and out for me."*

Envisioning What is Not Seen

Elucidating what is to be seen in an image is one thing but oftentimes what needs to be seen is actually not there. There may be conceptual aspects of the view or else things that are hidden from view.

At the start of the dissection step of a laparoscopic surgery the attending pauses and asks the resident, "Have we done a gallbladder together?" He replies in the affirmative and so she continues, "Yeah? So you know I like to select an imaginary line below it?" The resident again replies in the affirmative and continues for her, "So we are not going to cross [he traces a line across the artery and ducts with the electrosurery instrument]" and in unison they both say, "…this line right there."

In this case, what is being envisioned on the image is in actuality not present; however that imaginary line will guide the action taken throughout the surgery (Figure 6).

It is not always evident what anatomy is before them. Oftentimes the surgeon has to make inferences as to what is before him and where anatomy may be hiding. And this has implications on what actions will be taken.

As the resident is removing tissue early in the dissection process, the surgeon quizzes him, "So where do you think the artery is? Are you over it?" The resident pauses and looks at the screen. Then he begins, "The artery is riiighht…here." He starts to trace what he believes to be the arterial line. The surgeon indicates to move to the next phase of the surgery, "OK so you are past it."

In this example, the resident needed to stop to determine if he had passed the artery based on what he can see before him. This required an inference of the location based on the location of ducts and the liver along with the contours of the tissue.

Sometimes envisioning has to do with envisioning how actions will affect one's space for maneuvering. This is often evident in where to place the ports, but it is also evident in how tissue moves during the procedure.

As the cystic duct has been dissected away from the common duct, the resident asks the surgeon to move the tissue, "Can we see the artery back there – I think it [the artery] is right there [points to screen]." He then turns to the scrub nurse and asks, "Can I get a Maryland [dissecting forceps]." However, the surgeon stops the resident there and explains that that is not the best idea right now. "If it starts bleeding then you have to open." After they make the cut on the cystic ducts, the surgeon continues on to explain again why waiting was necessary. "See it springs away [from the common duct] quite a lot. So if I get into any trouble now I still have some room to maneuver with my laparoscopic tools."

Movement of the tissue explains why revealing anatomy was a continual occurrence throughout the surgery, but it also is an effect of dissection that must be envisioned in order to understand how the view will change after an action is undertaken.

Coming back around to the beginning of a laparoscopic surgery, envisioning what is not there is an important part of determining the best place for ports and instruments, requiring one to imagine the lines and movement in a confined space.

> *After looking around the interior of the abdomen and determining the case will be complicated due to an inordinate amount of connective tissue, the surgeon begins, "So let's think about where you want to put it." The resident points to a point on the external abdomen wall with her finger, "Probably right here" and begins to palpitate that point so they can see the resulting indentation on the laparoscopic video. "OK", says the surgeon. "Lower than usual", explains the resident. The surgeon continues, "That's going to be…", he moves the laparoscopic camera to first point to the proposed entry point and then to the internal organ area, "…parallel to the liver. I agree." The resident continues to explain her proposal, "I want to have some perspective. I don't want to be right on top." The surgeon affirms, "Yes good."*

Thus, 'seeing' an image often means envisaging information out of what they can see – whether that is how instruments will line up with anatomy, how tissue will move after an action is taken or an imaginary demarcation that cannot be crossed.

DISCUSSION

Our work has aimed to demonstrate the situated learning [35] that occurs in minimally invasive surgery in order to train surgical residents to perceive and appropriate digital representations of the body. We show that seeing a medical image during minimally invasive surgery is not an endpoint: it requires interaction and discussion. Our video recordings, augmented by conventional fieldwork, have enabled us to consider how seeing practices and training residents to see are accomplished through the interplay of embodied gesturing, talk, and the use of various instruments at their disposal. The revelations and guidance form a critical element of gestalt that enables an emergent perception of the area of work represented in the images. These are not achieved simply through moments of looking, but by virtue of seeing as the presentation unfolds. They enable an emergent repertoire of knowledge in how to see and act within 'indirect vision'.

Instructing one to see has to be positioned with regard to the proper performance of the task at hand. In fact, this is the only way one can 'see' in order to perform the task. The perception and determination of location of ducts and arteries, and the trainee's ability to comprehend why and where action is occurring are accomplished in and through the interaction between the surgeon, the trainee, and the images. The interaction provides the trainees with access to, and a way of seeing, the anatomy through the images. The trainee does not relate to the images in a merely representational manner, that is, as a disembodied gaze – he is an active participant.

Implications for Design of Surgical Training Systems

The broad implication here is that learning to create meaningful images and use them as a part of surgical practice is an integral aspect of minimally invasive surgical training. As it stands now, this training is primarily gained while observing and assisting a senior surgeon in the operating room. This situated learning embodies the seeing practices and highlights the tight interlink between seeing and action. For surgical instructional system designers, it highlights the need for further training beyond simply the motor skills associated with minimally invasive surgery. Situated training systems should provide resources for surgeons to allow students to 'see' what the senior surgeon sees.

This relates to our ongoing interests in developing situated interactive instructional systems for laparoscopic surgery. What we have learned is that a trainee needs to be able to seamlessly interact in a fashion to work out what he sees. Oftentimes this is done in the image itself, but the question is if we can provide an overlay or a secondary display to augment training to provide this interaction. Currently, there is no mechanism for aligning endoscopic views to contextualized anatomic identification and trajectory guidance. Alongside the real-time laparoscopic video display one could provide a guidance system. This system would provide 3D models of the chest and abdominal cavity that could be rotated, panned, and zoomed by both surgeons from either side of the table through gesture and voice control in order to view and interact with the 3D shape and structure of the anatomy of the chest and abdominal cavity. In addition, an infrared sensor would monitor the location and rotation of the laparoscopic camera tube in the hands of the surgeon and highlight the field of view on the 3D model. Although potentially leading to additional work for the senior surgeon, providing further information to residents and allowing that information to be accessed by the trainee or the senior surgeon for elucidation could improve the ability of residents to learn how to see the body in images and use them more effectively in their surgical practice.

Furthermore, the availability of senior surgeons can be an obstacle to repeated training in this situation. An interesting alternative can be a training system that includes guiding aids to simulate the practice of 'situated learning'. These guiding aids aim to reproduce the three learning situations observed in our study. For instance, virtual landmarks displayed on the novices' screen while interacting with a virtual body, can help them focus on the most important aspects of the field of view in a specific scenario. This metaphor represents the deictic referencing used by experts to attract the novices' attention. Moreover, the haptic guidance metaphor [13] can be adapted to direct the novices' hands through specific visual information while manipulating the camera. This metaphor was previously used to teach motor skills. In this situation, it can be used to replace the expert's hand guidance observed in our study.

Moreover, these interaction metaphors can be supplemented by contextual (verbal or textual) information for further explanations to the novices about context while they interact with the system.

CONCLUSION

Learning how to see and use intraoperative imaging systems for minimally invasive surgery requires a continually interactive process between the images, the instructor, and the instruments at hand. In our studies of this situated learning practice, we have found that the 'seeing' of images is an embodied process achieved through a coordination of visual information about the body and instruments and explorative actions with instruments on and in the body. The importance of the seeing process contrasts with the popular notion that surgical trainees simply need to view the images; instead, our intention has been to lay a foundation for the innovation of surgical training simulations and instructive systems for situated learning.

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