Asynchronous Confirmation of Anatomical Landmarks by Optical Capture in Open Surgery

Hypothesis: Asynchronous remote telementoring and teleproctoring with anatomical subject matter relevant to surgical procedures is an effective instructional tool for surgical trainees.

Design: A validation model was established to assess the capabilities of current technologies to conduct effective instruction of surgical procedures in a remote location relative to the actual surgical procedure. A total of 23 unilateral thyroid dissections in 13 patients using a laparoscope affixed to a stationary robotic arm were videotaped. Anatomical confirmation was sought for the superior flap, middle thyroid vein, carotid sheath, 2 parathyroids, inferior thyroidal artery, recurrent laryngeal nerve, and superior thyroid pole.

Main Outcome Measures: Ten surgical trainees reviewed video segments of these 8 anatomical landmarks at a later time after surgery. During observation of the video segments, these physicians were asked to validate the anatomical landmarks on a survey by choosing concur, do not concur, or uncertain. The review panel was also asked to score the images for quality of light, focus (clarity), field range, and contrast.

Conclusion: This study validates the use of asynchronous education with high-quality optical capture for distance education and collaboration in open surgery.

High-quality laparoscopic images allow sharing of the surgical environment with other operating room staff to achieve subsequent or asynchronous review and teaching. Videotaping the surgical procedure is achieved by placement of a fiber optic camera mounted on a stable arm, the Alpha port, in close proximity to the surgical field with the use of a voice-command driven robot, AESOP (automated endoscope system for optimal positioning) (Computer Motion Inc, Goleta, Ga). The Alpha port stabilizes the camera connection to a standard video monitor, which can be seen not only by the operating surgeon but also by surgical trainees, medical students, and other operating room personnel. Digital recordings of the surgical procedure can be reviewed at a later time to achieve asynchronous surgical education. There is a strong demand by surgeons to access advanced and basic training in surgical techniques and upcoming technologies without the confines of fixed scheduling. Previous work in our laboratory resulted in the development of technology for high-definition optical capture of images in open surgery. Earlier studies have validated that computer-assisted instruction can benefit surgical education by improving efficiency, effectiveness, standardization, and access.

Shared optical field allows viewing of the operative field for teaching purposes by an unlimited number of students and for asynchronous peer review. In the present study, an image-capture technique was validated by review of digitized videotape-recorded images of anatomical landmarks from standard open surgical procedures. The physicians were asked to score as the images by stating that they concur, do not concur, and are uncertain. The panel was also asked to score the images for quality of light, focus (clarity), field range, and contrast.

METHODS

All patients included in this study were undergoing routine thyroid or parathyroid procedures, and a single surgeon (R.C.M.) performed all operations. The surgeon positioned the laparoscopic camera within the surgical field by commanding voice-activated software (Hermes; Computer Motion Inc) to drive the robotic extension arm, AESOP, as detailed in this section.
A 10-mm fixed laparoscopic telescope was used to capture the image from the field of operation as established in an earlier study. The laparoscope was affixed to an Alpha port at the distal end as depicted in the Figure. The Alpha port serves as a fulcrum for manipulation of the scope in 3 axes. The telescope was attached proximally to the AESOP robotic arm, which is mounted to the surgical table in close proximity to the operating field. The robot extension arm was driven by voice-activated software, allowing the surgeon to place the laparoscope close to the surgical site without interrupting the surgical procedure. Only the operating room light was used with laparoscopic lighting.

The telescope was attached to standard laparoscopic video equipment (Stryker Endoscopy, Santa Clara, Calif), and the images were displayed on a 20-inch color video monitor (model PVM-20M2MDU; Sony Corp, Santa Barbara, Calif). Additionally, the images were recorded on a 4-head videocassette recorder (S-VHS; Panasonic, Seattle, Wash). The anatomical landmark images were captured during standard operating procedures for parathyroidectomies and thyroidectomies. These procedures were applied to 23 unilateral dissections conducted on 13 separate patients.

The image sets were replayed from the videotapes on a standard video monitor and reviewed by a panel of surgical residency trainees. For the reviewers, image tapes from each of the operations was edited for each relevant anatomical site, with minimal pause between each video segment, in sequential order of the anatomical landmarks as viewed by a surgeon with standard progression of the procedure. These landmarks are highlighted in Table 1.

While viewing the 1-minute video segment for each anatomical landmark, a Likert scale survey was completed by each reviewer to evaluate the image quality. The responses of concur, do not concur, or uncertain were selected for each video segment to confirm the identification of the surgical landmark in question. Surgical landmarks were listed on the survey in the order they appear during the course of a typical thyroidectomy.

The 8 anatomical landmarks were identified unilaterally on the viewing monitor and outlined with surgical instruments. Reviewers evaluated image data for degree of image quality and clarity. This required the respondents to complete a similar survey with a Stapel scale ranging from 1 to 5 regarding the quality of light, focus, visibility of the surgical field, and contrast of the images. The highest degree of excellence was given a value of 5, whereas a poor rating was given a value of 1.

**RESULTS**

Twenty-three unilateral thyroid dissections in 13 patients were videotaped using methods described herein. Specific image capture was sought for the superior flap, middle thyroid vein, carotid sheath, 2 parathyroids, inferior thyroidal artery, recurrent laryngeal nerve, and superior thyroid pole.

**RATING OF ANATOMICAL LANDMARK CONFIRMATION**

Surgical residents were able to identify the anatomical structures in sequence as noted in Table 1. The concur rate for clear visual confirmation of anatomical landmarks recorded from the surgeries was greater than 80% for each anatomical landmark with the exception of the inferior thyroid artery. The superior flap being the outermost structure was identified at a rate of 100%.

Ten surgical trainees examined the 8 anatomical structures asynchronously for confirmation. Concur-rence was 89.8% for the carotid sheath, indicating a clearly visible structure. The superior pole was observed to be identifiable during 84.2% of the overall viewing. Observation for the middle thyroid vein was confirmed at 89.8% of the total viewing images. The weakest concurrence was for the inferior thyroid artery at 47.4%. Deeper structures—parathyroid gland and the recurrent laryngeal nerve—were confirmed at 81.3% and 81.7%, respectively, of the total image viewings.

**SUBJECTIVE RATING OF IMAGE QUALITY**

Table 2 illustrates that image quality was not compromised with the methods applied in this study. A scale of 1 to 5 was used to rate the images, with poor character-
The standards for surgical training have used personal communication between mentor and student through interaction in the operating room, laboratory, classroom, and clinic. With technological advances, educational opportunities are further complemented with applications such as tele-education and surgical simulation. However, visual access of the open surgical field continues to dominate as the essential requirement for surgical care and training. This study validates the use of the Alpha port and laparoscopic optics to capture an open surgical field for subsequent confirmation of anatomical landmarks in thyroid and parathyroid surgery. Surgical exposure in these operations is quite limited and difficult to share. Application of laparoscopic optics to this open surgical field and sharing the content asynchronously permit interaction with other surgeons, surgical trainees, and medical students independent of time and provide content for distant classroom locations. Integration of image capture technology and asynchronous review capabilities offer ubiquitous and accurate content independent of time and place, outcome-oriented education, and student-centered mentoring. The critical aspect in this form of education is the fact that this video image serves as a “virtual” representation of the patient and is pivotal in the revolution of surgical training in the information era even with the student and mentor being separated in space and/or time. With the use of asynchronous education, there is then a disconnection between surgical mentoring and learning schedules, and the focus shifts to education relying on technologies with availability 24 hours a day, 7 days a week. The asynchronous protocols provide a global education arena accessible to a sizable population in varied locations. This educational mechanism tears down some artificial barriers to surgical training such as physical constraints when attempting to view the surgical field. With asynchronous education as described in this study, there is provision for discussion of surgical protocols and critical anatomical structures in order to achieve successful and uneventful surgical procedures. Additional benefit to asynchronous surgical education allows for inclusion of an increased number of students and provides opportunity to increase the scope of education.

The domain of focus in asynchronous education is the culmination of capture, integration, and access of content. Perfection of these variables can be integrated into virtual classrooms for more interactive education. Capture and digitizing of images address the variables of improving image quality as confirmed by earlier studies. Integration of content is relevant to develop a more interactive educational environment between collaborators. Access is relevant to the availability of not only the content by an asynchronous transfer mode over the network but also access to the mentor for interactive questions and answers. Inclusion of other technologies such as whiteboards can be implemented for public discussion of critical anatomical landmarks observed during the course of surgical procedures.

Thyroidectomy was selected for this study due to the critical requirement for anatomical precision and the very confined surgical field, which is difficult to share with surgical trainees during the surgical procedure due to physical constraints. Ten surgical trainees were able to simultaneously view the videotaped surgical field at a later time in a multimedia environment with the option for verbal interaction and discussion. The data confirm that the anatomical structures were clearly identifiable in an instructional environment with ample opportunity for discussion. This establishes a concrete framework for interactive instruction such that an open dialogue can be maintained to discuss cautions in proceeding with the surgical procedure and the anatomical landmarks to validate the technique. In contrast to evaluations by Cuschieri and Holden et al, the technology applied in this study presented no compromise to the im-

### Table 1. Responses From 10 Reviewers of Anatomical Landmarks in 13 Patients

<table>
<thead>
<tr>
<th>Anatomical Structure</th>
<th>Concur, %</th>
<th>Do Not Concur, %</th>
<th>Uncertain, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior flap</td>
<td>100.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Carotid sheath</td>
<td>89.8</td>
<td>0</td>
<td>10.2</td>
</tr>
<tr>
<td>Superior pole</td>
<td>84.2</td>
<td>5.9</td>
<td>9.9</td>
</tr>
<tr>
<td>Middle thyroid vein</td>
<td>89.8</td>
<td>5.7</td>
<td>4.6</td>
</tr>
<tr>
<td>Inferior thyroid artery</td>
<td>47.4</td>
<td>22.8</td>
<td>29.8</td>
</tr>
<tr>
<td>Parathyroid gland</td>
<td>81.3</td>
<td>5.0</td>
<td>13.8</td>
</tr>
<tr>
<td>Recurrent laryngeal nerve</td>
<td>81.7</td>
<td>5.0</td>
<td>13.3</td>
</tr>
</tbody>
</table>

*1 Indicates poor; 5, excellent.

### Table 2. Subjective Image Quality Rating of Anatomical Landmarks in 13 Patients

<table>
<thead>
<tr>
<th>Subjective Scale</th>
<th>Light, %</th>
<th>Contrast, %</th>
<th>Focus, %</th>
<th>Field, %</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1.7</td>
<td>1.3</td>
<td>1.6</td>
<td>0.8</td>
</tr>
<tr>
<td>2</td>
<td>9.8</td>
<td>16.1</td>
<td>10.8</td>
<td>10.2</td>
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<td>3</td>
<td>31.7</td>
<td>32.2</td>
<td>32.3</td>
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<td>4</td>
<td>38.9</td>
<td>35.9</td>
<td>33.3</td>
<td>36.9</td>
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<tr>
<td>5</td>
<td>17.8</td>
<td>14.5</td>
<td>22.0</td>
<td>28.8</td>
</tr>
</tbody>
</table>

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age quality in regard to 3-dimensional view of anatomical landmarks relative to surrounding structures.

Projected applications of the technical mechanisms evaluated herein can provide avenues for teleeducation, surgical planning, and telemanipulation in developing virtual reality models for eventual improved patient care. Preliminary evaluations reflect on the fact that applications of virtual reality training have provided a safe learning environment for perfection of surgical skill levels. The methods presented herein coincide with the concept of “information equivalent” as a component of emerging technologies for various facets of patient care such as diagnosis, treatment, consultation, and education. These technologies would be easily adopted to peer review as well.

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REFERENCES


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