Title
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Permalink
https://escholarship.org/uc/item/3h823543

Journal
JSLS : Journal of the Society of Laparoendoscopic Surgeons, 11(4)

ISSN
1086-8089

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Publication Date
2007-10-01

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Peer reviewed
Coordinated Multiple Cadaver Use for Minimally Invasive Surgical Training

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ABSTRACT

Background: The human cadaver remains the gold standard for anatomic training and is highly useful when incorporated into minimally invasive surgical training programs. However, this valuable resource is often not used to its full potential due to a lack of multidisciplinary cooperation. Herein, we propose the coordinated multiple use of individual cadavers to better utilize anatomical resources and potentiate the availability of cadaver training.

Methods: Twenty-two postgraduate surgeons participated in a robot-assisted surgical training course that utilized shared cadavers. All participants completed a Likert 4-scale satisfaction questionnaire after their training session. Cadaveric tissue quality and the quality of the training session related to this material were assessed.

Results: Nine participants rated the quality of the cadaveric tissue as excellent, 7 as good, 5 as unsatisfactory, and 1 as poor. Overall, 72% of participants who operated on a previously used cadaver were satisfied with their training experience and did not perceive the previous use deleterious to their training.

Conclusion: The coordinated use of cadavers, which allows for multiple cadaver use for different teaching sessions, is an excellent training method that increases availability of human anatomical material for minimally invasive surgical training.

Key Words: Cadaver, Surgical procedures, Laparoscopy, Education, Robotic.

INTRODUCTION

The clinical increase in laparoscopic and robot-assisted surgical procedures has necessitated training in these procedures for both postgraduate surgeons and resident trainees. Many studies have been performed to examine the effectiveness of different training modalities for minimally invasive surgery.1 These modalities include anatomic models, virtual reality laparoscopic video simulators, and animal training courses.

Although considerable advancement has been made in minimally invasive surgical training models, the human cadaver remains the gold standard for procedure-specific surgical training. All other training models strive to reproduce human anatomy and tissue handling. However, availability limits cadaver use for surgical training. Because cadaveric tissue provides superior surgical training, it is important to increase the availability of cadavers for training through coordinated use.

Herein, we describe our technique of the coordinated training use of human anatomic material to maximize the number of surgical procedure training sessions performed on a single cadaver. We report the initial impression of postgraduate surgeons from different subspecialty disciplines, using one fresh frozen cadaver, for a variety of robot-assisted surgical training techniques on multiple training days.

METHODS

Twenty postgraduate surgeons and 2 surgical assistants participated in a dedicated robot skills training course at the University of California, Irvine, Center for Minimally Invasive Surgery Education, between July 20, 2006 and November 16, 2006. Nine cadavers were used for a total of 12 training sessions. Three of the 9 cadavers were used in 2 training sessions. Of the 6 cadavers that were not reused, 1 cadaver had poor tissue preservation. The other 5 cadavers were not reused due to a proportionately greater demand from course participants utilizing the cadavers for urological training procedures. There were 12 urologists with 1 assistant and 8 cardiothoracic surgeons with 1 assistant learning the robot-assisted laparoscopic prostatectomy or cardiac surgery techniques, respectively.
Cadaver Preservation Technique

Human cadavers that met the qualitative and anatomic criteria for urological and cardiothoracic surgical training use were screened for the infectious diseases, HIV-1/HIV-2, Hepatitis B Surface Antigen, and Hepatitis C Virus Antibody. If a review of donor history and blood results determined the cadaver to be nonreactive for these diseases, the specimen was wrapped first in a cloth sheet for absorption and then wrapped in an outer plastic sheet for containment. The cadaver was taken from temporary 36°F refrigerated storage to -15°C frozen storage until final preparations. Unlike for embalmed cadaver preparation, “fresh use” cadavers were not exsanguinated before preservation.

Approximately 1 week before the scheduled training event, the cadaver was removed from frozen storage (-15°C) to the refrigerated storage (36°C) to slowly initiate the return to ambient temperature (60°C) and avoid any significant tissue degradation during this process. On the day before training, the cadaver was removed from refrigeration, and an enclosed container of hot tap water was placed on the abdomen or chest and changed throughout the day as necessary to ensure optimum temperature of the respective region of use for the course. Determination of adequate thawing was done by manual palpation to evaluate that the area of the cadaver to be dissected was no longer frozen. For objective quality control, future monitoring will be done with a rectal thermometer probe for the prostatectomy procedure to ensure the specimen core temperature has reached 60°C. Once the specimen had reached the optimum temperature condition, the cadaver was removed from the cloth and plastic sheets, the specimen was washed with soap and water and towel dried, and then placed in a durable pouch for storage and transportation to the course location.

After completion of the surgical training, the cadaver was transported to the holding facility for similar preparations for the coordinated reuse of the cadaver. If the subsequent time to reuse did not exceed more than 1 week, the specimen was simply refrigerated at 36°F until the day before the next event, utilizing similar preparations. Longer periods dictated refreezing to -15°C; 1 week before reuse, the cadaver was transferred to refrigeration at 36°C, and the day before treated with the hot water container. However, it has been noted that occasionally refreezing may be associated with some qualitative signs of tissue compromise. Thus, it was essential to bring the specimen to a slow and gradual temperature rise as much as possible by allowing frozen specimens to remain refrigerated for approximately 1 week before the training course. Hence, the deeper visceral content slowly thaws, while the integrity of the superficial anatomy, which may be more delicate and susceptible to signs of decomposition, is preserved. Additional placement of a hot tap water container on the affected region also proved helpful in the preparation of the cadaver for course use.

Questionnaire Evaluation

Following the training courses, all participants completed a questionnaire, rating the quality of the cadaveric tissue and their training experience. For each training session, the cadaver was draped, before the attendance of the surgeons to conceal any previous use. Only the area of interest, the chest for the cardiothoracic surgeons and the abdomen for the urologists, was visible for the specific training session. In addition, participants were asked to indicate whether they believed the cadaver to have been a previously used specimen before their training session. The qualitative evaluations were performed on a Likert 4-point scale (1=excellent, 2=good, 3=unsatisfactory, 4=poor). If more than one point was selected on the Likert 4-point scale for a question, which occurred in 3 surveys, the questionnaire was evaluated based on the lower rating.

RESULTS

All of the 22 course participants completed an end-of-course evaluation questionnaire. This was the first cadaveric training course for 14 of the participants, the second for 4 participants, and the third for 3 of the participants. One participant had had more than 3 prior cadaveric training courses (Table 1).

Nine of the participants rated the quality of the cadaveric tissue as excellent, 7 as good, 5 as unsatisfactory, and 1 as poor (Table 2).

| Number of Prior Cadaveric Training Courses Taken | Number of Participants |
|-----------------------------------------------|------------------------|
| 1                                             | 14                     |
| 2                                             | 4                      |
| 3                                             | 3                      |
| >3                                            | 1                      |

Table 1. Breakdown of Participants by Their Prior Experience with Robotic Cadaveric Training Courses
The 6 participants who rated the quality of the cadaveric tissue as unsatisfactory or poor used a total of 4 cadavers. One cadaver had poor tissue preservation, which made dissection difficult. This cadaver was not used in a second training session after this was identified at the first session. One cadaver was determined to have had a prior prostatectomy, which was not recognized before the surgical training session, thereby generating the understandably low ranking. Two of the cadavers had pleural disease, and one of these had prior abdominal surgery with extensive adhesions. While these situations mimic the reality of clinical practice, the skills training experience is less optimal when the cadaver tissue is more difficult to manipulate. An overview of the study results showed that only one of the less than satisfactory evaluations was due to the actual preservation process of the cadaver.

When asked to assess whether they thought the cadaver had been utilized for prior training purposes, 8 participants stated it was obvious that the cadaver had been previously used. However, in only 4 (50%) of these cases had the cadaver actually been used prior to that training session. For the participants who incorrectly identified prior use of the cadaver, half of their training partners correctly identified the cadaver as having no prior use. There were 3 cadavers that were incorrectly identified as having prior use. Of these, 1 cadaver had pleural disease, 1 had a prior prostatectomy, and 1 had friable tissue. Again, these observations were due to the inherent qualities of the cadaver and not the preservation technique. Thirteen of the participants stated it was not obvious to them whether the cadaver had been previously used. None of these 13 cadavers had been previously utilized. One participant was unable to make a determination of whether the cadaver had been previously used in a training session. In the overall assessment, participants correctly identified whether the cadaver had been previously used in 81.8% of the sessions (Table 3).

In the cadavers that had been previously used, participants rated the quality of the cadaver on the second use as excellent or good training material. Only one of the participants with a previously used cadaver rated the quality of the cadaver as poor, but this was due to abdominal adhesions from prior abdominal surgery and was not related to the previous training session use of that cadaver.

**DISCUSSION**

As laparoscopic and robot-assisted surgery become more prevalent in clinical practice, there will be a greater need for minimally invasive surgical skills training in these technically challenging procedures. Although much effort has gone into creating realistic models and virtual reality simulators, these methods for training have yet to replace the effectiveness of training on human anatomic material.1

Human cadaver surgical skills practice has been found to give greater confidence and skills mastery to training course participants.2–5 In addition, the use of animals in training health-care personnel is being banned in countries like Britain and Canada due to the concern of contamination of health-care workers with bovine spongiform encephalopathy (BSE) virus and other livestock-infecting diseases. However, only a 1.1% decrease occurred in the use of farm animals for educational training procedures requiring anesthesia in Canada from 2004 to 2005.6 In Britain, there are legal limitations on performing laparoscopic procedures on living animal models, and research is not regularly performed on cows or swine.7 Although animals are vital and vessels bleed if cut, the anatomy is all too often far from identical to human anatomy. Many skills can be learned through tissue manipulation and hemostasis exercises in animal training courses, but the human anatomic material still provides the best anatomical instruction for surgeons.

| Tissue Quality Rating | Number of Participants | Comments |
|-----------------------|------------------------|----------|
| Excellent             | 9                      |          |
| Good                  | 7                      |          |
| Unsatisfactory        | 5                      | Poor tissue preservation (1), pleural adhesions (2), unknown prior prostatectomy (1) |
| Poor                  | 1                      | Abdominal adhesions |

**Table 2.** Surgeon Evaluation of the Quality of Tissue in the Human Anatomic Model for the Skills Training Course

| Prior Tissue Use | Number of Participants | Number Correct (%) |
|------------------|------------------------|---------------------|
| Obvious          | 8                      | 4 (50%)             |
| Not Obvious      | 13                     | 13 (100%)           |
| Suspected        | 1                      | 1 (100%)            |
| Total            | 22                     | 18 (81.8%)          |

**Table 3.** Evaluation by Surgeons as to Whether the Cadaver Had Been Previously Used for Skills Training Course
participating in robotic and laparoscopic training courses.\textsuperscript{8,9} This is particularly true in learning the radical prostatectomy procedure, as no comparable animal model is available to represent the same surgical skills necessary for excision of the prostate.

Limitations on widespread use of human anatomical material for surgical skills training include a limited supply of cadavers, the difference in tissue quality between cadaveric and blood-perfused tissue, and the fact that cadavers may traditionally only be used once.\textsuperscript{10,11} However, because the cadaver offers an ideal anatomic representation, this outweighs all other concerns. The majority of the training course participants in this study who operated on a previously used cadaver assessed the tissue quality as excellent. The one participant who rated the tissue quality as poor, did so due to pre-existing abdominal adhesions that were unrelated to the prior training use of the cadaver. Detailed statistical analysis was not performed due to the small number of participants in the study. However, our main goal was to demonstrate that coordinated cadaver use could be carried out successfully as a high quality educational experience.

To our knowledge, this is the first minimally invasive surgical training program to implement coordinated use of cadavers for thoracoabdominal surgery. Fresh tissue preservation of cadavers has been successfully utilized in other laparoscopic training programs.\textsuperscript{9} In our experience, this preservation technique has provided excellent tissue quality for dissection and allows for refrigeration of the cadaver between the first and second use. The cadaver may also be frozen with minimal loss of tissue integrity if an extended time period passes before the subsequent use. Our results indicate that cadaver reuse increases the availability of cadaveric tissue without compromising tissue quality for dissection. This effectively reduces the cost of cadaver use for training by half.

Although simulator and model training for minimally invasive surgery is the most cost-effective training modality, laparoscopic simulators are quite expensive to obtain and maintain ($80,000 purchase price and $8,000 to $15,000/ year service contract). Likewise, porcine models are more cost effective than cadavers for single-use training at an approximate cost of $550 (for purchase of the animal, anesthesia, and technician fees), but the anatomy of porcine models differs significantly from that of humans, and animal models may only be used once. For example, the nephrectomy in the pig is much easier than in the human due to the relative absence of perirenal fat, smaller hilar vessels, and the fact that the line of Toldt lies medial rather than lateral to the renal hilum. Only the human cadaver overcomes these shortcomings. Although expensive, coordinated reuse of cadavers cuts the approximate cost per use in half, from $2,550 to $1,375 (Table 4).

Any time a cadaver is scheduled for surgical training use at our institution, all minimally invasive surgery-training directors are notified via email. This allows for scheduling a second use of the cadaver. There are also regular minimally invasive surgical training meetings to review all scheduled cadaver training courses and to coordinate training use of the cadaveric tissue between surgical departments.

**CONCLUSION**

We propose that coordinated, multiple-use of human anatomic material provides a very effective training format and helps to extend this limited, but valuable, resource. We have found high satisfaction among training course participants receiving their surgical training in the previously used human anatomic material. Because human cadavers remain the gold standard for anatomic training for several specific minimally invasive surgical techniques, the coordinated, multiple-use of cadaveric tissue maximizes the educational use of this important training format.

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