The Laryngoscope

Implementation of a Program for Surgical Education in Laryngology

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Objectives: To describe the implementation of a program for surgical education in laryngology.

Methods: Items necessary to modify a temporal bone lab for laryngeal dissection purposes were identified, and costs to do so were calculated. The prices and availability of human and canine laryngeal specimens to be used for teaching purposes were then compared. Endoscopic and open laryngeal surgery were performed on canine larynges to determine suitability as a teaching model. A laryngeal dissection course with teaching objectives was created and instituted in an Otolaryngology–Head and Neck Surgery residency training program.

Results: Modifications to convert an existing temporal bone lab into a laryngeal dissection lab cost $7,425. Canine larynges were found to strongly resemble human larynges and were easily used in a teaching model. They were more easily acquired and less expensive than human larynges. A novel dissection approach was created to maximize utility of a single cadaveric laryngeal specimen. Development of a laryngeal dissection manual facilitated a laryngeal dissection course.

Conclusions: A laryngeal dissection educational course can be instituted with simple and relatively inexpensive modifications to an existing temporal bone laboratory. Canine larynges can be substituted for human larynges for a substantial cost savings without educational compromise. The educational methods demonstrated can be easily duplicated at other training sites.

Key Words: Laryngology, laryngeal surgery, education, residency, surgery, microlaryngoscopy, laryngoplasty, patient safety.

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INTRODUCTION

Societal mandates on medical safety have increased dramatically over the last two decades. This stringency has come in many forms including resident work-hour restrictions enforced by the Accreditation Council for General Medical Education (ACGME) and increasing regulations overseen by The Joint Commission of Accreditation of Health Care Organizations (JCAHO). The importance of patient safety in surgery has been recognized as part of this movement. Unfortunately, the prioritization of patient safety in surgical training programs often leads to a diminution of resident operative responsibility as attending surgeons retain a greater degree of direct control of surgical cases. This may increase patient safety in resident training programs only to decrease patient safety in the early stage of a young surgeon's career. In an effort to resolve this dilemma, surgical simulation has been developed. Within otolaryngology, surgical simulation for otologic surgery has come through the means of temporal bone dissection. However, there is no standard pathway for surgical education in laryngology. The need for a laryngeal education pathway is driven by the fact that laryngeal surgery has a narrow margin for success and is inherently difficult to teach in vivo. Furthermore, although there has been a remarkable increase in the number of office-based, microsurgical, and open laryngeal procedures over the last 20 years, there is no standardized venue outside the operating room in which to learn and practice skills.

We expanded upon recently introduced teaching paradigms in laryngology[1,2] by developing a model for laryngeal education that was readily available, inexpensive, and provided an experience similar to in vivo human laryngeal surgery. A temporal bone lab was modified into a laryngeal dissection lab with minimal changes. The suitability of an ex vivo canine larynx to serve as a substitute for a human larynx was analyzed from a surgical and

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Fig. 1. Laryngeal dissection station. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

fiscal standpoint. A laryngeal dissection course with specific teaching objectives was formulated, which led to the creation of a laryngeal dissection manual. To maximize utility of a single cadaveric laryngeal specimen, a novel dissection approach was developed. A laryngeal dissection course was then instituted in an otolaryngology residency training program.

MATERIALS AND METHODS

Laboratory Modifications

The temporal bone laboratory at our institution was surveyed for changes necessary to perform cadaveric laryngeal dissection. The costs incurred to modify it were obtained from commercial vendors. Instruments to perform laryngeal dissection were identified and obtained. A second iteration of laryngeal dissection station (LDS) was manufactured to facilitate dissection.[1]

Specimen Analysis

The suitability of a canine larynx for laryngeal dissection purposes was determined by performing endoscopic and open laryngeal surgery on ex vivo canine larynges. The costs of using human larynges instead of canine larynges were obtained from a private company, which provides human specimens for research purposes. Availability of both specimens was determined by assessing local resources.

Specimen Procurement

Canine larynges were dissected ex vivo. All animals were primarily used by other medical researchers for research purposes. Shortly after animals were humanely euthanized, the laryngotracheal complex from tongue base to mid trachea was harvested. The specimen was then placed in sterile saline and frozen to −80°C. Specimens were removed from the freezer and gently thawed the night before the dissections took place.

Laryngeal Dissection Course

Teaching objectives for a laryngeal dissection course were determined, and a laryngeal dissection manual was created for participants to use. The method of cadaveric laryngeal dissection was explored to maximally utilize a single larynx to meet multiple purposes. A laryngeal dissection course was then instituted for the residents of the University of Wisconsin–Madison Otolaryngology–Head and Neck Surgery training program.

RESULTS

Laboratory Modifications and Financial Analysis

Modifications needed to change the temporal bone laboratory at the University of Wisconsin–Madison into a laryngeal dissection lab included procurement of a 350-mm microscope lens and a laryngeal dissection station (LDS) for each teaching station. Microscope lenses were obtained for $685 each, and laryngeal dissection stations were produced for $800 each. Instruments necessary for open and endoscopic laryngeal dissection were obtained free of charge from the operating room from a collection of surplus and no longer used instruments. The cost to modify a five-station lab was $7,425.00.

Laryngeal Dissection Station

To perform cadaveric laryngeal dissection in the laboratory setting, a second iteration of an LDS was developed[1] (Fig. 1). The LDS was made of stainless-steel parts that were fixed to a metal base, which made it portable and easy to clean. In the center of the LDS was a larynx holder, which securely clamped a cork-mounted larynx. The larynx holder could be positioned for either endoscopic or open laryngeal dissection. On one side of the LDS was a tubular examining speculum shaped like a laryngoscope, which could be rotated over the glottis to mimic operative laryngoscopy. Rigid telescopy, binocular microscopy, and phonomicrosurgery were performed in this position (Fig. 2). Once this was completed, the LDS and larynx holder were rotated 180°. Sutures were affixed to supraglottic structures, and the free ends were tied around compressed springs at the end of retraction rods. The retraction rods were adjusted to

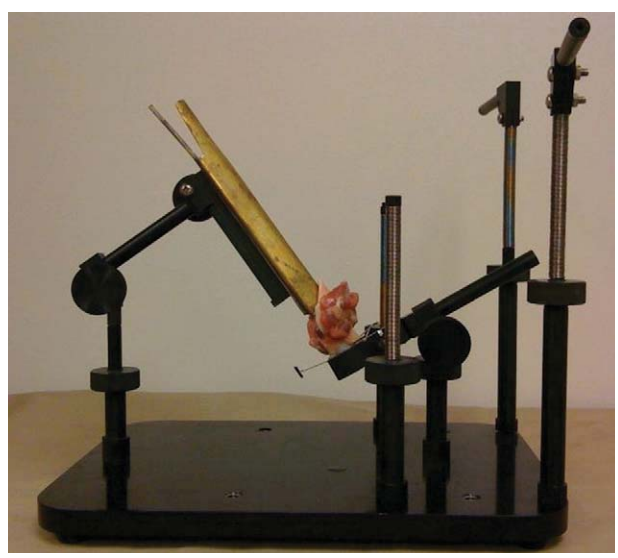

Fig. 2. LDS with a canine larynx positioned for endoscopic laryngeal surgery. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

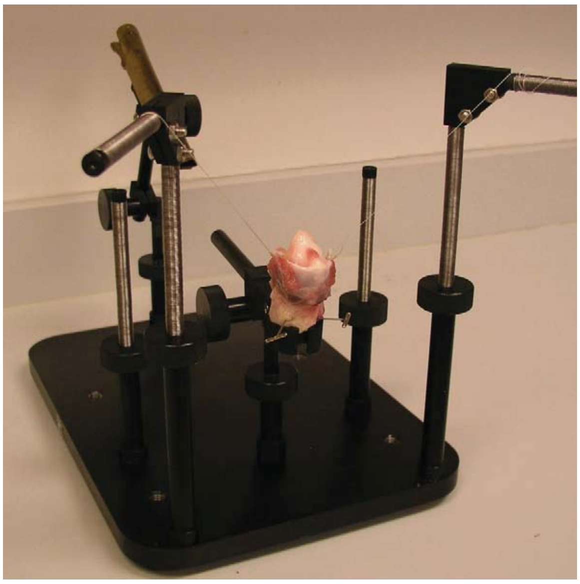

Fig. 3. LDS with a canine larynx positioned for open laryngeal dissection. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

maximize exposure of the larynx, and solo bimanual open dissection took place in this position (Fig. 3).

Investigation of Specimen Suitability

Endoscopic laryngeal procedures, including subepithelial fluid infusion, epithelial resection, microflap elevation, and cordotomy were successfully performed on an ex vivo canine larynx using an operating microscope and an LDS. Open procedures, including medialization thyroplasty, arytenoid adduction, and horizontal and vertical partial laryngectomies were easily executed as well.

Specimen Financial Analysis

Costs of human laryngeal specimens were obtained from a private supplier of human specimens for research purposes. The cost of purchasing specimens and arranging transport of these specimens to and from our facility was $2,407.22 for five larynges, or $481.45 per larynx. Canine larynges were obtained for free from other researchers within the institution who were using canines for other research purposes.

Laryngeal Dissection Course Objectives

The teaching objectives of the laryngeal dissection course were for participants to 1) learn the names and functions of instruments used in open and endoscopic laryngeal surgery; 2) learn how to properly expose the larynx endoscopically; 3) learn how to adjust the microscope, surgical bench, and surgeon chair to obtain proper ergonomic position during surgery; 4) understand the anatomic relationships of the larynx; 5) understand the terminology and importance of laryngeal subsites; and 6) practice endoscopic, laryngeal framework, and open laryngeal surgery.

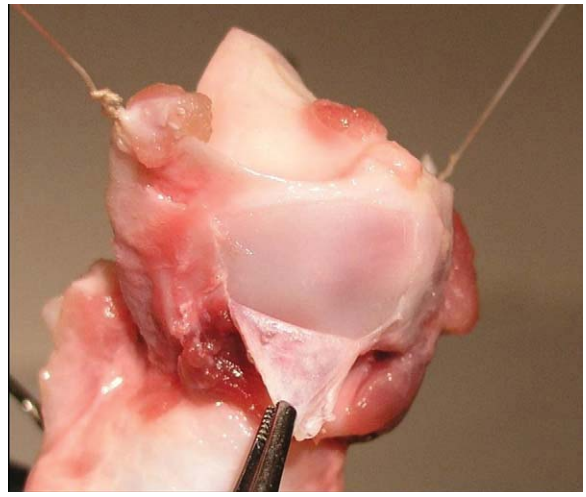

Fig. 4. Canine larynx suspended in a LDS demonstrating the creation an inferiorly based perichondrial flap. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Laryngeal Dissection Manual and Novel Dissection Approach

A laryngeal dissection manual was created for trainees. The manual outlined steps of dissection to maximize utility of a single specimen and meet all learning objectives. Clinically relevant teaching points relating to laryngeal anatomy and pathology were also part of the text. Photographs of a laryngeal prosection were included in the atlas. The dissection approach first focused on the external anatomy of the larynx, and then described endoscopic maneuvers including subepithelial infusion, epithelial resection, microflap elevation, injection laryngoplasty, and cordotomy procedures.

External laryngeal dissection was performed using an "outside-in" approach, which was also detailed in the text. The extrinsic muscles of the larynx were identified and severed from their attachments. Perichondrial flaps from the thyroid cartilage were then created (Fig. 4).

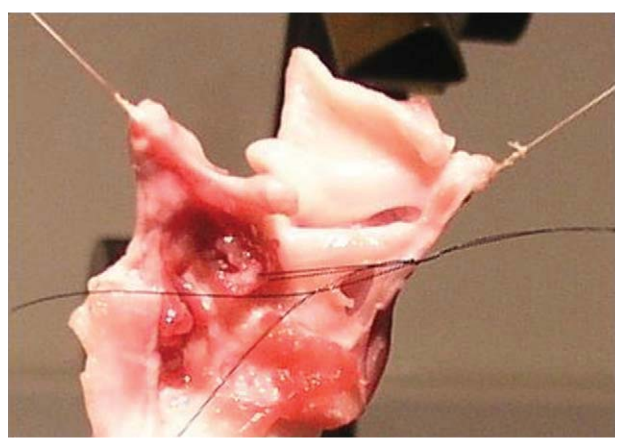

Fig. 5. Canine larynx suspended in a LDS with half of the thyroid cartilage removed. An arytenoid adduction stitch has been placed and secured with a knot. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Half of the thyroid cartilage was then removed to show the internal larynx and the attachments of the intrinsic muscles of the larynx. Gentle pull on the internal laryngeal musculature demonstrated the functions of each muscle. The arytenoid cartilage was identified, and arytenoid adduction sutures were placed on the hemilarynx with the thyroid cartilage removed (Fig. 5). The remaining hemilarynx with the thyroid cartilage intact was used to practice medialization thyroplasty with Gore-tex and simultaneous arytenoid adduction. Participants were then taught to perform either an open partial vertical or horizontal hemilaryngectomy.

Laryngeal Dissection Course

Participants were brought into the lab and familiarized with the operative microscope, LDS, adjustable chair, and surgical instruments. A cork-mounted canine larynx was placed in the larynx holder of the LDS and positioned under the laryngoscope by each course participant. Inspection of the larynx took place using straight and angled rigid Hopkins-rod telescopes. The operating microscope was then positioned for a view of the larynx. Endoscopic procedures as outlined by the laryngeal dissection manual were performed. The larynx holder was then rotated 180° so that laryngeal dissection could be performed. The nerves, arteries, veins, cartilages, and bones of the larynx were identified and relationships appreciated. Open dissection was performed as described in the laryngeal dissection manual. Instructors circulated throughout the course to facilitate dissections.

DISCUSSION

Numerous factors have changed the way in which medicine is practiced and taught, the most important being a public interest in medical safety. The need for safer practices in medicine drives the guiding mission of JCAHO to "continuously improve the safety and quality of care provided to the public."[3] Entire system-based approaches including formal "time-outs" before surgery, institution of the Surgical Care Improvement Project, and the National Surgical Quality Improvement Project help to ensure patient safety.[4] In creating a safer work environment for trainees, resident work-hour limitations mandated by the ACGME have led to fewer cases being performed by surgical residents at some training institutions.[5–7] Furthermore, economic forces also potentially decrease the number of surgical cases performed by physicians in training. As costs to practice health care increase and reimbursements decline, surgeons feel pressure to complete cases faster in order to be more productive;[4] however, the resident learning process translates to increased procedural times. Wang et al. found that resident physicians took almost one and a half times longer to complete a type I tympanoplasty compared with attending physicians, which translates to fewer cases being performed per day.[8] The operating room time "lost" in teaching a general surgery resident has been estimated at 11,816 minutes over the course of a trainee's five-year residency, which was extrapolated to a cost of $53 million dollars for the extra operating room time used to train general surgery residents annually.[9]

The increased importance of safety combined with a decreased number of cases being performed by trainees calls for surgical education to be performed outside of the operating room. Investigating these needs, a Blue Ribbon Committee for surgical education was formed by the ACS, the American Surgical Association, the American Board of Surgery, and the Resident Review Committee for Surgery. This committee recognized that surgical simulators and new teaching technologies should be introduced into residency education and that an educational paradigm should focus on "patient care characterized by high quality and safety."[10] Indeed, it has been shown that surgical simulation can enhance safety and improve surgical outcomes. Seymour et al. found that residents who underwent training with a laparoscopic virtual reality surgical simulator were 29% faster, five times less likely to injure surrounding tissue, and six times less likely to make errors than residents not trained on a simulator.[11] Fried et al. noted that residents who underwent endoscopic sinus surgery virtual reality training were faster, demonstrated more skill, and made fewer technical errors than colleagues who did not use virtual reality training.[12] The importance of surgical simulation was formally recognized in 2008 when the ACGME mandated that all general surgery residency training programs have access to resources that include simulation and surgical skills labs.

Otolaryngologists have long recognized the importance of surgical education outside of the operating room. Training in otology uses ex vivo temporal bone dissections, and a similar model for laryngology is necessary because of the inherent nature of laryngeal surgery, which is technically challenging, unforgiving, and difficult to teach. As Contag et al. noted, "Mastery of phonomicrosurgery is both challenging to achieve and difficult for the mentoring surgeon to teach while maintaining control of the operation."[13] Unlike a neck dissection and other open surgical procedures, the teaching surgeon cannot easily guide a trainee's hand during microscopic laryngeal surgery because of difficulties viewing the same field under binocular vision. The need for a formalized method of providing laryngeal education is further reinforced as laryngeal surgery is rapidly changing with new procedures and technologies constantly being introduced.

This need for a laryngology education model was met in our training program with the introduction of a formal laryngeal dissection course using an LDS and canine larynges in a modified temporal bone lab. This approach was easy to institute with existing resources, relatively inexpensive, and provided an experience very similar to surgery in humans. After an initial investment of $7,425 for a five-station laryngeal dissection lab, all future dissections were performed for free on canine larynges, which were obtained from euthanized research animals free of charge at our institution. In comparison, Bent and Porubsky created a single-station rhinology lab for $15,055 in 1996 prices—more than twice the price of our lab.[14]

Ideally, dissection would take place on ex vivo human larynges. However, in our experience, these specimens are costly and difficult to obtain. At our institution, we benefit from having an associated veterinary school where canine research is frequently performed and where larynges are easily harvested free of charge after animals are euthanized. The dog larynx is very similar to a human larynx: It contains a false and true vocal fold separated by a ventricle[15] and has a 15-mm membranous vocal fold length[15] and a three-layered lamina propria[16] like a human larynx. While the creation of a thin microflap in a dog larynx is difficult to perform due to its thicker superficial layer of the lamina propria,[16] all other open and endoscopic procedures were replicated on a canine larynx without difficulty.

The use of ex vivo canine larynges may not be possible at other institutions where canines are not employed in research or where policies may exist in which animals cannot be used in more than one experiment. An alternative would be to perform laryngeal dissection on live canines, which is difficult to coordinate, costly, and lacks the benefits of a laryngeal dissection laboratory. Harvesting larynges from a canine simply for use in the ex vivo setting is expensive and does not provide much of an advantage over the purchase of human cadaveric larynges. For individuals with these circumstances, the use of other cadaveric mammalian larynges may be an option. Porcine larynges can be acquired from slaughterhouses at little or no cost. Structurally, pig larynges also have a false and true vocal fold separated by a ventricle[15] but differ with a single muscular compartment posterior cricoarytenoid muscle.[17] Furthermore, the lamina propria in a pig vocal fold is made of two layers,[15,16] and creation of a microflap is hindered by submucosal glands in the glottis.[16] While pig vocal folds are similar to human vocal folds, Garrett et al. found the dog vocal fold to be most similar to a human vocal fold based on histologic analysis and location of a microflap plane of elevation.[16]

Recently Effat proposed using ex vivo cow larynges obtained from slaughterhouses as a tool to teach open laryngeal surgery to trainees.[18] However, cows lack a ventricle separating the false and true vocal fold, resulting in a "padlike" vocal fold that is larger and thicker than a human vocal fold.[19] While some procedures may be practiced easily on a cow larynx, the specimen is not ideal for injection medialization laryngoplasty, phonomicrosurgery, or supraglottic laryngectomy due to this anatomic difference, which minimizes the utility of such a specimen.

The concept of laryngeal anatomy education and laryngeal surgery simulation is not new. In 2004 Dailey et al. and Mohamed and McCulloch described tools to facilitate laryngeal dissection.[1,2] Amin et al. described a novel method of teaching vocal fold injection in which the "larynx" of an intubation mannequin was removed for insertion of a human cadaver larynx.[20] Peroral laryngeal injection took place with the assistance from the view provided by a transnasal laryngoscope. Contag et al. used a plastic model larynx with sheets of paper modeling the vocal fold to teach microlaryngeal surgery, and while the device was well received, a concern of subjects was the need for a "more 'lifelike' synthetic vocal fold."[13]

Ex vivo training can come in many forms including human cadaver dissections, synthetic dissection models, live animal surgery, and virtual reality surgical simulators.[11,12] Virtual reality simulators were modeled after flight simulators in which aviators spend many hours practicing "takeoffs and landings before they ever set foot in an airplane."[21] Unfortunately, the utility of virtual reality simulators can be limited by low availability, high costs, and lack of haptic feedback.

Prior to instituting this course, laryngeal education for our residents was an annual cadaver dissection course in which a single cadaver head and neck specimen was dissected by a group of 10 residents. This was the first time residents had an individual laryngotracheal specimen to dissect and perform model surgery on. This formalized laryngeal dissection course has been very well received, has improved resident satisfaction, and has enhanced resident education.

Several features of the laryngeal dissection course were reviewed by residents as highlights. The laryngeal dissection manual allowed residents to work at their own pace and ask for help when necessary, served as a study guide for resident education, and permitted them to return to the lab at another time to dissect larynges at their convenience. The "outside-in" dissection approach allowed course participants to perform procedures such as arytenoid adduction both with and without the thyroid cartilage present, which improved comprehension of procedures. The LDS allowed residents to perform solo dissections and permitted examination of the larynx from multiple angles throughout the course, which was not possible in whole-head cadaver dissections or during actual surgery.

While this approach has been helpful in educating residents, limitations do exist. Although tissues of a canine larynx are very lifelike, bleeding does not occur with cutting and tissue manipulation in the ex vivo model; arytenoid repositioning procedures in particular can be hindered by bleeding in vivo and may be unrealistically easy to perform in a cadaver model. Also, studies need to be performed to validate this as a helpful surgical training model.

CONCLUSIONS

With the national focus on safety becoming more prevalent and the current paradigm of training perhaps not sufficient, the need for a laryngeal dissection laboratory has arisen. At the University of Wisconsin–Madison, implementation of a laryngeal dissection course has allowed for surgical training that mimics operative experience with accuracy using canine larynges and an in-house-developed surgical manual. Most, if not all, residency programs are affiliated with a temporal bone laboratory where a laryngeal dissection course can take place. The model outlined is relatively inexpensive to institute, provides a true-to-life surgical experience, can be easily duplicated, and thus can easily be made a part of surgical education.

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