Endoscopic Selective Neck Dissection in a Porcine Model

David J. Terris, MD; Ashkan Monfared, BS; Adrian Thomas, BS; Neeraja Kambham, MD; Yamil Sáenz, DVM

Objective: To investigate the feasibility of accomplishing a selective neck dissection (SND) endoscopically.

Study Design: Prospective, nonrandomized experimental investigation in a porcine model.

Methods: Unilateral endoscopic SNDs were performed in Yorkshire pigs. A spacious operative pocket was developed using a combination of hernia balloon expansion followed by low-pressure (4 mm Hg) carbon dioxide insufflation. The sternomastoid muscle, thymus, submandibular gland, lymph nodes, and fibrofatty tissue were removed in a procedure approximating a human SND. Data (operative time, blood loss, arterial blood gas values, weight of the specimen, and complications) were prospectively recorded. The specimens were analyzed by a pathologist, and the number and size of lymph nodes were recorded.

Results: Fourteen endoscopic SNDs were successfully performed. No conversions to open surgery were necessary. The median operative time was 131 minutes (range, 95-235 minutes). The median estimated blood loss was 4 mL (range, 0-150 mL). The mean ± SD specimen weight was 42.9 ± 8.3 g; the mean number ± SD of nodes retrieved from the neck specimen was 4.8 ± 2.2, and the mean ± SD maximal nodal dimension was 2.4 ± 0.5 cm. The arterial PCO2 increased by an average of only 3.9 mm Hg from the beginning to the end of the surgery; correspondingly, the pH fell by only 0.02. There were no major complications, and no animals had to be euthanized prior to the completion of the procedure.

Conclusions: Endoscopic neck dissection in a porcine model can be accomplished with a combination of strategies to overcome the dilemma of creating and maintaining an operative pocket. The merger of SND with endoscopic technology offers the promise of truly minimally invasive surgery for the node-negative neck.

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Endoscopic surgery has emerged as a safe and efficacious alternative to traditional open surgery in a number of different disciplines, including laparoscopic abdominal procedures,1-4 thoracoscopic chest procedures,5 and endoscopic sinus surgical procedures,5,7 among others. With advances in technology and refinements of techniques, endoscopic approaches have become an attractive alternative to, and in some instances even rendered obsolete, previously accepted standard surgical procedures.

Endoscopic procedures in the neck have lagged in this technological evolution. Endoscopic surgery in the thyroid compartment has been performed with some success,8,9 but cumbersome techniques have limited its widespread use. Surgery in the upper neck has seen even fewer successes, primarily because of a number of additional inherent anatomic challenges, chief among which is the absence of a natural, well-contained space (analogous to the peritoneal or pleural cavities) in the neck. This has resulted in consequences of surgery that have made the transition to clinical application in the neck premature.10 In the past year, however, these challenges have been overcome using a number of distinct strategies. While some authors have relied on customized skin retraction devices11 or necklifting methods,12 we and others13-15 have used balloons (designed for laparoscopic herniorrhaphy) to create a surgical pocket, sustainable with a low level of carbon dioxide insufflation. With this hybrid of techniques, we have successfully and reliably performed endoscopic submandibular gland resection in an experimental model.13 Coincident with the innovations in endoscopic technology has been a continuing validation of the concept of a selective neck dissection (SND),16,17 based on the relatively predictable patterns of spread of
squamous cell carcinoma of the head and neck. The limited morbidity of SND has led to their widespread application, primarily as a staging procedure in radiographically and clinically node-negative necks in which the risk of occult metastasis exceeds 20%. This procedure lends itself to a minimally invasive surgical approach, such as an endoscopic neck dissection. We therefore undertook a prospective, experimental investigation of the feasibility of performing a SND endoscopically in a porcine model.

METHODS

A porcine neck dissection was conceived that is comparable in extent to a human SND (levels I-IV) (Figure 1). This procedure includes removal of the submandibular triangle contents (submandibular gland and associated lymph nodes), sternomastoid muscle, thymus gland (which, in pigs, is equivalent in size to a parotid gland), fibrofatty tissue, lymphatics, and lymph nodes. The neck dissection has as its boundaries the mandible superiorly, the level of the attachment of the sternomastoid inferiorly (the pig has no clavicle), the posterior border of sternomastoid muscle, thymus gland (which, in pigs, is equivalent in size to a parotid gland), fibrofatty tissue, lymphatics, and lymph nodes. The neck dissection has as its boundaries the mandible superiorly, the level of the attachment of the sternomastoid inferiorly (the pig has no clavicle), the posterior border of sternomastoid muscle posteriorly, and the strap muscles anteriorly.

ANIMALS, ANESTHESIA, AND MONITORING

Fourteen female Yorkshire pigs aged 5 to 6 months and weighing approximately 45 kg underwent unilaterial SND after institutional approval was obtained from the Stanford University Administrative Panel for Laboratory Animal Care, Stanford, Calif. The pigs were fasted overnight, premedicated for surgery with intramuscular atropine (0.04 mg/kg), and sedated with intramuscular tiletamine zolazepam (6 mg/kg). Anesthesia was induced with 3% halothane in oxygen delivered by face mask. All animals were intubated with endotracheal tubes from 6.5 to 7.0 mm in diameter. Anesthesia was maintained with 1% to 3% halothane in oxygen with mechanical ventilation (Halowell model 2000, Pittsfield, Mass), and ketamine (1 mg/kg) and diazepam (0.05 mg/kg) were delivered intravenously as needed. Venous and arterial catheters were placed percutaneously for drug and fluid administration and systemic arterial blood pressure monitoring. Body temperature, heart rate, electrocardiogram, and pulse oximetry (Critikon Dinamap Plus; Johnson & Johnson, Tampa, Fla) were also monitored. Arterial blood gases were obtained at 30-minute intervals in 12 of the 14 animals. Lactated Ringer solution (Abbott Labs, Deerfield, Ill) was administered intravenously at a rate of 10 to 15 mL/kg per hour throughout anesthesia.

Surgical Procedure

After induction of anesthesia, a 14-mm incision was created 9 cm lateral to the sternal notch, the platysma was divided using a Metzenbaum scissors (Figure 2A), and a 10/12-mm nonbladed trocar was introduced in the subplatysmal plane aiming toward the angle of the mandible (Figure 2B). Using the passage created by the trocar, a 1000-mL hernia balloon (AutoSuture PDB 1000; US Surgical, Norwalk, Conn) was introduced (Figure 2C) and an operative pocket created by inflating the balloon to 500 to 700 mL (Figure 2D). The same site was used as the camera port for a 10-mm 0° or 30° rigid endoscope introduced through a 10/12-mm trocar. The operative pocket was maintained by carbon dioxide insufflated at a pressure of 4 mm Hg.

Two 5-mm bladed trocars were inserted 4 cm lateral to each side of the camera port under endoscopic visualization. The blades are pressure loaded and disengage when resistance drops so that the likelihood of inadvertent visceral or vascular injury is minimized. The 5-mm ports were used for endoscopic graspers and ultrasonic devices such as scalpels and shears (Harmonic Scalpel; Ethicon Endosurgery, Cincinnati, Ohio).

Dissection was begun superiorly with the isolation of the submandibular triangle contents, including the submandibular gland along with its accompanying lymph nodes and fascia (see Monfared et al13 for the previously described technique). Proceeding inferiorly, the lateral edge of the sternomastoid muscle was isolated and retracted medially. The fascia attached to the lateral edge of the strap muscles, along with the thymus gland, was dissected from medial to lateral (Figure 3A and B). Finally, the proximal and distal attachments of the sternomastoid muscle were divided using the ultrasonic scalpel, completely detaching the specimen. Medium to large blood vessels such as the lingual artery were ligated with endoscopic clips and divided with endoscopic scissors (Figure 3C and D). A 30° angle 5-mm camera was then inserted through one of the 5-mm ports, and the specimen was gently removed through the incision of the camera port (Figure 4). Throughout the dissection, small vessels (<1 mm) were coagulated with the ultrasonic instrumentation, whereas larger vessels (arteries >1 mm and veins >2 mm in diameter) were either coagulated with a bipolar electrocautery or ligated using Endoclips (Ethicon Endosurgery).

It should be noted that every effort was made to achieve an en bloc resection of the specimen. However, the consistency and strength of the porcine fascia occasionally re-
sulted in a 2- or 3-segment specimen. All animals were carefully examined by neck palpation and chest auscultation to exclude subcutaneous emphysema or pneumothorax. The animals were euthanized with a lethal injection of barbiturates. The animals were euthanized with a lethal injection of barbiturates. Following euthanasia, the neck was opened widely, and the operative field was meticulously examined for evidence of air embolism, inadvertent damage to neck structures (particularly neurovascular), and the presence of residual lymph nodes. All resected specimens were carefully inspected, weighed, and preserved in formalin for gross and histological evaluation by a pathologist (accomplished in 12 of 14 specimens).

STATISTICAL ANALYSIS

Data are reported as medians when nonnormal (estimated blood loss and length of surgery) and as mean±SDs when they represented a normal distribution (specimen weight, number of nodes retrieved, and change in PO₂, PCO₂, and pH).

RESULTS

A unilateral SND was successfully performed on each of the 14 pigs. In no case was a conversion to open surgery required or even contemplated. Figure 5 reflects the rapid learning curve for the procedure, which was performed in 9 cases by the senior author (D.J.T.) and in 5 cases by a senior medical student (A.M.). The length of surgery ranged from 95 to 235 minutes, with a median of 131 minutes. The duration was no more than 2 hours and 10 minutes in each of the final 4 cases.

Porcine anatomy differs from that of humans: the lymph nodes are significantly larger even in the healthy state, but far fewer in number. In the present study, the mean number of nodes retrieved from the neck specimen (in addition to the submandibular gland, thymus, and sternomastoid muscle) was 4.8±2.2 (n=12), and the mean maximal nodal dimension was 2.4±0.5 cm. Importantly, no residual nodes were detected in the dissected field when the neck was opened and explored. The mean specimen weight was 42.9±8.3 g.

No major complications occurred in this series of animals. The median estimated blood loss was 4 mL (range, 0-150 mL). In 1 animal, a facial artery clip was inadequately placed, resulting in a brief period of brisk bleeding; a second clip was applied without further incident. No substantial changes in the blood pressure were appreciated (even during the period of balloon inflation). The arterial PCO₂ increased by an average of only 3.9 mm Hg from the beginning to the end of the surgery; correspondingly, the pH fell by only 0.02 (n=12).

COMMENT

Endoscopic technology has evolved to become an integral part of the surgical approach to many disease processes. No longer a novelty, endoscopic procedures have proven to be safe alternatives to traditional surgical procedures, in some instances rendering the open techniques obsolete. Coherent with this evolution has been the steady trend toward less aggressive and comprehensive surgery in favor of minimizing morbidity while maintaining the outcomes achieved with radical surgery. This balance has been
struck in a number of disciplines, including breast surgery, colorectal surgery, prostate surgery, and head and neck surgery, especially as it relates to SND.\textsuperscript{16,17}

We have joined other groups in pursuing the investigation of endoscopic neck surgery despite the several inherent obstacles this particular application of endoscopic technology poses.\textsuperscript{8-15} Chief among these obstacles has been the absence of a natural, well-contained space (analogous to the peritoneal or pleural cavities) in the neck. Dulguerov and colleagues\textsuperscript{14,15} have demonstrated impressive results in their efforts comparing endoscopic neck dissections with open neck dissections, both in a porcine and a cadaveric model.\textsuperscript{15} While we advocate some of the same endoscopic principles, our proposed technique departs from those of the Dulguerov group in that we use low-level insufflation, therefore minimizing the risk of subcutaneous emphysema, pneumomediastinum, pneumothorax, and air embolism and making the procedure one that will be safe.

![Figure 3](image1)

**Figure 3.** A, Endoscopic view of the operative field immediately after insufflation of the surgical pocket; the yellow arrow indicates the submandibular gland and the green arrow the submandibular lymph nodes. The external jugular vein (EJV) and the thymus (THY) are readily identified. B, The vein is skeletonized using an atraumatic grasper and the harmonic scalpel (HS). The ease with which medium to large blood vessels may be ligated is demonstrated in C and D. C, The linguofacial vein is ligated with endoscopic clips (black arrow indicates the vein and white arrow the first of the applied clips). D, An endoscopic scissors is used to divide the vessel (proximal and distal clips indicated by black arrows).

![Figure 4](image2)

**Figure 4.** Representative left selective neck dissection specimen. LN indicates cluster of lymph nodes; G, submandibular gland; SM, sternomastoid muscle; and T, thymus.

![Figure 5](image3)

**Figure 5.** Trend in length of surgery. Duration of the endoscopic selective neck dissection procedures reflecting the steady improvement in operative times.
to perform in humans.\textsuperscript{19} Combining a strategy of surgical pocket creation using a balloon (a concept popularized for laparoscopic hernia repair) and low-level carbon dioxide insufflation, we have been able to develop an endoscopic surgical field that easily accommodates the instrumentation necessary to complete a SND.

Our first priority was to determine the safety of this approach. We therefore carefully monitored not only the electrocardiogram, pulse rate, and arterial blood pressure, but also the arterial blood gases. Our findings confirm that a low level of carbon dioxide insufflation is easily tolerated in the neck, despite the absence of an airtight sac such as the peritoneum. Slight variations in arterial carbon dioxide may be adjusted by altering the minute ventilation, and there was no significant change in the arterial pH. The visualization was remarkable, in part as a result of the illumination and intense magnification that can be easily achieved with endoscopes. Therefore, no inadvertent structural or neurovascular injuries were incurred in the present study. The sample size was adequate to achieve a high degree of comfort with the procedure and to provide a reasonable assessment of the likelihood of complications with this approach. Because the investigation represented a consecutive case series with no control group, comparative statistical analysis was not indicated.

To approximate a human SND in our model, we pursued consultation with our veterinary colleagues and conceived an en bloc approach to the porcine anatomy. In some ways, a human SND will likely be easier to perform because of the better developed and more distinct fascial planes. The potential advantages of this approach to a neck dissection include the ability to hide scars low in the neck (just above the clavicle) and the expected rapid healing times (secondary to the reduced incision length). It is possible that the patients will experience less pain and a more expedient return to work as a result, but these remain to be proven.

The remarkable ease with which this procedure was performed, the absence of a need to convert any of the 14 operations to an open approach, and the consistent trend toward shorter operative times provide support for the promise that this approach affords. There are natural synergies between the evolution toward SND and the exploitation of endoscopic expertise. With a successful human endoscopic neck procedure already performed,\textsuperscript{19} we are guardedly optimistic about the likelihood of clinical applications of this technology.

A limitation of the present investigation is that it was not a survival study, so potential postoperative complications such as cerebrovascular accident, infection, or delayed wound healing could not be assessed. However, the likelihood of a cerebrovascular accident occurring in this setting in the absence of any intraoperative adverse events is low. The incidence of infection or delayed wound healing is also likely to be low and can reasonably be expected to be lower than that for open surgery, since there is a smaller portal for contamination and shorter incisions.

Potential future refinements of this technique can reasonably be expected. A natural adjunctive technology is the concomitant use of robotic devices (we currently have an experimental study under way). The imminent release of a newer generation of smaller instrumentation will also facilitate the ease of performing endoscopic neck procedures. As with the introduction of any new surgical procedure, the acquisition of the expertise necessary to perform the procedures in clinical practice must be conducted in a systematic way within a continuing medical education environment until the procedures are performed in a consistent way during residency.

Endoscopic SND in a porcine model can be accomplished by using a combination of strategies to overcome the dilemma of creating and maintaining an operative pocket. Standard laparoscopic instrumentation, electrocautery, and ultrasonic technology may be used, and the operative incisions are placed just above the clavicle so that they may be hidden, achieving a superior cosmetic result and likely promoting more rapid wound healing. The merger of SNDs with endoscopic technology offers the promise of truly minimally invasive surgery for the node-negative neck.

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Corresponding author and reprints: David J. Terris, MD, Department of Otolaryngology–Head and Neck Surgery, Medical College of Georgia, 1120 Fifteenth St, Augusta, GA 30912-4060 (e-mail: dterriss@mccg.edu).

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