



Natural Orifice Trans-Luminal Endoscopic Surgery (NOTES) in Thoracic Surgery

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Natural orifice transluminal endoscopic surgery (NOTES) proposes the possibility of less-invasive, incisionless surgery. Initially conceived to replace abdominal procedures, more recently interest has focused on mediastinal and thoracic procedures as possible logical applications of transluminal approaches. A survey of the literature as well as the author's own experience is performed, examining experimental and increasingly human use of mediastinal and thoracoscopic flexible endoscopy. Issues regarding instrumentation, orientation, and best access are discussed. The literature describes both direct transesophageal access to the mediastinum and pleural cavities and submucosal flap access. Other techniques include transgastric, transvesicular, and percutaneous access via a neck incision. Overall, the early results of transesophageal Heller myotomy show the most promise for early clinical adoption. NOTES has an interesting role in thoracic and mediastinal surgery. Although initially thought of as a highly improbable application, the "home run" of per-oral endoscopic myotomy is indicating that the thorax may be one of the most useful places for NOTES.

Semin Thoracic Surg 22:302-309 © 2010 Elsevier Inc. All rights reserved.

Keywords: NOTES, mediastinoscopy, POEM, Heller myotomy, endoscopic surgery, thoracoscopy, flexible endoscopy

The last 2 decades have been marked by an amazing shift in the practice of abdominal surgery, with the large incisions used for maximal exposure having been replaced by the miniscule incisions of minimally invasive surgery. After laparoscopic techniques were thoroughly evaluated for feasibility, safety, and potential benefit to the patients, more and more laparoscopic procedures have gained widespread acceptance and have been implemented in daily clinical practice.

In a similar fashion, the use of video-assisted thoracoscopy has changed the practice of thoracic surgery. The benefits appeared to be even more convincing than laparoscopy, with avoidance of large thoracotomy incisions and their associated postoperative pain, inferior cosmesis, and need for long hospital stays, not to mention complications, such as surgical site infections and chronic neuralgia. Initial applications for the treatment of benign diseases have now progressed to thoracoscopic oncological

resections of the lung,¹ esophagus,² pleura and other intrathoracic organs. Often, these have been shown to have similar cure rates, significantly decreased pain and physiological insult to the patients, as well as shorter periods of recovery.³⁻⁵

The indisputable benefits of laparoscopic and thoracoscopic surgery have changed how surgeons think about surgical access and at the same time ignited a new interest in the development of even less invasive techniques. Natural orifice transluminal endoscopic surgery (NOTES) is an example of pushing the boundaries of minimally invasive approaches in surgery. NOTES is based on the concept of using the body's natural orifices (mouth, vagina, rectum, urethra) to access the operative field and aims to perform surgery without incisions.⁶ Studies in animals have demonstrated the feasibility of transluminal endoscopic peritoneoscopy, cholecystectomy, liver biopsy, splenectomy, oophorectomy, tubal ligation, gastrojejunostomy, and distal pancreatectomy.⁷⁻²⁰ Clinical applications started being reported in 2007,²¹ are performed under human trial protocols, and mainly consist of transgastric cholecystectomies, transvaginal cholecystectomies, and transgastric appendectomies.^{6,22,23}

The development of NOTES for thoracic surgery has lagged its abdominal counterpart as reflected by

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the relatively small number of relevant publications.²⁴⁻⁴² The hypothetical benefits of avoiding transthoracic access by using a transluminal approach may exceed those observed when laparoscopy is compared with transvaginal or transgastric approaches. The proximity of the esophagus to target organs and the use of flexible instrumentation in the nonexpansile space of the thoracic cavity offer obvious potential benefits. However, the close proximity of major vital structures, the devastating results of mediastinitis, and the lack of familiarity of cardiothoracic surgeons with flexible endoscopy will certainly slow the translation of research protocols to clinical applications of NOTES in thoracic surgery.

PRINCIPAL CONSIDERATIONS IN THORACIC NOTES

The introduction of endoscopic ultrasound (EUS) has increased the use of flexible endoscopy in the surgical treatment of thoracic diseases. The detailed depiction it provides of the mediastinum has allowed for more accurate staging of lung cancer, particularly when combined with EUS-guided fine-needle aspiration biopsy.⁴³ This has also allowed visualization of the mediastinal compartments that are difficult to approach with standard rigid mediastinoscopy (inferior and posterior mediastinum). Endobronchial ultrasound supplements the endoscopic evaluation with imaging of the anterior compartment.⁴⁴ Combined use of the 2 techniques has sensitivity and negative predictive value of >93% in detection of involved mediastinal lymph nodes.⁴⁵

Flexible endoscopy, in general, has altered the way we treat esophageal and mediastinal pathology. The treatment of esophageal perforations by drainage of mediastinal fluid collections with transesophageal insertion of nasomediastinal drains, clip closure and stents is widely practiced.³¹ Furthermore, mediastinal abscesses have been debrided endoscopically in a manner similar to endoscopic pancreatic necrosectomies, offering evidence of successful use of true transluminal therapies in the human thorax.⁴⁶ In addition, EUS has emerged as a valuable tool in the future development of thoracic NOTES by guiding both the creation of safe entrance sites remote of critical mediastinal structures, and the preferential entrance of the right or left pleural cavity.³¹

As with the abdomen, investigators of thoracic NOTES are trying to sequentially address the specific principal issues related to the technique, ie, needed instrumentation for NOTES, the best approach to thoracic and mediastinal structures, safe transluminal access, clear visualization and orientation, safety and tolerance of CO₂ insufflation in the chest and

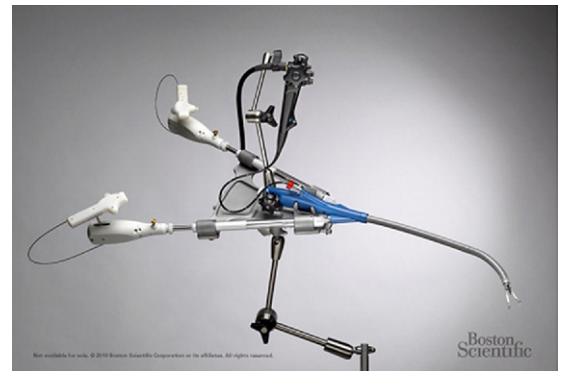


Figure 1. A new generation of flexible endoscope is being created for NOTES (DDES, Boston Scientific, Natick, MA). (Color version of figure is available online at <http://www.semthorcardiovascsurg.com>.)

mediastinum, and secure closure of the access site.^{24,31,33}

NOTES Instruments

One benefit of the “NOTES revolution” has been a radical rethinking of the instruments needed to perform such high-level endoscopic interventions. Current endoscopes are fine for endoluminal use and single-handed manipulations but are inadequate for more advanced surgery. New operating platforms, which convert flexible endoscopy to more of a laparoscopic paradigm, have been developed and are now just reaching the market (Fig. 1; direct drive endoscopic system [ie, DDES]; Boston Scientific, Natick, MA). These endoscopes separate the camera controls from the instrument manipulations and allow the surgeon to use both hands to operate. In addition, these endoscopes are designed to permit triangulation of the end-effectors, permitting traction-countertraction maneuvers. Another novel aspect of this new generation of flexible endoscopes is that they are specifically configured for extraluminal work: they are designed to be terminally sterilized and they are equipped with ports to allow the use of CO₂ insufflators.

A new generation of endoscopic tools is also becoming available, some replicating traditional laparoscopic tools and some being completely novel designs. Particularly important are tissue approximation tools, which will enable the critically important closures of viscerotomies (Fig. 2).

Approach to the Thoracic Cavity

The most accessible thoracic organ is the esophagus, and this is the route most extensively studied for transluminal access to the mediastinum and the pleural cavities.^{25,33-37,40-42} Upper endoscopy is followed by the

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