Robotic Benign Esophageal Procedures

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KEYWORDS

• Achalasia • Fundoplication • Paraesophageal hernia • Robotic surgery
• Benign esophageal disease

KEY POINTS

- Robotic master-slave devices can assist surgeons to perform minimally invasive esophageal operations with approaches that have already been demonstrated using laparoscopy and thoracoscopy.
- Robotic-assisted surgery for benign esophageal disease is described for the treatment of achalasia, epiphrenic diverticula, refractory reflux, paraesophageal hernias, duplication cysts, and benign esophageal masses, such as leiomyomas.
- Indications and contraindications for robotic surgery in benign esophageal disease should closely approximate the indications for laparoscopic and thoracoscopic procedures.
- Given the early application of the technology and paucity of clinical evidence, there are currently no procedures for which robotic esophageal surgery is the clinically proven preferred approach.

INTRODUCTION

As a pliable muscular tube that spans 3 body compartments in close proximity to the great vessels, the esophagus and its anatomic design impart formidable challenges to the surgeon. Operative approaches are made more difficult by the secondary physiologic insult inherent in prolonged operations that traverse both sides of the diaphragm.

Pulmonary complications historically provide impetus for evolving surgical approaches to the esophagus. Minimally invasive techniques limit mechanical and physiologic stress. Despite potentially increased technical difficulty, laparoscopy and video-assisted thoracoscopic surgery result in decreased hospital stay, rapid recovery, and decreased perioperative morbidity.

Robotic master-slave devices are relatively new tools in the surgeon's armamentarium. With port size equivalent to those of other minimally invasive techniques, the theoretical advantages of the da Vinci system are based on the application of improved 3-dimensional visualization with 10-fold magnification. The surgical arms allow fine dissection and suturing with movements similar to those of human wrists, augmented with scaling ability and tremor elimination.

This article describes robotic approaches to benign esophageal pathologic conditions. Several benign esophageal disorders are best treated with surgical intervention. Examined in detail are the most common of these that are amenable to minimally invasive surgery with robotic assistance.

HISTORY AND GENERAL CONSIDERATIONS

The Development of Robotic Esophageal Surgery

Minimally invasive surgical techniques have been applied to essentially all aspects of general and thoracic surgery since their introduction in the 1980s. Success with other minimally invasive

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approaches has facilitated the application of robotic devices to esophageal procedures. These robotic-assisted esophageal operations are still in the early stages of development, and typically mirror the approaches that have been clinically successful for thoracoscopy and laparoscopy.

A clear timeline describing the evolution of robotic technology in gastrointestinal surgery is complicated by the differences in the release of devices in the United States and Europe. Although Himpens and colleagues[1] performed the first telesurgical laparoscopic cholecystectomy in 1997, the Food and Drug Administration of the United States did not approve a telesurgical device for use in general surgery until July 2000. Reports of robotic-assisted esophageal surgery began to surface shortly after the device was released for general use, and generally paralleled the techniques for performing the laparoscopic or thoracoscopic procedures.

Advantages and Disadvantages of Robotic Esophageal Surgery

Clinically proven advantages of robotic surgery are limited but, as with laparoscopy and thoracoscopy, will most likely be elucidated in patients with limited physiologic reserve and challenging anatomy.

Robotic surgery is most advantageous in a narrow interior field where the benefits of the wristed movements of the endoinstruments are maximized. As the operative target is located at a greater intracorporeal distance from the instrument port site, tremors that would normally increase are filtered by the computer system, and movements are scaled accordingly.

These mechanical advantages have notable potential in esophageal surgery whereby meticulous dissection and identification of proper tissue planes are of utmost importance. These tissue planes are already challenging to manipulate because of the characteristics of the esophageal fatty submucosa and mucosa. Difficulties increase as the population presenting for surgery becomes older, with an increased prevalence of previous instrumentation.

The lack of haptic feedback is a particularly important consideration when evaluating a patient for possible adhesions and access to the esophagus. Thoracoscopic and laparoscopic manipulation generally affords the operator some degree of tactile feedback so that if unexpected resistance is encountered outside the visual field, it can be quickly and appropriately addressed with repositioning of both the instruments and the camera. Although visual cues can mitigate some of the limitations of the robotic device in the operative field, there are no corresponding safeguards for the path of the arms as they travel between the body wall and the robotic visual field.

Whereas laparoscopy and thoracoscopy are plagued by a fulcrum effect at the distal limits of instrumentation, the dexterity of the robotic wristed movements is maintained throughout the dissection. These dexterous advantages only exist for the endowrists and not the external robotic joints. A large joint exists at a fixed angle to the device shaft immediately outside the body; robotic instruments are plagued not only by the same fulcrum limitations as are traditional minimally invasive instruments but also by external collisions of the machinery. As the hiatus is fixed, and the esophagus is a linear organ, robotic esophageal surgery is feasible in that the target anatomy can be placed in a line between the robot cart and the camera, thus minimizing collisions between instruments.

Operating-Room Setup

All members of the nursing team must be familiar with all aspects of the system, including video setup, movement of the robot itself, management of the console, and instrument draping. Indeed, robotic esophageal surgery is a careful, premeditated procedure that not only entails a preoperative workup but also institutional guidelines and staff training on every level.

The robotic cart weighs 550 kg and takes up a considerable amount of space in the operating theater. Room selection is important. The device must have a clear path to the required operative field, and the arms must be able to function without intracorporeal or extracorporeal restrictions. Unlike laparoscopy, whereby the angle of the operator can be easily changed, the robotic system is at a fixed angle in reference to the patient.

Diagnosis and Assessment

Each series of radiologic and endoscopic tests must be tailored for the patient and disease entity. Preoperative evaluations are based on clinical history and examination. The esophageal wall is not normally seen on plain films unless the lumen is distended with air. Demonstration of the azygoesophageal line and esophagopleural stripe may indicate wall thickening from conditions such as diffuse esophageal spasm or infiltration by tumor. Although chest radiography may help define pulmonary status, an evaluation before minimally invasive surgery requires adjunctive radiographic studies.