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A Review of Robotic Thoracic Surgery Adoption and Future Innovations 1

John F. Lazar and Ann E. Hwalek

The embracing of new technology and surgical innovation has been one of the hallmarks of cardiothoracic surgery. The adoption of video-assisted thoracoscopic surgery was the paradigm-changing perspective shift that has enabled an entire culture of minimally invasive cardiothoracic surgery. From this foundation robotically assisted thoracic surgery has developed into mainstream practice. The aim of this review is to recount the technological and academic milestones of the past as well as describe future technological innovations that will shape the future of thoracic robotic surgery.

Starting and Developing a Robotic Thoracic Surgery Program 11

Eliza D. Hompe, Paul W. Furlow, and Lana Y. Schumacher

Robotic-assisted surgery has been widely adopted in the field of thoracic surgery as a safe, minimally invasive approach with distinct technical advantages. With increased utilization, it has become an integral part of training pathways for the next generation of thoracic surgeons. This review article highlights key steps in implementing a robotic thoracic surgery program at an academic center based on institutional experience and the available surgical literature.

Management of Complications in Robotic Thoracic Surgery 19


Matthew D. Stanley and Manu S. Sancheti

The rapid adoption of robotic-assisted thoracic surgery has led to increased interest in the management of complications. Overall rates of complication during robotic-assisted thoracic surgery are low. Reported complications include pulmonary vascular injury; great vessel injury; thoracic duct injury; erroneous transection; tracheobronchial injury; and esophageal, diaphragmatic, and abdominal organ injury. A robotic thoracic surgeon should understand and have a management plan for any potential complication. When a complication occurs, the priority is to stabilize the patient. Then, after stabilization, an assessment of the situation will determine whether the procedure can be continued robotically or whether conversion to thoracotomy or sternotomy is required.

Resident Training in Robotic Thoracic Surgery 25

Brian Mitzman, Brigitte K. Smith, and Thomas K. Varghese Jr

The use of a robotic surgical platform has become common place in thoracic surgery programs throughout the United States. Formal training paradigms need to be reevaluated to allow for effective and efficient training of thoracic surgery residents and fellows. The utilization of video-based coaching and simulation are effective adjuncts in robotics training.

- Robotic Lobectomy** 33
Kelly Fairbairn, Jonathan Rice, and Stephanie G. Worrell
- Robotic lobectomy volume in the United States has increased dramatically in the past 10 years. Improved perioperative outcomes and increased public demand for minimally invasive techniques continue to drive its popularity. Preoperative workup is similar to VATs lobectomy and includes appropriate tumor staging, pulmonary function tests, and imaging. Severe intraoperative complications are rare but can be catastrophic; individualized response to each is required.
- Robotic Segmentectomy** 43
Robert E. Merritt
- Pulmonary segmentectomy is a parenchymal-sparing alternative approach to lobectomy for the surgical management of stage I NSCLC. Segmentectomy is an anatomical resection that requires meticulous dissection and exposure of the segmental pulmonary artery, vein, and bronchus. The open thoracotomy approach has been gradually replaced by video-assisted thoracoscopy (VATS) and robotic-assisted minimally invasive approaches for performing segmentectomy for surgical resection for early-stage lung cancer. There are 2 recent randomized studies that demonstrated that pulmonary segmentectomy is equivalent to lobectomy for the surgical management of NSCLC tumors 2 cm or smaller. This article will review robotic-assisted segmentectomy techniques that are performed for the surgical management of stage I nonsmall cell lung cancer.
- Complex Robotic Lung Resection** 51
Farshad Amirkhosravi and Min P. Kim
- Performing robotic thoracic lung resection is becoming an option for patients with complex thoracic disease. The robotic-assisted approach has similar survival with decreased postoperative pain, morbidity, and hospital length of stay compared with the open approach in pneumonectomy, bronchoplasty, and arterioplasty. Appropriate patient selection based on medical and surgical history combined with surgeon experience is imperative for an excellent outcome. This article will discuss the use of the robot in pneumonectomy, arterioplasty, and bronchoplasty to provide information about the technical approach and postoperative management.
- Robotic Surgery for Tracheobronchomalacia** 61
Kenneth P. Seastedt, Jennifer L. Wilson, and Sidhu P. Gangadharan
-  Video content accompanies this article at <http://www.thoracic.theclinics.com>.
- Robotic tracheobronchoplasty (TBP) is a new approach to tracheobronchomalacia (TBM), which has undergone various technical iterations since the 1950s. The robotic approach to TBM may allow for more patients to undergo TBP, and in retrospective series has demonstrated equivalent outcomes compared to open TBP if not superior in terms of postoperative complications. Long-term data are eagerly awaited, and we describe our approach in this article.
- Robotic First Rib Resection and Robotic Chest Wall Resection** 71
Matthew R.L. Egyud and Bryan M. Burt
- Robot-assisted thoracoscopic surgery for the treatment of thoracic outlet syndrome and chest wall lesions are burgeoning topics on thoracic surgery. Following publication of the Society of Vascular Surgeons expert statement in 2016, the diagnosis and management of thoracic outlet syndrome is favorably evolving. Robot-assisted first

rib resection is a novel approach to the surgical management of thoracic outlet syndrome that may have advantages compared with traditional open surgical approaches. Robot-assisted chest wall resection is technically feasible for a variety of chest wall conditions and may also have advantages compared with thoracotomy approaches.

Robotic Minimally Invasive Esophagectomy

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Brian M. Till, Tyler R. Grenda, Olugbenga T. Okusanya, and Nathaniel R. Evans III

Robotic minimally invasive esophagectomy can be safely performed by adhering to key technical principles. Careful development of the gastric conduit with attention to blood supply and conduit orientation is critical. During thoracic dissection, capnothorax can distort the proximity of key mediastinal structures. In particular, care must be taken to avoid damage to the left mainstem bronchus during subcarinal nodal dissection. Robotic approach allows for an oncologically sound procedure and early mobilization of patients postoperatively, thus optimizing short and long-term outcomes.

Robotic Mediastinal Surgery

89

Kenneth P. Seastedt, Ammara A. Watkins, Michael S. Kent, and Cameron T. Stock


 Video content accompanies this article at <http://www.thoracic.theclinics.com>.

The robotic platform can be viewed as an advanced thoracoscopic instrument and can be utilized for any pathology amenable to thoracoscopic surgery. This ultimately comes down to surgeon comfort, but many have demonstrated the robotic approach to be useful in benign and malignant mediastinal disease in all compartments with at least equivalent—if not superior—outcomes compared to sternotomy for many metrics. There are various robotic approaches to the same compartments (such as with thymectomy), and no one robotic approach has proven superior to another. Here we describe our robotic approach to common mediastinal pathology.

Diaphragm Plication: Evaluation and Technique

99

Nicholas D. Tingquist and Erin A. Gillaspie

 Video content accompanies this article at <http://www.thoracic.theclinics.com>.

Diaphragmatic paralysis is an elevation of the diaphragm caused by a lesion along the neuromuscular axis and may be either bilateral or unilateral. Most commonly, paralysis is unilateral and iatrogenic in nature. Symptoms of this disease may be life-limiting, and when conservative measures fail, surgical therapy may be of significant benefit to patients. With the advent of robotic minimally invasive techniques, diaphragm plication can be a useful therapy for patients with resolution of symptoms, reduced length of hospitalization, and quickened recovery. This article provides an overview of the disease, diagnosis, and current therapies including robotic techniques.

Robotic Bronchoscopy for the Diagnosis of Pulmonary Lesions

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Kaitlin C. McLoughlin and Matthew J. Bott

Pulmonary nodules (lesions <3 cm in size) are commonly identified on computed tomographic scans, but radiographic features alone are inadequate to reliably differentiate between benign and malignant etiologies. Therefore, tissue biopsy remains the standard approach to determine the appropriate treatment course for many patients with pulmonary nodules. Although percutaneous biopsy is highly accurate, it

poses substantial risks of procedural complications, including pneumothorax and bleeding. Robotic bronchoscopy has recently been developed to overcome many of the limitations of previous navigational platforms. Here, we explore the currently available systems for robotic bronchoscopy—in particular, electromagnetic-navigation robotic-assisted bronchoscopy and shape-sensing robotic-assisted bronchoscopy.