Anesthesia for Robotic Assisted Esophageal Surgery
Katherine Grichnik, MD
Department of Anesthesia and Critical Care Medicine
Duke University School of Medicine

OUTLINE
1. Introduction:
   a. History and Development
   b. Surgical Reports
   c. ROBOT Trial

2. Practical Considerations
   a. The da Vinci® Robot Surgical System
   b. Cost
   c. Surgical Complications

3. Anesthetic and Perioperative Care
   a. Preoperative Assessment and Analgesia
   b. Positioning
   c. Intraoperative Management
   d. Intraoperative Complications
   e. Postoperative Care

INTRODUCTION

History
Esophageal cancer has increased with the incidence of adenocarcinoma now greater than squamous cell carcinoma. With this, the treatment of esophageal carcinoma has become more effective with declining morbidity and mortality. Further the surgical approach has changed from open esophagectomy to minimally invasive esophagectomy to robotic assisted esophagectomy. Although laparoscopic surgery was first widely used in 1989 for cholecystectomy, it was first reported for esophageal disease use in 1991 and was used for Nissan fundoplication.

Traditionally esophageal cancer has been treated with open surgery via a transhiatal or transthoracic (Ivor Lewis) approach. Then these procedures were "hybridized" to a minimally invasive techniques, where parts of the procedure were performed laparoscopically/thoracoscopically while other parts were via standard incisions. The first esophagectomy performed completely via laparoscopy through a transhiatal approach was in 1995 by DePaula et and via an Ivor Lewis technique in 1999, Watson et al.

However, now there is an increasing trend to move from minimally invasive esophageal surgery to robotically assisted or a totally robotic esophageal surgical
approach.

Who is appropriate for a robotic esophageal surgery: Patients with Barrett’s disease with high grade dysplasia, patient with resectable esophageal cancer in an anatomically favorable location and with limited nodal involvement. This includes: NO, N1, with T1 (invasion of the lamina propria or submucosa), T2 (invasion of the muscularis propria), and some instances of T3 lesions (invasion of the adventitia) cancers. Neoadjuvant chemoradiation is not a contraindication. respectively. Exclusion Criteria include carcinoma of the cervical esophagus, carcinoma of the gastroesophageal junction (GEJ) with major tumor in the gastric cardia and prior thoracic surgery at the right hemithorax or prior thorax trauma.

Surgical Reports
There have been multiple single center and small number surgical reports about the use of robotically assisted esophageal surgery. One of the latest publications by Dunn in 2013 reports on a transhiatal approach robotic esophagectomy (RE) in 40 patients. The results included 12.5% conversion to open surgery rate, median operative time of 311 min, median estimated blood loss 97.2 mL, median intensive care unit stay was 1 day (range, 0-16), and a median length of hospital stay was 9 days (range, 6-36). The postoperative complications observed were anastomotic stricture (n= 27), recurrent laryngeal nerve paresis (n= 14), anastomotic leak (n= 10), pneumonia (n= 8), and pleural effusion (n= 18). The 30-day mortality was 2.5% (1/40). The median number of lymph nodes removed was 20 (range, 3-38) and R0 resection was achieved in 94.7% of patients. The median disease free survival was 20 months (range, 3-45) and the authors concluded that transhiatal RE, by experience, is a feasible albeit evolving oncologic operation with low hospital mortality. The primary outcomes that have been questioned are the completeness of the lymph node dissection and the completeness of the oncological resection. This awaits long term assessment of survival and cancer recurrence.

ROBOT Clinical Trial
Due to inconsistent and primarily case report series about robotic surgery – the first randomized trial is being done – called ROBOT: a Monocenter Randomized Controlled Trial: Robot Assisted Minimally Invasive Thoraco-laparoscopic Esophagectomy Versus Open Transthoracic Esophagectomy for Resectable Esophageal Cancer. The description from clinicaltrials.gov is as follows:

- A Monocenter Randomized Controlled Trial
- Designed to compare robot assisted minimally invasive thoraco-laparoscopic esophagectomy with open transthoracic esophagectomy as surgical treatment for resectable esophageal cancer.
- Goal is to evaluate whether robot assisted minimally invasive thoraco-laparoscopic esophagectomy will result in a lower percentage of postoperative complications, lower blood loss, shorter hospital stay, but with at least similar oncologic outcomes and better postoperative quality of life compared with the open transthoracic esophagectomy (current standard).
• Estimated Enrollment: 112; Study Start Date: January 2012; Estimated Study Completion Date: January 2020; Estimated Primary Completion Date: January 2015 (Final data collection date for primary outcome measure)

PRACTICAL CONSIDERATIONS

The da Vinci® Robot Surgical System
The da Vinci Robot System was granted approval by the US FDA in 2000 and has since been used for a wide variety of surgical procedures. It consists of three parts: the Console, The Patient Side Cart and the Vision System. There are also multiple specialized instruments and positioning requirements for use of a robot for esophageal procedures. From a technical point of view and relative to minimally invasive surgery, the robot system allows increased magnification with 3D imaging, improved dexterity and articulation relative to the fixed minimally invasive surgery instruments, and seven degrees of motion: 1) in/out, 2) rotation, 3) pitch at wrist, 4) yaw at wrist, 5) pitch at fulcrum, 6) yaw at fulcrum, 7) grip strength. It also has improved motion stability and tremor filtration and motion scaling.

Types of surgery that can be approached robotically:
• Nissan fundoplication
• Esophageal dissection and evaluation
• Esophagectomy
  o Combined thoracic and abdominal approach vs. complete thoracoscopic approach
  o Transhiatal approach

Potential advantages to the Robot
• Da Vinci® robot can provide an extensive resection, with possibly better or at least equal radical (R0) resection rates and an equal number of dissected lymph nodes
• Reduced blood loss
• Reduced overall complications
• Shorter ICU and LOS

Potential disadvantages to the Robot
• Steep surgeon learning curve
  o Knowledge, Skills, Real Patient Experience, Operating time, Basic outcomes, Real outcomes, Proficiency
• Long set up time and specialized team training
• Limited instrumentation
• Surgeon separated from the field; trained assistant must be at the field
• Lack of tactile sensation
• Difficult to teach others while doing a robotic procedure
• Need for two surgeons – one for to do the robotic surgery and one to be sterile and stand at the operative site to immediately deal with any surgical misadventures.

Cost (from Reference 1)
The cost of a robotic system cannot be ignored. A comparison by Bolenz et al. about prostatectomies found that
• Direct cost was highest for Robotic procedure.
• Surgical supply costs were $1,830 higher.
• OR time costs were $1,187 higher.
• Robotic cases made up $495 on earlier discharge.
• Robotic Assisted surgery cost $2,315 (52%) more per case.

<table>
<thead>
<tr>
<th>Variables</th>
<th>RALP</th>
<th>LRP</th>
<th>RRP</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct cost, median (IQR)</td>
<td>6752 (6283-7368)</td>
<td>5687 (4941-5905)</td>
<td>4417 (3989-5141)</td>
<td>$0.0001</td>
</tr>
<tr>
<td>Surgical supply cost (fixed)</td>
<td>2015</td>
<td>725</td>
<td>185</td>
<td>-</td>
</tr>
<tr>
<td>Operating room cost, median (IQR)</td>
<td>2798 (2493-3175)</td>
<td>2453 (2130-2738)</td>
<td>1611 (1461-1955)</td>
<td>$0.0001</td>
</tr>
<tr>
<td>Anesthesia cost, median (IQR)</td>
<td>419 (378-464)</td>
<td>365 (297-411)</td>
<td>234 (189-297)</td>
<td>$0.0001</td>
</tr>
<tr>
<td>Medication cost, median (IQR)</td>
<td>297 (267-353)</td>
<td>271 (213-332)</td>
<td>272 (231-311)</td>
<td>0.0008</td>
</tr>
<tr>
<td>Lab cost, median (IQR)</td>
<td>299 (246-350)</td>
<td>386 (321-558)</td>
<td>609 (435-860)</td>
<td>$0.0001</td>
</tr>
<tr>
<td>Room and board cost</td>
<td>465 (405-900)</td>
<td>990 (405-990)</td>
<td>990 (990-1485)</td>
<td>-</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>778 (758)</td>
<td>873 (409)</td>
<td>1242 (678)</td>
<td>-</td>
</tr>
</tbody>
</table>

LRP = laparoscopic radical prostatectomy; RALP = robotic-assisted laparoscopic radical prostatectomy; RRP = retropubic radical

However additional considerations include the Jan. 2012 cost of da Vinci Si Firefly robot at $2,185,000, annual maintenance contract $150,000, resulting in additional fees of $3,667 per case which increased the total direct cost $10,419 vs. $4,437. It is not clear that reimbursement for robotic procedures closes this gap of cost.

Surgical Complications
Multiple surgical complications can occur including those that occur with open and minimally invasive esophageal surgery. Important reported complications to be aware of include:

• Position and length of surgery injuries
  o Corneal abrasions
  o Nerve injuries
  o Crush injuries
• Pneumoperitoneum
  o Hemodynamic instability
  o Pulmonary emboli
  o Subcutaneous emphysema
• Conversion to open and need for reoperation
• Prolonged intubation

Br J Urol Intnl; 2011, 109, 1222-1227
• Nearby organ injury
• Fire
• Robot equipment failure
  o Instrument failures
  o Arcing
  o Fragmentation
  o Patient side cart malfunctions
  o Console malfunction
  o Endoscope malfunction

ANESTHESIA and PERIOPERATIVE CARE
A growing literature is evolving regarding the care for patient undergoing all types of robotic surgery although there are limited reports about specific anesthetic implications for robotic esophageal surgery. Below is a compilation of key points.

Preoperative Assessment and Analgesia
A routine preoperative assessment should be done as one would for an open esophageal surgery as there is always the risk of conversion to an open procedure. This includes assessment of the aspiration risk, nutritional status, and routine lab work among all of the variables. One should be sure that patients are not taking any long acting antiplatelet drugs that could lead to bleeding in small spaces that is not readily identified. It is also important to evaluate the patient risk factors for tolerating a prolonged pneumoperitoneum and altered positions (lateral, prone, supine) – including severe COPD, significant cardiovascular disease, renal failure and overall body habitus. The extremes of age may represent a risk factor for prolonged intubation. Perhaps more specific to the surgery is an assessment of prior surgical procedures, radiation therapy and any other injury that could result in surgical adhesions as well as a difficult surgical dissection and exposure. The analgesic needs for this surgical population remain to be well defined. At this time it is not clear that thoracic epidural analgesia is indicated, unless there is a high likelihood of conversion to an open procedure.

Positioning
Positioning considerations for this procedure are significant. Not only will various positions be used – ranging from supine to lateral to extreme lateral to prone, but once a position is achieved and the robot has been put into place, table and position changes cannot occur without withdrawal of all of the robotic instruments and the console. Further, crush, facial and nerve injuries are an ever-present danger.

Intraoperative Management
Plan for a rapid sequence induction to avoid aspiration. A
dual lumen endotracheal tube or bronchial blocker is indicated to deflate the lung for surgical exposure. One must assure proper placement with fiberoptic bronchoscopy. The tenants of OLV ventilation management must be adhered to – including lung protective ventilation with low tidal volumes, higher respiratory rates and PEEP. One must also be aware of the likelihood of increased arterial carbon dioxide with the development of acidosis if CO2 insufflation is used for any portion of the procedure. The ventilator settings will have to be adjusted accordingly.

Choice of monitors is up to the individual anesthesiologist and as dictated by individual patient co-morbidities. However one should consider that the patient will be remote and potentially in an awkward position, which could limit access in an emergent situation. Further, especially with an inexperienced surgeon, the duration of surgery may be lengthy. Thus one should consider the use of invasive monitors such as an arterial line and a central line (on the opposite side of the cervical anastomosis or on the same side as a thoracic dissection. Excellent IV access should be assured after all position changes.

**Intraoperative Complications**
If pneumoperitoneum is used for an abdominal dissection, one can expect potential hemodynamic consequences including increases in MAP, and SVR with decreases in mesenteric, hepatic and renal blood flow. If the abdominal pressure is allow to increase too high, then the MAP will fall with decreased venous return.

One lung ventilation in positions other than true lateral can also be problematic with altered V/Q relationships and the significant potential for hypoxia. Thus patient with severe emphysema must be carefully evaluated.

Please see the section above for surgical complications. The risk of nearby organ or vascular injury is also ever present and would lead to the need for immediate conversion to an open surgical procedure.

**Postoperative Care**
It is the goal of all robotic procedure to extubate at the end of the procedure if not complications or contraindications have arisen. The role of ICU care is dictated by the intraoperative occurrences, the patient co-morbidity and institutional preference. A priori, with a straightforward and uncomplicated surgery there is no contraindication for transfer to a well-monitored ward bed (after appropriate postop care in a PACU/ICU) after a robotic esophageal procedure.

**SUMMARY**
This is a new and evolving area of surgical practice, which means that the best practices in perioperative anesthetic care remain to be defined. We can use our knowledge of other robotic surgical procedures, our knowledge of how to care for patients undergoing minimally invasive thoracic procedures and our knowledge
about the care of esophageal cancer patients to craft an anesthetic plan to ideally
care for these complex patients.

REFERENCES and SELECTED ARTICLES OF INTEREST
1. www.continuinged.ku.edu_kumc_anesthesiology_presentations_1045am_Dr_Mensch_Anesthesia_Implications . ANESTHETIC CONSIDERATIONS FOR ROBOTIC ASSISTED SURGERY, Jason T. Mensch, Assistant Professor, Department of Anesthesiology, University of Kansas
3. emedicine.medscape.com/article/1965556
4. ANESTHETIC CONSIDERATIONS FOR ROBOTIC ASSISTED SURGERY, Jason T. Mensch, Assistant Professor, Department of Anesthesiology, University of Kansas
8. British Journal of Urology International; 2011, 109, 1222-1227