The Learning Curve for Minimally Invasive Esophagectomy

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Esophageal Cancer

- Increasing in incidence faster than other solid tumors in U.S.
- Epidemiology: distal adenocarcinoma rather than mid squamous cell carcinomas
- Relationship to GERD
Esophageal Cancer

- 22% confined to the esophagus
- 30% spread to regional lymph nodes
- Surgery as first line therapy – T1N0, T2N0
- Induction therapy then surgery
  - T3 or T4
  - nodal involvement
  - Local invasion of potentially resectable structures – i.e. pericardium, pleura, diaphragm
- Unresectable – distant disease, treated with chemotherapy, radiation or palliative care
**TNM - esophageal cancer**

**Table: Stage definitions for esophageal cancer (both squamous cell and adenocarcinoma)**

<table>
<thead>
<tr>
<th>Primary tumor (T)*</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>TX</td>
<td>Primary tumor cannot be assessed</td>
</tr>
<tr>
<td>T0</td>
<td>No evidence of primary tumor</td>
</tr>
<tr>
<td>Tis</td>
<td>High-grade dysplasia*</td>
</tr>
<tr>
<td>T1</td>
<td>Tumor invades lamina propria, muscularis mucosae, or submucosa</td>
</tr>
<tr>
<td>T1a</td>
<td>Tumor invades lamina propria or muscularis mucosa</td>
</tr>
<tr>
<td>T1b</td>
<td>Tumor invades submucosa</td>
</tr>
<tr>
<td>T2</td>
<td>Tumor invades muscularis propria</td>
</tr>
<tr>
<td>T3</td>
<td>Tumor invades adventitia</td>
</tr>
<tr>
<td>T4</td>
<td>Tumor invades adjacent structures</td>
</tr>
<tr>
<td>T4a</td>
<td>Resectable tumor invading pleura, pericardium, or diaphragm</td>
</tr>
<tr>
<td>T4b</td>
<td>Unresectable tumor invading other adjacent structures, such as aorta, vertebral body, trachea, etc.</td>
</tr>
</tbody>
</table>

*Note: cTNM is the clinical classification, pTNM is the pathologic classification.

* At least maximal dimension of the tumor must be recorded and multiple tumors require the T(m) suffix.
* High-grade dysplasia includes all noninvasive neoplastic epithelia that was formerly called carcinoma in situ, a diagnosis that is no longer used for columnar mucosa anywhere in the gastrointestinal tract.

Used with the permission of the American Joint Committee on Cancer (AJCC), Chicago, Illinois. The original source for this material is the AJCC Cancer Staging Manual, Seventh Edition (2010) published by Springer New York, Inc.
Endoscopic ultrasound (EUS) of normal esophagus

EUS examination of the normal esophagus showing the typical five-layer pattern: first hyperechoic layer (interface between lumen and mucosa), second hypoechoic layer (deep mucosa including muscularis mucosa), third hyperechoic layer (submucosa), fourth hypoechoic layer (muscularis propria), and fifth hyperechoic layer (adventitia interface).

Courtesy of Enriqueta Vazquez-Sequeiros, MD and Maurits J Wiersema, MD.

Surgery for Esophageal Cancer

- Remains best treatment for early stage disease
- Combination therapy may add curative benefit particularly for locally advanced tumors
- Mortality and morbidity is significant
- Best results in high volume centers with experienced board certified surgeons
Surgical Options

- Transhiatal
- Ivor Lewis – abdomen and right chest
- Left Thoraco-abdominal
- Modified McKeown – right chest, abdomen and left neck
- Minimally Invasive – all forms of the above
- Robotic
- No Lymphadenectomy vs 2-field vs 3-field
Benefits of MIE

- Less morbidity and mortality
- Shorter length of stay
- Quicker recovery
- Improvement in QOL
- Better cosmesis
- Increased pool of operable patients due to the above

Biere et al. MIE vs open esophagectomy for patients with oesophageal cancer: a multicentre, open-label, randomised controlled trial. Lancet 2012
Mass et al. Quality of life and late complications after minimally invasive compared with open esophagectomy: results of a randomized trial. World J. Surg. 2015
Cost of MIE

- Technically more challenging than open
- Necessary equipment
- Must learn how to do it
MIE – Ivor Lewis abdominal component

- 6 ports, 4 12-mm and 2 5-mm, dissection done with ultrasonic shears
  - Exploration
  - Mobilize short gastric vessels
  - Mobilize esophagus at hiatus
  - Divide omentum from stomach several centimeters away from right GEA
  - Divide posterior attachments and internal kocher-type mobilization
  - Divide left gastric vessels with endostapler
  - Lymph node dissection
  - J tube
  - Create 4 cm wide gastric conduit from lesser curve crow’s feet to greater curve just distal to gastric fad pad and suture to proximal stomach
  - Close hiatus posteriorly with one endosuture
MIE abd greater curve video
MIE abd conduit creation video
MIE- Ivor Lewis- chest component

- 5 ports- 3 12-mm, 2 5-mm, CO2-8 mm Hg, ultrasonic shear dissection
  - Exploration
  - Start at level of inferior pulmonary vein and circumferentially mobilize the esophagus
  - Mobilize along anterior border (with lung) up to azygous vein
  - Divide azygous vein and continue anterior dissection to mid trachea (24-25cm from incisors)
  - Dissect posteriorly between esophagus and aorta from level of inferior vein up to mid trachea. Care to avoid thoracic duct or left mainstem bronchus injury
  - Care around carina, can take lymph nodes en-bloc or separately as long as they are completely removed, remove paratracheal lymph nodes
  - Mobilize distally from inferior vein to establish continuity with abdominal dissection
  - Bring conduit into chest, attention to orientation
  - Divide esophagus sharply at appropriate level (usually mid-trachea), check margins
  - Create EEA anastomosis, usually 28 mm, sew anvil into prox esophagus with 2 endosutures, open tip of conduit and place stapler with shaft exiting posteriorly about 5 cm from tip, complete anastomosis and inspect/perform endoscopy
  - Suture conduit to hiatus
MIE chest dissection and anastomosis video
BWH results – single surgeon

- 170 cases of MIE Ivor-Lewis, 2009-2016
- 221 total esophagectomies during interval (15 open and 36 MIE-3 hole), group total >800
- 143 (84%) had induction chemo/xrt, BMI 28
- 30 day mortality-0.6%, 90-day mortality- 3.9% without significant change over the time period
- 5 yr survival = 50.9%
- Operative time: 350 min (218 – 597 min): 387.5 min to 345 min from 1st quartile to fourth quartile
- Lymph nodes 19: 18 to 22, 1st to 4th quartile
- Leak rate: 7%, 11.6% to 0%, 1st to 4th quartile
- LOS: 8d, 10d to 8d, 1st to 4th quartile
- 90-day readmission: 26%, 39.5% to 16.7%, 1st-4th quartile
Learning curve and associated morbidity of minimally invasive esophagectomy. Workum et al. Ann Surg 2017

### TABLE 3. Analysis of Outcome Parameters in Quintiles (Q)

<table>
<thead>
<tr>
<th>Outcome Parameter</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median operative time, mins</td>
<td>Hospital 1: 438 mins</td>
<td>Hospital 2: 420 mins</td>
<td>Hospital 3: 435 mins</td>
<td>Hospital 4: 441 mins</td>
<td>Hospital 5: 376.5 mins</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Hospital 1: 303 mins</td>
<td>Hospital 2: 270 mins</td>
<td>Hospital 3: 278 mins</td>
<td>Hospital 4: 213 mins</td>
<td>Hospital 5: 192 mins</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Hospital 1: 275 mins</td>
<td>Hospital 2: 229.5 mins</td>
<td>Hospital 3: 219 mins</td>
<td>Hospital 4: 239.5 mins</td>
<td>Hospital 5: 240 mins</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>Hospital 1: 469 mins</td>
<td>Hospital 2: 390 mins</td>
<td>Hospital 3: 370 mins</td>
<td>Hospital 4: 371.5 mins</td>
<td>Hospital 5: 428.5 mins</td>
<td>0.010</td>
</tr>
<tr>
<td>Anastomotic leakage, N (%)</td>
<td>Hospital 1: 12 (33.3%)</td>
<td>Hospital 2: 3 (8.1%)</td>
<td>Hospital 3: 2 (5.6%)</td>
<td>Hospital 4: 1 (2.7%)</td>
<td>Hospital 5: 1 (2.8%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Hospital 2: 6 (15.8%)</td>
<td>Hospital 2: 14 (37.8%)</td>
<td>Hospital 3: 2 (5.3%)</td>
<td>Hospital 4: 1 (2.7%)</td>
<td>Hospital 5: 2 (5.3%)</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>Hospital 3: 8 (21.6%)</td>
<td>Hospital 2: 7 (18.4%)</td>
<td>Hospital 3: 9 (24.3%)</td>
<td>Hospital 4: 7 (18.4%)</td>
<td>Hospital 5: 1 (2.7%)</td>
<td>0.055</td>
</tr>
<tr>
<td></td>
<td>Hospital 4: 3 (16.7%)</td>
<td>Hospital 2: 4 (22.2%)</td>
<td>Hospital 3: 3 (11.8%)</td>
<td>Hospital 4: 3 (16.7%)</td>
<td>Hospital 5: 5 (27.8%)</td>
<td>0.572</td>
</tr>
<tr>
<td>Anastomotic leakage grade 2–3, N (%)</td>
<td>Hospital 1: 12 (33.3%)</td>
<td>Hospital 2: 3 (8.1%)</td>
<td>Hospital 3: 2 (5.6%)</td>
<td>Hospital 4: 1 (2.7%)</td>
<td>Hospital 5: 1 (2.8%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Hospital 2: 5 (13.2%)</td>
<td>Hospital 2: 13 (35.1%)</td>
<td>Hospital 3: 2 (5.3%)</td>
<td>Hospital 4: 1 (2.7%)</td>
<td>Hospital 5: 1 (2.6%)</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Hospital 3: 8 (21.6%)</td>
<td>Hospital 2: 7 (18.4%)</td>
<td>Hospital 3: 9 (24.3%)</td>
<td>Hospital 4: 7 (18.4%)</td>
<td>Hospital 5: 1 (2.7%)</td>
<td>0.055</td>
</tr>
<tr>
<td></td>
<td>Hospital 4: 3 (16.7%)</td>
<td>Hospital 2: 2 (11.1%)</td>
<td>Hospital 3: 1 (5.9%)</td>
<td>Hospital 4: 2 (11.1%)</td>
<td>Hospital 5: 5 (27.8%)</td>
<td>0.401</td>
</tr>
<tr>
<td>Textbook outcome, N (%)</td>
<td>Hospital 1: 13 (36.1%)</td>
<td>Hospital 2: 22 (59.5%)</td>
<td>Hospital 3: 18 (50.0%)</td>
<td>Hospital 4: 19 (51.4%)</td>
<td>Hospital 5: 16 (44.4%)</td>
<td>0.753</td>
</tr>
<tr>
<td></td>
<td>Hospital 2: 12 (31.6%)</td>
<td>Hospital 2: 11 (29.7%)</td>
<td>Hospital 3: 19 (50.0%)</td>
<td>Hospital 4: 24 (64.9%)</td>
<td>Hospital 5: 18 (47.4%)</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>Hospital 3: 16 (43.2%)</td>
<td>Hospital 2: 17 (44.7%)</td>
<td>Hospital 3: 13 (35.1%)</td>
<td>Hospital 4: 21 (55.3%)</td>
<td>Hospital 5: 19 (51.4%)</td>
<td>0.299</td>
</tr>
<tr>
<td></td>
<td>Hospital 4: 10 (55.6%)</td>
<td>Hospital 2: 7 (38.9%)</td>
<td>Hospital 3: 12 (70.6%)</td>
<td>Hospital 4: 8 (44.4%)</td>
<td>Hospital 5: 13 (72.2%)</td>
<td>0.296</td>
</tr>
<tr>
<td>90-day mortality, N (%)</td>
<td>Hospital 1: 1 (2.8%)</td>
<td>Hospital 2: 0 (0%)</td>
<td>Hospital 3: 1 (2.8%)</td>
<td>Hospital 4: 1 (3.4%)</td>
<td>Hospital 5: 0 (0%)</td>
<td>0.315</td>
</tr>
<tr>
<td></td>
<td>Hospital 2: 2 (5.3%)</td>
<td>Hospital 2: 2 (5.4%)</td>
<td>Hospital 3: 1 (2.6%)</td>
<td>Hospital 4: 0 (0%)</td>
<td>Hospital 5: 1 (2.6%)</td>
<td>0.243</td>
</tr>
<tr>
<td></td>
<td>Hospital 3: 0 (0%)</td>
<td>Hospital 2: 0 (0%)</td>
<td>Hospital 3: 2 (5.4%)</td>
<td>Hospital 4: 1 (2.6%)</td>
<td>Hospital 5: 1 (2.7%)</td>
<td>0.284</td>
</tr>
<tr>
<td></td>
<td>Hospital 4: 0 (0%)</td>
<td>Hospital 2: 0 (0%)</td>
<td>Hospital 3: 0 (0%)</td>
<td>Hospital 4: 1 (5.6%)</td>
<td>Hospital 5: 1 (5.6%)</td>
<td>0.134</td>
</tr>
</tbody>
</table>
Change in leak over time

Figure 2. Pooled incidences of AL and predicted leakage based on casemix. Interpretation: although there was no significant trend in predicted AL based on casemix factors, the observed incidence of AL decreased significantly as experience increased. The decrease in the incidence of observed AL is therefore not explained by casemix factors. AL indicates anastomotic leakage.

Learning curve and associated morbidity of minimally invasive esophagectomy. Workum et al. Ann Surg 2017
Textbook outcome

- Radical R0 resection
- No perioperative complications (≥grade 3)
- 15 or more lymph nodes removed
- No re-interventions or re-operations
- No ICU readmission
- No hospital LOS > 21 days
- No hospital readmissions within 30 days
- No in-hospital or 30 day mortality

Learning curve and associated morbidity of minimally invasive esophagectomy. Workum et al. Ann Surg 2017
Change in achieving textbook outcome over time

FIGURE 3. Pooled incidence of TBO and predicted textbook outcome based on casemix. Interpretation: although there was no significant trend in the predicted TBO based on casemix factors, the observed incidence of TBO increased significantly as experience increased. The increase in the incidence of observed TBO is therefore not explained by casemix factors. TBO indicates textbook outcome.
Operative time

FIGURE 4. Pooled OT and pooled predicted operative time based on casemix. Interpretation: although there was no significant trend in predicted OT based on casemix factors, the observed incidence of OT decreased significantly as experience increased. The decrease in the incidence of observed OT is therefore not explained by casemix factors. OT indicates operative time.

Learning curve and associated morbidity of minimally invasive esophagectomy. Workum et al. Ann Surg 2017
Summary – learning curve at 4 hospitals

• In terms of anastomotic leakage, 119 cases required to achieve maximal results
• 36 cases were deemed excess leak morbidity due to learning curve
• Must case-mix adjust to determine true curve since surgeons tend to take on more difficult cases as the confidence grows

Learning curve and associated morbidity of minimally invasive esophagectomy. Workum et al. Ann Surg 2017
Implementation of MIE in a tertiary referral center for esophageal cancer.

Nilsson et al. J Thor Dis. 2017

Figure 3: Anastomotic leakage rate over time.
Change in outcome with experience

Figure 4 Trends of blood loss, operation time, number of harvested lymph nodes and hospital stay over time.

Summary – MIE learning curve

• MIE – Ivor-Lewis is an excellent approach to esophagectomy for most esophageal cancer

• With experience the leak rate and other outcomes are excellent

• Number of cases to achieve this is not clear, perhaps 50-100 to plateau depending on experience of surgeon at start of journey

• With these excellent outcomes, your practice of esophagectomy will increase