Minimally invasive oesophagectomy more expensive than open despite shorter length of stay†

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Abstract

OBJECTIVES: The minimally invasive oesophagectomy (MIO) approach offers a number of advantages over open approaches including reduced discomfort, shorter length of stay and a faster recovery to baseline status. On the other hand, minimally invasive procedures typically are longer and consume greater disposable instrumentation, potentially resulting in a greater overall cost. The objective of this study was to compare costs associated with various oesophagectomy approaches for oesophageal cancer.

METHODS: An institutional Resource Information Management System (RIMS) was queried for cost data relating to hospital expenditures (as opposed to billings or collections). The RIMS was searched for patients undergoing oesophagectomy for oesophageal cancer between 2003 and 2012 via minimally invasive, open transthoracic (OTT) (including Ivor Lewis, modified McKeown or thoracoabdominal) or transhiatal approaches. Patients that were converted from minimally invasive to open, or involved hybrid procedures, were excluded.

RESULTS: A total of 160 oesophagectomies were identified, including 61 minimally invasive, 35 open transthoracic and 64 transhiatal. Costs on the day of surgery averaged higher in the MIO group ($12,476 ± 2,190) compared with the open groups, OTT ($8,202 ± 2,512, P < 0.0001) or OTH ($5,809 ± 2,575, P < 0.0001). The median costs associated with the entire hospitalization also appear to be higher in the MIO group ($25,935) compared with OTT ($24,440) and OTH ($15,248). The average length of stay was lowest in the MIO group (11 ± 9 days) compared with OTT (19 ± 18 days, P = 0.006) and OTH (18 ± 28 days, P = 0.07). The operative mortality was similar in the three groups (MIO = 3%, OTT = 9% and OTH = 3%).

CONCLUSIONS: The operating theatre costs associated with minimally invasive oesophagectomy are significantly higher than OTT or OTH approaches. Unfortunately, a shorter hospital stay after MIO does not consistently offset higher surgical expense, as total hospital costs trend higher in the MIO patients. In an increasingly strained health care economy, efforts to reduce costs associated with the minimally invasive approach should address the inpatient hospitalization as well as operating theatre expenses.

Keywords: Oesophageal surgery • Operations • Oesophageal cancer • Cost analysis

INTRODUCTION

Oesophagectomy for oesophageal cancer is a complex and morbid procedure approached through a variety of incisions involving the neck, chest and abdomen. While the optimal approach is the subject of much debate, surgeons have generally chosen between procedures associated with lower morbidity (transhiatal), and those capable of more extensive removal of perioesophageal tissues and lymph nodes (transsthoracic) [1–3].

The MIO has become increasingly adopted as an alternative to the traditional approaches, offering the possibility of transsthoracic mobilization with morbidity profiles more in line with the transhiatal approach [4–6]. Previous studies have shown MIO patients to experience less blood loss, fewer blood transfusions and a shorter hospital stay than patients undergoing open procedures [7–9]. Early reports of the oncologic efficacy appear encouraging, suggesting that the MIO may ultimately become the dominant resection approach for oesophageal cancer [5, 6, 8–10].

Unfortunately, the MIO requires a specific minimally invasive skill set, the use of specialized instrumentation, and a number of disposable components, all of which may affect the total cost of the procedure [6, 11, 12]. The overall impact of the MIO approach on the cost of surgically managed oesophageal cancer is unclear, as day of surgery costs may be offset by savings through MIO’s expedited recovery. Therefore, we attempted to characterize operative and hospitalization costs during MIO and open approaches to oesophagectomy for oesophageal cancer to
better understand the financial implications of the less invasive approach.

MATERIALS AND METHODS

Patients

A retrospective review of patients undergoing oesophagectomy at Yale-New Haven Hospital between 2003 and 2012 was performed in accordance with an Institutional Review Board-approved protocol. Eligible patients included those that had undergone oesophagectomy for oesophageal cancer by way of minimally invasive (with an intrathoracic or cervical anastomosis), open transsthoracic (OTT) (including Ivor Lewis, modified McKeown or thoracoabdominal) or transhiatal approaches. One patient who was converted from MIO to transhiatal because of adhesions between the right gastroepiploic arcade and the transverse mesocolon was included in the MIO cohort.

Planned hybrid procedures (those that included a planned portion that was performed minimally invasively, and a planned portion that was performed by traditional approach including a laparotomy or thoracotomy, n = 2) were excluded. Only patients with complete procedural and pathologic data were included in this study.

Cost data

The hospital’s financial management database (Resource Information Management System (RIMS), Eclipsys Corporation, Atlanta, GA, USA) was queried for case-level cost data and details of hospitalization. Cost data are subcategorized into specific departmental groupings (Cardiac, Clinics/Outpatient, Emergency Department, intensive care unit (ICU), Lab, M&S Supply, Nursing Units, operating room (OR), Pharmacy, physical therapy/occupational therapy/respiratory therapy, Radiation, Yale Lab electrophysiology diagnostic imaging) and is comprised of direct costs. Direct costs refer to the labour and supplies/materials directly related to the care of the patient, and do not reflect negotiated contracts by insurance carriers (unlike ‘hospital charges’ which can vary significantly by payer mix). Direct costs are also more directly influenced by the process of care than indirect costs, which are often spread evenly across departments, services and patient populations.

Surgical procedures

Minimally invasive approach to oesophagectomy. In this study, all MIOs were performed by a single surgeon (Daniel J. Boffa). The MIO was characterized by a thoracoscopic mobilization and a laparoscopic gastric mobilization, with either a cervical (MIO modified McKeown) or thoracic (MIO Ivor Lewis) anastomosis. The procedures included a pyloroplasty and a feeding jejunostomy.

Open. General surgical oncologists or board-certified thoracic surgeons performed all open transhiatal (OTH) procedures in this study. The OTH procedures were performed only by board-certified thoracic surgeons (Daniel J. Boffa did 14 of these cases). These OTH procedures included the Ivor Lewis, modified McKeown and thoracoabdominal approaches. All hybrid or converted cases that combined minimally invasive and open approaches were excluded to ensure a direct comparison between the techniques.

Statistics

The comparative analyses were performed using Statview or the Statistical Analysis System version 9.2 (SAS Corporation, Cary, NC, USA). To analyse the clinicopathological and lifestyle covariates, means and standard deviations were computed for the continuous covariates, and frequency distributions were computed for nominal covariates. For bivariate comparisons with surgical procedure, analysis of variance was used for continuous data, while χ² was used for nominal data.

Significant differences in hospital costs were detected via the independent Student t-test. A two-sided statistical test was computed, with a value of P < 0.05 considered statistically significant.

The complete MIO experience (cases that were successfully completed by MIO, n = 60) was also evaluated in terciles (20 sequential cases in each) and compared to understand how costs may have changed over time and the impact of a learning curve in this experience. While the ‘intention to treat principle’ was invoked to include the converted case as an MIO for the overall cost analysis, for the MIO-specific learning curve analyses (operative time, cost) only complete MIOs were considered (the converted case was excluded) because the converted case was an outlier (total cost $72,617).

RESULTS

Patient demographics

This study identified 160 patients that had undergone oesophagectomy for oesophageal cancer between 2003 and 2012, including 61 MIO, 35 OTT and 64 OTH patients (1 patient converted from MIO to transhiatal esophagectomy (THE) was coded as MIO). The demographics and baseline characteristics of the three groups are listed in Table 1. While the gender distribution, average BMI and average age among all three groups were similar, fewer patients had a smoking history in the OTH (65%) cohort than the OTT (83%) and MIO (85%) cohorts. The majority of patients were Stage III (41%), and most patients were treated with neoadjuvant therapy (80%) prior to surgery.

Surgical procedures

The distribution of surgical approaches is given in Table 2. The OTH approach was used in the majority (66%) of the open oesophagectomies. Surgeons performed various OTT procedures, including left thoracoabdominal (54%), modified McKeown (29%) and Ivor Lewis (17%) oesophagectomies. During the study time period, the Yale Esophageal Cancer Program adopted and transitioned towards the MIO approach, as illustrated by (Fig. 1).

Operative time

Operative time was calculated for the various approaches. The minimally invasive approach appeared to require longer operative times (MIO = 8.5 h) than open approaches (OTT = 7.8 h and OTH = 5.4 h). As this series contains our initial experience with MIO, we surveyed for a learning curve by dividing the sequential experience (complete MIOs, n = 60) into three subgroups of 20. The operative times for MIO did shorten substantially with increasing experience (Fig. 2).
Postoperative findings

The complication rate was defined as the number of patients experiencing a complication in each cohort. Patients in the MIO cohort had a lower incidence of complications (34%) than patients in the OTT (40%) and OTH (44%) cohorts. The operative mortality rate, defined as death within 30 days of surgery or during same hospitalization, was similar in MIO (3.3%), OTT (8.6%) and OTH (3.1%) cohorts. The median length of stay in the MIO cohort (8 days) was shorter than the length of stay (LOS) in both the OTT (11 days) and OTH (9 days) cohorts.

Costs

The costs associated with the various oesophagectomy techniques at Yale-New Haven Hospital are given in Table 3. The median costs associated with the entire hospitalization appear to be higher in the MIO group ($25,935) compared with OTT ($24,440) and OTH ($15,248) groups.

Total hospital costs were broken down into specific components (day of surgery OR cost, ICU cost and nursing unit costs). The median day of surgery cost was highest in MIO patients ($12,240) in

Table 1: Baseline characteristics

<table>
<thead>
<tr>
<th></th>
<th>MIO</th>
<th>OTT</th>
<th>OTH</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cases</td>
<td>61</td>
<td>35</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>Male (%)</td>
<td>75</td>
<td>91</td>
<td>83</td>
<td>0.14</td>
</tr>
<tr>
<td>Body mass index (mean ± SD)</td>
<td>28 ± 5.6</td>
<td>27 ± 5.2</td>
<td>28 ± 4.7</td>
<td>0.80</td>
</tr>
<tr>
<td>Age at surgery (mean ± SD)</td>
<td>63 ± 10.6</td>
<td>63 ± 10.4</td>
<td>62 ± 10.5</td>
<td>0.96</td>
</tr>
<tr>
<td>History of smoking (%)</td>
<td>85</td>
<td>83</td>
<td>65</td>
<td>0.001</td>
</tr>
<tr>
<td>Clinical stage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>6 (9.8%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>I</td>
<td>9 (15%)</td>
<td>5 (15%)</td>
<td>7 (16%)</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>15 (25%)</td>
<td>7 (21%)</td>
<td>19 (42%)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>31 (51%)</td>
<td>18 (33%)</td>
<td>17 (38%)</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>0 (0.0%)</td>
<td>4 (12%)</td>
<td>2 (4.4%)</td>
<td></td>
</tr>
<tr>
<td>Neoadjuvant therapy</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>None</td>
<td>14 (23%)</td>
<td>5 (14%)</td>
<td>13 (20%)</td>
<td>0.0075</td>
</tr>
<tr>
<td>Chemotherapy only</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>8 (13%)</td>
<td></td>
</tr>
<tr>
<td>Chemo-radiation</td>
<td>47 (77%)</td>
<td>30 (66%)</td>
<td>43 (67%)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Procedure

<table>
<thead>
<tr>
<th></th>
<th>Minimally invasive (n = 61)</th>
<th>Open (n = 99)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ivor Lewis (thoracic) (%)</td>
<td>75</td>
<td>6</td>
</tr>
<tr>
<td>Modified Mckeown (cervical) (%)</td>
<td>23</td>
<td>10</td>
</tr>
<tr>
<td>Thoracoabdominal (%)</td>
<td>NA</td>
<td>19</td>
</tr>
<tr>
<td>Transhiatal (%)</td>
<td>NA</td>
<td>65</td>
</tr>
<tr>
<td>Converted to transhiatal</td>
<td>2% (1 case)</td>
<td>NA</td>
</tr>
</tbody>
</table>

Figure 1: Distribution of surgical approach over time. The relative frequency of each surgical approach is given (Y-axis) for each of the study years (X-axis).

Figure 2: OR times over experience for MIO. The MIO cohort was split into three time intervals (X-axis) and median OR time was calculated for each interval (Y-axis).
The median ICU costs were also highest in the MIO group ($5031) compared with OTT ($4382) and OTH ($1960). The number of days spent in the ICU were the highest in the transthoracic esophagectomy (TTE) cohort (median 4) followed by MIO (median 3) and lowest in the THE (median 2).

The median inpatient care costs (non-ICU nursing unit) were lower in OTH ($5405) patients than in MIO ($8195) and OTT ($8045) patients.

In an effort to examine the impact of rising costs over time (as MIO cases were clustered towards the end of the study period), transhiatal oesophagectomy costs were evaluated prior to the adoption of MIO (2003–2007, n = 38) and during the MIO era (2008–2012, n = 26). The median cost did rise over time for transhiatal oesophagectomy ($14 611 rose to $17 793). However, MIE was considerably more expensive than transhiatal oesophagectomies performed during the same time period (median $25 935 vs $17 793). Similarly, intensive unit care costs increased over the study period. The ICU cost per day in the THE patients were examined prior to the MIO era and during the MIO era. The average daily cost of the ICU for THE patients increased from $1018 per day to $1329. This remained lower than the daily cost of ICU for the MIO patients ($1727).

**MIO costs with increasing experience**

The MIO population represents the initial experience with this technique. In order to assess the impact of a learning curve on the cost analysis, the MIO cases were compared according to increasing experience.

The median total hospital cost for MIO actually increased with increasing experience (earliest group of 20 cases = $19 771, middle group = $27 329 and most recent group = $29 670). The median day of surgery cost for MIO did not appear to change with increasing experience (earliest group of 20 cases = $11 646, middle group = $12 509 and most recent group = $12 214), despite the significant decrease in operative time. Interestingly, the increase in overall costs appeared to be driven by ICU costs as they actually rose with increasing experience (earliest group of 20 cases = $1655, middle group = $4404 and most recent group = $7473).

**Reaction to ICU cost data in 2013**

In response to this study data, the oesophageal cancer surgical team attempted to reduce ICU time for MIOs in the first 6 months of 2013 (n = 10) by more careful scrutiny over the need for ongoing ICU care. For MIOs performed in 2013, the median length of stay in the ICU decreased to 1 day (from median of 3 days) and ICU costs were reduced to $2120 (from $4998).

**DISCUSSION**

The evidence supporting the minimally invasive approach to oesophagectomy (MIO) has mirrored the experience with other oncologic procedures and includes reduction in postoperative pain, fewer complications and a faster recovery to baseline [13, 14]. However, the upfront costs of MIO are significant. In order to determine the cost-effectiveness of MIO, we investigated its expense relative to the thoracic and transhiatal open oesophagectomy approaches.

The overall major complication and mortality rates were on par with other thoracic series [15, 16]. The minimally invasive patients were less likely than OTT or OTH groups to experience an adverse event, which is similar to what has been reported for other
minimally invasive thoracic procedures [17]. The duration of hospitalization after surgery in the current study was in line with previous reports for oesophagectomy admissions [14, 18]. The MIO patients were discharged earlier than the open cohorts in this study. This may reflect less tissue trauma, less pain or a reduction in complications. It may also reflect the practice strategy of the MIO surgeon, as the MIO cohort are the most recent and were cared for in an era of increasing comfort with early discharge from oesophagectomy.

The day of surgery costs were considerably higher in the MIO cohort than the open cohorts, a finding shared by other MIO groups reporting cost data [9, 19–23]. The operative times were longer in the MIO patients, which likely contributes to this cost differential. The MIO procedures do require the use of a number of disposables (ports, endoscopic staplers, jejunostomy kits etc.), which also drive higher costs. Parameswaran et al. [6] also found that MIO’s surgical cost (£3763) was higher than OTT (£2357), most likely due to MIO’s equipment expense and its lengthier operating times. Interestingly, the MIO cohort seemed to require progressively shorter operative times as the surgeon gained experience (10.6–8.5 h), yet the day of surgery costs did not change much during this time period ($11646–$12214), suggesting that while OR time is important, it is not the dominant driver of day of surgery costs.

The total hospital costs were highest in the MIO cohort compared with the open approaches to oesophagectomy. This is contrary to the shorter length of stay and the lower complication rate in the MIO cohort. Parameswaran et al. [6] found that the shorter LOS of MIO offset its higher surgical costs, and consequently, the total hospital costs of OTT and MIO were similar. Likewise, other studies found that the total cost of MI procedures was less than its open alternatives due to shorter LOS and lower blood transfusion requirements [19, 21–23]. Potential drivers of this cost differential in the present study include overuse of ICU, which is consistent with other minimally invasive cost-effectiveness studies and our findings that ICU costs were disproportionately higher in the MIO cohort [12, 24, 25]. In the current study, one factor is the average cost of the ICU units, as the cardiothoracic ICU (where the MIO patients go), can cost several hundred dollars more per day than the surgical ICU’s (where the THE patients go because the general surgeons had performed these operations) relating to differential staffing and support structures. The length of stay in the ICU is a bit longer in the MIO compared with THE, which may contribute to the ICU cost differential as well, however both appear lower than the TTE cohort. Another tempting explanation would be that the earlier MIO experience represented a highly selected patient population and that as experience grew, the MIO eligibility criteria expanded, and patients became more complex. While this may be a factor, in reality this cannot explain the entire phenomenon, as the surgical approach converted to MIO rather abruptly, with the vast majority of oesophagectomies being directed to the minimally invasive approach (minimizing the ‘selection’ factor). We suspect this was unfortunately more a factor of culture or convenience, with patients having surgery on Thursday and not being transferred out of the ICU until Monday. In fact, once the team had the opportunity to react to these data, and a conscious effort was made to reduce the number of days in the ICU, the ICU costs were cut in half.

The rising costs of health care over time in the study period are significant and appear to influence the cost differential between approaches, as evidenced by the 20% increase in median cost of the THE between those performed prior to the MIO era, to those done during the MIO era. However, the MIO expense remains higher when the analysis is limited to contemporary cases.

Most of the limitations of this study relate to important differences in the three cohorts that significantly detract from the ability to compare the three groups. The study marks a transition in technique, indicating that the MIO patients dominated the more recent time period (which would be associated with higher costs), but also capturing the period of time in which MIO was adopted (and thereby including a ‘learning curve’ period in which costs were likely higher). It is also possible that the early MIO patients were a highly select patient population with fewer comorbidities and more favourable anatomy. Although the operative times decreased considerably with increasing experience (supporting a learning curve) the day of surgery costs did not follow this decreasing trend. The vast majority of the ‘open’ procedures were by a separate group of surgeons, and as such, some of the cost differential could be tied to surgeon preferences and pace. Interestingly, although the detail of the consumed disposables was not available for this study, the ‘open surgeons’ reported a preference to use a surprisingly similar array of disposables such as staplers and coagulation devices. This potentially reflects minimally invasive aspects of these ‘open surgeons’ practice for procedures other than oesophagectomy (and they have therefore grown more accustomed to the minimally invasive set up). What is less clear is the extent to which the observed cost differentials are intrinsic to the approach or reflect the other mentioned differences in provider or experience. Unfortunately, these aspects are not able to be defined by the current hospital data resource. Finally, the study represents a single hospital in the USA, which may have a cost structure that differs from other hospitals in the USA or abroad.

Summary

In a single North American academic institution, MIO was associated with higher surgical and overall hospitalization costs than the open approaches despite its shorter LOS and fewer complications. The cost differential appeared to persist beyond the typical MIO learning curve. Greater scrutiny over ICU usage in response to these findings were able to cut ICU costs in half without detracting from outcomes.

CONCLUSIONS

In order to capitalize on the expedited recovery of MIE patients, surgeons must alter traditional care algorithms, particularly with respect to ICU usage. We recommend applying cost containment strategies not only to the day of surgery (shorter OR times, blood conservation etc.) but to the entire hospitalization (reducing ICU stay, prophylaxis against complications, early discharge planning etc.). Future studies to enhance the cost-effectiveness of surgically managed oesophageal cancer are warranted.

Conflict of interest: none declared.

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[1] Stark SP, Romberg MS, Pierce GE, Hermeck AS, Jewell WR, Moran JF et al. Transhiatal versus transthoracic esophagectomy for adenocarcinoma of

APPENDIX. CONFERENCE DISCUSSION

Dr T. Lerut (Leuven, Belgium): It is an interesting study, and, of course, cost in the States, cost in Europe, it’s hard to compare. To reduce the length of stay in an ICU, I just wonder whether you extubate your patients on the table? We have gone through a similar process, where it was very hard to convince our anaesthesiologists to extubate the patients sooner and eventually on the table, which in fact happens now in the majority of the cases. In our setting, patients stay overnight in the recovery room, and are transferred to the ward the next morning. In other words, there is no stay in the ICU in the vast majority of the patients. So I am interested in your extubation policy.

Dr Dhamija: That is a great question. Personally, I am a medical student and I haven’t actually performed any of these oesophagectomies, but I would be glad to run the question by Dr. Boffa and Dr. Detterbeck and get back to you.

Dr. Lerut: Well, as a medical student, you performed excellently. Congratulations.

Dr F. Detterbeck (New Haven, CT, USA): The plan was to extubate all the patients in the operating room, and that did in fact happen for essentially all of them. I think there were one or two who might have been intubated for a few hours, but they were all extubated. We had some bed issues with being able to transfer people out of the ICU which I think was a greater issue than what we had expected. So despite the fact that these patients were actually doing well and didn’t have complications, they were kind of lingering in the ICU because we couldn’t get them out to the hospital ward.

Dr Lerut: Is the ICU run by the surgeons or by the anaesthesiologists?

Dr D. Dutterbeck: It was just that the hospital was bursting at the seams, and we ended up having more ICU beds than we had regular beds.

Dr D. Sugarbaker (Boston, MA, USA): I want to just say a word about extubation on the table. Scott Swanson reported on our initial experience back in 2001, and we have just submitted an abstract which has been accepted at the American College of Surgeons. We have 14 surgeons doing it, but I would say at least 10 would routinely leave the patient intubated overnight. What we have seen in the data is that we have the lowest reported pneumonia rate in any of the major series, which is a primary contributor to extended length of stay. So I am not sure that leaving the patients intubated overnight, bronching prior to extubation the following morning, is really such a bad idea, and I think it may actually contribute to lower pneumonia rates and therefore facilitated discharge.

Dr K. McManus (Belfast, Ireland): Like Tony Lerut’s group, we extubate them all on the table; we don’t send them to the ICU. We send them back to our ward, but we do have them monitored there. And one of the secrets regarding the pneumonia side of things, and the sputum retention which leads to the pneumonia, is that we routinely put in a Mini-Trach in all of these patients. Ours all have stomach to neck, so they have got abdomen, chest and the neck operation, and you have taken all the vagi off the trachea so the cilia don’t work so well, so you can predict that they are going to have a degree of sputum retention. Therefore routine Mini-Trach, that’s really what facilitates the fact that ours don’t have to go back intubated.

Dr S. Cassivi (Rochester, MN, USA): Thanks for some very good discussion. We’ll have to end it right there. I think what you have demonstrated is that there is a lot of paraphernalia that gets used in the OR during these minimally invasive oesophagectomies, and also that the accountants rule the day at the end of the day.