Robotic enucleation of oesophageal leiomyoma technique and surgical outcomes

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Abstract

Introduction: Complete enucleation of oesophageal leiomyoma is the treatment of choice, traditionally performed by open surgery. Minimally invasive thoracoscopic approaches have been proposed as an alternative to thoracotomy. Robotic surgical systems with improved dexterity, tremor filtration and stereoscopic vision are advancement over conventional thoracoscopy and may make the preservation of mucosal integrity relatively easier. We present herein our technique of robotic-assisted thoracoscopic (RATS) enucleation of oesophageal leiomyoma along with surgical outcomes and intermediate follow-up of 11 cases.

Materials and Methods: The present study retrospectively reviews patients undergoing robotic portal oesophageal leiomyomectomy from March 2012 to October 2019. The collected data were analysed for demographic details, clinical presentation, size, shape, tumour location, operating time, post-operative complications, length of hospital stay and recurrence on follow-up.

Results: Twelve patients underwent robotic portal oesophageal leiomyomectomy with a clinical diagnosis of oesophageal leiomyoma. Of these, 11 patients were included in the study. The average operative time was 110 min, with a mean blood loss of 26 ml. There was no conversion in this series. At a median follow-up of 44 months (range 6–78 months), all patients were symptom-free with no recurrence or diverticula.

Conclusion: Our series demonstrates the safety and feasibility of RATS oesophageal enucleation with good short and intermediate outcomes. In our opinion, the robotic system’s technical advantages are particularly beneficial for oesophageal leiomyoma enucleation.

Keywords: Oesophageal leiomyoma, robotic enucleation of oesophageal leiomyoma, robotic oesophageal surgery

INTRODUCTION

Leiomyomas are the most common benign tumours of the oesophagus, comprising about 70% of them.1,2 These tumours arise from the hyperproliferation of smooth muscle cells and are mostly found in the middle and lower third of the oesophagus.3,4 They are slow-growing and present as incidental detection in asymptomatic individuals or with varying degrees of dysphagia, retrosternal/epigastric pain, cough or dyspnoea.1,5 Complete enucleation is the treatment of choice, traditionally performed by open
surgery. Video-assisted thoracoscopic surgery (VATS) has recently been proposed as an alternative to thoracotomy, although two-dimensional (2D) vision and limited range of movement of instruments make dissection challenging. Robotic-assisted surgery offers exceptional dexterity and 3-dimensional stereoscopic vision making preservation of mucosal integrity relatively easier. We present herein our technique of robotic-assisted thoracoscopic (RATS) enucleation of oesophageal leiomyoma along with surgical outcomes and intermediate-term follow-up of 11 cases.

**MATERIAL AND METHODS**

This is a retrospective analysis of a prospectively maintained data of patients who underwent robotic enucleation for oesophageal leiomyoma at a tertiary care centre from March 2012 to October 2019. The data were analysed for demographic details, clinical presentation, size, shape, tumour location, intraoperative variables, post-operative complications, mortality and recurrence. The institutional ethics review board approved this study.

**Patient selection and pre-operative workup**

All patients in the study group were subjected to:

1. A contrast-enhanced computed tomographic scan of the chest and upper abdomen with oral contrast to know the location, size and extent of the tumour, any extraluminal component, relation with mediastinal structures as well as any other chest abnormality to help in surgical planning
2. An upper gastrointestinal (GI) endoscopy was done to directly visualise the mucosa over the lesion, which is essential in differentiating from oesophageal cancer
3. An endoscopic ultrasound (EUS) was done in all the patients providing information about the lesion homogeneity, sharpness of the margins, depth of invasion and any associated lymphadenopathy
4. EUS biopsy was not done because of the lack of accuracy on cytology to rule out malignancy and to avoid mucosal scarring, which increases the risk of mucosal injury.

**Patient inclusion**

All patients who underwent RATS enucleation of oesophageal leiomyoma at our centre from March 2012 to October 2019 were included in the analysis. Patients with computed tomography (CT) scan imaging suggestive of a leiomyoma together with no evidence of mucosal involvement on upper GI (UGI) endoscopy and EUS were selected for a robotic approach. Patients with a previous history of tuberculosis, any thoracic surgery or those in whom post-operative histology revealed a diagnosis other than leiomyoma were excluded. The surgical procedure was named as robotic portal oesophageal leiomyomectomy (RPEL-3) as per the consensus statement on definitions and nomenclature for robotic thoracic surgery.4

**Surgical technique**

All patients were operated under general anaesthesia with lung isolation achieved using a double-lumen tube endotracheal tube.

**Position and side selection**

The patients were operated in the semi-prone position [Figure 1a] either in the right lateral or left lateral depending on the location and the laterality of tumour projection. Tumours in the upper and middle third of the thoracic oesophagus were approached from the right side. For lower-third tumours, the side was chosen based on the laterality of tumour projection. A nasogastric tube (NGT) was placed in all patients.

**Port placement**

We used a 4-port technique with three ports (one 12 mm and two 8 mm ports) for robotic instruments and an additional 12 mm port for assistance. To start a 5 mm port was placed about a cm below and anterior to the scapular tip. CO₂ insufflation was started at 8 cm of H₂O. A diagnostic thoracoscopy was performed to assess the feasibility of the thoracoscopic approach. Two additional ports were then placed at a distance of 9–10 cm from the camera port one cephalad and the other caudal. A 12 mm assistant port was placed between the camera and the caudal port [Figure 1b]. The 5 mm port was finally converted to a 12 mm port for the robotic camera.

The port placement varied according to the location of the tumour and its relation to the azygous vein. For tumours that were located cephalad to the vein, the ports were placed to achieve a good triangulation to the tumour, and the robotic cart was docked from over the patient’s shoulder at an angle, as shown in Figure 2a. For tumours caudal to the azygous vein, the arc was rotated counterclockwise.
to achieve a better triangulation in the lower part of the oesophagus, and the robotic cart was docked from over the patients back, as shown in Figure 2b.

**The surgical steps**

The dissection was started with a Maryland Bipolar/Cautery Hook in the right arm and a Cader forceps in the left arm. The mediastinal pleura over the tumour were incised [Figure 3a and b] longitudinally and the oesophagus mobilised as required. If the mass could not be identified (as is common for lesions <2 cm in size), an intra-operative oesophagogastroduodenoscopy was performed on the table. This trick is beneficial as it bulges the small lesion based in the oesophagus wall and makes it more readily identifiable. The longitudinal muscle over the lesion was then incised along the length of the oesophagus to expose the tumour. At this stage, a 1-0 suture, 8–10 cm in length on a round body needle was used to take two large bites through the middle of the tumour in an orthogonal fashion. This suture was then used for retraction during dissection. The tumour was then carefully mobilised away from the surrounding muscle layer and underlying mucosa. After complete mobilisation [Figure 3c], the tumour was placed in a specimen bag and kept aside for later retrieval.

The muscle layer and the mediastinal pleura were approximated back with interrupted 3-0 Polydioxanone and 3-0 Vicryl, respectively [Figure 3d]. If a leak test is desired on table methylene blue can be used, but it is messy. We pulled the NGT into the oesophagus and injected air while the oesophagus was held underwater to check for any air leak. The NGT was removed before the patients awoke. A single 24 F chest tube was placed adjacent to the repaired area and an intercostal block using 0.125%

Bupivacaine with epinephrine was administered from the 2nd to 10th intercostal space. The specimen was retrieved through the camera port, which was enlarged as needed. All patients were extubated on the table.

**Post-operative care**

All patients underwent an oral gastrograffin swallow the next morning to check for mucosal integrity after which the patients were allowed a liquid diet. If no leak was found, the chest drain was removed, and the patients were discharged on the same day with advice to continue the liquid diet for 4 days and soft semi-solid diet for a week after that.

**Follow-up**

All patients were followed up in the outpatient clinic after discharge with chest X-ray to check for the status of lung expansion and any other complication. Follow-up was done every 6 months for the first 2 years and then yearly for up to 5 years. All patients were evaluated a UGI endoscopy every 6 months for the 1st year and annually thereafter for 5 years.

**Statistical methods**

Statistical testing was conducted with the Please replace with IBM SPSS Statistics for Windows, Version 23.0. Armonk, New York, IBM Corp.). Continuous variables were presented as mean ± standard deviation or median (interquartile range). Categorical variables were expressed as frequencies and percentages.

**RESULTS**

From March 2012 to October 2019, 12 cases of suspected oesophageal leiomyoma underwent RPEL-3 in our unit. Out of these, one patient was found to have a
gastrointestinal stromal tumour of lower oesophagus on post-operative histology and was excluded from the study. Finally, 11 cases of oesophageal leiomyoma were included in the study. There were 7 males and 4 females with an average age of 32.7 years. All patients presented with symptoms of dysphagia to solids > liquids of variable duration and intensity, while 2 had retrosternal pain also. At UGI endoscopy, a submucosal tumour was seen in the upper third in one patient, mid oesophageal location in four and lower oesophageal location in six patients. The details on demographic profile, tumour location, surgical approach and complications are summarised in Table 1.

The average docking and operative times were 12 and 110 min, respectively. The mean blood loss was 26 ml. There was no conversion.

Gastrograffin dye study was done on the post-operative day 1 in all patients; it showed no leak and smooth clearance in all, so liquid-diet was started and advanced to soft diet after that. All patients had uneventful recovery except one, who developed pericardial tamponade on post-operative day 3 and was managed with image-guided pericardiocentesis and no further intervention. The average intercostal drain removal was at 1.2 days after surgery and mean hospital stay was 3.5 days. All patients were discharged after the removal of the chest tube. The final histopathology was reported to be leiomyoma with average tumour size of 3.8 cm (Range 1–8 cm). At a median follow-up of 44 months (range 6–78), all patients were asymptomatic with no recurrence or diverticula.

### DISCUSSION

Oesophageal leiomyomas are the most common benign tumours of oesophagus originating from its smooth muscle layer. They are commonly found in the lower one-third of the oesophagus, and the reported incidence in literature is 10%, 30% and 60%, respectively, in the upper, middle and lower third of the oesophagus.[2] They can occur at any age but are more commonly reported between the age of 20 and 69 years with the highest incidence reported in the 5th decade of life and more commonly in male.[3] Most patients in our study were male between the age group of 22–49 years.

Most patients are asymptomatic, and these tumours are usually detected incidentally. On the other hand, as the tumour enlarges, it compromises the lumen and presses on surrounding structures, leading to dysphagia, epigastric discomfort and cough or retrosternal pain.[3]

They appear as smooth semilunar filling defect forming a right angle or slightly obtuse angle with oesophageal wall on barium swallow.[4] Contrast-enhanced CT usually shows a uniform density mass originating from the wall of the oesophagus. All such cases should undergo a UGI endoscopy and EUS which help delineate the nature of the mass, its intramural extent and its relation with mediastinal structures. On EUS, these tumours are hypoechoic and homogeneous with clear margins.[7] Pre-operative tissue diagnosis of these tumours is a debatable issue because biopsy can lead to adhesion to underlying mucosa and increased chances of rupture or mucosal injury at surgery.[8] In patients where an attempt at pre-operative diagnosis is made cKIT testing can be done on the EUS FNA sample. Ninety-five percent of the gastrointestinal stromal tumour will be positive for cKIT (CD117). In contrast, leiomyoma will be positive for actin and desmin and negative for cKIT and S100.[9] However, we do not perform pre-operative needle biopsy for the diagnosis in any of our patients as it has been reported to increase the rate of mucosal injury.[9]

Intervention is warranted in all symptomatic patients, and for asymptomatic patients, the indications are large tumour size >5 cm, tumours that increase in size on follow-up or demonstrate mucosal ulceration and to rule out malignancy in doubtful cases.[10] There are few reports where smaller tumours have been removed.

### Table 1: Details on demographic profile, location of the tumour, surgical approach and complication

| Characteristics                  | Frequency | Range/% |
|----------------------------------|-----------|---------|
| Age (years), (mean)              | 32.7      | 21-46   |
| Age distribution (years)         |           |         |
| 21-30                            | 3         | 27      |
| 31-40                            | 5         | 46      |
| 41-50                            | 3         | 27      |
| Gender                           |           |         |
| Male                             | 7         | 64      |
| Female                           | 4         | 36      |
| Body mass index, (mean)          | 23.7      | 15.6-40.5 |
| Co-morbidities                   |           |         |
| No                               | 8         | 72      |
| 1 co-morbidity                   | 2         | 18      |
| >1 co-morbidities                | 1         | 9       |
| Location                         |           |         |
| Upper                            | 1         | 9       |
| Mid                              | 4         | 36.4    |
| Lower                            | 6         | 54.6    |
| Approach                         |           |         |
| Right                            | 10        | 91      |
| Left                             | 1         | 9       |
| Surgery                          |           |         |
| Enucleation                      | 11        |         |
| Esophagectomy                    | 0         |         |
| Mucosal injury                   | 0         |         |
| Others                           |           |         |
| Pericardial tamponade            | 1         | 9.09    |
successfully through endoscopic excision techniques such as endoscopic submucosal excavation or submucosal tunneling endoscopic resection.\[11\]

The conventional surgical approach is transthoracic extramucosal enucleation through left- or right-sided thoracotomy.\[12\] However, it is associated with significant peri-operative morbidity relatively higher mucosal injury rates and longer hospital stay.\[13\] In recent times, VATS and laparoscopic enucleations have been increasingly utilised for the treatment of symptomatic oesophageal leiomyomas. The thoracoscopic approach has been shown to result in shorter hospital stay and lesser chest tube duration when compared to thoracotomy suggesting better morbidity outcomes.\[14\]

Traditional thoracoscopy has limitations due to 2D vision and counterintuitive movements of long rigid instruments. These make dissection and intracorporeal suturing difficult and lead to a significant learning curve. The robotic surgical system addresses all these limitations exceptionally well by providing a three-dimensional stereoscopic vision and articulating EndoWrist™ instruments with 7 degrees of freedom of movement offering exceptional dexterity allowing for a meticulous dissection which helps in mucosal preservation, the most crucial step of the procedure. It is vital to enter this correct plane, which is usually avascular and dissect the tumour slowly off the mucosa by careful blunt dissection. Minor bleeds can be controlled by bipolar diathermy or packing the area with an adrenaline-soaked gauge piece for 5 min. The robot is also very well equipped to handle suturing of the muscular defect.

The use of the surgical robot has been reported in benign oesophageal tumours by many surgeons.\[15\] After the initial case report of two cases by Elli et al,\[16\] several case reports have been published on robotic enucleation of oesophageal leiomyoma [Table 2] wherein tumors as large as 10 cm have been successfully removed using robotic assistance. All these reports have shown no conversion and good post-operative recovery.

In our series also, there were no conversions. There was one complication, a delayed pericardial tamponade on the third post-operative day, which was serious and deserves elaboration. It happened in the case of a lower oesophageal leiomyoma just above the GE junction which was approached from the left side. We reviewed the video recording of the surgery multiple times for any injury caused during the surgery. However, none could be found. An inadvertent injury to any pericardial vessel by the needle used for suturing could be a possibility, although we could not demonstrate it in the video review.

We used the semi-prone position as it offers all the advantages of the full-prone position over lateral decubitus. These include a clearer view of oesophageal bed and posterior mediastinum with a gravity-assisted clearance of blood from the surgical field along with obviation of the need for lung retraction which moves away from the field aided by gravity and pneumothorax. The major disadvantage of the prone position is the difficulty it offers should the case require conversion to thoracotomy, which is particularly troublesome if an emergency conversion is required. From our experience in esophagectomy in full prone position both by thoracoscopic and robotic-assisted approach, we know that the visualisation of the oesophagus is better in semi-prone position as the vertebral bulge becomes less prominent due to more anterior placement of the camera port. Furthermore, semi-prone position allows for a more anterior placement of all the ports where the rib spaces are wider, leading to lesser torque at the entry points and lesser trauma to the neurovascular bundle. Anterior ports also mean a straighter course of the instruments to the target anatomy, particularly for the cephalad port which in the prone position is usually placed posterior to scapula leading to the entry of instrument at a steep angle limiting the range of movement. Furthermore, conversion if required is straightforward.

The use of the fourth arm for retraction has been reported by others.\[13\] In our series however we have used only three robotic arms. It allowed us to save the cost. Measures to reduce the cost are essential for sustaining a robotic program, particularly in developing countries.

The average hospital stay in our study is 3.5 days. This may seem a little on the longer side. However, most of our patients were admitted a day before surgery because of their insurance policies which allowed reimbursement of investigations only for admitted patients and not on an outpatient basis. Due to this limitation, an additional day of hospital stay was unnecessarily added. If patients could be admitted on the day of surgery, the majority of them could have been discharged the very next day after dye study ruled out any leak. Hence, there is a potential to reduce the hospital stay even further.

The limitations of our study include the retrospective nature of the study with small sample size. A more well-designed prospective study using a control-armed comparison with open and conventional thoracoscopic surgery is warranted to assess long-term outcomes. The two most significant disadvantages of using the robotic system are the lack of haptic feedback and cost. For us, the high-quality stereoscopic vision more than compensates for
Table 2: Reports of robotic enucleation of oesophageal leiomyoma[13-22]

| Author                  | No. of Cases | Duration of surgery | Conversion | Hospital stay | Tumour size |
|-------------------------|--------------|---------------------|------------|--------------|-------------|
| Kernstine et al.        | 1            | 104                 | 0          | 1            | 40          |
| Elliott et al.          | 2            | 120                 | 0          | N/A          | 38.7        |
| Victor Tomulescu et al. | 2            | 180                 | 0          | 5.5          | 40          |
| Bodner et al.           | 1            | 147                 | 0          | 7            | N/A         |
| Natalie et al.          | 1            | 155                 | 0          | 2            | 38          |
| Augustin et al.         | 1            | 147                 | 0          | 4            | 20          |
| Abed et al.             | 1            | 200                 | 0          | 3            | 40          |
| DeUgarte et al.         | 1            | N/A                 | 0          | 5            | N/A         |
| Chiu et al.             | 1            | N/A                 | 0          | 6            | N/A         |
| Compean et al.          | 1            | N/A                 | 0          | 3            | 100         |

N/A: Not applicable

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the lack of haptic feedback. This leaves us with the cost as the most important limiting factor. As more and more surgeons start to experience the advantages the robotic system offers, the usage will increase and bring the cost down in the future.

CONCLUSION

Our series demonstrates the safety and feasibility of RPEL-3 with good short and intermediate outcomes. In our opinion, the robotic system’s technical advantages are particularly beneficial for oesophageal leiomyoma enucleation.

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Conflicts of interest
There are no conflicts of interest.

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