

Just breathe: 12-step robotic tracheobronchoplasty



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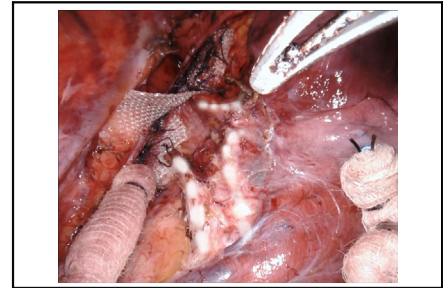
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Carinal sutures and medialization of tracheobronchial angles restore bronchial patency.

CENTRAL MESSAGE

Tracheobronchomalacia is a common, yet uncommonly diagnosed. Robotic tracheobronchoplasty, is reproducible and improves patients whose symptoms are attributed to severe central airway collapse.

Video clip is available online.

Tracheobronchomalacia (TBM) is a disease characterized by narrowing of the central airways, including the trachea and mainstem bronchi.¹⁻⁴ Symptoms may include progressive dyspnea, intractable cough, and recurrent infections. Diagnosis of TBM is facilitated by ultra-low-dose dynamic computed tomography scanning⁵ and awake dynamic flexible bronchoscopy with >90% collapse seen in severe cases.¹

Tracheobronchoplasty (TBP) for symptomatic patients with severe TBM requires restored airway geometry to resolve expiratory airway obstruction. TBP is well described through robotic-assisted video assisted thoracic surgery (RA-VATS). The feasibility of robotic-assisted TBP was first described in 2015.⁶ Subsequent series demonstrated durable improvement in quality of life and pulmonary function for moderate to severe disease with minimal morbidity utilizing this approach.^{7,8}

A permanent mesh is sewn to the cartilaginous edges of the airway while pleating the posterior membrane to the mesh, providing a platform to restore and maintain a more normal airway geometry during expiration.^{1,9,10} We describe a safe and reproducible technique for robotic-assisted TBP in 12 steps.

TECHNIQUE

Step 1: Ports and Initial Setup

Following intubation with a 35Fr left-sided double lumen tube the patient is placed into the left lateral decubitus

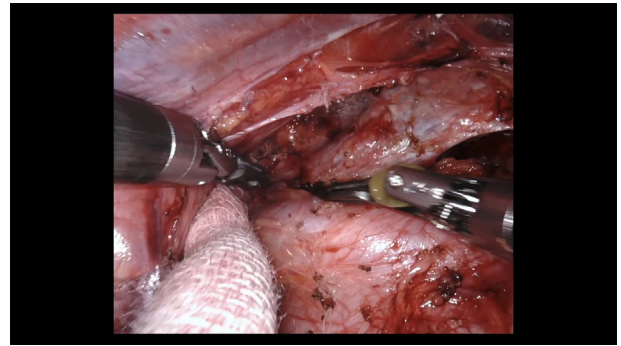
position, prepped and draped, and single lung ventilation is initiated. Preemptive analgesia with a local anesthetic is utilized. Ports are aligned to optimize exposure of the trachea and bilateral mainstem bronchi with the patient in the left lateral decubitus position. An 8-mm camera port is placed approximately 10 cm inferior to the tip of the scapula at the highest point on the chest wall (midaxillary line). A 12-mm nonrobotic assistant port is then placed above the costal margin at the anterior axillary line. Multiple intercostal nerve blocks are performed. Three additional 8-mm robotic ports are placed, 1 posteriorly and 2 anteriorly. Robotic ports are placed 8 to 10 cm apart. After docking the da Vinci XI (Intuitive Surgical Inc) robot with the boom rotated to position it over the head of the patient. A Cadieere forceps is inserted into arm 1, camera in arm 2, long bipolar forceps in arm 3, and tip-up fenestrated grasper in arm 4 (Video 1). See Appendix E1 for instrumentation.

Steps 2 and 3: Airway Exposure, Level VII Node Dissection, and Division of the Azygous Vein

The lung is retracted anteriorly to expose the middle mediastinum. The mediastinal pleura anterior to the esophagus is divided using bipolar energy beginning at the level



VIDEO 1. Video available at: [https://www.jtcvs.org/article/S2666-2507\(23\)00186-4/fulltext](https://www.jtcvs.org/article/S2666-2507(23)00186-4/fulltext).



VIDEO 3. Video available at: [https://www.jtcvs.org/article/S2666-2507\(23\)00186-4/fulltext](https://www.jtcvs.org/article/S2666-2507(23)00186-4/fulltext).

of the inferior pulmonary vein (Video 2). A complete sub-carinal lymph node dissection is performed using bipolar cautery to minimize lateral thermal damage (Video 2). The dissection exposes the medial cartilaginous rings of both mainstem bronchi. Anterior and medial adjustment of retraction at this point will improve exposure of the left mainstem bronchus and bring the left inferior pulmonary vein into view. The lateral cartilaginous rings of the left mainstem bronchus are then carefully exposed.

The mediastinal pleura anterior to the esophagus is further divided cephalad to the thoracic inlet dividing the azygous vein, which exposes the trachea. The right vagus nerve is mobilized and preserved (Video 3).

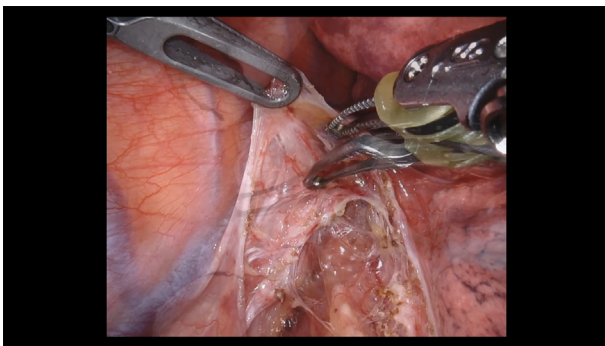
Steps 4 and 5: Left Bronchoplasty

Mesh sizing can be determined utilizing preoperative measurements from bronchoscopic evaluation, computed tomography images with or without 3-dimensional reconstruction, or utilizing a ruler intraoperatively and should be determined by the surgeon.

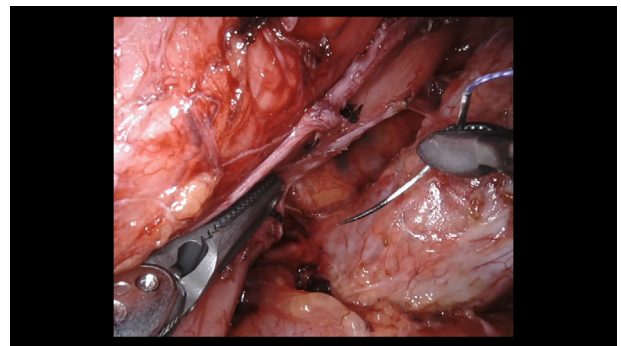
Reconstruction of the left mainstem bronchus requires 3 columns of partial thickness suture (4-0 Vicryl RB -1;

Ethicon Inc) and a 5 cm × 16 mm polypropylene mesh. The lateral columns are placed 3 mm from the edge of the mesh to the posterior bronchial cartilage. The middle column of sutures secure the membranous airway to the mesh, are placed in a horizontal mattress fashion from mesh to membrane, and incorporate several partial-thickness membranous bites from lateral to medial before turning and running from medial to lateral. The lateral columns of sutures are tied before tying the middle column of sutures (Videos 4 and 5).

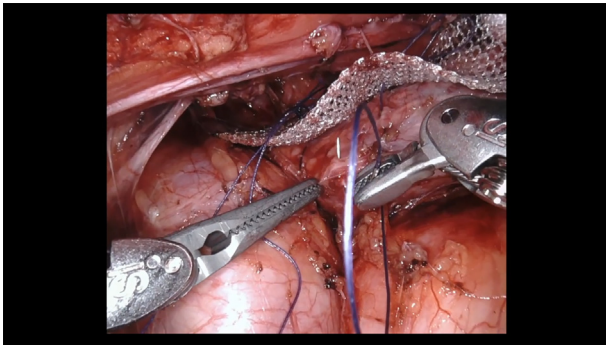
During placement of column 2 sutures, intermittent apnea and withdrawal of the endotracheal tube is utilized to place these sutures and minimize the risk of full-thickness sutures and endotracheal tube/cuff incorporation. Communication with anesthesia is essential and we refer to this maneuver as stop, drop, and roll.⁹ Ventilation is stopped, the bronchial balloon cuff is dropped, and the tube is withdrawn to a more proximal position (Video 5). Tracheal balloon deflation is required and this also facilitates exposure of the left cartilaginous wall of the intrathoracic trachea.



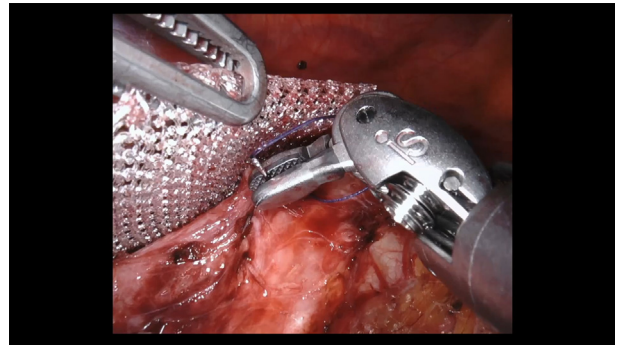
VIDEO 2. Video available at: [https://www.jtcvs.org/article/S2666-2507\(23\)00186-4/fulltext](https://www.jtcvs.org/article/S2666-2507(23)00186-4/fulltext).



VIDEO 4. Video available at: [https://www.jtcvs.org/article/S2666-2507\(23\)00186-4/fulltext](https://www.jtcvs.org/article/S2666-2507(23)00186-4/fulltext).



VIDEO 5. Video available at: [https://www.jtcvs.org/article/S2666-2507\(23\)00186-4/fulltext](https://www.jtcvs.org/article/S2666-2507(23)00186-4/fulltext).



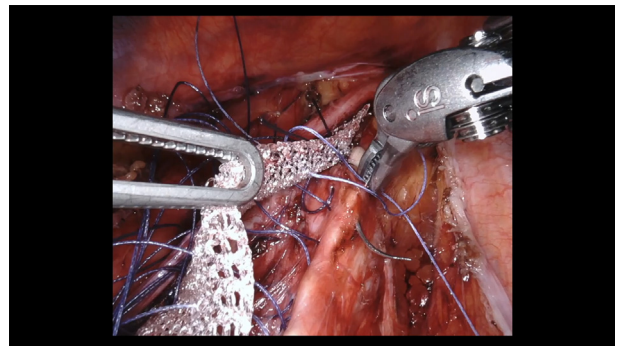
VIDEO 7. Video available at: [https://www.jtcvs.org/article/S2666-2507\(23\)00186-4/fulltext](https://www.jtcvs.org/article/S2666-2507(23)00186-4/fulltext).

After the 3 columns of sutures are tied, the endotracheal tube is repositioned in the distal left mainstem bronchus. No air should be required in the bronchial cuff due to the narrowed dimension of the airway without compromise of ventilation. Alternating suture colors facilitates suture management for tying.

Steps 6, 7, 8, and 9: Tracheoplasty

The procedure goal is to repair the pathologic severe central airway collapse from proximal to distal. Repair of the intrathoracic trachea requires an 8 cm × 24 mm mesh and 4 columns of suture. Column 1 sutures are placed 4 mm from the edge of the mesh to the left posterior tracheal cartilage and are tied as they are placed (Video 6). Columns 2 and 3 are horizontal mattress sutures between the mesh and posterior membrane (Video 7). Column 2 runs from lateral to medial, then medial to lateral. As before, these are left untied. Columns 1 and 4 are enantiomorphs; columns 2 and 3 are also enantiomorphs.⁹ Columns 3 and 4 sutures are tied after securing the mesh to the right posterior tracheal cartilage. Column 4 sutures are placed 4 mm

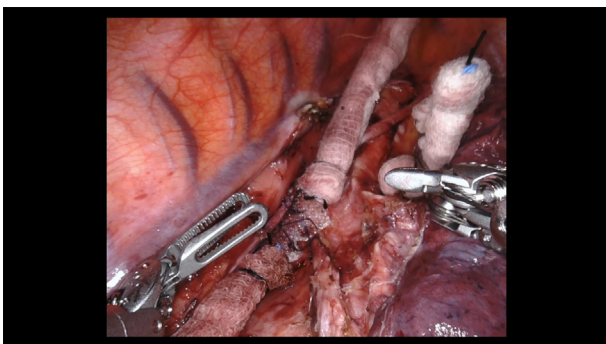
from the edge of the mesh to the right posterior tracheal cartilage and are tied as they are placed (Videos 8 and 9).



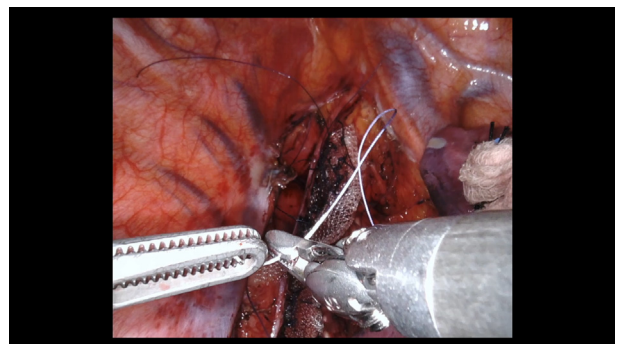
VIDEO 8. Video available at: [https://www.jtcvs.org/article/S2666-2507\(23\)00186-4/fulltext](https://www.jtcvs.org/article/S2666-2507(23)00186-4/fulltext).

Steps 10 and 11: Right Bronchoplasty

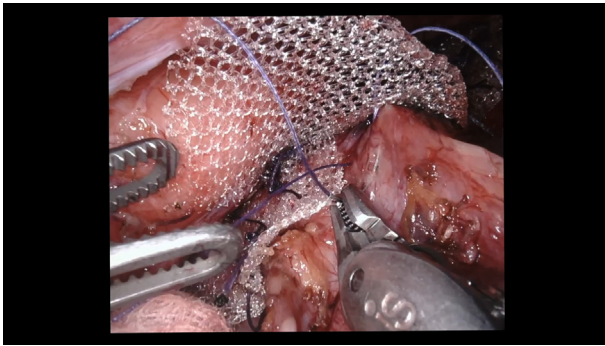
The right mainstem and bronchus intermedius are repaired using a 5 cm × 16 mm mesh similar to the left mainstem bronchus repair with 3 columns of sutures (Videos 10



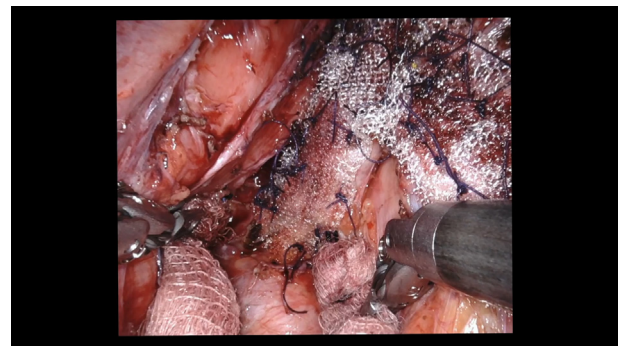
VIDEO 6. Video available at: [https://www.jtcvs.org/article/S2666-2507\(23\)00186-4/fulltext](https://www.jtcvs.org/article/S2666-2507(23)00186-4/fulltext).



VIDEO 9. Video available at: [https://www.jtcvs.org/article/S2666-2507\(23\)00186-4/fulltext](https://www.jtcvs.org/article/S2666-2507(23)00186-4/fulltext).



VIDEO 10. Video available at: [https://www.jtcvs.org/article/S2666-2507\(23\)00186-4/fulltext](https://www.jtcvs.org/article/S2666-2507(23)00186-4/fulltext).



VIDEO 12. Video available at: [https://www.jtcvs.org/article/S2666-2507\(23\)00186-4/fulltext](https://www.jtcvs.org/article/S2666-2507(23)00186-4/fulltext).

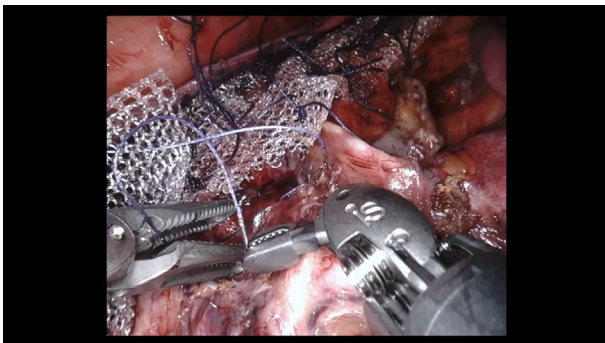
and 11). Removal of the 11R (sump) node aids in repair of bronchus intermedius.

Step 12: Case Completion

A 24Fr chest tube is inserted and positioned posteriorly to the apex (Video 12). The patient is placed in the supine position and awoken. Before removal of the endotracheal tube, intraoperative bronchoscopy is performed to assess the integrity of the repair. The patient is extubated over the bronchoscope to assess the full extent of the tracheal repair.

DISCUSSION

Previous studies have demonstrated the feasibility of robotic-assisted TBP with good short- and intermediate-term outcomes. The operation is based on the principles of surgery through a posterolateral thoracotomy. Here, we present a safe, reproducible approach to robotic assisted TBP in 12 steps based on extensive experience with this modality.



VIDEO 11. Video available at: [https://www.jtcvs.org/article/S2666-2507\(23\)00186-4/fulltext](https://www.jtcvs.org/article/S2666-2507(23)00186-4/fulltext).

CONCLUSIONS

The technique demonstrates a standardized methodology for intrathoracic exposure and repair of the airway. Future innovation may include adjuncts to diagnosis of TBM, development of prediction models to facilitate patient selection, and use of preoperative imaging to customize reconstruction.

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**APPENDIX E1. ROBOTIC
TRACHEOBRONCHOPLASTY CASE CARD**

- Thoracic minor tray
- Ports
 - 4 to 8 mm robotic ports
 - 1 to 12 mm nonrobotic port
- Insufflator
- Robotic instruments
 - Cadiere
 - Long bipolar grasper
 - Tip up fenestrated
 - Mega-suture cut
 - Vessel sealer
- Rolled gauze sponges
- 4 to 0 Vicryl on RB-1
- Polypropylene mesh