

# Creation of a Balloon-Expandable Bifurcated Covered Stent to Treat a Complex Left Anastomotic Stricture in a Lung Transplant Recipient

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## Established Facts

- In vivo creation of bifurcations in balloon-expandable metallic stents is a strategy used in interventional cardiology and vascular medicine to manage complex vascular stenosis.

## Novel Insights

- In vivo creation of a bifurcated balloon-expandable covered stent may be an option to treat complex airway stenosis when other standard options have failed.

## Keywords

Lung transplantation · Interventional pulmonology · Stent · Bronchoscopy

## Abstract

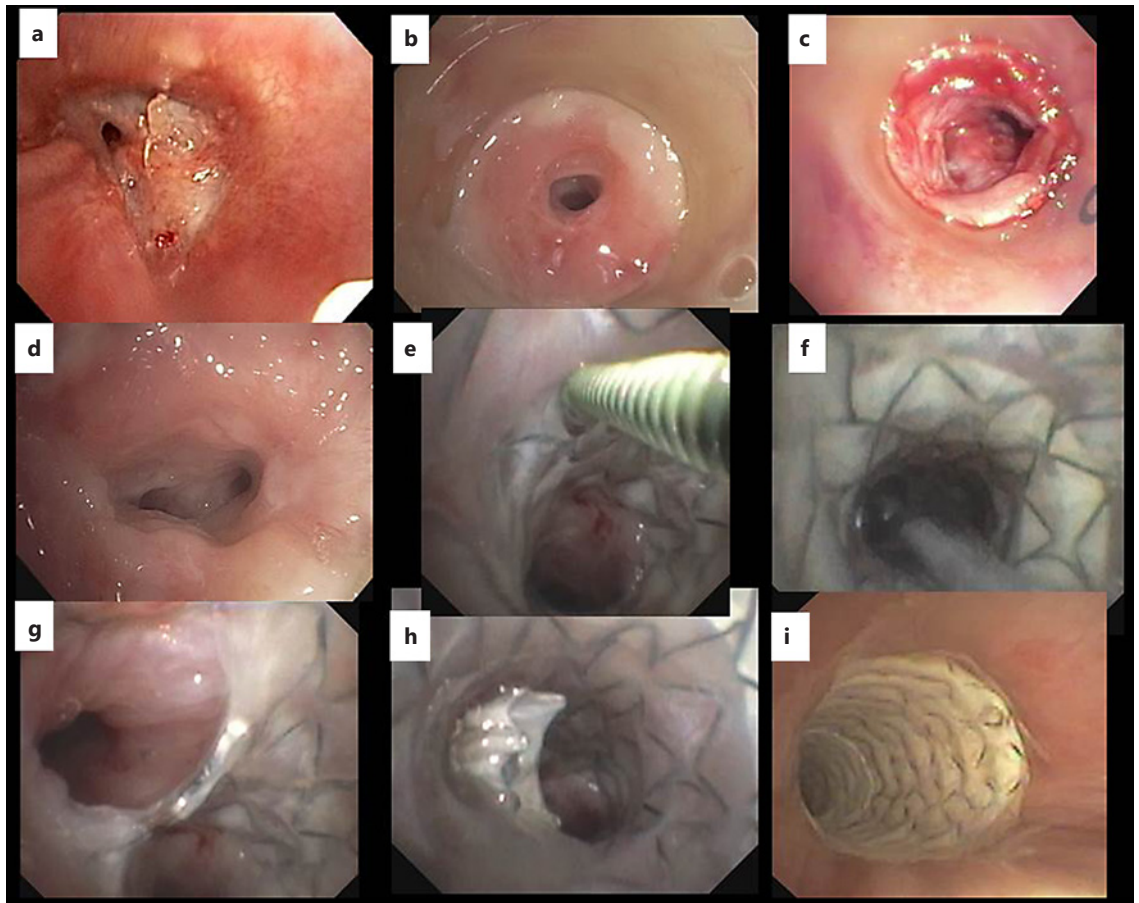
Airway complications after lung transplant occur in approximately 10–15% of the recipients and often occur at the anastomosis, largely due to ischemia. To decrease anastomotic ischemia, surgeons minimize the length of the donor bronchus. However, a shortened donor bronchus creates technical challenges if a stent is required to treat an airway complication. We present a case of a lung transplant recipient with the combination of left main stem bronchial malacia and a triad of severe strictures at the left anastomosis, entrance to the left upper lobe, and left lower lobe. After failing several

attempts using other modalities, success was achieved with in situ creation of a bifurcated fully covered balloon-expandable metallic stent. We describe a novel technique of punching a side branch hole through the wall of the stent to allow a left upper lobe stent to be placed through a stent directed into the left lower lobe in a Y configuration with a good clinical outcome.

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## Introduction

Airway complications remain a significant source of morbidity after lung transplant (LT) [1–3]. Many surgical techniques have been tried to minimize airway complications at the anastomosis. One currently preferred



**Fig. 1.** Bronchoscopic images. **a** Initial anastomotic stricture. **b** Typical view at the distal end of the left main stem stent before dilations. **c** Typical view at the distal end of the left main stem stent after dilations. **d** Left upper lobe orifice on the left, left lower lobe orifice on the right after left main stem stent removal. **e** Hole in the

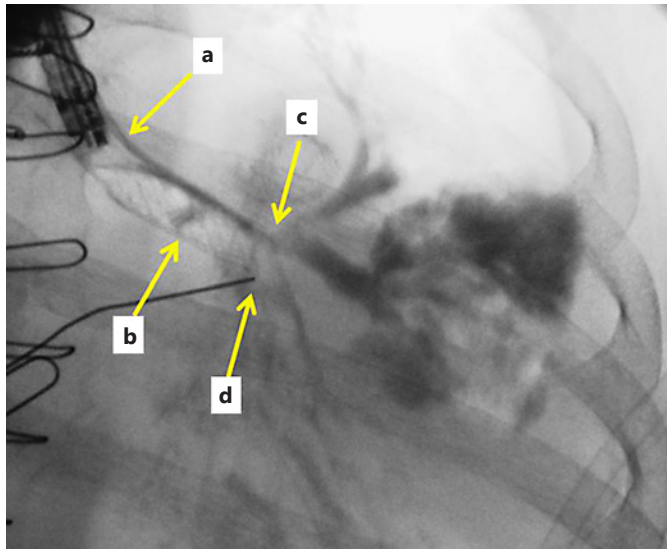
iCAST stent with guide wire passed into the left upper lobe. **f**  $5 \times 20$  mm balloon dilating hole to create access to the left upper lobe. **g** Hole in the iCAST stent revealing the left upper lobe. **h**  $6 \times 16$  mm iCAST stent in the left upper lobe. **i** Proximal view of the left main stem, showing a seam between 2 iCAST stents.

technique is to perform an end-to-end anastomosis minimizing the length of the donor bronchus as much as possible [4]. Though this technique may reduce airway complications, the shortened donor bronchus complicates stenting, particularly on the left side due to the bifurcation of the left upper lobe (LUL) and left lower lobe (LLL).

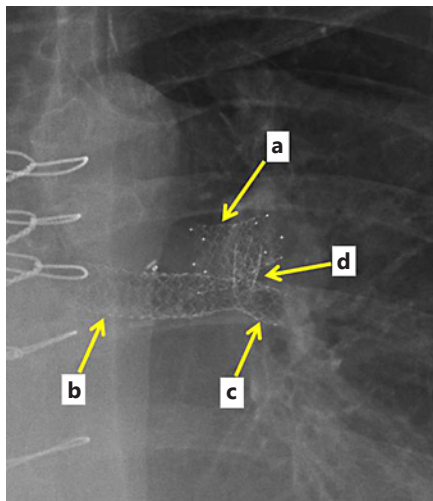
If a stent is needed on the left side, a straight stent may not be effective, and bifurcated silicone Y-stents with limbs going into the LUL and LLL have been used by our institution and others [5–7]. Upper lobe departure holes can be created in silicone stents, but for anatomical reasons, that strategy is usually more useful on the right than the left [8]. In cardiovascular medicine, bifurcations and side branches of blood vessels fre-

quently pose a challenge for stent placement. Vascular interventionalists have developed techniques to “punch a hole” in the wall of a stent to allow blood flow or placement of another stent to create a bifurcated or “side branch” stent [9].

We present a case of an LT recipient with distal left main stem bronchial malacia with a triad of recurrent severe strictures of the anastomosis, LUL, and LLL orifices refractory to numerous interventions. We describe the successful treatment of this problem with the creation of a Y-configured bifurcated fully covered balloon-expandable covered metallic stent (BECMS) composed of 3 separate BECMS (iCAST Balloon Expandable Covered Stent; Atrium USA, Hudson, NH, USA).



**Fig. 2.** Contrast bronchogram of the left upper lobe. **a** 4-Fr angled guide sheath initially placed into the left upper lobe through rigid bronchoscope so that contrast could be instilled into the left upper lobe to mark the left upper lobe orifice. **b** Deployed 8 × 38 mm iCAST stent that had migrated back no longer going into the left lower lobe. **c** Orifice to the left upper lobe with upper division and lingular branches filled with contrast. **d** Marker used to indicate the proximal superior segment of the left lower lobe to avoid occluding with the distal end of the stent.



**Fig. 3.** Postprocedural chest X-ray. **a** Pulmonary artery stent. **b** Proximal left main stem bronchus stent, postdilated from 8 to 10 mm. **c** Distal left main stem iCAST stent, 8 mm diameter. **d** Left upper lobe branch stent, 6 mm diameter.

## Case Report

A 50-year-old female underwent bilateral LT for fibrotic lung disease secondary to usual interstitial pneumonia. Her post-LT course was complicated by pulmonary emboli, a stricture at the left pulmonary artery anastomosis treated with stenting of the pulmonary artery, and acute cellular rejection (grade A3). She developed a severe stricture at the left anastomosis by 90 days after LT (Fig. 1a). The stricture was treated with balloon dilation, rigid dilation, and finally placement of an LC2 Y stent 4 months after LT. The stent occluded with mucus multiple times and was removed 10 months after placement. Unfortunately, the anastomotic stricture recurred, and she developed new strictures to the LUL and LLL. Replacement of the silicone Y stent was not technically possible. The left main bronchus (LMB) malacia was treated with a straight stent, and the LUL and LLL strictures were treated with serial dilations. Because the patient was requiring bronchoscopy and dilation on a biweekly or monthly basis, we opted to try a novel technique of creating an in vivo custom stent with a side branch into the LUL.

### Procedure Description

The patient was brought to the interventional pulmonary suite and was intubated with a rigid bronchoscope. The existing fully covered self-expanding metal stent was removed, the LUL and LLL were dilated with a small rigid bronchoscope (outer diameter 7.5 mm), and we proceeded with a series of interventions.

We ultimately placed 3 BECMS, which come preloaded on a fixed diameter balloon but can be dilated further after deployment. The scaffold of the stent is made with stainless steel and is covered in 2 layers of polytetrafluoroethylene (PTFE) that completely cover the metal struts. The length of the stent slightly shortens as the stent is dilated. It is not self-expanding and maintains shape after dilation. We first placed an 8 × 38 mm stent across the LMB stricture into the LLL. We dilated the proximal half to 10 mm using a 10 × 20 mm vascular balloon (Charger vascular balloon; Boston Scientific, USA) which caused the stent to migrate proximally as the length shortened. A contrast bronchogram using a 50% mixture of Iohexol (Omnipaque 300; GE Healthcare, USA) and normal saline was performed so we would have a reference point to the LUL orifice (Fig. 2).

Because of the migration, we then telescoped a second 8 × 38 mm stent from the middle portion of the previously placed stent into the LLL, just overhanging the superior segment of the LLL. We then used an 8-mm-long 21-G peripheral biopsy needle (superDimension aspirating needle; Medtronic, USA) to make a small hole at the region of the LUL orifice. We used fluoroscopy to help us determine where to puncture. We advanced a steerable angled 0.035" guidewire (Storq Steerable Guidewire; Cordis/Cardinal Health, USA) through the hole into the LUL under fluoroscopic guidance (Fig. 1e). A 5 × 20 mm vascular balloon (Charger vascular balloon, Boston Scientific) was then inserted over the wire into the LUL and inflated to 12 atmospheres of pressure with a resulting hole (Fig. 1f, g). The steerable guidewire was essential in allowing us to make the angle. Finally, a 6 × 16 mm stent was placed over the same wire into the LUL (Fig. 1h). A post-procedure chest X-ray demonstrates configuration (Fig. 3). The ends of the stent were flared by the use of forceps and gentle manipulation of a 5-mm balloon. The resulting stents allowed patency of the entire LMB, LUL, and LLL. The superior segment of the LLL is partially occluded by the distal end of the stent.

### Clinical Outcome

The patients' FEV<sub>1</sub> in 1 s improved from 1.51 L (55% predicted) to 1.95 L (70% predicted) immediately following stenting with dramatic improvement in exertional dyspnea and cough. At 5 months following the procedure, the FEV<sub>1</sub> has remained stable at 2.01 L (73% predicted). A follow-up bronchoscopy 5 months after the procedure showed minimal granulation tissue and patent stents. She has not had any complications in the 6 months after stent placement and has been maintained on 3% inhaled saline 4 times per day. She does endorse intermittent coughing up cylindrical plugs of mucus.

### Discussion

We present the first report of *in vivo* creation of a bifurcated BECMS to treat combined LMB malacia with a triad of strictures at the left anastomosis, LUL, and LLL in an LT recipient. Due to variations in anatomy between donors and recipients, there is not an ideal stent for all clinical scenarios. We have found that in some scenarios, the ability to post-dilate balloon-expandable stents may be advantageous for small airways and to address complex anatomical issues, such as in our case.

BECMS have reportedly been used to treat lobar stenosis [10]. Other bare metal balloon-expandable stents have been used to treat short lobar stenosis for nonanas-

tomotic complications after LT [11]. To our knowledge, the creation of a hole in the wall of a BECMS with creation of a side branch has never been reported in the literature to treat a LT recipient. *In situ* customization of stents is established practice in cardiac and vascular interventions [9] but is a novel approach in the airway. It is unknown if this stent type and configuration will increase the risk of granulation tissue and mucus plugging. This will continue to be monitored. As the field of interventional pulmonology evolves, we expect that other techniques translated from other fields, such as our creation of a bifurcated stent, will become more common. The procedure that we performed was technically challenging, and we expect this to remain a salvage therapy for now.

### Statement of Ethics

Institutional review board approval was not required for this study.

### Financial Disclosure and Conflicts of Interest

Dr. Kern has a past consulting relationship with Olympus Corporation of the Americas and Auris Surgical Robotics.

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