Airway Stent Insertion Simulated With a Three-Dimensional Printed Airway Model

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A 30-year-old man underwent right single-lung transplantation for chronic obstructive pulmonary disease. The bronchial anastomosis developed ischemic change, resulting in stenosis of the intermediate bronchus. A modified Y-shaped airway stent with the fabricated orifice of the upper lobe was inserted by rigid bronchoscopy. Before the operation, a three-dimensional printed bronchial model of this patient was made for surgical simulation. This model enabled us to perform the operation easily, quickly, and successfully. The patient's condition improved after airway stent insertion.

Three-dimensional model (3D) printing is a process for making a solid 3D object of virtually any shape from a digital model. It can be uniquely customized according to a patient's anatomic and pathologic characteristics [1]. Thus, it has been widely used in many medical fields, such as simulation of anesthesiology [1], liver transplantation [2], and thoracic operations [3, 4]. However, there have been few reports about airway stent insertion using a 3D printed model. We present a case of successful modified airway silicone stent insertion for bronchial stenosis after lung transplantation using a 3D printed model, which facilitated the understanding of the patient's anatomy and the surgical procedures during the operation.

A 30-year-old man underwent right single-lung transplantation for chronic obstructive pulmonary disease. He had been receiving a standard triple-immunosuppressant regimen, comprising tacrolimus, mycophenolate mofetil, and prednisolone. Ischemic change of the bronchial anastomosis developed after transplantation, resulting in bronchial stenosis and malacia (Fig 1A). This made it difficult for him to expectorate sputum, so frequent bronchoscopic airway toileting was needed.

The patient experienced several episodes of Staphylococcus aureus pneumonia derived from the sputum (as suggested by Gram staining), which then changed to methicillin-resistant Staphylococcus aureus infection. Fortunately, each of these infectious episodes were successfully treated by intravenous antibiotics, but the bronchial stenosis and malacia gradually worsened (Fig 1B). Therefore, airway stenting was considered 5 months after transplantation to dilate the bronchial stenosis and facilitate sputum expectoration.

3D graphics were created with an Artec 3D scanner (Artec, Luxembourg, Luxembourg) and customized with Geomagic Free Form graphics (Geomagic, Cary, NC). These 3D graphics were entered into an Objet 260 Con...
nex printer (Stratasys, Eden Prairie, MN) with a stereolithography form. The resulting model was durable and was taken to the operating room.

Because the stenosis and malacia extended to the intermediate bronchus, a Dumon Y stent with an opening for the upper bronchus at its right arm was specially modified according to the 3D printed model to pass the bronchoscope easily (Fig 2). The size of the stent was determined by measuring the length of the lesion and the diameters of the airway using this 3D printed model. Stent insertion was successfully and correctly done by rigid bronchoscopy.

The patient’s condition improved after airway stent insertion, and he was discharged 6 months after transplantation, without any symptoms. Chest computed tomography and bronchoscopic findings showed the stent was located in the desired position (Figs 3A–3B). No allograft rejection was identified during this period.

Comment

This report describes a clinical case of successful, modified airway silicone stent insertion after lung transplantation using a 3D printed model. Bronchial complications, such as ischemia, stenosis, dehiscence, and malacia, are still common after lung transplantation because the oxygen supply for the lung allograft, including the site of bronchial anastomosis, depends on the retrograde “venous” blood supply [5]. In that situation, an airway silicone stent has been widely used as a first choice. Dutau and colleagues [6] reported that silicone stents were inserted in 17 of 117 lung transplant recipients (14.5%) to palliate 23 anastomotic airway stenoses. Successful stent removal was achieved in 16 of 23 cases (69.5%), without recurrence of stenosis. According to this report, airway stent insertion is not rare, but once inserted successfully, a higher success rate would be anticipated.

Preoperative surgical procedure planning is essential for secure insertion of the stent. We always determine the size of the stent and the diameters of the airways by measuring with bronchoscopy and on the X-ray fluoroscopic table during the operation. These are somewhat cumbersome procedures, and they sometimes take a long time and cause stent displacement and dislocation, especially for modified stent insertion, when the precise length and hole for the upper lobe of this stent are essential.
In the present case, however, the 3D printed model that was made before the operation enabled preoperative planning of the surgical procedure, including decision making related to the precise length and the hole for the upper lobe of this stent more sterically than the image of multiplanar reconstruction created by chest computed tomography, with not only the surgeons but also the anesthesiologists and nurses able to insert the airway stent safely and correctly and save operating time.

Moreover, the 3D model helped obtain the patient’s informed consent for this operation and helped students understand the anatomy of the bronchus. Thus, we advocate that use of this technology be widely expanded to all medical fields. Moreover, Chang and colleagues [7] reported a trachea using a 3D printing scaffold coated with mesenchymal stem cell seeds. This promising report lets us hope that a “reconstructed graft” using 3D printing could be transplanted to patients in the future.

There are cost and creation time problems when making a 3D printed model. We would not use these models in standard surgical procedures or in emergency cases, but in complicated cases, as in the present patient, we believe that the additional cost and time needed to create a 3D printed model may be compensated by the reduced operating time and the higher success rate of the surgical procedure [8].

In conclusion, to our knowledge, this is the first report in which a 3D printed airway model provided sufficient preoperative understanding of the anatomy and planning of the insertion of a silicone airway stent. There is great potential for this to also become a valuable educational tool.

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References