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Treatment of airway stenosis with a customized bronchial stent using a three-dimensional printer and flexible filaments

Toshihiro Ojima & Naoya Kitamura

Department of Thoracic Surgery, Kurobe City Hospital, Toyama, Japan.

Keywords
Airway stenosis, bronchial stent, Dumon stent, flexible filament, three-dimensional printing.

Correspondence
Toshihiro Ojima, Department of Thoracic Surgery, Kurobe City Hospital, 1108-1, Mikkaichi, Kurobe-City, Toyama 938-8502, Japan. E-mail: ojitoshi@hotmail.co.jp

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Abstract

Stent placement is recommended for patients with airway stenosis. However, ready-made stents may be difficult to fit over lesioned areas. In the current case report, we describe the creation and placement of a custom stent in an 84-year-old woman with airway stenosis. We made a bronchial mould and customized stent with a three-dimensional printer and flexible filaments. This stent was able to successfully maintain our patient's airway patency.

Introduction

Cancer-induced airway stenosis can cause serious ventilation disorders. In such cases, airway stenting is recommended. As it is sometimes difficult to place ready-made stents, a customized stent can be designed using chest computed tomography (CT) images. However, fitting stents over lesions can be difficult, and the stent's shape may need to be changed intraoperatively. Here, we report our experience in creating a silicone bronchial stent using flexible three-dimensional (3D) printing.

Case Report

An 84-year-old woman with progressive dyspnoea was admitted to our department upon presentation with respiratory distress (oxygen saturation (SpO_2): 80% on room air). A chest X-ray showed left atelectasis (Fig. 1A). Chest CT revealed an occluded left main bronchus (Fig. 1B). The patient was admitted to the intensive care unit, where bronchoscopy confirmed left main bronchus occlusion. Bronchial toileting was able to open the left upper bronchus, but not the left lower bronchus, which was completely occluded by a tumour and was bleeding. A later histopathological examination revealed the tumour to be an adenocarcinoma with a positive epidermal growth factor receptor (EGFR) gene mutation. After bronchial toileting, the patient's SpO_2 improved to 95% under inhaled oxygen (2 L/min flow); an X-ray revealed that the left upper lobe could almost inflate. On day 3, she had progressive dyspnoea and decreased SpO_2 caused by reocclusion of the left main bronchus. Bronchial toileting improved the path to the left upper bronchus, but the left bronchial occlusion required repeated treatment. We thus decided to place a stent to maintain airway patency before beginning chemotherapy.

We prepared a customized silicone stent using a 3D-printer and lexible filaments. We obtained 3D data of the lesioned area using Osirix MD (Pixmeo SARL, Switzerland) and chest CT data (Fig. 2A). We used the 3D-printer (DREAMER; FLASHFORGE JAPAN, Japan) to create a bronchial 3D mould with flexible filaments (FilaFlex®; Recreus, Spain), composed of a polyurethane copolymer. We then customized a ready-made stent (Dumon BD; Novatech SA, France) to fit the printed mould (Fig. 2B, C).

The patient underwent rigid bronchoscopy and customized stent placement. Tumour debulking extended the lesion's lumen, and the stent was placed from the left main bronchus to the upper bronchus, where it achieved a snug

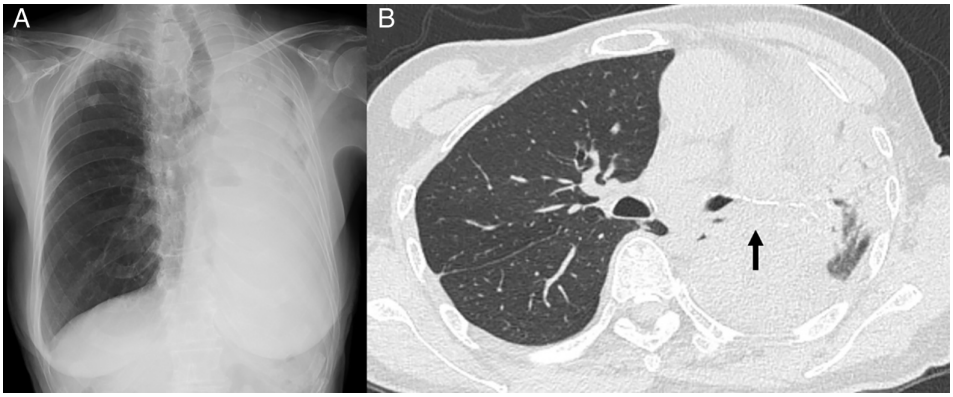

Figure 1. (A) Chest X-ray showing left pulmonary atelectasis. (B) Chest computed tomography revealing a completely occluded left main bronchus.

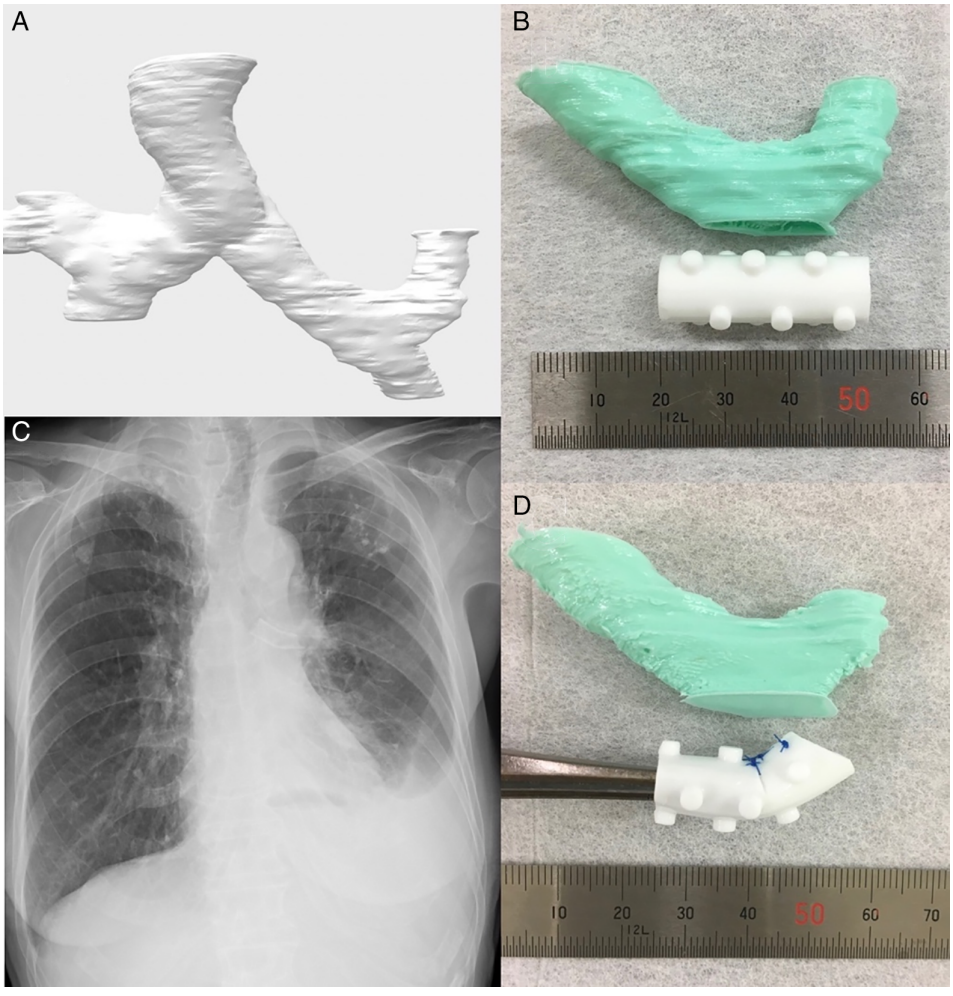

Figure 2. (A) Three-dimensional (3D) model of the patient's bronchial wall using converted STL-format data for 3D printing. (B) A 10-mm ready-made Dumon stent. (C) The stent is modified to bend with a length of 30 mm and a tapering point. (D) Chest X-ray showing that the stent is able to maintain left upper lobe airway patency.

fit and allowed the left upper lobe to maintain ventilation (Fig. 2D). The patient followed an uneventful course postoperatively. After receiving gefitinib therapy (250 mg), she was discharged from our department. Although she continued receiving chemotherapy, she died 11 months after stent placement.

Discussion

Airway stenting can act as a mediator in anticancer treatment. Because such treatments may allow the stent to be removed, we recommend removable and customizable Dumon stents for patients with airway stenosis caused by malignant tumours. Several studies have reported on the efficacy of customized stents for the treatment of airway diseases [1,2]. Freitag et al. printed a stent with polyurethane filaments for a patient with a huge gastrobronchial fistula [3]. However, the stent was made with material that was not authorized for medical procedures. Guibert et al. used a customized silicone stent, produced by a manufacturer, for a patient with bronchial stenosis after lung transplantation [4]. Reighard et al. printed a stent using computer-aided design and 3D printing for a patient requiring laryngotracheal reconstruction [5]. All groups reported that the printed stents could be easily inserted.

In the present case, we used a 3D printer and flexible filaments to make the bronchial mould and customized stent. We consider our technique to be beneficial for the following reasons: (1) 3D models are generally made from acrylonitrile butadiene styrene (ABS) copolymer or polylactic acid (PLA) copolymer, which are hard plastics. Bronchial moulds made from ABS or PLA are difficult to customize due to their hardness. However, flexible filaments have some elasticity and are easily customizable by cutting and suturing, making them suitable for bronchial stenting. (2) We customized a ready-made stent that was authorized for medical use. (3) Our stent was made on-site. Manufactured stents require a few weeks to produce. However, patients may not be able to wait this long. In addition, our 3D printer was made for personal use and is less expensive than the industrial printers ($1200). The mould we used cost just a few dollars.

Disclosure Statement

Appropriate written informed consent was obtained for publication of this case report and accompanying images.

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