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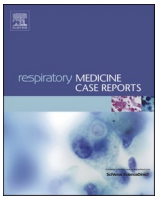

Case report

Removal of a foreign body by rigid bronchoscope after virtual reality-aided presurgical planning: A case report

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ABSTRACT

Flexible bronchoscopy is becoming increasingly important for the removal of airway foreign bodies. However, in cases of risk of coughing during the procedure, rigid bronchoscopic intervention should be performed under general anesthesia. A 22-year-old man presented with history of several episodes of fever, for which he was administered antibiotics at a private clinic. In an annual chest X-ray and chest computed tomography examination, a foreign body, which appeared to be an orthodontic appliance, was discovered in the left main bronchus. It was deemed difficult to remove the foreign body using flexible bronchoscopy because of granulation tissue formation. Therefore, the patient was referred to our institution. We simulated the clinical situation using virtual reality, which indicated that the proximal and distal metallic parts of the appliance had grown into the bronchial mucosa. First, we inserted a rigid bronchoscope under general anesthesia and cut the granulation tissue using an insulation-tipped diathermic knife. Thereafter, we removed the appliance with grasping forceps under rigid bronchoscope guidance. In cases of risk of foreign body encroachment into the bronchial mucosa or granulation tissue development, rigid bronchoscopic intervention is effective. Furthermore, a VR-based intervention may be a useful option in such cases.

1. Introduction

Rigid bronchoscopic intervention plays a major role in removing airway foreign bodies. However, flexible bronchoscopes can reach narrower bronchi. Recently developed devices (e.g., baskets, cryogenic probes) help in both diagnosis and dislodgment of airway foreign bodies [1]. The grasping forceps of the rigid bronchoscope have more power to remove foreign bodies, and operators can perform the procedure in cases of risk of the patient coughing under general anesthesia. Therefore, rigid bronchoscopy is recommended for the management of some cases.

Abbreviations: CT, computed tomography; 3D, 3-dimensional; VR, Virtual Reality; IT knife, insulation-tipped diathermic knife; APC, argon plasma coagulation.

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2. Case report

A 22-year-old man lost his orthodontic appliance one night in October 2016. In June 2017 and March 2018, he had a fever over 38 °C for a few days and was prescribed oral antibiotics at a private clinic, and his condition improved. In April 2019, an abnormality was detected in the annual chest X-ray examination. Chest computed tomography (CT) showed a foreign body lodged in the left main bronchus. Flexible bronchoscopy under local anesthesia was attempted, but it was difficult to retrieve the object using the grasping forceps of a flexible bronchoscope. Subsequently, he was referred to our institution. His physical and blood examination results were unremarkable.

Fig. 1 shows the CT images obtained at our institution (Fig. 1A and B) and three-dimensional (3D) CT (shown in Fig. 1C). The foreign body, which was the orthodontic appliance, was located the left main bronchus and some of its parts were near the pulmonary artery. The metallic wire portion of the appliance contained cobalt and chromium, and the middle part meant for attaching teeth consisted of resin. To understand the positional relationship in more detail, we created virtual reality (VR)-based simulation from CT images (2 mm thin slices) using Banana Vision™ (Colorado State University, USA), which converts the DICOM data (the ideal CT slice thickness is under 1 mm but you can be available as this case) to VR images. These images reveal foreign objects more clearly and can zoom and handle solidity. It suggested that both proximal sides and one part of the posterior side (mediastinal space side) of the appliance had grown into the bronchial mucosa (shown in Fig. 2) and a granulation tissue had formed around it. We planned to resect the granulation tissue using an Insulation-Tipped diathermic knife (IT knife), which is widely used for tumor resection in the gastrointestinal field. Before the intervention, the output was managed in VR simulation. Because the appliance was located near the pulmonary artery and inadvertent bleeding was expected, the respiratory surgeon waited and watched the intervention.

First, we inserted a rigid bronchoscope (outside diameter, 13.2 mm) under general anesthesia and closely combined it with a flexible bronchoscope. The proximal side was located approximately 3 cm from the entrance of the left main bronchus. Because of the presence of granulation tissue and sputum we changed to thin bronchoscope, and were able to pass through and reach the distal side of the appliance and found it not growing into the mucosa. Second, we excised the granulation tissue at the proximal side using the IT knife as the cut section faced the mucosa vertically (shown in Fig. 3A). Almost no bleeding occurred while cutting enough tissue to reveal the metallic parts. Thereafter, the mobility of the foreign body improved, and it was removed using grasping forceps under rigid bronchoscope guidance (shown in Fig. 3B).

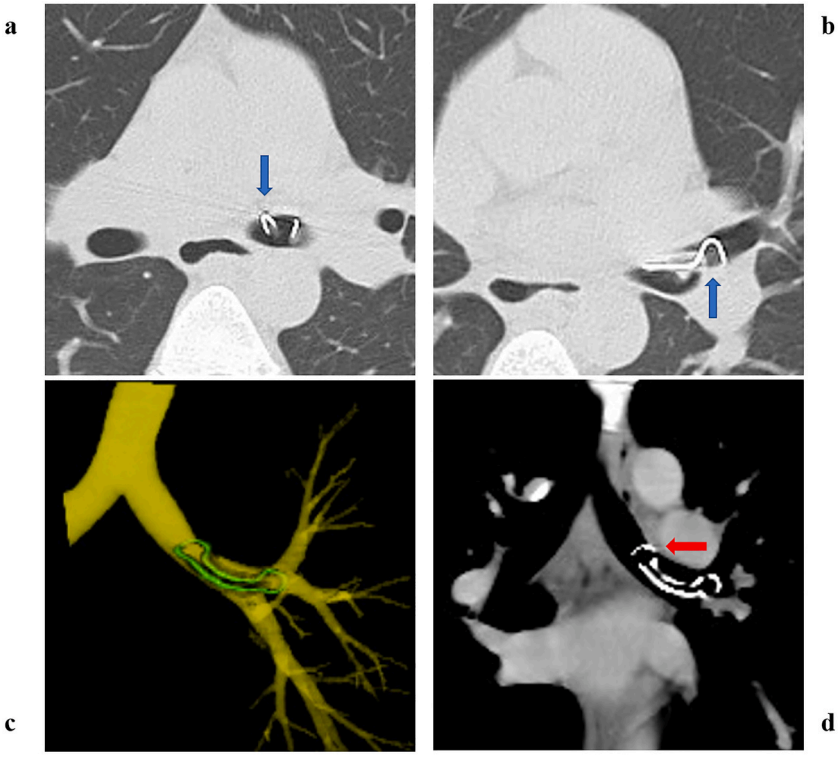

Fig. 1. Chest computed tomography (CT) shows an orthodontic appliance lodged in the left main bronchus. Anterior (a, blue arrow) and posterior portions (b, blue arrow) of the appliance appear to be embedded in the bronchial wall. (c) Three-dimensional-CT reveals the structure of the foreign body and relationship with the left main bronchus more clearly. The coronal view (d, red arrow) of contrast-enhanced chest CT shows the anterior site of foreign body embedded near the left main pulmonary artery. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

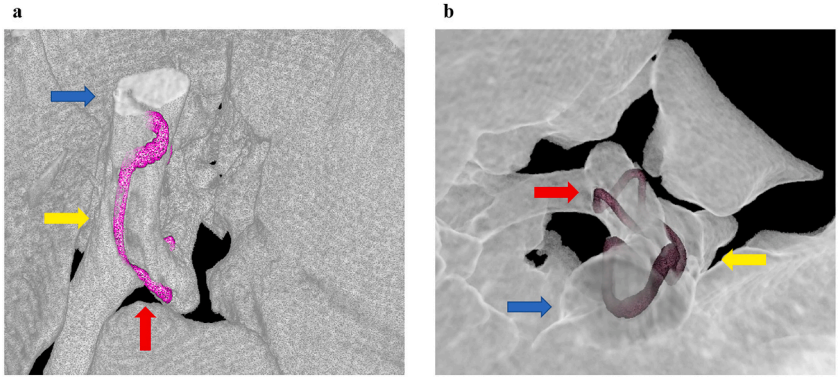

Fig. 2. Virtual reality (VR) images from the left main bronchus inlet clearly show the structure of the foreign body and can be used to evaluate it from all angles (the blue arrow indicates the anterior portion, red arrow the posterior portion, and yellow arrow the left main bronchus) (a). Using a controller, specific structures (e.g., only bronchus and pulmonary artery) could be selected and evaluated internally through the left main bronchus (b). Features like "resolution" and "ability to zoom" can help operators understand the anatomy of it, and they suggested that the anterior and posterior sides were both buried and difficult to remove. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

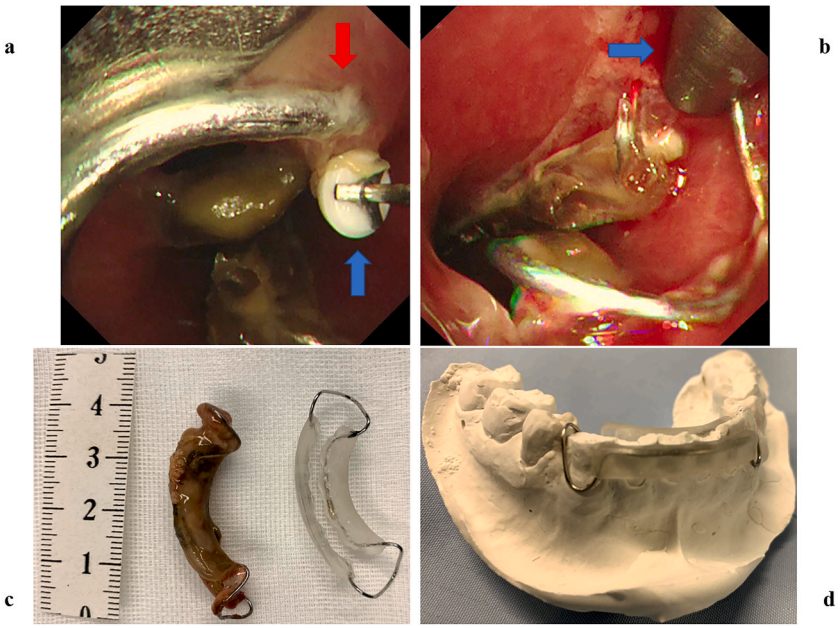

Fig. 3. (A) Insulation-tipped diathermic knife (IT knife) (indicated by blue arrow) was used to cut the bronchial wall at the proximal embedded site (indicated by red arrow). (B) The foreign body was removed by rigid forceps (indicated by blue arrow). (C) The retrieved orthodontic appliance. (D) Duplicated appliance for reference. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

3. Discussion

Airway foreign body aspirations usually occur in children, elderly persons, and adults with underlying diseases (e.g., dementia, cerebrovascular disease) or those taking sleeping pills and have a weakened cough reflex. In children, respiratory symptoms, such as cough, sputum, and fever appear, but are less frequent. Foreign bodies that are made of organic materials are not radiopaque. Therefore, the diagnostic rate of chest X-rays in the emergency room is 22.6%, and the ratio of negative radiographs with suspected aspiration varies between 5 and 30% in children to 8–80% in adults [2]. Furthermore, several reports have demonstrated lodgment of airway foreign bodies for more than several years. Airway foreign bodies located too late are often enveloped in the granulation tissue, and the risk of adverse events, such as bleeding is high. It was reported that if the duration of foreign body presence was longer than 1 month, granulation tissue was found in 89.7% of cases [3]. Furthermore, in cases where the foreign body was located after more than 3 weeks, the use of a cryoprobe to control bleeding has been recommended [4]. In this case, it took more than 2 years to locate the foreign body and granulation tissue had formed at the posterior aspect of the object; thus, it was difficult to remove it by flexible bronchoscopy.

VR is useful for presurgical planning and has immense potential as an educational tool in the field of neurosurgery. "Resolution"

and "ability to zoom" can help operators and trainers understand the anatomy of visceral tissues clearly, which is advantageous compared to a 3D printed model [5]. Sugiyama et al. reported that the VR modeling program Banana Vision™ effectively improved the surgical strategy for cerebrovascular neurosurgery [6]. In the field of respiratory surgery, the usefulness of a 3D imaging model for lung robotic segmentectomy has been reported [7]. In the field of respiratory medicine, virtual bronchoscopic navigation is common, but it is not effective in understanding the anatomical relationships in the bronchus. Using VR-based simulation, we were able to understand the invasion range and depth of the metallic parts more clearly than with 3D CT. Therefore, the planning for removal was changed to not only use gripping forceps but also to cut the granulation tissue and remove the metallic part. Thus, VR may aid in the removal of airway foreign bodies using bronchoscopic intervention (for example, airway stenosis).

In the present case, it was difficult to remove the granulation tissue by coagulation, and in order to prevent breaching the mediastinal space, we had to cut the space between the mucosa and the appliance. Therefore, it did not seem suitable to use argon plasma coagulation (APC) in this case. Furthermore, because of the risk of peeling off normal mucosa, using a cryoprobe was also not viable. Therefore, we considered cutting using an IT knife, which is widely used for endoscopic submucosal dissection in the gastrointestinal field because its cutting face is fixed in the horizontal direction. The experience of using an IT knife with bronchoscopy is rare, but Yoon et al. reported that it cuts the tracheal mucosa safely [8]. In this case, there were no adverse events, such as bleeding or bronchial injury. If the tissue needs to be cut horizontally, it may be an option, but more discussions are needed for adaptation.

Recently, several devices, such as baskets, balloon catheters, and forceps, have been introduced. Furthermore, cryoprobes can be used for foreign bodies with water content (chewing gum and mouthcare sponges) [9]. Thus, the role of flexible bronchoscopy is becoming more important. However, when respiratory fluctuation occurs due to cough, stronger gripping forceps must be used. Additionally, in cases where it is difficult to safely remove the foreign body through the vocal cords, rigid bronchoscopic intervention seems more effective.

In conclusion, it may be possible to plan for endobronchial interventions using VR-based simulation. Airway foreign bodies lodged for a long time often result in granulation tissue formation, thus the use of a rigid bronchoscope is a better alternative compared to a flexible bronchoscope in managing such cases.

Author contribution statement

Atsushi Torii, Masahide Oki, and Hideo Saka contributed substantially to the writing of the manuscript, Masaki Anzai and Chitose Honjo contributed substantially to the critical review of the manuscript, Tod Clapp and Chad Eitel contributed to the VR devices, All authors reviewed and approved the final version of the manuscript.

Ethics statement

Written informed consent was obtained from the participant for publication of the details of the medical case and any accompanying images.

Funding statement

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Declaration of competing interest

The authors have no conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rmcr.2022.101698.

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