Thoracoscopic anatomical subsegmentectomy of the right S2b + S3 using a 3D printing model with rapid prototyping

Takeo Nakadaa,*, Tadashi Akiba, Takuya Inagakia and Toshiaki Morikawab

a Department of Surgery, The Jikei University Kashiwa Hospital, Kashiwa, Chiba, Japan
b Department of Surgery, The Jikei University Hospital, Minatoku, Tokyo, Japan

* Corresponding author. Department of Surgery, The Jikei University Kashiwa Hospital, 163-1 Kashiwashita, Kashiwa, Chiba 277-8567, Japan. Tel: +81-4-71641111; fax: +81-4-71641197; e-mail: takeo521@hotmail.co.jp (T. Nakada).

Received 17 March 2014; received in revised form 26 April 2014; accepted 2 May 2014

Abstract
Thoracoscopic segmentectomies and subsegmentectomies are more difficult than lobectomy because of the complexity of the procedure; therefore, preoperative decision-making and surgical procedure planning are essential. In the literature, we could successfully perform thoracoscopic anatomical subsegmentectomy of the right S2b + S3 using a 3D printing model with rapid prototyping. This innovative surgical support model is extremely useful for planning a surgical procedure and identifying the surgical margin.

Keywords: Rapid prototyping technique • Pulmonary subsegmentectomy • Lung cancer • Thoracoscopic surgery

INTRODUCTION
Combined segmentectomy is a reasonable procedure for patients with poor pulmonary function, chronic lung disease, previous major lung resection or insufficient cardiac function, as well as for older individuals. Although segmentectomy or subsegmentectomy requires thorough knowledge of the 3D bronchovascular anatomy of the lung, we were able to perform safely thoracoscopic anatomical subsegmentectomy using a 3D printing model with rapid prototyping. The rapid prototyping technique could provide sufficient preoperative comprehension of the anatomy for anatomical segmentectomy or subsegmentectomy.

CASE REPORT
Rapid prototyping technique
Based on the volume analyser Synapse Vincent data (Fujiﬁlm Medical Co., Ltd, Tokyo, Japan) derived from contrast medium-enhanced computed tomography (CT) scans, we were able to fabricate 3D mixed-colour replicas of the pulmonary anatomy using a 3D model printer (Connex, Stratasys, Ltd, Japan). In these models, the bronchi, pulmonary arteries and veins appear in different colours because of differences in density. We obtained institutional ethics committee approval before this research. The models were durable and were taken to the operating room.

Case
An 83-year old female presented with coughing. She received medication for premature ventricular contraction and hypertension. Chest CT revealed a lung mass located in the S3 of the right upper lobe and chronic atelectatic middle lobe. Bronchoscopy biopsy was performed, and adenocarcinoma was diagnosed at a previous hospital. The patient was then referred and admitted to our hospital for the treatment of right lung cancer. Routine blood biochemistry was normal. Chest and abdominal CT, head magnetic resonance imaging and bone scintigraphy revealed cT1bN0M0 c-stage IA according to the World Health Organization classiﬁcation. The pulmonary mass was 25 mm in S3 of the right upper lobe, near S2b (Fig. 1). Preoperative respiratory function testing revealed the following: vital capacity (VC): 1.64 l, %VC: 91.1%, forced expiratory volume 1 s (FEV1.0): 1.1 l, and FEV1.0%: 70.5%. Hugh–Jones classiﬁcation was 3. We planned thoracoscopic anatomical subsegmentectomy of the right S2b + S3 that encompassed a sufﬁcient surgical margin while preserving postoperative respiratory function.
with sampling of the hilar lymph nodes in the right upper lobe. Temporary re-inflation of the ipsilateral lung was performed to demarcate the plane after bronchial divisions. Inter-segmental and subsegmental planes were divided by a stapler, keeping it 3 cm away from the tumour. The total operative duration was 335 min, and total blood loss was 100 ml.

Postoperative course

The postoperative course was uneventful. The chest tube was removed on the first postoperative day and the patient was discharged on the 4th postoperative day. Pathologically, there was no evidence of lymph node metastasis or vascular invasion. The right middle lobe showed complete fibrous organization with localized intrapulmonary haemorrhage. Five months after surgery, the patient had no evidence of recurrence.

DISCUSSION

Compared with lobectomy, the greatest advantage for patients who undergo segmentectomy is the preservation of the pulmonary parenchyma. To preserve the postoperative respiratory function, it is important to not only preserve the remaining lung volume, but also minimize surgical damage to respiratory muscle. Thoracoscopic segmentectomies or subsegmentectomies are still controversial because of their complexity. They need to detect deep pulmonary vessels and bronchi [1]. In addition, preserving adequate surgical margins is important for distinguishing between lung structures to be preserved or resected. Preoperative decision-making and surgical procedure planning are essential.

We have been advocating the tailor-made ‘virtual lung’, which shows the detailed anatomy of the bronchi, pulmonary vessels and inter-segmental plane using CT angiography and bronchography [2, 3]. Recently, we have started exploring the impact of 3D models using rapid prototyping techniques [4]. Experienced surgeons can perform this surgery without these techniques. However, we must improve the safety of surgeries and develop new surgical techniques. For inexperienced thoracic surgeons, 3D printing techniques can improve the interpretation and knowledge of the anatomy. Furthermore, using this model, surgeons can effectively plan the optimal operative procedure by detecting deep pulmonary structures and identifying surgical pitfalls. In this case, this realistic model helped us to identify the surgical margin as well as the inter-segmental plane, vessels and bronchi related to S2b + S3 in the right upper lobe more clearly than 3D CT images. Other advantages include the ease of bringing the apparatus into the operation theatre and expeditiousness in identifying the anatomy without manipulating imaging monitors. We believe that such easy-to-understand models are useful for performing complicated surgeries more safely.

Figure 1: Computed tomography (CT) images shown in (A–D) in the cranial-to-caudal direction. Chest CT revealed a lung mass located in the anterior segment (S3) of the right upper lobe and complete middle lobe atelectasis (*). The pulmonary nodule was near the anterior part of the posterior segment (S2b), and V2b (arrow) was set as an inter-segmental surgical margin.
Thoracoscopic surgeries have gained in popularity more than thoracotomy or sternotomy because they are less invasive, result in decreased general morbidity and require a shorter hospital stay [5]. We think that thoracoscopic segmentectomy is a combined surgery that preserves the lung volume with less invasiveness. As surgical techniques and imaging support systems continue to improve, thoracoscopic segmentectomy will be increasingly adopted in the near future for selected patients with small tumours, previous pulmonary resections and limited cardio-pulmonary reserve.

Conflict of interest: none declared.

REFERENCES