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Swine model for training surgeons in minimally invasive anatomic lung segmentectomy

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Background: Despite the increasing demand for thoracoscopic lung segmentectomy, the appropriate training method is not well established. Therefore, we developed a swine model for anatomical thoracoscopic lung segmentectomy training.

Methods: Three-month-old pigs, weighing 40 to 45 kg, were used in this model. Anterior segmentectomy of the left cranial lobe and segmentectomy of the most anterior left caudal lobe were performed under general anesthesia and differential ventilation. Participants from several institutions participated in this program, which included training lectures and surgical skill drills.

Results: From 2010 to 2015, 33 pigs were used for the lung segmentectomy training with 51 trainees. Eight pigs were operated on using the hybrid approach, and 25 pigs were operated on using the complete thoracoscopic approach. Among 25 pigs in which the complete thoracoscopic approach was used, conversion to thoracotomy was required in 3 pigs, owing to hemorrhage in two and failure of differential ventilation in one. The no-touch method in supine position provided sufficient intersegmental delineation of 20 (76%) planes among 26 left anterior segmentectomies in the cranial lobe.

Conclusions: Our live swine model of anatomical thoracoscopic lung segmentectomy is considered a good choice for training surgeons on how to perform minimally invasive lung segmentectomy in humans.

Keywords: Thoracoscopy; segmentectomy; training; animal model

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Introduction

With an increasing number of patients with small-sized non-small-cell lung cancer, the importance of pulmonary segmentectomy has been increasing (1,2). Additionally, indeterminate non-palpable lung nodules, including non-solid ones, are becoming frequently detected with the increasing use of computed tomography. Limited resections combined with a minimally invasive operation are highly desired in patients with these lesions (2,3); however, the procedure for thoracoscopic lung segmentectomy has been considered more complex than that for lobectomy. Particularly, the identification and dissection of the intersegmental plane are considered difficult when the resected segment becomes smaller or has two or more intersegmental planes (4,5).

When introducing a new therapeutic method, appropriate training is important to ensure patient safety and the understanding of anatomical aspects, especially for younger surgical trainees (6). Therefore, we developed a swine model for anatomical thoracoscopic lung segmentectomy training.

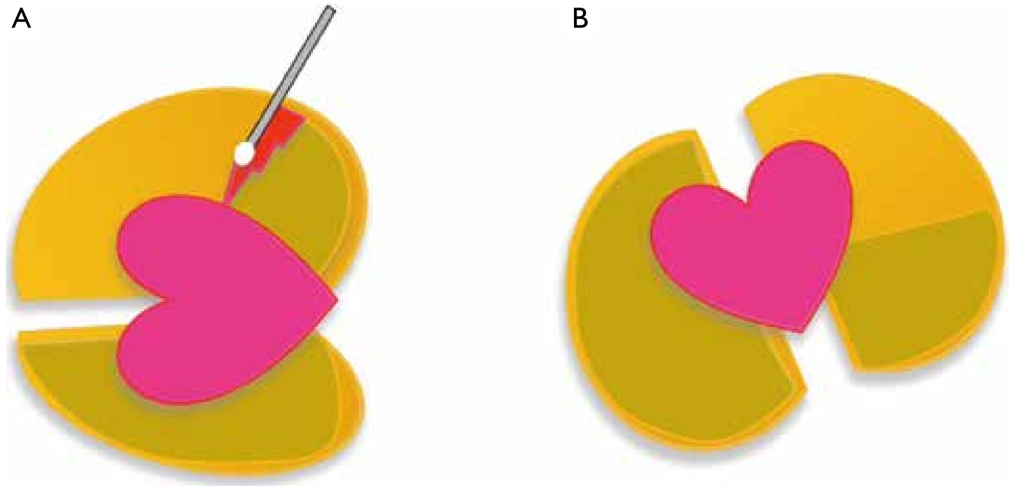

Figure 1 Effects of positioning in thoracoscopic segmentectomy of the swine lung. (A) In the lateral decubitus position, lung compression to maintain the surgical field can easy result in hematoma or alveolar bleeding of the lung parenchyma; (B) in the supine position, the lung drops downward spontaneously owing to gravity.

Methods

Our training programs were performed in the laboratory of the Medical Innovation Institute of Technology, Johnson & Johnson, Inc., Sukagawa, Fukushima, Japan. Participants from several institutes took part in training lectures and surgical skill drills with an animal (3-months-old pigs; weighing 45 kg; were used for this program). All animals received humane care in accordance with the "Guideline on the Humane Care & Use of Animals" produced by the Johnson & Johnson, Inc.

Animal model

Animals were intubated under general anesthesia, and the lung was isolated with a double-lumen endotracheal tube under controlled ventilation. They were positioned in the supine position with about a 15° to 30° body tilt to the right side. In general, the right lateral decubitus position is used to perform thoracoscopic, left anterior lobectomy training. However, this position is unsuitable for thoracoscopic lung segmentectomy training. The reason why we do not use the lateral decubitus position is because the pig's lung is fragile enough to develop hematoma or alveolar bleeding, which prevents delineation of the intersegmental plane, i.e., the inflation-deflation line, when an assistant retracts the lung to obtain a sufficient surgical field.

In our training method using the lung of young pigs, we used the supine position to avoid compression of the lung parenchyma to prevent the occurrence of hematoma or alveolar bleeding of the lung parenchyma, which was dissected later anatomically. In the supine position, the lung drops downward spontaneously after thoracotomy owing to gravity (*Figure 1*). The anesthesiologist verified that the animal was in a surgical plane of anesthesia by confirming that its vital signs were stable.

Surgical procedure and operative technique

Generally, surgeons stood on the right side of the pig, and assistants stood on the left side of the pig. Four skin incisions were made to access the left thorax, and the rib cage was retracted using a cotton sling to maintain a sufficient thoracic cavity for surgical maneuver. Nakakuki reported that the swine left lung is interpreted differently among authors, and he called the left cranial lobe the middle lob. However, it has been reported that in veterinary anatomy, the lobes of the right lung are designated as the cranial, middle, caudal, and accessory lobes, and those of the left lung are the cranial and caudal lobes, except in the horse lung (7). In our report, the left lung lobe of the pig refers to the cranial and caudal lobes. The left cranial lobe consists of anterior and posterior segments, which resembles the left upper lobe in humans that consists of the left upper division segment and lingular segment (*Figure 2*).

We collapsed the left lung under differential ventilation and started to dissect the root of the anterior pulmonary vein, avoiding compression of the lung parenchyma, as

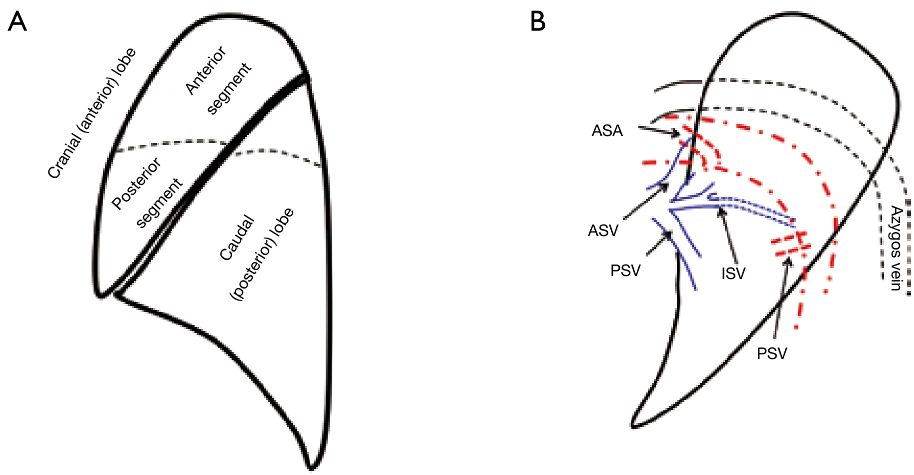

Figure 2 Schema of the swine left lung. (A) Segments in the left cranial and caudal lobes; (B) vascular structure in the left cranial lobe. ASA, anterior segmental artery; ASV, anterior segmental vein; PSV, posterior segmental vein; ISV, intersegmental vein; PSA, posterior segmental artery.

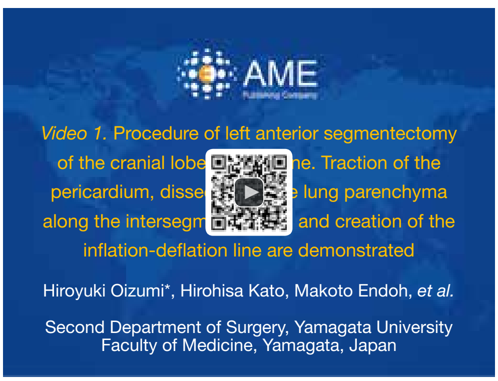

Figure 3 Procedure of left anterior segmentectomy of the cranial lobe in the swine. Traction of the pericardium, dissection of the lung parenchyma along the intersegmental vein, and creation of the inflation-deflation line are demonstrated (9).
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mentioned previously. If the visual field of an operator was obstructed by the heart, we sutured the pericardium beside the venous root and retracted it to the medial side using a percutaneous puncture hook device. Mechanical irritation of the heart caused by the manipulation of rigid instruments can also be avoided by this suture retraction as the pressure to the heart is kept uniform, and mild.

Usually, there are three main veins, anterior, intersegmental, and posterior, that resemble human veins V1 + 2, V3, and V4 + 5, respectively. The anterior vein was divided first if the intersegmental vein (ISV) was not observed; however, if the ISV was present, we first dissected the lung parenchyma along the ISV. We think this enables easy dissection of the bronchus and intersegmental plane later. Next, we encircled and divided the anterior vein. Subsequently, we opened the left pulmonary arterial sheath; isolated the first arterial branch, which resembles the anterior segmental artery (ASA) in humans; and divided it using a stapler or sealing device. Then, we dissected the bronchus of the anterior segment of the cranial lobe, encircled it using a monofilament polypropylene suture, and made a slip knot outside the thorax (8). The anesthetist started bilateral lung ventilation, and the surgeon pulled one end of the string so the knot slips, reaching the bronchus without a knot-pusher. The left lung was collapsed again, with ligation blocking the outflow of anterior segmental air. Thus the anterior segment remained expanded. Conversely, the posterior segment gradually becomes collapsed during division of the bronchus. We retracted the distal cut end of the bronchus and dissected the inflation-deflation intersegmental plane using electrocautery, an energy device, or stapler (*Figure 3*).

The merit of keeping the resected segment inflated is that we can accurately define the surgical margin distance of the lesion in an inflated segment in human lung segmentectomy.

After completing left anterior segmentectomy of the cranial lobe, we also performed resection of the most anterior segment of caudal lobe using the same method. In this second segmentectomy, the swine's position may be changed to the lateral position, as the surgical field becomes wide after the first segmentectomy and surgeons do not

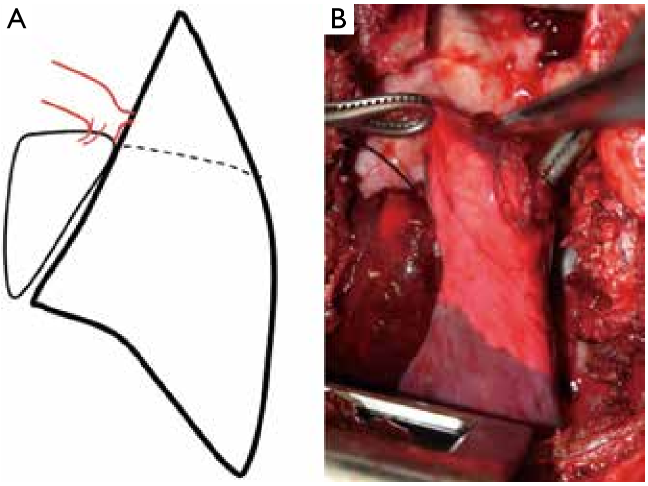

Figure 4 Segmentectomy of the most anterior caudal lobe after anterior segmentectomy of the cranial lobe. (A) Schema of the left caudal lobe after anterior segmentectomy of the cranial lobe; (B) open chest view of the inflation-deflation line created using the slip knot method.

need to avoid compression or retraction of the lower lobe (*Figure 4*).

Results

From September 2010 to September 2015, 33 pigs were used for lung segmentectomy training with 51 trainees. Eight pigs were operated on using the hybrid approach, and 25 pigs were operated on using the complete thoracoscopic approach. Among 25 pigs in which the complete thoracoscopic approach was used, conversion to thoracotomy was required in 3 pigs, owing to hemorrhage in 2 and failure of differential ventilation in 1.

In 2010, operations were preliminarily performed in the right lateral decubitus position for 7 pigs using the slip knot bronchial ligation method. Delineation of the intersegmental plane was obtained in 4 pigs; however, it was obscure in 3 owing to the occurrence of hematoma due to lung compression or retraction. Since 2011, we used the supine position, and sufficient intersegmental delineation of 20 (76%) planes among 26 left anterior segmentectomies in the cranial lobe was obtained. Additionally, sufficient intersegmental delineation of 24 (88%) planes among 26 left-most anterior segmentectomies in the caudal lobe was observed.

Pericardial retraction was performed in 9 pigs. Hemorrhage from the venous root was observed in 1 pig with this procedure, in which hemostasis was obtained by compression using a swab stick.

Discussion

The importance of surgical training is increasing for younger surgeons, especially in minimally invasive operation (6). For thoracoscopic operative training, live swine models seem to be one of the methods for lung lobectomy in various countries, and they have been used in our country. However, the systematic anatomical thoracoscopic segmentectomy model has not been clearly developed or described despite the increasing demand of this procedure.

During open thoracotomy segmentectomy, the intersegmental plane can be dissected bluntly by maintaining a sufficient margin by direct palpation of the tumor. However, during thoracoscopic operation, in which a surgeon's hand cannot be inserted directly into the thoracic cavity, it is important to perform the operation with a clear understanding of anatomy (10). Various clinical methods to delineate the intersegmental plane have been reported, and the inflation-deflation line is considered a simple, reliable way. Generally, to perform lung segmentectomy, occlusion of the segmental bronchus in an airless, whole lung is followed by expansion of the lung (11). However, clear delineation of the intersegmental plane is not consistently obtained.

Okada *et al.* described their selective segmental inflation method using jet ventilation that provided a clear intersegmental plane (11). It has the merit of enabling the precise assessment of a real surgical margin in the inflated lung, especially for malignant lung lesions; therefore, it might have become common to perform segmentectomy in some countries.

However, jet ventilation is not generally available when it comes to training models that use live animals. We described a simple slip knot method using monofilament thread to create an inflation-deflation line with our institution's standard operation procedure. We found it useful, because it enables the surgeon to ligate the bronchus during ventilation of the lung and consequently identify the inflation-deflation line while the other segments are collapsed.

Bilateral lung ventilation is needed temporarily; however, it has the following advantages: it is simple and available everywhere, as it only needs a monofilament thread; it does not require additional equipment; it does not require an experienced anesthetist to identify the bronchus appropriately.

The problem with creating the inflation-deflation line during anatomical thoracoscopic segmentectomy in swine is fragility of the lung. A hematoma or alveolar bleeding of the lung parenchyma can easily develop in young swine, which makes it difficult to provide the best inflation-deflation line; therefore, we changed the position from the lateral decubitus to semi-supine position. Intersegmental delineation has become acceptable after using this method to prevent compression or retraction of the lung parenchyma.

In lung lobectomy training, each set of two participants usually uses one pig, and the participants work together to perform single lobectomy, with each surgeon only performing part of the procedure (12). However, in our lung segmentectomy training model, one participant performs anterior segmentectomy of the cranial lobe, and then another participant performs the whole procedure of segmentectomy of the most anterior caudal lobe.

In conclusion, our live swine model for anatomical thoracoscopic lung segmentectomy is considered a good choice for training surgeons on how to perform lung segmentectomy training in humans.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: All animals received humane care in accordance with the Guide for the Care and Use of Agricultural Animals in Research and Teaching formulated by the Federation of Animal Science Societies, as well as with the Guide for the Care and Use of Laboratory Animals prepared by the Institute of Laboratory Animal Resources and published by the National Institute of Health (NIH publication no. 86-23, revised 1996). The animal care protocol in this training program was also approved by the institutional review board of Johnson & Johnson, Inc.

References

1. Asakura K, Izumi Y, Kohno M, et al. Effect of cutting technique at the intersegmental plane during segmentectomy on expansion of the preserved segment: comparison between staplers and scissors in ex vivo pig lung. Eur J Cardiothorac Surg 2011;40:e34-8.
2. Kato H, Oizumi H, Inoue T, et al. Port-access thoracoscopic anatomical lung subsegmentectomy. Interact Cardiovasc Thorac Surg 2013;16:824-9.
3. Oizumi H, Kanauchi N, Kato H, et al. Total thoracoscopic pulmonary segmentectomy. Eur J Cardiothorac Surg 2009;36:374-7; discussion 377.
4. Oizumi H, Kanauchi N, Kato H, et al. Anatomic thoracoscopic pulmonary segmentectomy under 3-dimensional multidetector computed tomography simulation: a report of 52 consecutive cases. J Thorac Cardiovasc Surg 2011;141:678-82.
5. Iwata H, Shirahashi K, Mizuno Y, et al. Surgical technique of lung segmental resection with two intersegmental planes. Interact Cardiovasc Thorac Surg 2013;16:423-5.
6. Kajiwara N, Kakihana M, Usuda J, et al. Training in robotic surgery using the da Vinci® surgical system for left pneumonectomy and lymph node dissection in an animal model. Ann Thorac Cardiovasc Surg 2011;17:446-53.
7. Nakakuki S. Bronchial tree, lobular division and blood vessels of the pig lung. J Vet Med Sci 1994;56:685-9.
8. Oizumi H, Kato H, Endoh M, et al. Slip knot bronchial ligation method for thoracoscopic lung segmentectomy. Ann Thorac Surg 2014;97:1456-8.
9. Oizumi H, Kato H, Endoh M, et al. Procedure of left anterior segmentectomy of the cranial lobe in the swine. Traction of the pericardium, dissection of the lung parenchyma along the intersegmental vein, and creation of the inflation-deflation line are demonstrated. Asvide 2017;4:213. Available online: http://www.asvide.com/articles/1523
10. Oizumi H, Kato H, Endoh M, et al. Techniques to define segmental anatomy during segmentectomy. Ann Cardiothorac Surg 2014;3:170-5.
11. Okada M, Mimura T, Ikegaki J, et al. A novel video-assisted anatomic segmentectomy technique: selective segmental inflation via bronchofiberoptic jet followed by cautery cutting. J Thorac Cardiovasc Surg 2007;133:753-8.
12. Meyerson SL, LoCascio F, Balderson SS, et al. An inexpensive, reproducible tissue simulator for teaching thoracoscopic lobectomy. Ann Thorac Surg 2010;89:594-7.

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