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Video-assisted thoracoscopic surgery in swine: an animal model for thoracoscopic lobectomy training

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Abstract

OBJECTIVES: Minimally invasive thoracic procedures have been increasingly used; however, only a small number of lobectomies are performed by videothoracoscopy, showing the need for training on this technique. The objective of this study is to demonstrate the technique of lobectomy using videothoracoscopy in swine, highlighting the steps to be taken during its use in surgical experimentation.

METHODS: During the advanced course on video-assisted and thoracoscopic procedures carried out at IRCAD Latin America, Barretos, Brazil, 40 swine were used for the hands-on course on video-assisted upper left lobectomy. Monopulmonary ventilation was performed by blocking the left main bronchus. Surgical procedures were performed using three ports and the anterior dissection technique (fissureless approach). The pulmonary hilar structures were dissected using conventional open surgery and video-assisted surgical tools. The first structure treated in the approach of the hilar structures was the upper lobe vein, followed by the bronchus and the branches of the pulmonary artery.

RESULTS: The mean time required to anaesthetize the animals was 3 h. Intraoperative hypoventilation was observed in 26 animals (65%) and 4 (10%) of them had a poor outcome and died in the last third part of the surgery. Eight (20%) animals had bradycardia, and six responded to the use of atropine. In two (5%), it was not possible to revert the bradycardia and the animals died at the end of the procedures. The surgical procedures had a mean duration of 3 h and the total time of anaesthesia was about 6 h.

DISCUSSION: Swine have been frequently used for hands-on training in surgery but there are no reports in the literature describing the anatomical, anaesthetic and technical peculiarities that must be observed during videothoracoscopic lobectomy training in swine. Video-assisted thoracoscopic surgery lobectomy using swine is an adequate method to train thoracic surgeons. For surgeons to make the best use of minimally invasive technique training, it is essential that issues related to the anatomy, anaesthesia, monopulmonary ventilation and surgical technique described in this study are taken into account.

Keywords: Thoracic surgery • Video-assisted • models • Animal • Minimally invasive surgery • Thoracoscopic surgery • Swine • Training

INTRODUCTION

Minimally invasive procedures have been increasingly used in thoracic surgery because of their benefits such as lesser thoracic drainage and hospitalization time and lower postoperative pain and complication rates. Furthermore, video-assisted thoracoscopic surgery (VATS) is recommended as the treatment of choice for early-stage lung cancer treatment [1].

However, even in more developed countries, only part of lobectomies is performed by video-assisted thoracoscopy, indicating the need of training for this technique [2]. This is especially true in countries where the workforce in thoracic surgery is young and large [3].

Several resources have been used as training methods for surgeons starting their learning curve in VATS, such as 'black boxes', simulators or even animal tissue blocks [4, 5].

However, these methods do not accurately represent the surgery in humans and animal models are mostly used when new surgical techniques are developed or for the training of surgeons [6, 7].

The use of swine in surgical research has increased in the last few years owing to the anatomical and physiological similarities of these animals with humans. It is also reasonable to suppose that this practice will tend to increase in the future due to the impossibility of using dogs in animal models [8, 9].

The objective of the present study is to report the lobectomy technique by video-assisted thoracoscopy in swine and, more importantly, highlight the peculiarities of these animals and the measures to be taken during their handling in experimental surgery laboratories.

MATERIALS AND METHODS

On 22 and 23 September 2014, during the course on advanced video-assisted and thoracoscopic procedures, carried out at IRCAD Latin America, Barretos, Brazil, swine were used as the animal model for the training of video-assisted lung resections. Animals were treated according to the norms of the Guide for the Care and Use of Laboratory Animals (Institute of Laboratory Animal Resources, National Academy of Sciences, Washington, DC, 1996) and the Ethical Principles in Animal Experimentation of the Brazilian College of Animal Experimentation (COBEA). The study was approved by IRCAD/FACISB's Ethics Committee for the use of animals (CEUA), report 034/2014.

Forty large white animals were used, 20 for each day of the course, at over 6 months of age, weighing between 25 and 30 kg, supplied by a specialized breeder and considered to be healthy after clinical examination.

After fasting without food for 8 h and water for 2 h, the surgical laboratory team including one veterinarian and five nurses specialized in intensive care administered the intramuscular preanaesthetic medication which consisted of dextro-ketamine hydrochloride 5 mg/kg, midazolam 0.5 mg/kg and acepromazine 0.1 mg/kg combined in the same syringe.

After 15 min, the animals were placed in the lateral decubitus position on the surgical table for catheterization of the auricular veins. The right auricular vein catheter was used for fluid therapy with 0.9% NaCl solution at 5 ml/kg/h using a pulsatile infusion pump. General anaesthesia was induced through the left ear catheter with thiopental 4 mg/kg or until the animal no longer presented medial lid reflex, and there was a consequent lack of laryngotracheal reflex.

The swine were then placed in the dorsal decubitus position with maximal neck extension. Tracheal intubation was performed with a 7.5- or 8.0-mm orotracheal tube balloon cuff.

After fixation of the orotracheal tube, the three-way adaptor of the 9-Fr endobronchial blocker (Arndt Endobronchial Blocker, Cook Medical, USA) was connected to the distal end of the tube and the branch dedicated to ventilation was connected to the inhalation anaesthesia device with a universal vaporizer for the administration of 3.0% isoflurane, diluted in 1 l/min with FiO_2 of 1. An anaesthetic circuit with partial inhalation of gases was used and the animals were maintained on pressure-controlled ventilation and at a maximum peak of 12 cmH_2O and 30 breaths per minute [9].

After 30 min of anaesthesia, the swine were then placed in the right lateral decubitus position and the upper and lower limbs were immobilized. The endobronchial blocker was then placed in the left main bronchus with the help of a bronchofibrescope (Karl Storz). Bronchofibroscopy was also used to check if the upper right lobe was not inadvertently blocked by the orotracheal tube.

One hour prior to the beginning of the procedures, a 2-mg/kg lidocaine bolus was administered followed by a continuous 50 μg/kg/min infusion diluted in 0.9% NaCl solution. The isoflurane concentration was adjusted for each animal to maintain an adequate anaesthetic level [10, 11].

Monitoring was started after the left lung was blocked. The nurses (one for every four animals) took turns on the tables measuring oxyhaemoglobin saturation and heart rate with an oximeter placed on the tongue of the animals. Normal heart rate was considered as 80–120 beats per minute and bradycardia as less than 50 beats per minute.

Adjustments in the respiratory rate of the ventilator and/or recruitment manoeuvres, with a peak pressure of 15 cmH_2O and a 5-s pause, were made if O_2 saturation of the animals went below 95% [12].

The parameters used to evaluate the depth of anaesthesia were heart rate, a decrease in tone of the mandibular muscles and toe and claw reflex, where pain reaction was tested by the absence of leg withdrawal following a toe pinch stimulus and the lack of reflex at pinching of the tail [9, 13].

Left side ventilation blockage was only performed moments before the beginning of surgical procedures.

Surgical technique of upper left lobectomy

Surgical procedures were performed with three ports using the anterior dissection technique (fissureless approach) [14].

The procedures were started with a 4-cm incision in the fourth left intercostal space. The lens was introduced in the pleural cavity using this incision, and two ports were placed under direct visualization: a 11.5-mm port in the medial position in the seventh intercostal space to place the 10-mm 30° lens (Karl Storz, Germany) and another 15-mm posterior port in the eighth intercostal space to assist the passage of the endoscopic stapler (Fig. 1).

Although there were thoracoscopic instruments available, dissections of the pulmonary hilar structures were performed mainly using conventional open surgery and video-assisted surgery tools. The lungs were pulled posteriorly and the assistants maintained the upper lobes pulled upwards using atraumatic graspers through the auxiliary ports.

Dissections were performed by utility incisions and the upper lobe vein was the first structure to be dissected. After complete isolation, the vein was sectioned and stapled (Endo GIA Ultra, Covidien) with an articulating beige load for vascular tissues (Curved Tip 30 mm Reload), introduced by the auxiliary port (Fig. 2).

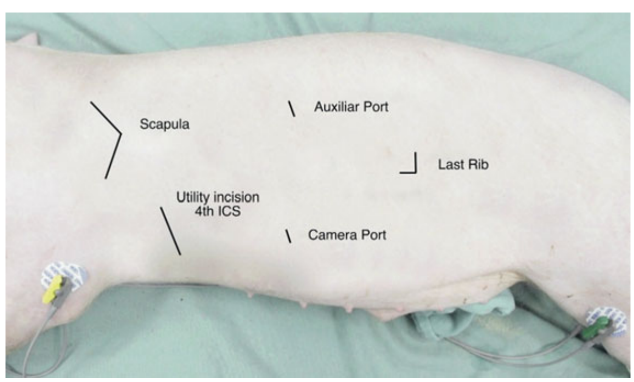

Figure 1: Animal position, port placement and utility incision in the 4th intercostal space.

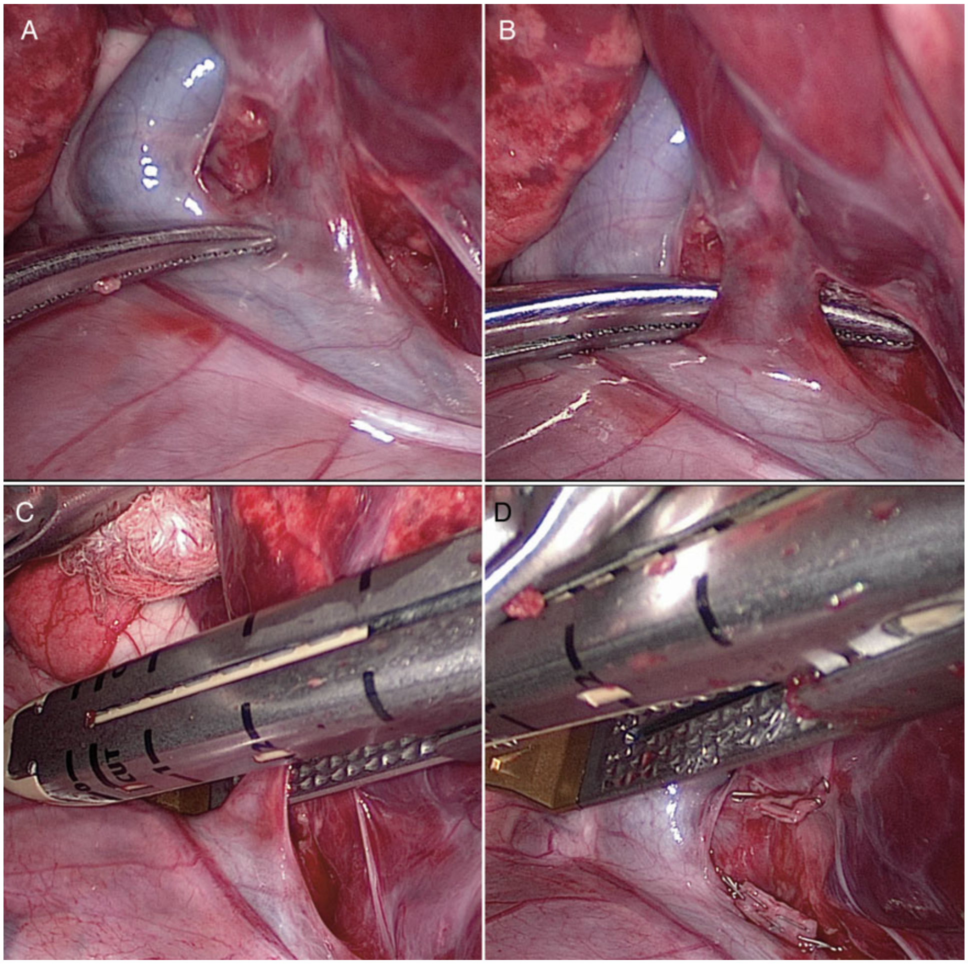

Figure 2: Vein approach: (**A**) left upper lobe vein; (**B**) vein dissected; (**C**) stapler positioned with curved tip load; (**D**) vein stapled and sectioned.

Next, the upper lobe bronchus was dissected using a vessel sealing device (LigaSure 5 mm Blunt Tip, Covidien). After complete dissection, the bronchus was clamped and the ipsilateral lung was ventilated to guarantee permeability of the lower lobe bronchus. The upper lobe bronchus was then stapled and sectioned with the stapler using an articulating load for thick tissues (Curved Tip Black 45 mm, Covidien), introduced by the auxiliary port (Fig. 3).

With a grasper that was introduced through the utility incision, the distal bronchial stump was pulled, and the pulmonary arteries of the upper lobe were dissected and isolated. Swine usually have two or three arterial branches for the upper left lobe. After a complete identification of the arteries, vascular clips were used for proximal control and LigaSure for distal division, or they were stapled and sectioned using an articulating beige load for vascular tissues (Tri-Staple Curved Tip 30 mm, Covidien), which was introduced by the assistant (Fig. 4). Fissure division was completed with one or two firings of 45-mm articulating black reload, and the upper lobe was removed from the cavity (Fig. 5).

RESULTS

The mean time required to prepare and anaesthetize the animals before the surgical procedures was 3 h. Monitoring was performed intermittently with 5- to 10-min intervals between each animal.

With regard to the anaesthesia, the balloon cuff of one (2.5%) of the bronchial blockers was perforated and had to be replaced. Six (15%) of the other bronchial blockers had to be repositioned during the procedures because they were dislocated and were introduced too distally in the bronchia of the animals. In another case (2.5%), the bronchial stapling included the blocker, but this did not prevent the procedure from being concluded.

Intraoperative hypoventilation after blockage of the left bronchus was observed in 26 (65%) animals, which required recruiting manoeuvres, increase of respiratory rate or temporary bilateral ventilation. Four (10%) of them had a poor outcome and died in the last third part of the surgery.

During the procedures, 12 (30%) animals had sinus tachycardia but, in only 2 animals (5%), a deeper anaesthetic level was required. Four other animals (10%) had sinus tachycardia. The mandibular tone in these animals was increased when compared with the others and isoflurane vaporization was adjusted to 3.0%. After 2 min, the anaesthetic level was stabilized and the procedure was restarted.

Eight (20%) animals had bradycardia, and six responded to the use of atropine. In two (5%), it was not possible to revert bradycardia and the animals died at the end of the procedures.

The surgical procedures lasted a mean time of 3 h and the total time of anaesthesia was ~6 h.

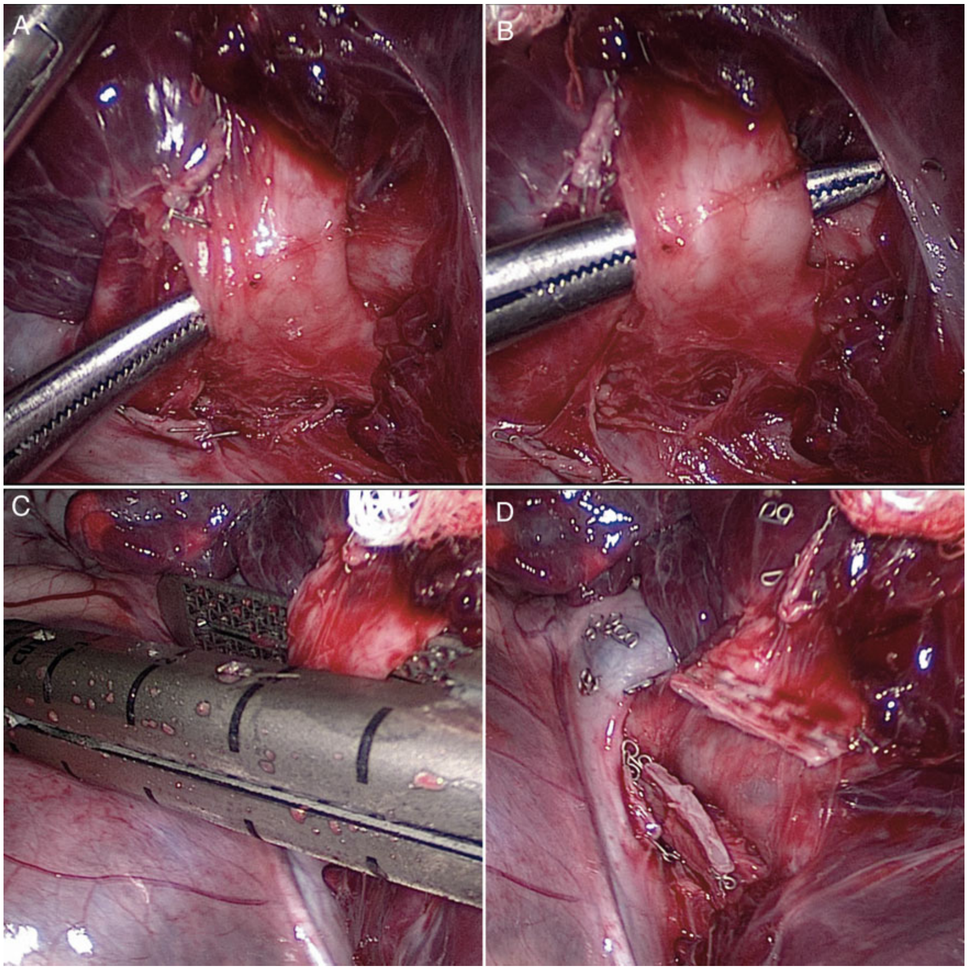

Figure 3: Dissection and stapling of bronchus: (**A**) upper lobe bronchus; (**B**) bronchus encircled; (**C**) stapler positioned with black load; (**D**) bronchial stump after stapling.

DISCUSSION

Computer simulation is a great resource as a method of surgical training because of the possibility of direct monitoring of surgical characteristics such as economy of movement and tissue handling. Unfortunately, computer simulation is not a disseminated resource in our country. And even in places where they are available, usually they are not available in so great a number (20) as were the number of attendees for each session of the present course.

On the other hand, dealing with animal models raises ethical questions and there is a trend in avoiding such practice. A recent released announcement of the ESTS School at the Congress: Practical Skills Workshop to be conducted during the 2015 European Congress stated '...to experience cutting edge technology on porcine tissue', showing that live animals will not be used, only porcine tissue. But in a situation where computer simulators were not available, the animal model was an unavoidable option. And in this scenario, it is essential to get Ethics Committee approval and treat the animals with the agreed standards of animal care, as explained in the Methods section.

Swine have been largely used for training in gastrointestinal, gynaecological and cardiovascular surgery. However, there are no reports in the literature describing anatomic, anaesthetic and technical peculiarities that must be observed during training in VATS lobectomy in swine. Furthermore, complications associated with surgeries involving the cardiovascular system are different from those associated with lung surgeries [9].

The anatomical characteristics of the pig as a thoracic surgery model are not ideal since the pig has a narrow and short thoracic cavity when compared with its whole size. The use of larger animals does not solve this problem. Swine weighing more than 30 kg increase their musculature but do not significantly develop their rib cage. Therefore, the working space is reduced and to avoid injuring sub-diaphragmatic organs, it is convenient that the ports are placed under direct visualization. In addition, the visceral pleura and the pulmonary tissue are fragile and may be easily lacerated causing bleeding.

Swine have a poor cardiopulmonary reserve, which makes them susceptible to cardiac arrhythmias such as tachycardia and ventricular fibrillation, both spontaneous and induced. Avoiding manipulation of the pericardial region or inhibiting preoperative stress by means of preanaesthetic medication as was the case in this series helps reduce the incidence of arrhythmias in the animals.

In the intraoperative period, continuous lidocaine infusion may be used to decrease myocardial sensitivity to arrhythmias [11, 15, 16].

Of the 8 cases of bradycardia observed in this series, only 2 did not respond to the use of atropine. However, there is recommendation in the literature that atropine should be used prophylactically

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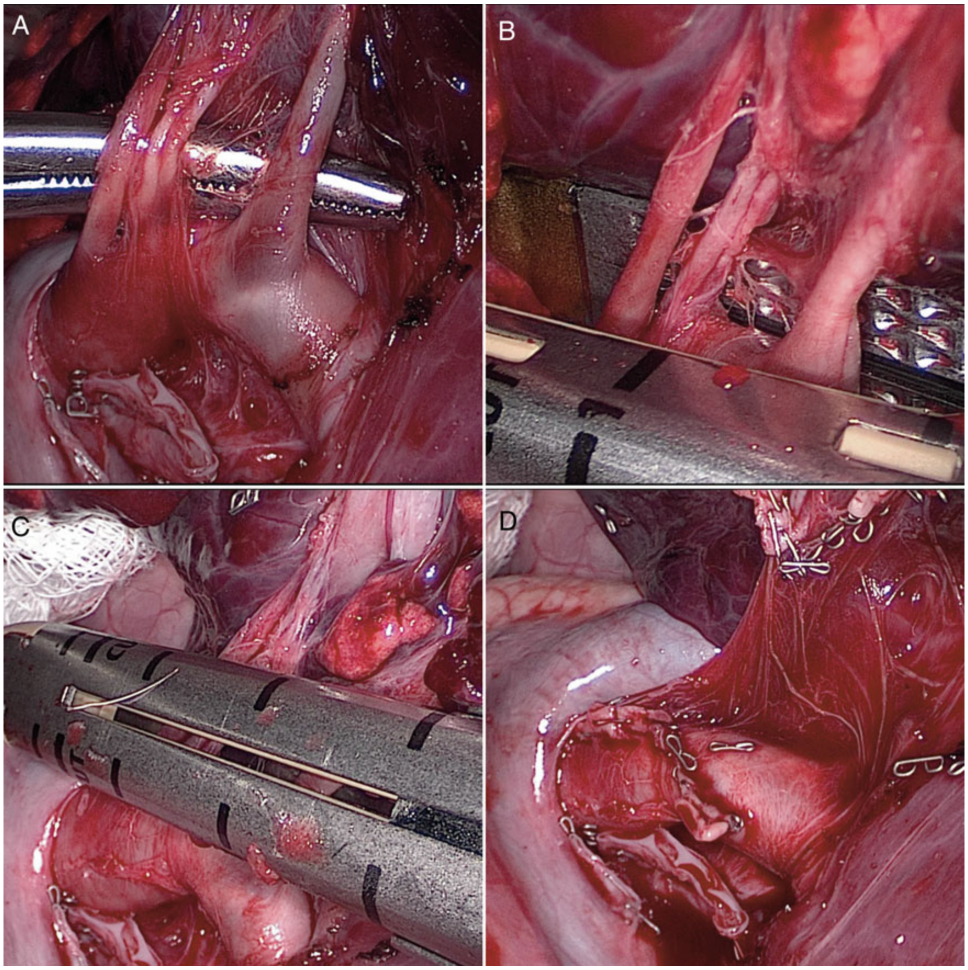

Figure 4: Upper lobe arterial approach: (**A**) arterial branches dissected; (**B**) stapler introduced without vascular injury; (**C**) stapler in the correct position avoiding the left main artery; (**D**) stumps of vein, bronchus and arteries.

before bronchial clamping and trans-sectioning to avoid undesirable vagal responses [9].

During intubation, it is difficult to visualize the glottis due to the extremely caudal position of the epiglottis in the oral cavity. Thus, a safe exposure of the epiglottis is essential for a successful intubation [13].

In right side procedures, monopulmonary ventilation should be performed with left selective intubation using a 28- or 35-Fr double lumen tube, or a simple 7-Fr tracheal tube. Because these tubes do not reach the left main bronchus by orotracheal access, they must be introduced by tracheostomy.

For left side procedures, monopulmonary ventilation should not be used with selective intubation. As the right upper lobe bronchus originates directly from the trachea, right, selective intubation does not ventilate this lobe, causing desaturation and hypoxaemia. Therefore, for left side procedures, ventilation with simple orotracheal intubation and left endobronchial blocker is recommended, as it was the case in this series.

In our series, we had 4 (10%) deaths due to hypoxaemia. In these cases, it is indicated to increase the respiratory rate with the use of 5 cmH_2O positive end-expiratory pressure (PEEP), which was not done because the ventilators did not have PEEP available [17, 18].

Even though the nomenclature is not the same in the literature, swine have four pulmonary lobes on the right side: the cranial or upper lobe (with a direct origin from the trachea), the median, caudal or lower lobe and the intermediate or mediastinal lobe. On the left side, there are the cranial or upper lobes, and caudal or lower lobes. The lobes are not proportional in terms of size and weight and the lower ones are larger than the upper ones [19].

VATS lobectomy training may be performed on the right or left side. On the right side, the median lobe is the best to perform this procedure since it has an adequate size and is not as big as the lower ones. The vascular structure and the bronchus have a good calibre for dissection and clamping of the structures may be performed through the fourth or fifth intercostal space. On the other hand, the upper lobe has a cranial position and its vascular structures are thin. The lower lobe is large and hard to manipulate.

On the left side, the upper lobe is the best option, since it is not as large as the lower one, has adequate vascularization and bronchus for dissection and is easily accessed from the fourth or fifth intercostal space. Another advantage is that the anatomy of this lobe in swine is similar to the human anatomy. Therefore, upper left lobectomy is the procedure of choice for VATS lobectomy training.

In terms of the technique, VATS lobectomy in swine may be performed with one, two, three or four ports. The single port or the four-port technique are the most difficult ones, due to the small rib cage of swine. In this animal model, training with two or three ports is more effective. To train beginning surgeons, the use of three ports is recommended. For those with more experience, two ports may be used [20].

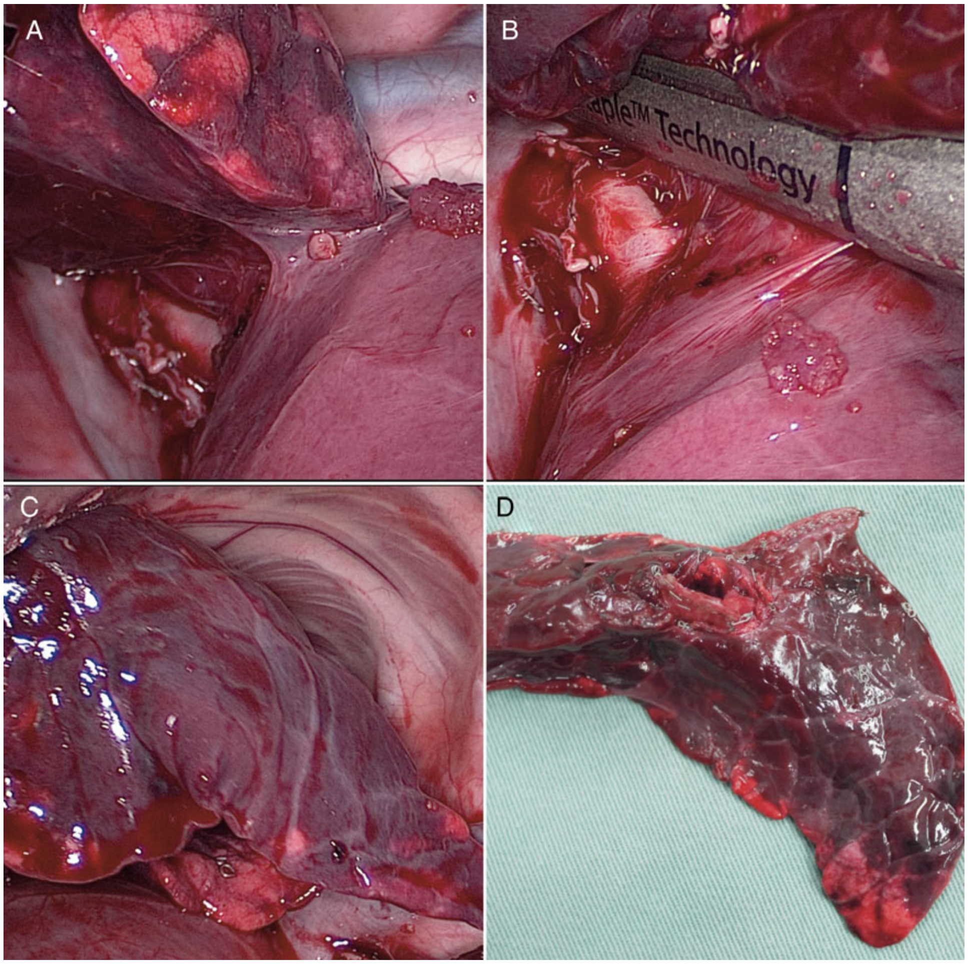

Figure 5: (**A**) Left pulmonary fissure; (**B**) fissure stapling; (**C**) lobe removal; (**D**) left upper lobe at the end of the procedure.

Even though there is a specific surgical instrument for VATSs, these procedures may be performed using conventional long instruments. It should be noted that the pulmonary parenchyma in swine is fragile and must be handled carefully.

In terms of the animal model, the anatomy of sheep is closer to human anatomy than swine, and their thoracic cavity is wider [21]. On the other hand, they are more expensive, and besides the monetary problem, we could not find a specialized breeder of sheep in the neighbourhood. As until now the use of sheep has not been well known in that area, we hope to find breeders as soon as the interest in these animals as surgical models increases.

In this scenario, VATS lobectomy in swine is an adequate method to train thoracic surgeons and to make the best use of minimally invasive technique training, it is essential that issues related to the anatomy, anaesthesia, monopulmonary ventilation and surgical technique described in this study are taken into account.

Conflict of interest: none declared.

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