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CASE REPORT

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Chest wall lift for thoracoscopic lung lobectomy: Technique and results in two cats

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Abstract

Objective: To report the technique and outcomes of utilizing chest wall lift to perform thoracoscopic surgery in two cats.

Study design: Short case series.

Animals: Client-owned cats ($n = 2$).

Methods: A geriatric cat was referred for pleural effusion secondary to a left cranial lung lobe mass. A thoracoscopic exploration of the left hemithorax was planned with a lift device used for laparoscopy and attached to a ceiling mount. A young cat was referred for a foreign body lodged in the right caudal bronchus. Attempted bronchoscopic retrieval was unsuccessful. Thoracoscopic lung lobectomy was planned using a bent Steinmann pin as a lift device placed at the eighth intercostal space, along one of the cannula.

Results: Thoracic lift was achieved with the patient in right lateral recumbency for the first cat, leading to immediate improvement in the oxygenation and ventilation status of the patient while simultaneously allowing for continued thoracoscopic exploration of the hemithorax. With two additional ports, thoracoscopic dissection of the adhesions was performed prior to thoracoscopic assisted lung lobectomy at the fourth intercostal space. For the second cat, thoracic lift was performed with the patient in left lateral recumbency and allowed successful 3-port thoracoscopic lung lobectomy. No complication related to the use of either lift device was noted.

Conclusion: Chest wall lift improved anesthesia respiratory status in one cat and increased the working space to perform thoracoscopic procedures in both cats.

Clinical significance: This novel and simple technique could increase working space without anesthesia impairment, allowing thoracoscopic procedures in selected feline patients.

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1 | INTRODUCTION

With the growing enthusiasm of pet owners for minimally invasive surgeries,[1] requests to achieve standard thoraco-abdominal surgeries through smaller incisions are increasing. The reported benefits of key-hole surgeries over standard approaches include improved visualization, decreased postoperative pain, shorter hospitalization times, faster return to normal activity, and decreased wound complications.[2,3] Small patients such as cats create unfavorable conditions with a narrow working space and insufficient distance between ports.[4] However, simple and advanced laparoscopic procedures have been successfully performed in cats and smaller mammals.[5,6] The compliance of the abdominal wall allows for increased working-space with carbon dioxide insufflation (CDI). In contrast, the more rigid ribs and sternum significantly limit expansion of the chest wall, and intrathoracic CDI increases working space by compressing the organs, causing significant cardiorespiratory compromise.[7] One-lung ventilation (OLV) is the most popular technique to increase visualization and working space in the chest by freeing one side of the thoracic cavity of pulmonary parenchyma and motion.[8] Simultaneous use of CDI and OLV has been evaluated in an experimental study in cats, but was noted to be time consuming and unsuccessful in nearly half of the attempts.[9]

The chest wall compliance per unit lung volume of cats is more than 23 times and 16 times higher than that of men and dogs, respectively.[10] The thoracic wall is consequently more flexible, and added to the smaller feline bodyweight, significantly less force is needed to compress or expand the chest in cats.

Lifting the sternum was first introduced in the human literature in the 1970s to improve access to the cranial abdomen during vagotomy,[11,12] and it was revisited more than a decade later for transcervical thymectomy.[13] Retractors connected to metallic rods or chains were fastened to rigid poles while lifting the sternum as forcefully as possible.[11,12] Lifting the thoracic wall during thoracoscopy was first reported in the 1990s to improve working space during a mediastinal approach.[14] Several methods to lift the sternum, costal arch or ribs have been reported since then for thoracic endoscopic surgeries.[15] Each device aims at improving operability while remaining minimally invasive and user-friendly,[15] but they remain too large for the smaller thoraxes of small animal patients.

Lift laparoscopy has been successfully reported for gas-less surgery in client-owned cats,[16] but to the best of our knowledge, the veterinary literature is devoid of reports on using thoracic chest wall lift. The purpose of this small case series was to describe utilization of this novel technique during thoracoscopic surgery and report its outcome in two cats. We hypothesized that this technique would increase the visibility and working space sufficiently enough to allow thoracoscopic exploration and manipulations.

2 | MATERIALS AND METHODS

2.1 | Signalment and preoperative findings

Cat 1 was a 14-year-old female spayed domestic short-hair cat (bodyweight: 3.5 kg) referred for pleural effusion. The cat had a 3-week history of lethargy and decreased appetite, with dyspnea over the last few days. Thoracic radiographs revealed a large amount of pleural effusion, which was drained percutaneously via thoracocentesis. Macroscopic and microscopic fluid analysis was consistent with sterile serosanguinous effusion, with marked neutrophilic inflammation. A complete blood count revealed marked neutrophilia ($35 \times 10^3/\mu L$). Serum chemistry and ELISA tests for FeLV, FIV, and heartworm were unremarkable. A thoracic computed tomography (CT) was performed without and with contrast (Figure 1A). A left cranial lung lobe mass was identified, with multiple nodules on most lung lobes and within the chest cavity, and enlarged sternal lymph nodes noted. Despite the main suspicion of pulmonary carcinoma with intrapulmonary and pleural metastases and the grave prognosis given, the owner requested surgical exploration and removal of the mass if possible.

Cat 2 was a 7-month-old female spayed domestic short-hair cat (bodyweight: 3.6 kg) referred with a 6-day history of coughing. Complete blood work was within normal limits. Thoracic radiographs were performed and a foreign body (FB) was noted in the right caudal mainstem bronchus (Figure 1B). Bronchoscopic retrieval was attempted but unsuccessful: a glass FB was visualized with a moderate amount of purulent discharge and could be grasped but traction led to breaking off a small piece off its edge because it was too firmly anchored to be dislodged. The cat was awakened without complication.

2.2 | Preparation and anesthesia

2.2.1 | Cat 1

Premedication consisted of fentanyl (3 μg/kg intravenously [IV]) followed by midazolam (0.2 mg/kg IV) while providing flow-by oxygen at 1 L/min. Anesthesia was induced with propofol (2.2 mg/kg IV) and ketamine (1.1 mg/kg IV). Anesthesia was maintained with

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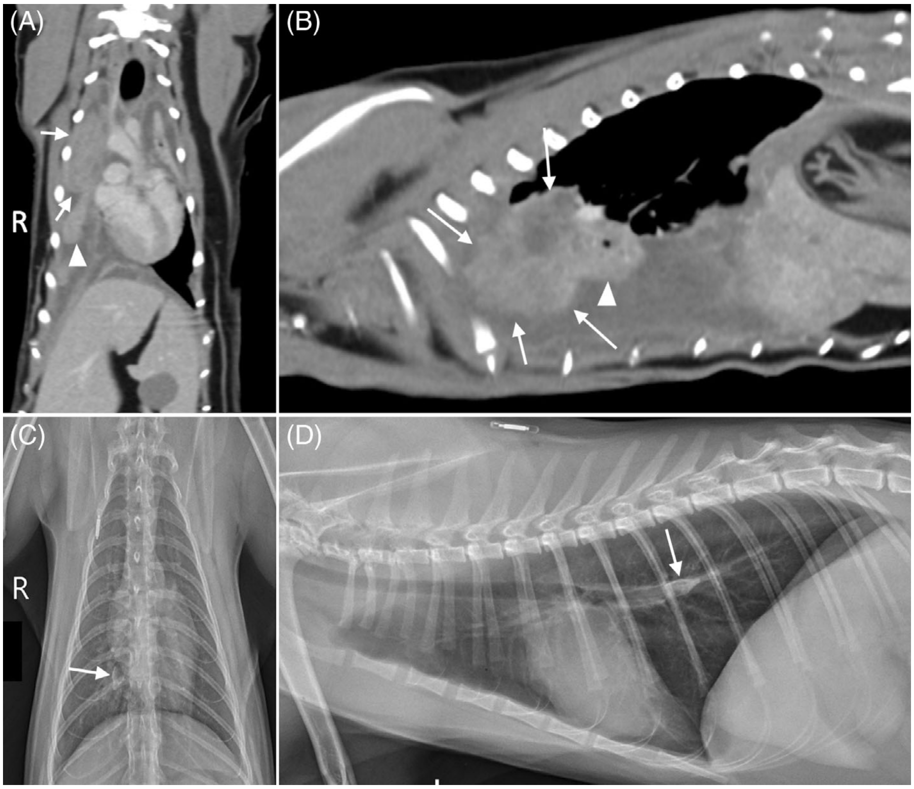

FIGURE 1 Preoperative imaging for (A) Cat 1 (top row), and (B) Cat 2 (bottom row) showing the location of the lesions. On Cat 1 images, note the hypodense and heterogenous cranial subsegment of the left cranial lung lobe (arrows) compared with atelectatic caudal subsegment (arrowheads). On Cat 2 images, the arrows point at the foreign body.

sevoflurane titrated to effect in 1–2 L/min of 100% oxygen carrier gas, ketamine (10 μg/kg/min continuous rate infusion [CRI] IV) and fentanyl CRI (0.1–0.3 mg/kg/min IV) titrated throughout the procedure. Lactated Ringer's solution was administered at 3 mL/kg/h IV during surgery as well as ampicillin sodium/sulbactam sodium at 30 mg/kg IV every 90 min intraoperatively.

After positioning the cat in right lateral recumbency, the left lateral thorax and cranial abdomen were clipped and prepped with chlorhexidine gluconate surgical scrub 4% diluted to 50:50 with sterile water for irrigation. An intercostal block (T9–12) was performed with 1.25 mg bupivacaine.

During preparation, the patient exhibited mild hypoxemia, with oxygen saturation ranging between 92% to 95%. An arterial blood gas indicated an inappropriately low PaO_2 of 179.4 mmHg for a patient receiving 100% oxygen (PaO_2/FiO_2 ratio of 179.4). Manual ventilation was started to address the hypoxemia. Once the patient was moved into the operating room, intermittent positive pressure ventilation (IPPV) was performed using volume-controlled ventilation, started at a tidal volume (TV) of 40 mL, peak inspiratory pressure (PIP) of 10 cmH_2O and adjusted as needed throughout the procedure to maintain acceptable ventilatory parameters. A dopamine CRI was titrated throughout the anesthetic period due to mild hypotension. Throughout the anesthesia, the patient also experienced periods of intermittent tachycardia, mild bradycardia, and hypotension. The patient depended on oxygen delivered via facemask during recovery after extubation.

2.2.2 | Cat 2

Premedication consisted of dexmedetomidine (5 μg/kg IV) with hydromorphone (0.1 mg/kg intramuscularly [IM]). Anesthesia was induced with propofol (0.5 mg/kg IV), ketamine (0.5 mg/kg IV), and midazolam (0.2 mg/kg IV). Maintenance and preparation were performed similarly to the first cat, with the cat instead being placed in left lateral recumbency. An intercostal block was performed with 1.5 mg bupivacaine at the anticipated surgical site (exact intercostal nerves blocked were not recorded). The patient was maintained on sevoflurane titrated to effect administered in a 100% oxygen carrier gas and a ketamine CRI (10 μg/kg/min). Cefazolin (22 mg/kg) was administered intraoperatively every 90 min. Upon moving into the OR, the patient received IPPV, started at TV 20 mL, PIP 8 cmH_2O and adjusted as needed throughout the procedure to maintain acceptable ventilatory parameters. Oxygen saturation was within normal limits throughout the entire procedure, and arterial blood gas prior to the start of surgery and prior to recovery from anesthesia indicated PaO_2 of 512.4 and 358.0 mmHg, respectively. Bradycardia was treated

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with glycopyrrolate (0.01 mg/kg) intraoperatively. The patient received an additional dose of hydromorphone (0.05 mg/kg) followed by a fentanyl bolus (2 μg/kg) and subsequent fentanyl CRI IV (0.1–0.3 mg/kg/min) titrated to effect intraoperatively due to suspected reactivity to surgical stimulation, as indicated by periods of increased blood pressure and heart rate. A bolus (5 mL/kg) of Lactated Ringer's solution was also administered in response to an increase in heart rate. The patient experienced excitement in recovery that was treated with dexmedetomidine (2 μg/kg IV), propofol (0.5 mg/kg IV), and acepromazine (0.01 mg/kg IV) for sedation for possible emergence of delirium and anxiety, followed by flumazenil (0.01 mg/kg) for potential paradoxical excitation from midazolam, and naloxone (0.01 mg/kg IV) for potential opioid dysphoria, but was able to maintain normal oxygen saturation after extubation.

2.3 | Surgical treatment

2.3.1 | Cat 1

A 5 mm skin incision was made in the middle of the 10th intercostal space with a #11 scalpel blade. The subcutaneous fat was bluntly dissected away from the deeper tissues. Hemostasis of bleeding vessels was achieved using bipolar electrocautery. Using a mosquito forceps, the intercostal muscles were bluntly dissected until entry into the thoracic cavity was confirmed through establishment of a pneumothorax. The forceps were replaced by a 3.9-mm threaded endoscopic cannula (Ternamian Endo-TIP; Karl Storz Endoscopy, Goleta, California) fed with a 3.3-mm 30° endoscope (Hopkins Telescope, Karl Storz Endoscopy). Exploration of the thoracic cavity was limited due to the small intrapleural space. A 10 mm incision was made cranial and ventral to the first incision, at the sixth intercostal space, to insert a custom made lift device used for laparoscopy as described previously (Figures 2A, 3B and 6).[17] The thoracic wall was gently lifted manually while effect on the thoracic volume was monitored with the endoscope (Figure 3C). Once maximal effect was deemed to be achieved, the device was attached to a ceiling mount using a sterilized 2-inch self-adhering cohesive bandage (Vetrap Bandaging Tape, 3 M, St. Paul, Minnesota) (Figure 2A). When the lift was performed, there was a noted improvement in oxygenation status as indicated by an improvement in oxygen saturation, with oxygen saturation at 95% reaching above 98%. Recheck PaO_2 (306.3 mmHg) on arterial blood gas later in the procedure was improved from that collected at the beginning of anesthesia. Upon exploring the chest cavity, pleural nodules on the thoracic wall and broad adhesions between the cranial lung mass and the thoracic wall over the third and fifth ribs were identified (Figure 3D). Two additional 5 mm instrument portals

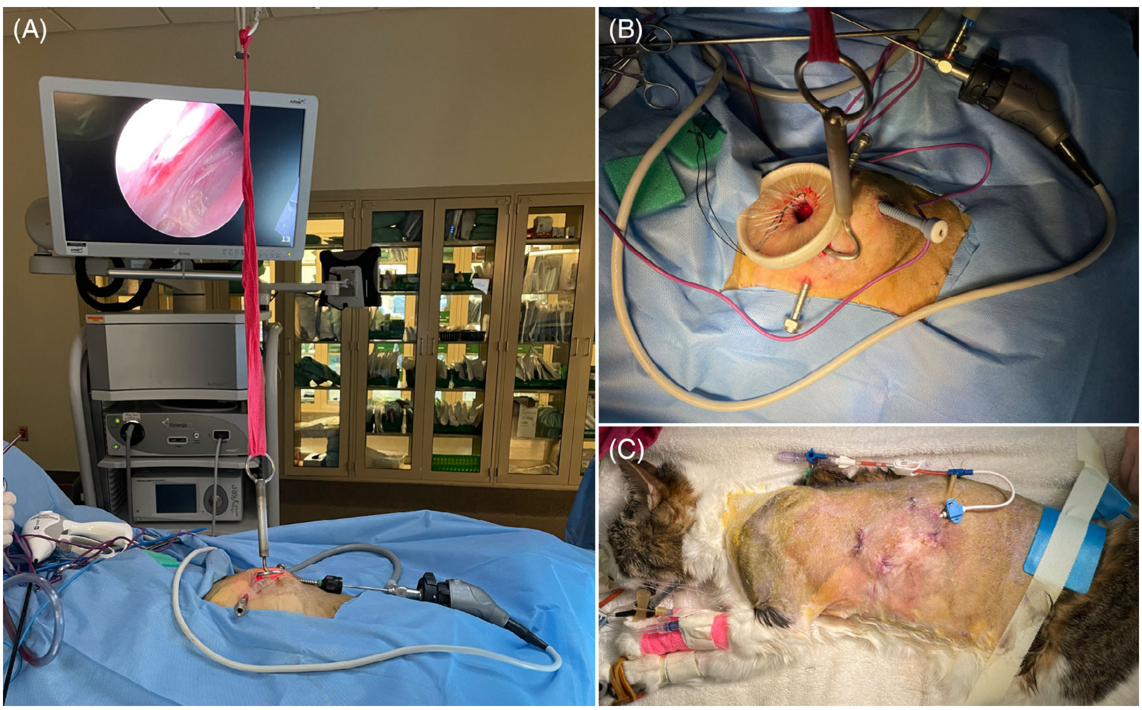

FIGURE 2 Intraoperative images of Cat 1. (A) The lift device used for peritoneal lift has been placed and hanged to a ceiling point. (B) The wound retractor has been placed. (C) Intrapleural drain and wounds closed prior to recovery.

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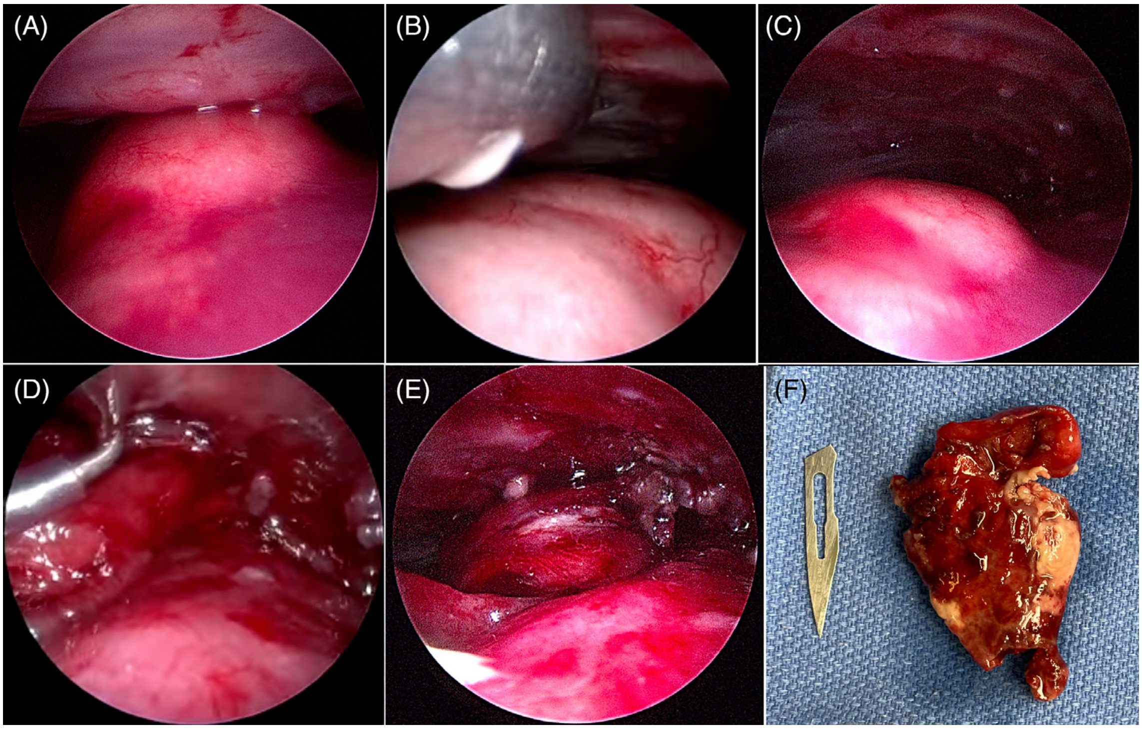

FIGURE 3 Thoracoscopic images of Cat 1. (A) Limited thoracoscopic exploration prior to the lift. (B) Insertion of the lift device under thoracoscopic guidance. (C) Increased field of view and working space after lift has been placed. (D) Dissection of the tumor adherences using a monopolar L-hook device. (E) Tumor dissected prior to removal. (F) Lung lobe removed with the tumor.

were placed, one more ventrally and one more dorsally at the fifth and ninth intercostal spaces, respectively (Figure 2B). The adhesions were dissected using a combination of a 5 mm vessel sealing device (Ligasure Dolphin Tip, Medtronic, Minneapolis, Minnesota), laparoscopic monopolar L-hook (Medtronic) and a blunt 5 mm probe (Figure 3D). Once the lung lobe mass was freed (Figure 3E), a 2.5 cm incision was made at the middle of the fourth intercostal space. A small wound retractor (Alexis wound retractor, Applied Medical, Rancho Santa Margarita, California) was placed and the cranial left lung lobe was gently manipulated to ease placement of a pretied-ligature loop (PLL) (2-0 Endoloop ligature [Ethicon, Johnson & Johnson Med Tech, Warsaw, Indiana]). The ligature was placed at the level of the hilus under endoscopic guidance. Once the lung lobe was ligated, it was transected 5 mm distally from the ligature with Metzenbaum scissors, removed through the Alexis wound retractor and submitted for histopathology. Samples of pleural wall nodules were also obtained with laparoscopic biopsy forceps and submitted for histopathology. The sternal lymph nodes were unable to be adequately visualized due to the presence of adhesions and therefore a sample was not obtained. The thoracic cavity was thoroughly lavaged. A leak test was performed with a breath hold at 20 cmH_2O for 5 s and confirmed absence of air leakage. Excess fluid was evacuated using a Poole suction cannula through the retractor. Placement of a 14G chest tube (Mila International, Florence, Kentucky) was performed in a routine fashion with thoracic entry at the level of the left ninth intercostal rib space. The chest tube was sutured in place using 3–0 nylon (Ethicon) suture. Then 5.3 mg/kg of bupivacaine liposome injectable suspension (Nocita, Elanco, Greenfield, Indiana) was infiltrated into the musculature and subcutaneous tissues using a moving-needle technique. The thoracoscopic ports and retractor were removed and muscular layers were closed using 3−0 polydioxanone (PDS, Ethicon) suture in a cruciate pattern. The subcutaneous tissue was closed with a buried, simple continuous suture pattern or cruciate patterns using 3−0 poliglecaprone 25 (Monocryl, Ethicon). The skin was closed with skin glue. Air and serosanguineous fluid were evacuated from the chest tube until negative pressure was achieved. Surgery duration was 117 min with an estimated blood loss of 3 mL.

2.3.2 | Cat 2

The patient was placed under general anesthesia and positioned in left lateral recumbency. The ribs were palpated and a 1 cm skin incision was made in the fifth

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intercostal space with a #11 scalpel blade. The subcutaneous fat was bluntly dissected away from the deeper tissues. Hemostasis of bleeding vessels was achieved using bipolar electrocautery. Thoracic entry was performed in a similar fashion as previously discussed. The 3.9-mm threaded endoscopic cannula was inserted into the incision followed by the 3.3-mm 30° endoscope (Karl Storz Endoscopy). The thoracic cavity was explored but visualization was very limited. Another incision was made caudal and dorsal to the first incision at the eighth intercostal space. A bent 2 mm Steinmann pin (Figure 4) was inserted through this incision and used as a hook on the eighth rib in order to lift the thoracic wall. This pin was attached to a ceiling mount with a sterilized self-adhering cohesive bandage (Vetrap Bandaging Tape, 3 M) while monitoring for maximal effect achieved (Figure 5A,B). An additional incision was made under thoracoscopic guidance, dorsally to the camera portal, at the fifth intercostal space. The right caudal lung lobe was retracted ventrally using a 3 mm palpation probe (Karl Storz Endoscopy) passed through the caudalmost incision to expose the right pulmonary ligament. The ligament was transected using 3 mm laparoscopic scissors (Karl Storz Endoscopy) (Figure 5C). A PLL was passed around the right caudal lung lobe (Figures 6A and 5D) to the level of the hilus and tightened under thoracoscopic guidance (Figure 5E). The camera was moved to the most caudal incision, alongside the lift device, and the incision

FIGURE 4 Devices used to lift the chest wall for the first case (left), and second case (right).

for the camera port was enlarged slightly to gently pull the lung lobe through (Figure 6B). The right caudal lung lobe was transected 5 mm from the ligature with Metzenbaum scissors outside the thoracic cavity. The foreign body was confirmed to be removed entirely with the lung lobe, which was sampled for culture and sensitivity testing. The pedicle was assessed for hemorrhage and the thoracic cavity was lavaged with warm saline solution. A leak test was performed twice via a breath hold at 20 cmH_2O for 5 s, with no air leakage noted. Closure of the incisions and placement of a chest tube were performed as described for the first case, and bupivacaine liposome injectable suspension (Nocita, Elanco) was similarly administered via an infiltrative block. Surgery duration was 141 min with an estimated blood loss of 1 mL.

3 | RESULTS

3.1 | Cat 1

The patient had an uneventful but slow recovery from anesthesia. She was hypothermic at 32.9°C at the time of extubation and dependent on mask oxygen to maintain normal saturation, so she was kept in a heated oxygen cage overnight for supportive care and easier surveillance. She was kept on IV fluids and gabapentin (10 mg/kg orally three times daily). Odansetron (0.5 mg/kg IV twice daily) was given prophylactically given the patient's preoperative dysorexia and to prevent postoperative anorexia secondary to nausea. Considering the concerns for complications due to surgery duration and significant hypothermia during the procedure and the recovery period, antibiotics (ampicillin/sulbactam, 30 mg/kg IV three times a day) were continued for 24 h postoperatively. Rescue analgesia (hydromorphone, 0.05 mg/kg IV) was available if deemed necessary, but was not administered. The following morning, she was bright and alert, was comfortable and ate readily. Over the following days, she had static serosanguinous pleural effusion at 12 to 16 mL/day. Frequency of aspiration was decreased, and at 5 days post-surgery, the chest tube was aspirated once daily without impairment on her respiratory status. The owner requested to have the chest tube removed and the patient discharged to spend some quality time at home. She was discharged on gabapentin and mirtazapine (1.88 mg orally once daily) as needed.

3.2 | Cat 2

Subsequent recovery was uneventful, and she was kept on IV NaCl 0.9% at a maintenance rate. Hydromorphone

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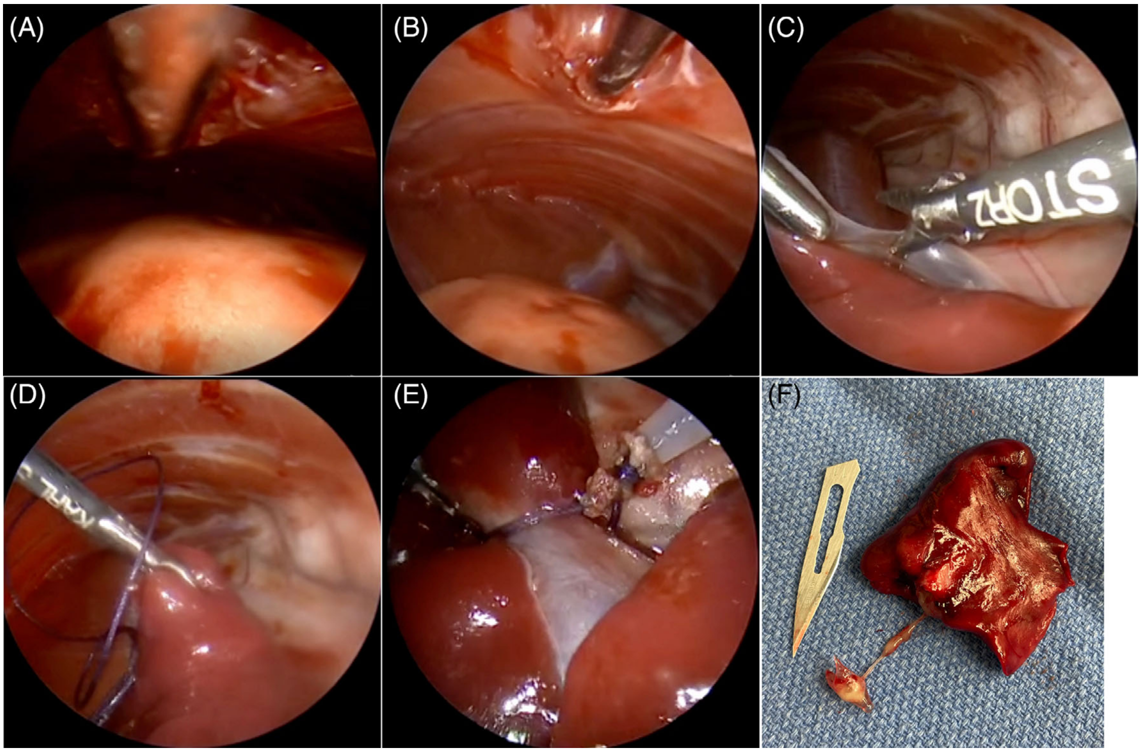

FIGURE 5 Thoracoscopic images of Cat 2. (A) Field of view with the lifting device visible dorsally, prior to the lift. (B) Field of view at the same location once tension has been placed on the device. (C) Dissection of the pulmonary ligament until the hilus. (D) Self-ligating loop suture placement. (E) Tightening of the suture at the hilus. (F) Lung lobe with the foreign body exteriorized from the bronchus.

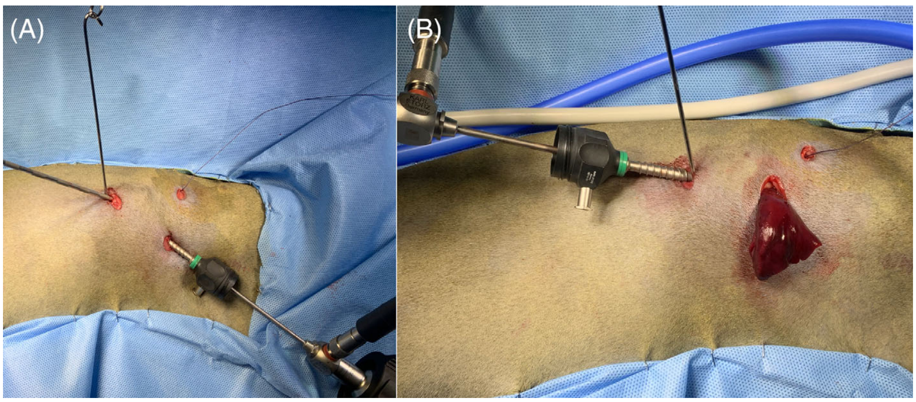

FIGURE 6 Intraoperative images of Cat 2. (A) A bent Steinmann pin is used to lift the thoracic wall through the caudal most incision. The probe is used to help placement of the suture at the hilus (A). (B) The lung is exteriorized through the middle incision under thoracoscopic guidance through the caudal incision.

was given every 6 h at 0.05 mg/kg IV. Gabapentin (14 mg/kg three times a day orally) was continued. She was very bright a few hours post-surgery but had no appetite, which was attributed to a rise in her body temperature at 40.2°C, so IV antibiotics (ampicillin sodium/sulbactam sodium, 20 mg/kg) were started. The following morning, she remained very bright and comfortable, but persistently hyperthermic and anorexic. The opioids were discontinued and robenacoxib (1 mg/kg orally) was started. The chest tube was removed as it was minimally productive since recovery. Two days postoperatively, she had a good appetite and her temperature had decreased to 39.7°C, which remained stable after the IV fluids were discontinued. She was sent home later that day on amoxicillin/clavulanic acid (17.8 mg/kg twice daily orally) for 10 days, gabapentin (10 mg/kg twice daily orally) for 10 days, and robenacoxib (1 mg/kg once daily orally) for 3 days. The culture revealed growth after enrichment of a Pasteurella multocida with intermediate sensitivity to amoxicillin. It was elected to not change the antibiotic course as owners reported that the patient was doing very well at home on follow-up.

For the first cat, histology of the mass was consistent with a pulmonary carcinoma with intrapulmonary and pleural metastases. The owner elected to pursue humane euthanasia at 10 days postoperatively due to development

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of sudden lethargy and increased respiratory effort in the patient, and declined further imaging investigation. For the second cat, the wounds had healed nicely at the 2-week recheck post-surgery and she had been doing well at home according to the owners. One year later, the owner was contacted by phone and reported that she had been doing excellent since the surgery.

4 | DISCUSSION

Thoracic wall lift was successfully used to perform thoracoscopic surgery in two cats. This is the first reported use of this technique in veterinary medicine. The technique avoided conversion to an open intercostal thoracotomy on the first cat and allowed successful three-ports video assisted thoracoscopic surgery (VATS) lung lobectomy on the second cat. Furthermore, although specific devices exist in humans, using a simple bent Steinmann pin inserted through the same incision of a thoracoscopic portal is considered relatively simple to execute and resulted in significant working space increase without added morbidity.

VATS procedures are gaining popularity for diagnosis and treatment in dogs, but are less commonly reported in cats.[4] At the time of writing, successful evaluation and/or management of undiagnosed pleural effusion, vascular ring anomaly, and treatment of chylothorax are the only published reports in cats, totaling six cases.[18–21] Thoracoscopic assisted procedures are also uncommon, with thoracoscopic-assisted pulmonary surgery (TAPS) reported in only three cats,[22] and one case report of a subtotal pericardectomy.[21]

Exploration with one camera portal was attempted on the first cat in the present report but visualization was too limited to proceed any further without additional steps. The working space of the feline thoracic cavity is a real challenge and remains small even when the end tidal volume is reduced by 50%.[4] Several techniques have been implemented in other species to increase the working space during thoracoscopy. OLV is technically difficult to perform on cats.[9] CDI has been shown to be well tolerated with insufflation pressures of 3 mmHg, despite changes on cardiopulmonary variables, but the cats enrolled in the study were healthy.[23] CDI is used by some surgeons at lower insufflation pressures of 1–2 mmHg to decrease potential cardiovascular effects,[4] which concur with the authors' personal experience with CDI in cats with thoracic disease. These options were ruled out considering the relatively unstable anesthetic status of the first patient. For the second cat, CDI was not considered because the working space that would be gained was believed to be inferior to what could be achieved with the lift technique. Moreover, CDI requires portal placement with a tight seal to avoid CO_2 leakage, which is not needed with other techniques that allow faster and easier port insertion and placement of the lift device alongside. Lifting the thoracic wall required an additional incision but allowed improved visualization and was not expected to impede the anesthesia. On the contrary, the oxygenation status of the patient improved immediately following the lift procedure. In lateral recumbency, the upper lung expands at the expense of the lower one,[24] which is compressed and limited in its expansion by the overlying weight of the heart and mediastinum, the higher abdominal pressure on the dependent section of the diaphragm, and the rigid surface that supports the dependent rib cage.[25] Masses in the upper lung may also interfere with lung function as they can contribute to decreasing the availability of functional lung parenchyma as well as further compress the lower lung.

With small patients such as cats, thoracic lift is suspected to enlarge the thorax directly by its effect on the upper hemithorax and indirectly by lifting the chest off the table, which may allow the dependent hemithorax to expand. This technique improved ventilatory parameters in the first patient during surgery but no changes were noted in the second patient. The second case did not exhibit any significant respiratory compromise during anesthesia which may explain the lack of response. However, further studies are needed to confirm the potential benefits of chest lift during anesthesia.

The thoracic lift improved the visualization to pursue the thoracoscopic exploration and offered enough improvement in the working space to not warrant conversion to open thoracotomy. In a previous study on diagnostic thoracoscopy for pleural effusion in 18 cats and dogs, one dog had to be converted to a sternotomy due to impaired visualization from adhesions.[18] For the first case, the adhesions were initially dissected thoracoscopically, but ultimately a TAPS procedure was performed, creating a wider incision and four small incisions for the ports and the lifting device. TAPS is normally performed through two incisions.[22] A small incision is made caudally for the camera portal, allowing exploration and mass identification, and a wider incision is made under direct thoracoscopic visualization 1 to 2 intercostal spaces caudo-dorsal to the lesion for cranial lung lesions.[22] Due to the broad adhesions of the tumor to the chest wall, dissection through a mini-thoracotomy for a standard TAPS approach would be technically challenging or impossible. Additional smaller portals were used to facilitate the dissection without having to convert to an open intercostal thoracotomy. Despite these multiple incisions, no rescue analgesia was needed and the patient was eating within 24 h post-surgery, which is similar to patients undergoing

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conventional TAPS.[22] Nevertheless, minimizing the number of incisions should be attempted to decrease surgical trauma, and this was achieved on the second patient by placing the lift at one of the port's incisions. This did not interfere with instrument manipulation, but evaluation of more cases is needed to confirm this finding.

The first lift was performed using a commercial device made for laparoscopy and therefore the design and thickness may not be ideal for lift thoracoscopy in cats. Some human devices have been specifically designed for chest wall lifting but most are made to lift the sternum,[15] and their size is not appropriate for the smaller feline thorax. When considering options for a lift device, readily available material that can be used or manipulated was desired. Sutures or other grasping instruments can be placed circumcostally to provide lift; however, these would apply pressure caudal to the ribs directly over the intercostal nerves, potentially inducing significant pain.[26] An unbent Kirschner wire placed subcutaneously achieved satisfactory anterior chest wall lift in human adult patients,[27] but was unsuccessful when tested by the authors of this study on feline cadavers. Kirschner wires have a diameter inferior to 1.5 mm, which makes them very flexible. Moreover, in lateral recumbency, subcutaneous placement of any device did not lead to satisfactory chest wall lift, which required direct traction of the ribs. Costal hooks placed behind the ribs have been reported,[28] so a 2 mm Steinmann pin was selected for its superior stiffness but easy contouring, allowing it to be shaped like a hook. The pin can be designed according to each patient anatomy intraoperatively, using orthopedic or conventional pliers. The sharps tips can be cut to decrease iatrogenic trauma, the intrathoracic portion can be bent to span transversally two ribs and thus distribute the forces,[29] and the external tip can be bent to ease suspension to a rigid frame or the ceiling of the operating room after tension has been placed on the chest wall. Lastly, the pin could be inserted through a very small incision prior to portal placement if indicated.

The thoracic lift technique can be suitable for cats and dogs as thoracic wall compliance is inversely correlated to the bodyweight in mammalian species,[10] and their chest wall is more flexible than that of humans,[10] whose thoracic wall can be uplifted by 3 cm with a 3 kg pulling force.[28] However, the amount of lift achieved may be difficult to predict in small animals, due to breed variations and decrease in thoracic wall elasticity with increasing age.[30] Comparison of the lift achieved in the younger and older patient in this report could not be made, because the lifting technique used was different, and the surgeon's experience with it was minimal. A larger case series is needed to evaluate expected chest wall lift and increase in working space volume in cats, and complication rate associated with the technique. Anticipated complications are the inability to gain sufficient working space in older and larger patients, iatrogenic injury to the thoracic organs especially the lungs and the intercostal neurovascular bundle.

Neoplasia is the most common indication for lung lobectomy, which is more prevalent in older patients.[22,31] The cat with pulmonary carcinoma was euthanized 10 days post-surgery for suspected recurrence of pleural effusion. This is in accordance with the shorter survival time reported for cats with pulmonary carcinomas and preoperative pleural effusion of 2 to 12 days versus >15 months for those without effusion.[31] Unfortunately, the diagnosis could not be confirmed prior to surgery. Ultrasound-guided fine needle aspiration of pulmonary lesions has been shown to be safe,[32] but this was declined by the owner because it required general anesthesia and has a reported diagnostic accuracy of 82% in cats and dogs,[32] potentially lower when pleural effusion is present,[18] which was too low for their expectations. Performing a biopsy with a cup forceps under lifted thoracoscopic guidance could be considered for a less invasive option over TAPS, but it was weighed against the risks of postoperative bleeding, pneumothorax, and non-diagnostic sampling.[18]

Upper airway foreign bodies are rarely diagnosed in cats, with the main location being the trachea and carina.[33] Various foreign bodies have been reported, including stones, plant material, a safety pin, wood mulch, teeth, coal, gravel and bone.[34] The reported success rate of bronchoscopic or fluoroscopic guided removal in cats ranges from 40% to 100% depending on the study.[33,34] However, the overarching conclusion of these studies report that the success rate is influenced by the location of the lesion, with foreign bodies at the carina or just cranial to it with a high success of retrieval.[33] When located more distally, or if there is presence of pneumothorax, pyothorax or lobar consolidation, a lung lobectomy by thoracotomy is indicated.[33] The most common location is the right caudal lung lobe.[35] In the case of this report, bronchoscopic retrieval was still attempted considering the unusual nature of the foreign body.

Both lung lobectomies were performed using a pretied ligating loop. This method has only been reported in a small case series in dogs via open thoracotomy.[36] Thoracoscopic assisted lung lobectomy in client-owned cats and cadavers has been reported using staplers.[22,37] However, these devices are too large to be easily and safely used in the thoracic cavity of cats without risk of iatrogenic damage to the surrounding structures.[38] A cadaveric study comparing a self-locking ligation (SLL) device to a thoracoabdominal stapler during TAPS in cats found a lower incidence of leak and closer placement to the hilus with the device than with staples.[38] The SLL was

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not readily available at the authors institution, but regardless, its benefits over a PLL for cats lobectomies are questioned. In the second case in this report, the PLL allowed us to remove the whole lobe close enough to its hilus to include the foreign body, and considering its smaller size in comparison to the wider SLL, it likely allowed us to remove more bronchial tissue. The PLL can be manipulated and tied using its plastic tube through one instrument portal, whereas the SLL needs either a specific custom instrument or two forceps for ligation.[36,38,39] On the other hand, the stiffness of the SLL should allow easier placement, whereas the suture of the PLL needs constant manipulation and guidance to encircle the tissue. Lastly, cutting the PLL once applied is easy, and the stump consists of a soft knot with only two strands of suture, whereas the 4 mm wide and 0.65 mm thick SLL is more difficult to cut and can leave sharp edges.[40] When used in vivo on dogs and pigs,[39,40] no postoperative complication was reported, but a cautious approach to prevent potential lung perforation would be to avoid having the cut edges face the surrounding lung parenchyma, which can make application more complex. Lastly, PLL is cheaper than SLL.

This is the first report of thoracic lift in veterinary medicine. Chest wall lifting was a viable option in two feline patients and may provide improved visualization and working space during thoracoscopic procedures.

AUTHOR CONTRIBUTIONS

Aertsens A, DVM, MRCVS, DECVS: Performed the surgeries, drafted, revised and approved the submitted manuscript. Tsoi H, DVM: Assisted in surgery, collected and analyzed the data, revised and approved the submitted manuscript. Esala M, DVM: Collected and analyzed the data, revised and approved the submitted manuscript. Wheeler E.P, DVM, DACVAA: Performed the anesthesia, revised and approved the submitted manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest related to this report.

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