Evaluation of short-term outcome after lung lobectomy for resection of primary lung tumors via video-assisted thoracoscopic surgery or open thoracotomy in medium- to large-breed dogs

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Objective—To describe clinicopathologic features of dogs that underwent lung lobectomy for resection of primary lung tumors via video-assisted thoracoscopic surgery (VATS) or open thoracotomy (OT) and to compare short-term outcomes for dogs following these procedures.

Design—Retrospective cohort study.

Animals—46 medium- to large-breed dogs with primary lung tumors.

Procedures—Medical records of dogs that underwent a lung lobectomy via VATS (n = 22) or OT (24) for resection of primary lung tumors between 2004 and 2012 were reviewed. Dogs were included if they weighed > 10 kg (22 lb) and resection of a primary lung tumor was confirmed histologically. Tumor volumes were calculated from preoperative CT scans where available. Surgical time, completeness of excision, time in the ICU, indwelling thoracic drain time, postoperative and total hospitalization time, incidence of major complications, and short-term survival rate were evaluated.

Results—VATS was performed with a 3-port (n = 12) or 4-port (10) technique and 1-lung ventilation (22). In 2 of 22 (9%) dogs, VATS was converted to OT. All dogs survived to discharge from the hospital. There were no significant differences between the VATS and OT groups with regard to most variables. Surgery time was significantly longer for VATS than for OT (median, 120 vs 95 minutes, respectively).

Conclusions and Clinical Relevance—In medium- to large-breed dogs, short-term outcomes for dogs that underwent VATS for lung lobectomy were comparable to those of dogs that underwent OT. Further studies are required to evaluate the effects of surgical approach on indices of postoperative pain and long-term outcomes. (J Am Vet Med Assoc 2013;243:681–688)

Lung lobectomy via VATS is a standard-of-care procedure for resection of many primary lung tumors in humans. This minimally invasive approach has advantages and disadvantages, but it is generally recognized that VATS can result in less acute and medium-term postoperative pain in human patients, compared with OT.1,2 Some studies3–8 have shown lower morbidity rates and lower incidence of complications, including postoperative pneumonia, sepsis, and death, in human patients who underwent VATS than in those who underwent OT; additionally, thoracic drain retention times and hospitalization times were shorter, and analgesic drug requirements were lower, in patients that underwent VATS.3–8 However, other studies9,10 have failed to demonstrate a clear advantage of VATS over OT for lung lobectomy, and this remains a controversial subject in human medicine.

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Abbreviations

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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>ICU</td>
<td>Intensive care unit</td>
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<tr>
<td>OT</td>
<td>Open thoracotomy</td>
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<td>VATS</td>
<td>Video-assisted thoracoscopic surgery</td>
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Small case series reports of thoracoscopic-assisted lung lobectomy and lung lobectomy via VATS exist in the veterinary literature.11–13 In a report12 of 9 dogs that underwent lung lobectomy by means of VATS for management of pulmonary tumors, conversion to an OT was required in 4 patients. The most common reasons for conversion to the open procedure in that patient population were inability to successfully establish 1-lung ventilation and poor visualization of the surgical field. To our knowledge, no studies have been published in the veterinary literature comparing clinicopathologic data of canine populations undergoing lung lobectomy via VATS versus OT for resection of primary lung tumors.

The purpose of the study reported here was to describe clinicopathologic features of medium- to large-breed dogs that underwent lung lobectomy for resection of primary lung tumors via VATS or OT and to compare short-term outcomes for dogs that underwent these procedures.
Materials and Methods

Case selection—Medical records of dogs that underwent either VATS or OT for resection of primary lung tumors from January 2, 2004, to August 30, 2012, were reviewed. Dogs were included if they were of medium to large breeds (body weight, > 10 kg [22 lb]) and resection of a primary lung tumor was confirmed by histopathologic review. Dogs were not excluded from the VATS group if the surgical procedure was converted to an OT, but the data for those dogs were excluded from the comparison of surgical time and outcome measures between VATS and OT groups. The OT procedure was performed during a 6-year period prior to the implementation of VATS as the routine approach for resection of primary lung tumors in the candidate population at the institution where the study was completed. During the period that VATS was used for lung lobectomy, no dogs underwent OT for this purpose if they were considered candidates for VATS.

Dogs that had undergone OT were excluded from the study if the primary lung mass was considered too large for lobectomy via VATS (our current recommendations are that tumors < 8 cm in diameter or < 175 cm³ are reasonable candidates for VATS in dogs > 30 kg [66 lb]). For purposes of the present study, dogs weighing 10 to 30 kg with tumors up to approximately 5 cm in diameter or < 100 cm³ were considered reasonable candidates for the procedure.

Medical records review—Information collected from the medical records included age, breed, body weight, body condition score (scale, 1 to 9, where 1 is emaciated, 5 is ideal, and 9 is obese), sex, presence of clinical signs, and diagnostic and surgical procedures performed. In all dogs that underwent a CT scan, tumor volume was calculated with a commercially available imaging analysis software package; volume was recorded directly and as normalized to body weight (tumor volume/body weight). Outcome measures recorded and compared between dogs of the VATS and OT groups included surgical time (measured from skin incision to the completion of skin closure), completeness of excision (as determined by histologic evaluation), time in the ICU, indwelling thoracic drain time, and postoperative and total hospitalization time as well as the incidence and types of intraoperative and major postoperative complications (eg, leakage of air into the thoracic cavity, hemorrhage, or pneumonia) and short-term survival (up to 1 month after discharge).

Anesthesia and patient preparation—All dogs in the study underwent general anesthesia with institutional protocols at the discretion of the attending anesthesiologist. In all dogs that had lung lobectomy via VATS, attempts were made to induce 1-lung ventilation by direct visualization of differential lung lobe ventilation. Success or failure of 1-lung ventilation and technical difficulties in establishment of 1-lung ventilation were recorded. Dogs were positioned in lateral or dorsal recumbency, and the surgical site was widely clipped of hair and scrubbed according to routine protocols.

VATS—In all cases, either a 3- or 4-port technique was used, with a combination of 6-mm nondisposable trocarless threaded cannulae and 11.5-mm disposable threaded cannulae. Ports were placed in a variety of configurations at the discretion of the primary surgeon. Generally, 2 to 3 ports were placed in a triangulating pattern in the more caudal intercostal spaces (seventh to ninth) for resection of cranial lung lobes and in the cranial intercostal spaces (third to fifth) for resection of caudal lobes. A single right middle lung lobectomy was performed via a 3-port technique with ports placed at the 5th, 9th, and 10th intercostal spaces. In some cases, a port was placed directly over the anticipated site of the pulmonary hilus to allow placement of an instrument or gloved finger intrathoracically to directly manipulate the pulmonary hilus to be resected or to manipulate a larger mass into position for resection. Once 1-lung ventilation had been established in dogs undergoing caudal lung lobe resections, the pulmonary ligament was sectioned with either laparoscopic scissors or 1 of 2 vessel-sealing devices. With a blunt probe or another laparoscopic instrument, the pulmonary hilus of the lung lobe to be resected was manipulated to provide visualization of the pulmonary artery, vein, and bronchus. An endoscopic surgical stapler was then introduced into one of the 11.5-mm ports and manipulated into position around the pulmonary hilus. When possible, a blunt probe or other instrument was used to push the lung tissue into the jaws of the stapler to minimize the risk of lung tissue sliding out of the stapler jaws as they were closed. In all procedures, endoscopic stapler devices had a 3.5-mm staple-clip length and 30- to 60-mm cartridge length were used. In all dogs, tissue was placed into a specimen retrieval bag after resection of the lung lobe. If the sample did not completely fit into the retrieval bag, a 3- to 4-cm enlargement of the port incision was made, and a retraction device was inserted to facilitate exteriorization of the lung lobe from the thoracic cavity. All ports were closed by placement of simple interrupted absorbable 2-0 or 3-0 monofilament sutures in the intercostal muscles, more superficial body wall muscles, or both. Skin closure was accomplished with interrupted cruciate sutures of 2-0 or 3-0 nylon or a continuous intradermal closure alone with 2-0 or 3-0 poliglecaprone 25 without subsequent skin suture placement.

OT—Dogs in the OT group underwent traditional thoracotomy through either an intercostal approach or median sternotomy. Lung lobectomy was performed with a thoracoabdominal surgical stapler or via primary suturing of the pulmonary hilus. Closure of the thoracotomy or sternotomy incision was routine in all cases.

Postoperative care—All dogs had a thoracic drain placed following lung lobectomy and were allowed to re-
cover in an ICU until deemed stable to move to a surgical ward to await discharge. All dogs received postoperative analgesics at the discretion of the attending clinician.

Statistical analysis—To determine comparability between the VATS and OT groups, age, body weight, body condition score, sex, tumor volume, and tumor volume normalized to body weight were compared between dogs of the 2 groups. Sex and body condition score were compared via $\chi^2$ tests for independence, and other outcomes were compared via $t$ tests (if data were normally distributed), $t$ tests based on log-transformed variables (if log-transformed data were normally distributed), or Mann-Whitney tests. Normality was assessed on the basis of pooled residual errors from both populations by means of Shapiro-Wilk tests. For comparisons of outcome measures between groups, data were analyzed for normality with a Shapiro-Wilk test. A Fisher exact test was used to compare categorical responses, and data were otherwise analyzed with $t$ tests (if normally distributed or transformable to normality) or with Mann-Whitney tests. All analyses were conducted with a commercially available statistics software package. $^{1}$ Values of $P < 0.05$ were considered significant.

Results

Of 46 dogs that met inclusion criteria for the study, 22 underwent VATS and 24 underwent OT for lung lobectomy. This included all dogs in which VATS was used to attempt resection of a primary lung tumor at the primary author’s institutions during the study period, with the exception of 1 dog that weighed < 10 kg and was thus excluded. The OT group included only dogs that would have been considered reasonable candidates for VATS lobectomy. There were no significant differences between the VATS and OT groups for age, sex, body weight, body condition score, tumor volume (where measured), or tumor volume normalized to weight.

VATS group—Ten dogs were castrated males, 10 were spayed females, and 2 were sexually intact males. The group included 4 mixed-breed dogs, 3 Labrador Retrievers, 3 Golden Retrievers, 3 Bernese Mountain Dogs, 2 Standard Poodles, 2 Doberman Pinschers, and 1 each of Australian Shepherd Dog, Boxer, Elkhound, English Setter, and Rat Terrier. Median body weight was 31.4 kg (69.1 lb; range, 13.1 to 51.1 kg [28.8 to 112.4 lb]). Median age was 11 years (range, 6 to 15 years). Some dogs had multiple clinical signs or lesions. In 13 dogs, lung masses were diagnosed as an incidental finding during diagnostic evaluation for another condition. Clinical signs, when noted, included cough ($n = 8$), dyspnea (1), and lethargy (1). Physical examination did not reveal any findings specific for the presence of a primary lung tumor in any dog.

Thoracic radiography reports were available for review in 20 of 22 cases and revealed evidence of a pulmonary mass in all dogs. Additionally, one dog had a suspected mass in a lung lobe remote from the primary mass, and another dog had a cranial mediastinal mass. Abdominal ultrasonographic examination was performed as part of the diagnostic evaluation in 16 of 22 dogs. Findings were considered normal in 4 dogs. Seven dogs had variably sized splenic nodules. Other abnormalities included unilateral or bilateral adenomegaly ($n = 4$), renal cyst (1), and hypoechoic liver (1).

Computed tomography with IV contrast administration was performed in 21 of 22 dogs. In all dogs, the primary lung lobe tumor was characterized, and the proximity to other organs was evaluated. Enlargement of the tracheobronchial lymph node size. Four dogs had pulmonary bullae detected incidentally. Two dogs were considered likely to have metastatic lesions within the same lung lobe as the primary tumor on the basis of presence of smaller nodules in addition to the primary mass. One dog had a cranial mediastinal thymoma measuring 9.5 X 6 X 4 cm.

One-lung ventilation was attempted in all 22 dogs and was deemed successful in 20. In the 2 dogs in which 1-lung ventilation was unsuccessful, it was achieved initially but then failed intraoperatively either once or more than once. In both cases, this contributed to a decision to convert VATS to an OT procedure. The following modalities were used to achieve 1-lung ventilation (in some cases, > 1 modality was used in 1 dog): endobronchial blocker ($n = 12$), double-lumen endobronchial intubation (9), and selective intubation (3). Endobronchial blockers were either 7F or 9F size. Double-lumen endobronchial tubes ranged in size from 28F to 41F. Of 20 dogs for which details of 1-lung ventilation were adequately recorded, 13 had ≥ 1 intraoperative loss of ≥ 1-lung ventilation, and 7 had no problems encountered with this procedure. Complications that occurred included 1 or more of the following: intraoperative loss of 1-lung ventilation, complete airway obstruction caused by prolapse of double-lumen endobronchial tube or endobronchial blocker balloons into the trachea, double-lumen endobronchial tube placement into incorrect bronchus, insufficient double-lumen endobronchial intubation length to reach the mainstem bronchus, and inability to block the right cranial lung lobe with an endobronchial blocker.

Primary lung tumors were located in the following lobes: right caudal ($n = 8$), left caudal (3), right cranial (3), left cranial (3), and right middle (1). Tumor volumes, measurable in 20 of 22 dogs, were a median of 41.1 cm$^3$ (range, 1.7 to 174.4 cm$^3$). Ratio of tumor volume normalized to body weight was a median of 1.2 cm$^3$/kg (0.55 cm$^3$/lb; range, 0.06 to 6.70 cm$^3$/kg [0.03 to 3.0 cm$^3$/lb]).

In 12 dogs, a 3-port technique was used, and in 10 dogs, a 4-port technique was used. A single endoscopic stapler$^2$ cartridge with a 30- to 60-mm length and 3.5-mm staple-leg length was used in 8 dogs, 2 were used in 11 dogs, and 3 were used in 1 dog (endoscopic staplers were not used in the 2 dogs for which VATS was converted to OT). In 3 dogs, laparoscopic hemoclips were used to either supplement hilar closure or seal a small remnant of tissue that remained after application of the stapler. In all dogs, a specimen retrieval bag was used for removal of the lung lobe. In 3 of these, a wound retractor$^3$ was used in addition to the specimen retrieval bag.

JAVMA, Vol 243, No. 5, September 1, 2013 Scientific Reports 683
In 2 dogs that underwent lung lobe resection via VATS and in 2 for which VATS was converted to OT, a tracheobronchial lymph node was excised after the lobectomy was completed. In 1 dog, a thymoma was also resected along with the sternal lymph node with a VATS technique as described in another report. Median surgical time for lung lobectomy (with lymph node resection if performed) via VATS was 120 minutes (range, 70 to 170 minutes). The decision to convert to OT was made because of poor visualization of the tumor (partly related to failure to achieve complete 1-lung ventilation) in one dog (weight, 28.7 kg [63.1 lb]), whereas in the other dog (weight, 26.0 kg [57.2 lb]), intermittent loss of 1-lung ventilation and presence of a large tumor (volume, 174.4 cm³) contributed to the decision.

Intraoperative complications occurred in 4 of 20 (20%) dogs in which lung lobectomy was completed with VATS. In 1 dog, a small iatrogenic tear caused by cannula impingement in a distant lung lobe required surgical stapling. In another dog, a small area of a central lobe was accidentally sealed with a vessel-sealing device but did not result in air leakage or require treatment. In 2 dogs, intercostal artery hemorrhage at the site of a thoracoscopic port required circumsuteral suturing. In the postoperative period, aspiration pneumonia developed in 1 dog, and 1 dog had persistent air leakage into the thoracic cavity for 24 hours that resolved spontaneously with no further treatment beyond intermittent aspiration via the indwelling thoracic drain. Histologic evaluation of resected lung lobes in all cases confirmed primary lung tumors classified as the following types: papillary adenocarcinoma (n = 8), pulmonary carcinoma (4), bronchoalveolar carcinoma (4), histiocytic sarcoma (4), adenosquamous carcinoma (2), and osseous carcinoma (1). One dog had both a bronchoalveolar carcinoma and a histiocytic sarcoma within the same lobe. In 12 cases, the pathology report for lung tissue indicated that the margin of resection was considered free of tumor cells, whereas in 1 case, tumor cells were visible at the margin. In the remainder of cases, margin of resection was not specifically commented on in the histopathology report. One of 4 dogs that had a tracheobronchial lymph node resected had metastatic spread to the resected lymph node, whereas the others had no evidence of metastasis.

**Primary lung tumor types in this group of dogs included papillary adenocarcinoma (n = 6), bronchoalveolar carcinoma (6), pulmonary adenocarcinoma (4), papillary adenoma (3), bronchoalveolar adenoma (2), histiocytic sarcoma (2), and undifferentiated sarcoma (1). In 13 dogs, the margin of resection was deemed free of tumor cells, and in 1 dog, tumor cells were seen at the surgical margin. In all other cases, pathology reports did not include comments on margin of resection. Nonneoplastic changes were seen in the lymph nodes of all 3 dogs that underwent tracheobronchial lymph node excision.

**Postoperative care**—After surgery, all dogs were treated with an analgesic regimen consisting of an opioid analgesic administered for at least 24 hours after surgery IV either on an intermittent basis or as a constant rate infusion at the discretion of the attending clinician (hydromorphone hydrochloride at 0.1 mg/kg [0.05 mg/lb]; IV q 4 h; butorphanol tartrate at 0.1 mg/kg, IV q 4 h; buprenorphine hydrochloride at 0.01 mg/kg [0.005 mg/lb], IV q 6 h; or fentanyl citrate at 2 to 10 µg/kg/h [0.9 to 4.5 µg/lb/h], IV). Upon discharge, tramadol hydrochloride was prescribed (2 to 4 mg/kg [0.9 to 1.8 mg/lb], PO, q 8 h for 3 to 5 days), along with an NSAID unless contraindicated by other patient comorbidities (deracoxib at 1 mg/kg [0.5 mg/lb], PO, q 24 h for 3 to 7 days, or carprofen at 2.2 mg/kg [1.0 mg/lb], PO, q 24 h for 3 to 7 days).

**Outcome measures**—Median surgical time for the OT group (95 minutes) was significantly (P = 0.01)
shorter than that of the VATS group (120 minutes). There was no significant difference in the number of dogs in each group that had incomplete tumor excision determined on the basis of histopathologic evaluation. Dogs in the OT and VATS groups were maintained in the ICU for a median of 19 hours (range, 16 to 75 hours) and 18 hours (range, 12 to 138 hours), respectively. The time that an indwelling thoracic drain was in place after surgery was a median of 18 hours (range, 12 to 72 hours) for OT and 18 hours (range, 16 to 36 hours) for the VATS group. Median postoperative hospitalization time for OT and VATS groups was 47.5 hours (range, 24 to 93 hours) and 48 hours (range, 24 to 144 hours), respectively. Median total hospitalization time for the OT and VATS groups was 2.5 days (range, 1 to 5 days) and 2 days (range, 1 to 7 days), respectively. There were no significant differences between the VATS and OT groups for indwelling thoracic drain time, ICU time, postoperative or total hospitalization time, or incidence of major intra- or postoperative complications, including air leakage, bleeding, transfusion requirements, or pneumonia.

All dogs in the VATS and OT group survived to discharge from the hospital. One dog in the VATS group developed severe progressive hip and lumbar pain 1 week after surgery and was euthanized. All other dogs in the VATS group remained alive for at least 1 month after surgery. Twenty-one of 24 dogs in the OT group survived at least 1 month after surgery, whereas 3 of 24 were lost to follow-up prior to that time. The time that an indwelling thoracic drain was in place was a median of 18 hours (range, 12 to 72 hours) for the OT group and 48 hours (range, 24 to 144 hours), respectively. Median total hospitalization time for the OT and VATS groups was 2.5 days (range, 1 to 5 days) and 2 days (range, 1 to 7 days), respectively. There were no significant differences between the VATS and OT groups for indwelling thoracic drain time, ICU time, postoperative or total hospitalization time, or incidence of major intra- or postoperative complications, including air leakage, bleeding, transfusion requirements, or pneumonia.

Discussion

In the present study, clinicopathologic features and short-term outcomes were compared between dogs that underwent lung lobectomy for resection of primary lung tumors via VATS or OT. Dogs were only included in the OT group if they would reasonably have been considered candidates for a VATS approach on the basis of patient size and size and location of the lesion. Dogs weighing <10 kg or for which tumors were larger than 175 cm²) were excluded from the study OT population. Although dogs were not randomly assigned to VATS or OT approaches, these populations were reasonably well matched, and there was no difference in age, sex, body weight, body condition score, tumor volume, or tumor volume normalized to body weight between groups. A randomized study would have been superior to this retrospective cohort design in minimizing the risk that confounding factors would be different between groups. However, as has been encountered in human medicine, it would be challenging to randomly assign client-owned animals to an OT group because of the natural desire for owners to have their dogs treated in a minimally invasively manner when that option exists.

Video-assisted thoracoscopic lung lobectomy has been a standard-of-care procedure for approximately 20 years in human surgery. By 2006, in North America, 10% of primary lung tumors that were surgically treated in people were approached with a VATS technique. Proven advantages of VATS in humans over OT include less postoperative pain and immunologic compromise, lower analgesic requirements, more rapid return to normal activity, shorter hospital stays, and lower overall cost. To the authors’ knowledge, only 1 study in the veterinary literature to date has prospectively compared outcomes between dogs undergoing VATS and those treated with OT. In that study, dogs that had a pericardectomy performed via VATS had less evidence of postoperative pain, as assessed on the basis of a subjective pain-scoring scale, and a lower requirement for analgesics after surgery, compared with dogs that had pericardectomy performed with an OT approach. The present study was the first to compare VATS to OT for lung lobectomy in clinically affected canine patients with primary lung tumors. Unfortunately, because of the retrospective nature of the study, no assessment of postoperative pain or return-to-function outcome measures were evaluated. Analgesic administration was not evaluated statistically because of the many potential confounding factors that are inherent to evaluation of retrospective data regarding prescribing habits and lack of consistency in medical record keeping. Future studies comparing these surgical modalities should evaluate signs of pain in the postoperative period and return to function in patients prospectively.

The surgical techniques used in the cases reported here were similar to those described by Lansdowne et al. Generally, 3 or 4 ports were placed, with the fourth port principally placed to aid in manipulation of the pulmonary hilus or because the surgeons anticipated that entry of the endoscopic stapler from a different angle might be beneficial. Although port site placement was not uniform among dogs, the authors favored an approach previously described by others, where cranial lung lobes are resected with caudally placed ports located in a triangulating pattern at the seventh to ninth intercostal spaces and caudal lung lobes are resected from cranially located intercostal ports located at the third to fifth intercostal spaces; however, the authors did stray from these exact locations in several situations. In the only middle lung lobectomy performed with this approach, ports were placed at the 5th, 9th, and 10th intercostal spaces. None of the dogs in the VATS group of the present study underwent accessory lung lobe removal, although one of the authors (PDM) has used VATS for accessory lung lobe resection in dogs with nonneoplastic disease.

One-lung ventilation was used in all cases of VATS in this study and is considered mandatory for successful performance of this procedure. The failure to obtain complete 1-lung ventilation was responsible in large part for conversion to an OT in 2 cases and was the principal reason for conversion from VATS to OT in a previous report of dogs undergoing lung lobectomy. In the study reported here, 3 commonly used techniques for achieving 1-lung ventilation were used routinely: double-lumen endobronchial intubation, endobronchial blockade, and selective intubation by use of a long endotracheal tube with the tip positioned within the mainstem bronchus of the lobe contralateral to the lesion. The authors have found that all of these techniques may be useful, considering that one technique might be more appropriate for dogs of a particular size,
whereas in other situations, technical failure of one technique might be remedied by attempting to use a different technique. We principally used endobronchial blockers and double-lumen endobronchial tube placement to achieve 1-lung ventilation. In all 12 dogs that had an endobronchial blocker placed, bronchoscopic guidance was used. Endobronchial blockers can be used in dogs of a wide range of weights, although it can be difficult to block the right cranial lobar bronchus with this device because of its immediate proximity to the carina. In dogs with right cranial lung lobe tumors, the authors prefer double-lumen endobronchial tubes because the problem of blocking the cranial lobar bronchus is circumvented by having the tube positioned in the left side. Endobronchial blockers, similar to double-lumen endobronchial tubes, are prone to dislodgement if dogs are moved intraoperatively, and the balloons are sometimes too small to fully occlude the mainstem bronchi of very large-breed dogs. Double-lumen endobronchial tubes can be placed blindly in a proportion of cases but are typically long enough only in dogs weighing up to 25 to 30 kg (55 to 66 lb). Selective intubation was only used in 3 dogs in this study and is generally reserved for very large-breed dogs in which double-lumen endobronchial tubes are too short and endobronchial blocker balloons may be too small to fully occlude the mainstem bronchus.

In all dogs that underwent lung lobectomy via VATS, the endoscopic stapler was used and found to be a highly reliable device for pulmonary hilar closure with the 3.5-mm leg length; this stapler was used in all sizes of dog entered into the study (> 10 kg). Use of the stapler resulted in no cases of hemorrhage; air leakage was only detected in 1 dog in this study and resolved within 24 hours. It is not known whether this represented a staple line leak or iatrogenic damage to a lung lobe distant to the surgical site. In humans, staple line leakage following lung lobectomy with VATS appears to be a major cause of postoperative morbidity and has spurred the development of an array of staple line augmentation technologies, such as the incorporation of buttressing strips into the stapler cartridge or use of tissue adhesives such as fibrin sealants applied to the staple line after resection. The technical issue with the use of the staplers in this report was incomplete sectioning of the entire hilus with 1 endoscopic stapler cartridge, which required the use of > 1 cartridge (in 12/20 dogs) or the use of small numbers of laparoscopic hemoclips (in 3 dogs) if a small area of parenchyma remained attached after completion of hilar stapling. This issue may be inevitable in some dogs but adds considerably to the cost of the procedure. To minimize the need to use multiple stapler cartridges, the authors generally use the longest cartridge size available (60 mm), although these can be difficult to manipulate in the thoracic cavity of smaller dogs. It may be possible for a surgeon to minimize slippage of the hilar tissue out of the stapler cartridge in some situations by using a laparoscopic instrument to hold the tissue within the jaws of the stapler cartridge.

Patient selection for lung lobectomy via VATS has evolved over the course of the last few years as experience with the procedure has increased. In the report by Lansdowne et al., recommendations were made that in the early part of the learning curve, use of VATS for this procedure should be restricted to dogs with small, peripherally located lesions. The authors of this study concur that these recommendations are entirely appropriate, especially in the early phases of the learning curve. However, we have found that larger lesions and those located closer to the hilus can be successfully approached with a VATS technique. This is in part possible because of the flexibility of the endoscopic stapler used in the present study, which can be positioned very close to the pulmonary hilus. We hypothesize that as complete a lobectomy as can be achieved through OT is achievable with VATS. In the study reported here, only 1 of 13 dogs that underwent lung lobectomy via VATS and had the surgical margin evaluated for completeness of excision had tumor cells detected at the margin. One of 14 dogs in the OT group similarly had an incomplete margin of tumor resection.

The balance between dog size and lesion size appears to be one of the most important factors in selection of patients for lung lobectomy via VATS. Tumors up to 750 cm³ in volume (lesion measured approx 7 × 5 × 4.5 cm on CT scan) were successfully removed by use of VATS. However, in a 26-kg Labrador Retriever, conversion to an OT was required to resect a tumor with an approximate volume of 174 cm³ (approx 9 × 6 × 5 cm on CT scan) because of the combination of tumor size and weight. This dog had the highest tumor volume normalized to body weight (6.7 cm³/kg), and this was therefore the largest tumor in the VATS group relative to body weight. This, along with intermittent failure of the 1-lung ventilation, made it very difficult to perform excision in this dog via VATS. On the basis of this experience, the authors suggest that tumors < 8 cm in diameter or < 150 cm³ in volume may be reasonable criteria for selecting VATS for lung lobectomy in dogs weighing > 30 kg when the surgeons have experience in thorascoscopic surgery. For smaller dogs, it is intuitive that the upper limits for lesion diameter and volume would be smaller than this. Greater experience and evaluation of a larger number of patients will be required to make more concrete guidelines for patient selection for this procedure; however, selection criteria may change as surgical techniques are refined with further advances in experience and technology.

In the present study, only 8 dogs in either the VATS (n = 5) or the OT group (3) had lymph node biopsy or resection performed. One of 7 dogs in which a tracheobronchial lymph node sample was evaluated was found to have metastatic carcinoma, and the only dog that had a sternal lymph node excised had metastatic thymoma in the lymph node. It is well-known that lymph node status is an important prognostic indicator for primary lung tumors, so the ability to use VATS for tracheobronchial lymph node biopsy or resection in combination with lung lobectomy will be important to develop. Lymph node excision was performed in 2 dogs in combination with lung lobectomy via VATS in the present study. A technique for tracheobronchial lymph node excision through VATS has been described in healthy dogs and will likely be used in more clinical patients in the future for improved staging of primary lung tumors.
Short-term complications in the present study were similar between the VATS and OT groups for all variables examined. Complications were relatively rare, and both groups generally had good outcomes, with no in-hospital deaths in either group. Only 1 dog in the VATS group was known to die < 1 month after surgery because of an unrelated pathological process (although 3 dogs in the OT group were lost to follow-up prior to 1 month after surgery). Great care needs to be taken during VATS lobectomy to avoid iatrogenic damage to other lung lobes, as happened in 2 dogs in this study. Iatrogenic damage caused by cannulae is rare but can be minimized by the use of good cannula positioning (ie, avoiding placement of cannulas too deeply within the thorax); successful 1-lung ventilation, which can avoid contact between constantly ventilating lung tissue and cannulae; and the use of blunt-tipped cannulae, which are less likely to damage the lung surface upon contact. Postoperative hospitalization and ICU times were not different between groups. Effusion and air leaks are known to be rare postoperative issues when resection of a primary lung tumor from a patient with an otherwise healthy pleural cavity is performed via OT,1,2 and these complications were also rare in the VATS group in the study reported here. Measures such as hospitalization time, ICU time, or duration of indwelling thoracic tube placement were not referenced to any objective clinical outcomes such as time to ambulation, indices of postoperative pain, or volume or fluid characteristics of thoracic fluid removed via chest tube. It is therefore possible that these variables were affected by differences in case management practices, and evaluation might be different if these practices were evaluated prospectively with clearly defined clinical benchmarks.

One disadvantage of VATS, compared with OT, was the greater surgical time in this study. Surgical time for VATS lobectomy was approximately 25% longer than for OT (120 vs 95 minutes, respectively, P = 0.01). In humans, few comparative studies of VATS versus OT have documented surgical times, but investigators of those studies generally found no significant differences between techniques3,10 or found that VATS had longer operative times than OT.3,11 It is likely that as experience with these techniques increases, surgical time will decrease; however, the need for specialized equipment setup and the initiation of 1-lung ventilation may cause overall surgical time to remain longer for VATS, compared with OT lobectomy.

In the present study, dogs that underwent VATS lobectomy for resection of primary lung tumors had short-term complications similar to those found for OT, and all patients survived to discharge from the hospital. Further studies in canine patients are required to compare signs of postoperative pain and return to function after VATS lobectomy, compared with OT, and to evaluate the effects of surgical approach on immune function and longer-term oncological outcomes in these patients.

References

Validation of a commercially available enzyme immunoassay for measurement of plasma antidiuretic hormone concentration in healthy dogs and assessment of plasma antidiuretic hormone concentration in dogs with congestive heart failure

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Objective—To validate the use of a human enzyme immunoassay (EIA) kit for measurement of plasma antidiuretic hormone (ADH) concentration in dogs and evaluate plasma ADH concentrations in dogs with congestive heart failure (CHF) attributable to acquired cardiac disease, compared with findings in healthy dogs.

Animals—6 healthy dogs and 12 dogs with CHF as a result of chronic degenerative valve disease or dilated cardiomyopathy.

Procedures—Plasma samples from the 6 healthy dogs were pooled and used to validate the EIA kit for measurement of plasma ADH concentration in dogs by assessing intra-assay precision, dilutional linearity, and spiking recovery. Following validation, plasma ADH concentrations were measured in the 6 healthy dogs and in the 12 dogs with CHF for comparison.

Results—The EIA kit measured ADH concentrations in canine plasma samples with acceptable intra-assay precision, dilutional linearity, and spiking recovery. The intra-assay coefficient of variation was 11%. By use of this assay, the median plasma concentration of ADH in dogs with CHF was 6.15 pg/mL (SD, 3.2 pg/mL; range, 4.18 to 15.47 pg/mL), which was significantly higher than the median concentration in healthy dogs [3.67 pg/mL (SD, 0.93 pg/mL; range, 3.49 to 5.45 pg/mL)].

Conclusions and Clinical Relevance—Plasma ADH concentrations in dogs can be measured with the tested EIA kit. Plasma ADH concentrations were higher in dogs with CHF induced by acquired cardiac disease than in healthy dogs. This observation provides a basis for future studies evaluating circulating ADH concentrations in dogs with developing heart failure. (Am J Vet Res 2013;74:1206–1211)