Video-Assisted Thoracoscopic Extirpation of the Tracheobronchial Lymph Nodes in Dogs

Michele A. Steffey[1], DVM, Diplomate ACVS, Leticia Daniel[1], MV,
Philipp D. Mayhew[1], BVM&S, Diplomate ACVS, Verena K. Affolter[2], DVM, PhD, Diplomate ECVP,
Joao H. N. Soares[3], MV, DSc, Diplomate ACVAA, and Andrea Smith[3], DVM

[1] Department of Surgical and Radiological Sciences, University of California-Davis, Davis, California ,[2] Department of Pathology, Microbiology and Immunology, University of California-Davis, Davis, California and [3] Veterinary Medical Teaching Hospital, School of Veterinary Medicine, University of California-Davis, Davis, California

Corresponding Author
Michele A. Steffey, DVM, Diplomate ACVS, Department of Surgical and Radiological Sciences, School of Veterinary Medicine, University of California-Davis, Davis, CA.
E-mail: masteffey@ucdavis.edu

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Objective: To describe a technique for video-assisted thoracoscopic surgery (VATS) extirpation of the tracheobronchial lymph nodes (TBLN), and to describe the quality of biopsy specimens obtained.
Design: Experimental study.
Animals: Purpose-bred male hound-mix research dogs (n = 8).
Methods: Dogs were randomized to groups of left-sided or right-sided VATS approaches. One lung ventilation was used and TBLN dissection was achieved using a vessel-sealing device.
Results: TBLNs ipsilateral to the approach were successfully identified and removed thoracoscopically in 7 dogs. A 3-port technique was used in 6 dogs and 4 ports were used in 2 dogs. Observed complications included mild-moderate hemorrhage from the perinodal tissue controlled thoracoscopically (n = 2), inability to locate any TBLN (1), and difficulty achieving or maintaining one-lung ventilation (4). No other major complications occurred and all dogs recovered uneventfully. Median percentage surface area of the bisected lymph nodes affected by crush artifact was 20% (range, 0–40%). Areas of crush artifact were present in central (7/11) and peripheral (9/11) locations.
Conclusions and Clinical Relevance: Thoracoscopic TBLN extirpation is a feasible technique in dogs with normal TBLN and may be useful for obtaining more detailed staging on microscopic disease status in oncologic patients with normal-sized TBLNs. Further study is warranted to determine the feasibility and limitations of this technique in clinical patients with overt lymphadenopathy.

Locoregional lymph node staging is important in the therapeutic planning of most solid cancers, and identification of metastatic disease can significantly alter surgical and adjuvant treatment recommendations. Pulmonary lymphatics drain into 3 groups of tracheobronchial lymph nodes (TBLN) located around the tracheal bifurcation,[1] and are the primary site of lymphatic metastasis for pulmonary neoplasms. Assessment of TBLN for metastatic disease is an important predictor of outcome in dogs with primary bronchoalveolar carcinoma,[2–4] but TBLN are very challenging to access for percutaneous preoperative fine needle aspiration or biopsy because of their location at the pulmonary hilus, dorsal to the heart, and intimately associated with major neurovascular structures. Because of this, it is currently recommended that when lung tumor excision is performed, as part of the surgical procedure TBLN should be palpated and biopsied if enlarged.[5]

There is substantial owner-driven interest in minimally invasive surgical options for many types of cancer in dogs, including pulmonary neoplasms. Video-assisted thoracoscopic (VATS) lung lobectomy is a standard of care approach for resection of many primary lung tumors in people, demonstrating reduced morbidity compared with open procedures, with equivalent oncologic outcomes.[6–11] While techniques, parameters, and outcomes for VATS lobectomy have been described for veterinary patients,[12–14] detailed information on VATS approaches to the tracheobronchial lymph nodes in dogs is not currently available, and a VATS procedure precludes direct digital palpation of the pulmonary hilus. Because of this, many surgeons may not pursue TBLN biopsy if a VATS lung lobectomy procedure is elected, potentially compromising staging information needed to make optimal therapeutic recommendations. While a significant difference in survival has been described for dogs with primary lung tumors with evidence of metastatic disease to the tracheobronchial lymph nodes compared to those without evidence of TBLN metastasis at the time of surgical resection of the primary tumor,[2] existing

data do not differentiate between patients with microscopic metastatic disease and gross metastatic disease. The identification of microscopic metastatic disease during regional lymph node staging has been shown to impact therapeutic recommendations and outcome in human lung cancer patients,[15] but we are only at the beginning of characterizing the best approaches for dogs. A safe and effective minimally invasive approach to the TBLN could improve staging in canine lung tumor patients, allowing earlier detection and possibly earlier treatment of metastatic disease.

We hypothesized that the TBLN could be approached thoracoscopically, consistently identified, and an excisional biopsy safely performed by a VATS technique in lateral recumbency. Our purposes were: (1) to develop and describe a minimally invasive approach to the surgical extirpation of TBLN in dogs; (2) to describe any complications of the procedure; and (3) to describe the quality of the biopsy specimens obtained.

MATERIALS AND METHODS

Surgical Technique

This study was approved by the Institutional Animal Care and Use Committee (IACUC). Eight healthy, purpose-bred male hound-mix research colony dogs were enrolled in this experimental study, and to capture anatomic differences between left and right sided approaches, dogs were randomized to groups of left-sided (n = 4) or right-sided [4] surgical approaches using block randomization. Dogs were anesthetized using a standardized protocol of premedication with morphine (0.3 mg/kg) and atropine (0.02 mg/kg) subcutaneously, induction with propofol (5 mg/kg intravenously [IV] to effect), and maintenance on isoflurane in oxygen to effect. Subcutaneous buprenorphine (0.01 mg/kg every 6–8 hours as needed for 48 hours) and carprofen (2 mg/kg once) were administered for postoperative analgesia.

Dogs were positioned in lateral recumbency according to their randomization group, widely clipped, and aseptically prepared for surgery. In all dogs, attempts were made to induce one-lung ventilation (OLV) either by use of a double-lumen endobronchial tube (Rusch™ Robert-Shaw Endobronchial tube, Teleflex Medical, Durham, NC) or an endobronchial blocker (Arndt Endobronchial blocker, Cook Medical, Inc., Bloomington, IN, or Univent™, LMA North America, San Diego, CA). Establishment of OLV was bronchoscopically-assisted. VATS portals were established in the intercostal spaces with 11.5 mm disposable threaded cannulae (Thoracoport™, Covidien, Inc., Mansfield, MA). Ports were placed in a variety of configurations; however, in general a camera portal was established at intercostal space 5, with an additional 2–3 portals placed in a triangulating pattern cranial and caudal to the camera portal. The pleural cavity was visually explored using a 5 mm × 29 cm laparoscope (Hopkins II™, Karl Storz Veterinary Endoscopy, Goleta, CA) and visible lymph nodes were recorded.

Once all portals were established, a laparoscopic Kelly forceps or right-angle forceps were introduced through the instrument portals to allow manipulation of the pleural tissue. The pleura was incised over the identified TBLN, and the lymph nodes were extirpated with a combination of blunt dissection and sectioning with a vessel-sealing device (Ligasure, Covidien, Inc.). To minimize tissue trauma, manipulation of the lymph node was performed by grasping perinodal tissue whenever possible. Once dissected free from all attachments, resected lymph nodes were withdrawn from the pleural cavity through 1 of the 11.5 mm cannulae. Thoracic drains were placed to evacuate air from the chest and subsequently removed when negative pleural aspirations were obtained twice in a row, at least 10 minutes apart, and an arterial blood gas sample demonstrated appropriate oxygenation and ventilation variables.

Portal sites were closed by placement of simple interrupted monofilament absorbable sutures in the intercostal musculature, followed by closure of dead space in the subcutaneous layer with monofilament absorbable suture material in an interrupted pattern. An intradermal suture layer of monofilament absorbable suture material and/or interrupted skin sutures of monofilament nylon were placed according to the preference of the surgeon. All dogs were recovered from anesthesia.

TBLN dissection times, port placement, anatomic landmarks, ability to identify other regional LNs, ability to approach the contralateral TBLN, any alterations to dog or table positioning, length and width of resected TBLN, and perioperative complications were recorded.

Histopathologic Evaluation

Excised TBLN were immersed in 10% buffered formalin, bisected longitudinally, and processed for histopathologic evaluation with hematoxylin and eosin staining. A single pathologist (V.A.) reviewed the morphology of all TBLN specimens. Histologic artifacts were characterized as central (pinch/pressure/crush artifacts affecting larger central areas of the lymph node) or peripheral (pinch/pressure/crush artifacts affecting perinodal tissue, capsule, and the superficial cortex/paracortex of the lymph node) in location. Identified histologic artifacts were scored according to the following criteria: 0 = no artifact, 1 = minimal/marginal deformation, 2 = mild crush, 3 = moderate crush, 4 = severe crush). When different areas within a central or peripheral region of a given lymph node received a range of scores, the worst score received was assigned to that lymph node as the overall score. Both halves of the cut surface of the bisected TBLN were evaluated, and the total cross-sectional area of the cut surface of the TBLN affected by histologic artifact was estimated by the reviewing pathologist. Lymph node volumes and surface area of the bisected lymph nodes were calculated by the mathematical formulae for the volume of an ellipsoid ($4/3\pi \times r1 \times r2 \times r3$) and surface area of an ellipse ($\pi \times r1 \times r2$) based on TBLN measurements after removal from formalin.

RESULTS

Median dog weight was 21.2 kg (range, 20.2–24.3 kg) and median age was 7 months (range, 6–8 months). All dogs were considered systemically healthy based on the results of physical examination and hematologic evaluation of packed cell volume and serum total protein concentration. OLV was established in 5 dogs using an endobronchial blocker and by use of a double lumen endotracheal tube in 3 dogs (Table 1).

Surgical Findings

TBLN were successfully identified in 4/4 right-sided approaches and 3/4 left-sided approaches. There were no major perioperative complications and TBLN were successfully removed in all dogs in which they were identified. Subjectively, the best portal configuration for approach to the hilus was at intercostal spaces 3, 5, and 7 or 8, with the caudal portal placed slightly dorsal to the other portals (Fig 1). A table tilt of 15° from lateral toward the operator was needed to facilitate lung retraction in 6 dogs.

The left TBLN was not identified in 1/4 dogs undergoing a left-sided approach. In 3/4 dogs, the left TBLN was identified from a left-sided approach, dorsal to the bronchus and left pulmonary artery and ventral to the aorta; the contralateral TBLN was not identified (Fig 2). The left branch of the vagus nerve was also identified in close proximity to the left TBLN. Median dissection time for the 3 identified left TBLN was 13 minutes (range, 7–50 minutes). Median measured length of extracted left TBLN was 16 mm (range, 9–17 mm) and median width was 6 mm (range, 3–8 mm).

In 4/4 dogs, the right TBLN was identified from a right-sided approach, caudal to the vertical portion of the azygos vein, dorsocranial to the cranial lobar bronchus; the contralateral TBLN could not be identified (Fig 3). Median dissection time for right TBLN was 12.5 minutes (range, 10–26 minutes). Median measured length of extracted right TBLN was 11 mm (range, 8–17 mm) and median width was 7.5 mm (range, 4–14 mm).

We attempted to identify the central TBLN in all 8 dogs; however, the 4/8 central TBLN that were identified were identified from a right-sided approach, ventral to the horizontal portion of the azygos vein, dorsocaudal to the caudal lobar bronchus (Fig 3). During the initial 2/4 central TBLN dissections it was thought that the TBLN was removed in its entirety, but upon inspection while it did not appear that there was parenchymal transection, the lymph node did not have the described bi-lobed appearance of the central TBLN.[1] In the subsequent 2 dissections, with traction the entire bi-lobed central TBLN could be seen within the mediastinum, although it narrowed to a very thin tubular isthmus, with an appearance more consistent of 2 separate lymph nodes connected by a short lymphatic vessel. The central TBLN was amputated at this isthmus in these subsequent dissections, and grossly there was no apparent parenchymal transection. The central TBLN was not identified from the left-sided approach in any of the 4 dogs in which a left-sided approach was performed, and exploration of this region from the left was limited by the position of the esophagus.

Median dissection time of the 4 central TBLNs was 11 minutes (range, 5–14 minutes). Median measured length of extracted central TBLN was 13 mm (range, 9–20 mm) and median width was 3.5 mm (range, 3–6 mm). The right branch of the vagus nerve was observed in close proximity to the right and central TBLN. Other regional lymph nodes were observed in 7 dogs and included sternal lymph nodes in 6 dogs (median = 1; range 0–2), cranial mediastinal lymph nodes in 7/8 dogs (median = 1; range, 0–3), and intercostal lymph nodes in 1 dog (median = 0; range, 0–2). Observed complications associated with this procedure included: mild-moderate hemorrhage from the perinodal tissue during dissection that was controlled thoracoscopically (n = 2), inability to locate any TBLN (1), and difficulty achieving or maintaining OLV (4).

No dogs had postoperative signs of voice change, stridor, labored breathing, or exercise intolerance that might be associated with laryngeal paralysis secondary to iatrogenic recurrent laryngeal nerve damage during dissection. Postoperative laryngeal examinations were performed on 6 dogs before recovery from anesthesia, and demonstrated normal laryngeal function in all dogs. Two dogs did not have laryngeal examination because of relatively rapid anesthetic recoveries; however, no subsequent clinical signs (e.g., voice change, stridor, exercise intolerance) that might be attributed to laryngeal paralysis were noted with clinical follow-up of several months. All dogs recovered uneventfully from anesthesia and thoracostomy tubes were removed within 2 hours of extubation.

Histopathology

All extirpated TBLN were available for histologic evaluation (Table 1). Extirpated TBLN had a wide range of sizes, with calculated TBLN volumes ranging from 176 to 5024 mm^3. Of 11 TBLN, 10 had at least some minor histologic artifact (Figs 4 and 5), 7 had central artifacts, and 9 had peripheral artifacts. The median central artifact score for all TBLN was 2 (range, 0–3), and median peripheral artifact score for all TBLN was 2 (range, 0–3). For all TBLN, the median percentage of surface area of the cut surface of the lymph nodes identified as affected by histologic artifact was 20% (range, 0–40%).

DISCUSSION

We report a minimally invasive technique for excisional biopsy of the TBLN, which could be used for evaluation of nodal metastasis in dogs with pulmonary or other intrathoracic neoplasia, and have described histologic artifacts associated with this method of biopsy in normal lymph nodes. Primary lung tumors are highly aggressive and tend to metastasize to the TBLN and other lung lobes.[5] A very important prognostic factor in dogs with solitary lung tumors is regional lymph node involvement.[2–4] However, most previous studies defined lymph node involvement by the presence of visible or palpable

Table 1 Summary Data for 8 Dogs That Video-Assisted Thoracoscopic Extirpation of the Tracheobronchial Lymph Nodes

Dog no.	1		2		3	4	5	6		7		8
Body weight (kg)	21		21		24.3	20.2	22.7	22.7		20.9		21.4
Side operated	Right		Right		Left	Left	Left	Right		Right		Left
Port sites used	ICS 3, 5, 7		ICS 2, 4, 6 high, 6 low		ICS 3, 5 low, 5 high, 7	ICS 3, 5, 8	ICS 3, 5, 7	ICS 3, 5, 8		ICS 3, 5, 8		ICS 3, 5, 7
TBLN identified	Right	Central	Right	Central	Left	Left	Left	Right	Central	Right	Central	None
Time of dissection (minutes)	10	9	26	13	50	13	7	11	14	14	5	N/A
Procedural complications	None		Ports placed too cranial, initially too dorsal in chest. Dissection challenging, difficult to deploy vessel sealer w/o injuring lung, so more hemorrhage w/ reduced viewing		TBLN very hard to locate—small and deep in tissue—needed to open pleura ventral to aorta. Lost OLV midway through dissection, significant time to re-establish, some hemorrhage mildly inhibitory to viewing	None	None	None		Could not maintain OLV. Very challenging dissection due to lung motion/inflation and mediastinal shift		Unable to identify any TBLN, despite pleural dissection between aorta, bronchus, and PA until limited by right branch of PA
Difficulties establishing and/or maintaining OLV (method used)	No (DLET)		Yes (DLET)		Yes (BB)	Yes (BB)	No (BB)	No (BB)		Yes (DLET)		No (BB)
Gross TBLN size after removal from formalin (mm)	$10 \times 5 \times 3$	$7 \times 3 \times 2$	$10 \times 8 \times 4$	$18 \times 5 \times 3$	$20 \times 8 \times 5$	$10 \times 15 \times 8$	$10 \times 3 \times 3$	$13 \times 5 \times 2$	$15 \times 5 \times 3$	$13 \times 6 \times 6$	$10 \times 6 \times 5$	N/A
TBLN volume (mm^3)	628	176	1340	1130	3349	5024	377	544	942	1959	1256	N/A
TBLN surface area (mm^2)	157	66	251	283	502	471	94	204	235	245	188	N/A
Central artifacts score (Grade 0–4) of TBLN	2	0	0	3	1	3	0	3	0	3	2	N/A
Peripheral artifacts score (grade 0–4) of TBLN	0	0	3	3	1	3	2	2	1	3	3	N/A
Total % surface area of evaluated TBLN affected by artifact	30	0	25	40	5	20	20	40	10	10	30	N/A

OLV, one lung ventilation; PA, pulmonary artery; ICS, intercostal space; DLET, double lumen endotracheal tube; BB, bronchial blocker.

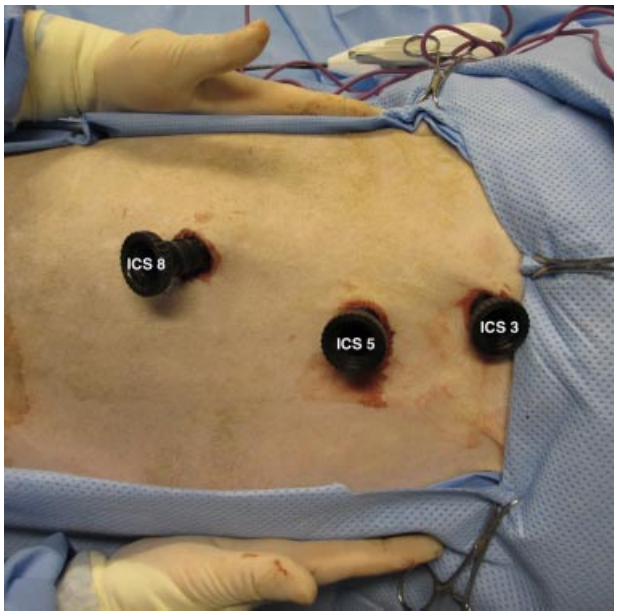

Figure 1 Operative image showing relative dorsoventral positioning of thoracoscopic ports at intercostal spaces 3, 5, and 8.

lymphadenomegaly, and this does not differentiate, or even always identify, microscopic metastatic disease. Evaluation with CT is more accurate than radiography for preoperative assessment of the TBLN in dogs, with a reported sensitivity of CT for correctly assessing TBLN status of 83%, and specificity of 100% in 14 dogs.[16] However, the reported accuracy of CT for evaluating regional mediastinal lymph nodes in people with pulmonary neoplasia is variable with reported sensitivities ranging from 25% to 95% and specificities ranging from 46% to 100%, affected by factors such as subjectivity of individual radiologists, small node size, microscopic metastasis, and concurrent inflammation or hyperplasia.[16] CT is therefore not the perfect discriminatory test for nodal stage. A combination of positron emission tomography with CT has been described in evaluation of a pulmonary tumor yielding accurate differentiation between neoplastic and reactive tissue in a single dog,[17] but this is not an imaging modality that is available to most veterinarians, and surgical staging is still likely to be very important in directing therapy in this disease.

Assessment of the regional lymphatic basin by sentinel lymph node (SLN) biopsy has become the standard of care in people for a number of neoplastic diseases. The presence or absence of tumor cells in the first lymph node or nodes within a lymphatic drainage basin (the SLN) is considered to be indicative of the disease status within the lymphatic system. Because micrometastases may take many months to produce lymphadenomegaly detectable by imaging or palpation, early histologic evaluation of the SLN can allow for a more accurate assessment of stage. In numerous studies, the SLN has been shown to be a highly sensitive and specific indicator of the patient's true metastatic status.[15,18–20] Increased sensitivity in the detection of micrometastases in SLN allows for upstaging of patients who might have been staged as negative for nodal metastasis (N0) based on imaging characteristics or aspirates of regional lymph nodes alone. Human studies have demonstrated up to 30% of patients, previously staged as N0 before SLN evaluation, benefited from upstaging and subsequent adjustments in therapeutic plan after detection of micrometastases in a variety of neoplastic disease.[18–20]

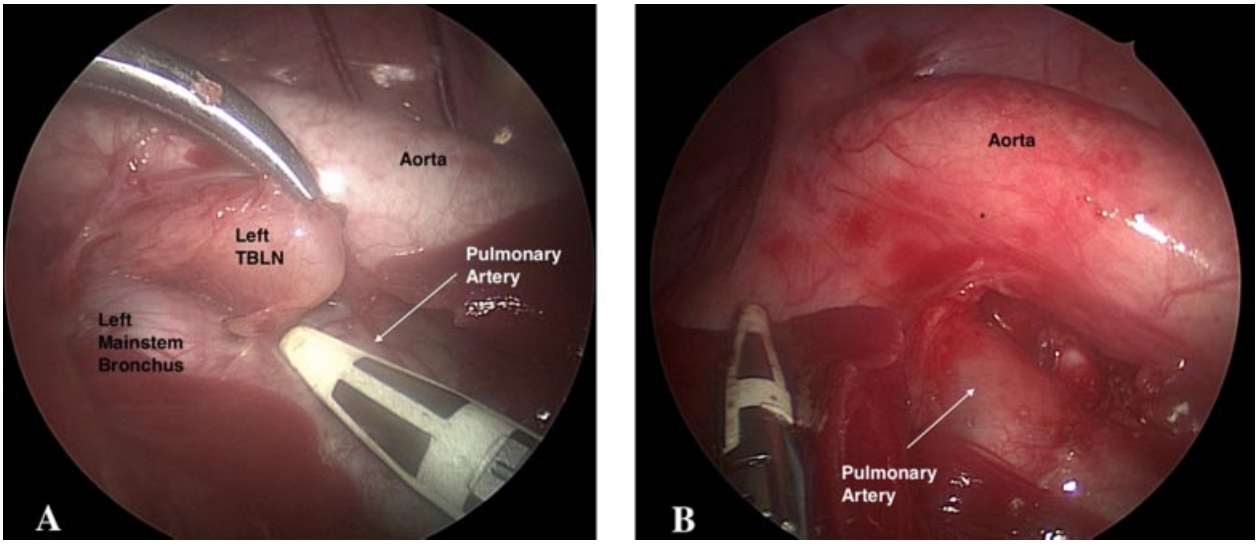

Figure 2 Intraoperative image demonstrating dissection of the left TBLN (A), and the regional anatomy after extirpation of the left TBLN (B). The vagus nerve is not visible in these images but runs across the bronchus and pulmonary artery in a cranial to caudal direction, ventral to the dissection of the elevated TBLN.

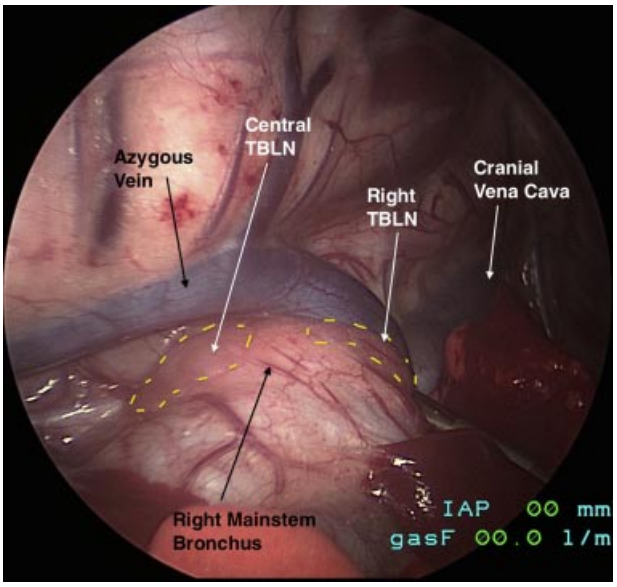

Figure 3 Intraoperative image showing pre-dissection right-sided regional anatomy of the TBLNs. The position of the central and right TBLNs are outlined in yellow.

The use of SLN mapping is in its infancy in veterinary medicine, but it has been described in a cohort of dogs with mast cell neoplasia and, based on the histopathology of the identified SLN, resulted in 42% of dogs in that study receiving additional treatment that would not have otherwise been offered.[21] In a recent study of human lung cancer, occult nodal metastasis was detected by cytokeratin immunohistochemistry in 22% of patients with tracheobronchial and mediastinal lymph nodes that were initially diagnosed as N0 on standard hematoxylin and eosin staining of the same lymph nodes, and

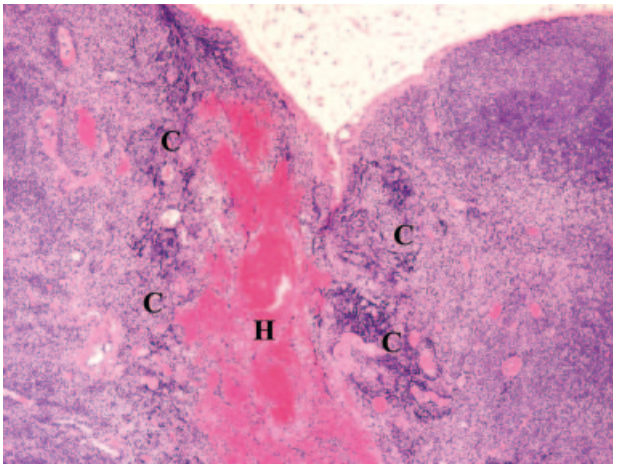

Figure 4 Hematoxylin and eosin stained histologic section of TBLN (40× magnification) showing moderate (grade 3) central crush artifact (C) associated with hemorrhage (H).

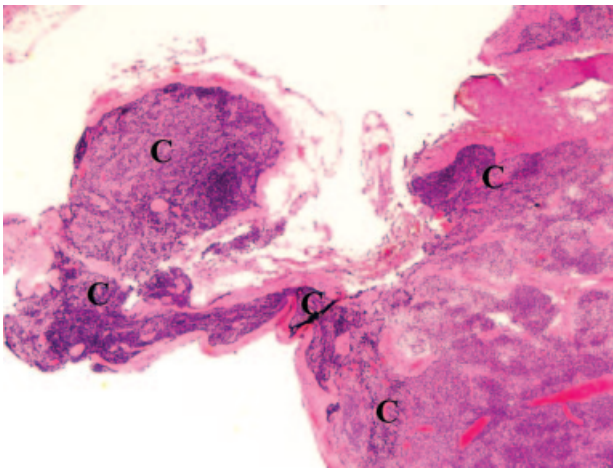

Figure 5 Hematoxylin and eosin stained histologic section of TBLN (20× magnification) showing severe (grade 4) peripheral and central crush artifact (C).

this occult nodal metastasis was associated with decreased disease-free and overall survival.[15] On the basis of their results, Rusch et al.[15] recommended that immunohistochemical evaluation of N0 lymph nodes should be performed to identify patients that may benefit from combined modality treatment, and should be incorporated into future trials of adjuvant chemotherapy. The role of cytokeratin immunohistochemistry in N0 lymph nodes merits study in animals with primary lung tumors. It is conceivable that earlier identification of low-volume metastatic disease in the TBLN of dogs with lung cancer could alter treatment recommendations and prognosis in our patients as well.

Advantages of minimally invasive thoracic procedures over open surgical procedures have been demonstrated in people and dogs.[22,23] In people, VATS is the approach of choice for diagnosis and treatment of early stage non-small cell lung cancer and evaluation of hilar and mediastinal lymph nodes.[23,24] Oncologic outcome including lymph node staging and surgical resection margins attained by VATS are identical to those obtained by open thoracotomy.[6–10,23–25] VATS lung lobectomy has been described in the dog with good success in removal of the primary tumor; however, approach to the TBLN and histologic information on TBLN status has been limited in these case series.[12–14] A recent canine study reported that surgical times for VATS lung lobectomy in dogs were ~25% longer than an open lung lobectomy technique.[14] Surgeons might feel reluctant to further extend the operating time to perform TBLN extirpation, but the addition of excisional biopsy of a TBLN during a VATS lobectomy procedure is unlikely to prolong surgical time so markedly as to preclude the procedure. As long as the lymph node dissection can be safely achieved, the risk of improper staging is likely to be greater than extending the duration of the operation. In people, VATS systematic mediastinal lymph node dissection extends the operative time by 30 minutes in the right chest and between

45 and 60 minutes in the left chest.[26] Because we were allocating operative time toward investigation of regional anatomy and evaluation of port placement options in this study, and these experimental dogs were concurrently used for OLV training for an anesthesiology resident, recording of total surgical time including time needed for instrumentation was precluded, and we instead recorded TBLN dissection times. Of 11 TBLN removed, time of dissection for each node was <15 minutes for 9 TBLN. The 2 TBLN with dissection times >15 minutes (50 minutes and 26 minutes) were associated with procedural complications. In the dog requiring 50 minutes to extirpate the TBLN, loss of OLV and difficulty re-establishing OLV led to severe compromise in viewing and difficulties in dissection. In the dog requiring 26 minutes for dissection, moderate perinodal hemorrhage was experienced that was controlled thoracoscopically with the vessel-sealer, but inhibited viewing of perinodal anatomy and slowed dissection.

OLV ventilation was used for all TBLN extirpation in this report and is considered mandatory for successful performance of this procedure. Loss of established OLV made viewing and dissection more challenging because of lung motion, and dissection generally could not be completed until OLV was re-established, although we did manage to complete dissection without re-institution of OLV in 1 dog. In addition to the specific study goals, these procedures were used for supervised OLV training for an anesthesia resident. This aspect of the study was not standardized, but we do not believe that it precluded the data obtained, as it would be difficult to standardize the method of OLV administration in clinical patients, and would be a potential issue in any case undergoing a VATS procedure requiring OLV.

In 1/8 dogs, the TBLN could not be identified thoracoscopically. In a clinical patient, it is standard practice at our institution to perform preoperative CT scans on all lung tumor patients, so had this been a clinical case, we would have had additional anatomic imaging information to determine if this dog did or did not have a lymph node on that side (anatomic variation is possible). In clinical patients, this challenge might also be mediated by using intraoperative lymphography. Peritumoral injection of optical dyes such as the vital blue dyes has been described and while optical dyes are not considered accurate enough to use as the sole agent for SLN identification in the relatively complicated mediastinal lymphatic basin in human lung cancer patients, it can be a useful aid in lymph node localization.[18–21,27,28] Anecdotally, the primary author has successfully used peri-tumoral injection of methylene blue in a canine lung tumor patient during a VATS lung lobectomy procedure to localize an otherwise difficult to identify, normal-sized TBLN for VATS excisional biopsy of the node.

No major operative complications were observed in this experimental cohort of young, normal dogs; however, unexpected or unanticipated complications are possible, and the operating surgeon should be prepared to convert to an open technique rather than compromise patient safety. In addition to the proximity of nearby major vascular structures, the surgeon should also be acutely aware of the relative proximity of, and risk of damage to, the pulmonary parenchyma, esophagus, and vagus nerves. On the left side of the thorax, the surgeon should also be aware of the relative proximity of the recurrent laryngeal nerve where it passes around the ligamentum arteriosum, and while operative trauma to this structure was not observed in this cohort of dogs, this complication could result in temporary or permanent iatrogenic unilateral laryngeal paralysis. Recurrent laryngeal nerve palsy was identified in 6/410 cases in a recent human case series of VATS lobectomy and mediastinal LN dissection.[23]

The central TBLN has been described as a bi-lobed lymph node.[1] During retraction and dissection of the 4 central TBLN in the dogs of this study, and under the magnification provided by the endoscope, it was observed that the central TBLN narrowed to a very thin tubular isthmus connecting the 2 lobes at what would be the cranial apex of the lymph node, and the lymph node(s) tended to easily separate at this isthmus during dissection. Whether this indicates that these structures are actually 2 separate, closely affiliated lymph nodes, or truly 1 bi-lobed lymph node is unknown. The clinical implication of this observation is that if it is desired to extirpate both lobes, attention must be given to ensure that both lobes are actually removed and not just the ipsilateral lobe.

In general, it was very difficult to completely avoid direct manipulation of TBLN during dissection. The pleural tissue is loose, and can be grasped near the TBLN to elevate and manipulate the lymph nodes away from neurovascular structures, but it also tears easily. Cardiopulmonary motion also contributes substantially to dissection challenges, especially notable at higher heart rates or with incomplete establishment of OLV. At some point in the procedure, some grasping of the TBLN directly becomes required for retraction and dissection. Care must be taken not to crush the tissue in the attempts to sample it. In the lymph nodes sampled in this study there was a wide range of the proportion of the surface of the area LN affected by artifact identified. It was the opinion of the reviewing pathologist that the observed artifacts were unlikely to be a diagnostic problem unless there were only very small numbers of very focal lesions present (small aggregates of tumor cells limited solely in location to within the area of artifact). While this is promising, as the goal of SLN biopsy is to identify low volume micrometastatic disease if present, even minor crush artifact could be clinically important, and care should be taken by the thoracoscopic surgeon to minimize handling of the TBLNs. While the number of lymph nodes removed in this study is too small to assess correlation of artifact with procedure experience statistically, it is our impression that there is a moderately steep learning curve to approaching the TBLN, and sample handling improves with correct port placement, adequate OLV, and operator experience.

A clinical limitation of the approach to the TBLN we report is that the contralateral TBLN cannot be seen or biopsied from the same surgical approach, and patient re-positioning would be required to access all TBLN. This may be of clinical importance especially in dogs with caudally located left-sided primary lung tumors in which the closest regional LN (and possibly the true SLN) is the central TBLN, which is not easily accessible from a left-sided VATS approach, at least when not enlarged. While there are only usually 3 TBLN in the dog, the

consistency of lymphatic drainage patterns for pulmonary neoplasia in dogs is not known. Therefore, whether the anatomic limitations of a lateral approach will be a major clinical limitation to accurate staging, or whether biopsy of the left TBLN alone would be sufficient for SLN staging of all left-sided primary lung tumors, remains to be seen.

To date, this technique has been successfully implemented for excisional biopsy in 2 dogs with a solitary primary lung tumor and normal-sized TBLN undergoing VATS lung lobectomy.[14] Further study is also warranted to determine the feasibility and limitations of this technique in dogs with overt lymphadenopathy. In a recent study of dogs with radiographic evidence of tracheobronchial lymphadenomegaly, in 84% this was associated with a diagnosis of neoplasia, of which 60% were lymphoid in origin and 24% were non-lymphoid.[29] Minimally invasive TBLN extirpation could play an important role in diagnosis and treatment recommendations in these cases in which the specific diagnosis cannot be made another way. However, marked mediastinal lymphadenomegaly has been described as a contraindication to VATS lobectomy for lung tumors in people.[30] Dissections in patients with overt lymphadenopathy are likely to be significantly more challenging because of the regional vascular anatomy and relative difficulty in retraction of grossly enlarged TBLN. Use of advanced imaging to assess for local invasion and relative position of nearby structures, and careful case selection will be needed in any consideration of extrapolating this technique to clinical patients with grossly enlarged TBLN.

Thoracoscopic TBLN extirpation is a feasible technique in dogs with normal TBLN and may be useful for obtaining more detailed staging on microscopic disease status in onocologic patients with normal-sized TBLN. The TBLN ipsilateral to the VATS approach can be consistently identified in normal dogs. Minimal handling of the extirpated TBLN is important to minimize histologic artifact that could hamper identification of micrometastatic disease in clinical patients. Further study is warranted to determine the feasibility of this technique in dogs with lymphadenopathy. The central TBLN should be approached from the right side of the thorax.

DISCLOSURE

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