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CLINICAL RESEARCH

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Short-term outcomes of dogs and cats undergoing lung lobectomy using either a self-ligating loop or a thoracoabdominal stapler

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Abstract

Objective: To assess clinical outcomes of lung lobectomies in dogs and cats using either self-ligating loops (SLLs) or thoracoabdominal (TA) staplers, aiming to inform sample size calculations for future superiority trials.

Study design: Retrospective study.

Animals: A total of 72 dogs and 15 cats.

Methods: Records from January 2003 to October 2023 at a single institution were reviewed. Cases with lung lobectomy performed via TA stapler or SLL with a minimum 14-day postoperative follow-up were included. Pre-, intra-, and postoperative data were collected, with outcomes of interest including the frequency of intra- and postoperative complications. Outcome comparisons between techniques were performed to inform sample size calculations.

Results: A total of 101 lung lobectomies were performed. The TA stapler was used in 83 (82.2%) and the SLL in 18 (17.8%) lung lobectomies. Intraoperative complications were identified in 14/101 lung lobectomies (13.9%), including intraoperative hemorrhage in 12/101 lobectomies (11.8%) and air leakage in 2/101 lobectomies (1.9%). Postoperative complications were identified in 12/87 cases (13.8%), including 4 (4.6%) catastrophic complications and 5 (5.8%) major complications. All intra- and postoperative complications occurred in cases having undergone stapled lung lobectomy; however, no differences were identified between surgical technique and either intraoperative ($p = .069$) or postoperative complications ($p = .112$). A sample size of 103 lobectomies per technique group would be required for appropriate evaluation.

Conclusion: Lung lobectomy using either surgical technique provided a good short-term outcome in this population.

Clinical significance: Self-ligating loop lung lobectomy provided a comparable alternative to stapled lung lobectomy. Further studies are needed to assess technique superiority.

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1 | INTRODUCTION

Total or partial lung lobectomies in dogs and cats are commonly performed procedures for various conditions, including pulmonary neoplasia, ruptured pulmonary bullae or blebs causing spontaneous pneumothorax, lung lobe torsions, pulmonary abscesses, or migrating foreign bodies.[1–3] Lung lobectomies may involve individual vessel/bronchus suture ligation and oversew, partial/total stapled lung lobectomy, partial lung lobectomy via hemostatic suture placement, or partial lung lobectomy via vessel sealing device.[1–11] Alternatively, total lung lobectomy via en bloc ligation or lung biopsy using self-ligating loops (SLLs) has been reported.[12–14] However, limited evidence-based outcome data comparing surgical techniques exists.

Commercially available SLLs, such as the Surgitie (Covidien, Minneapolis, Minnesota) and the Endoloop (Ethicon, Raritan, New Jersey), consist of pretied suture loops with self-ligating knots encased within a plastic knot-pushing tubing device.[12,15] Self-ligating loops have been assessed as safe and effective in human and veterinary studies for hepatic and pulmonary surgeries.[12–20] Researchers have demonstrated that SLLs may provide advantages over stapling devices in ex vivo studies, showing improved leakage profiles for both airway and vascular ligation in various comparisons.[12,20,21] Furthermore, Cronin et al. reported no intra- or postoperative complications during a 6-month follow-up period in a small case series of canine SLL lung lobectomies.

Unfortunately, limited literature on complication rates in dogs and cats undergoing partial or total lung lobectomies with SLLs exists. The primary objective of this study was to evaluate the outcomes of dogs and cats undergoing lung lobectomies using either a SLL or thoracoabdominal (TA) stapler to inform future comparison trials.

2 | MATERIALS AND METHODS

2.1 | Case identification

An IACUC exemption was obtained (Cornell University Veterinary Clinical Studies Number 051724-10). Medical records from January 2003 through October 2023 at a single institution were reviewed for dogs and cats undergoing partial or total lung lobectomy. Cases were excluded if lung lobectomy was performed using techniques other than TA stapler or SLL application, or if both methods were used on the same lung lobe. Cases were included if different techniques were applied to distinct lung lobes during the same surgery. Cases lacking intraoperative data or appropriate follow-up were excluded. Appropriate follow-up was defined as a minimum of 14 days or until death, whichever occurred first.

2.2 | Data acquisition

Preoperative data acquired included age, weight, sex, neuter status, breed, and modality of diagnostic imaging (thoracic radiographs and/or computed tomography).

Intraoperative data acquired included surgical approach, surgical technique, lung lobe(s) resected, if a caudal lung lobe was resected (right caudal, left caudal, or accessory), type of resection (partial or total), number of TA staplers or SLLs used, stapler size, the presence or absence of intraoperative bronchus leakage following ligation and transection, the presence or absence of intraoperative hemorrhage following ligation and transection, and whether a chest tube was placed. Cases in which multiple lung lobes were excised were counted separately by each lobe removed.

Postoperative data acquired included frequency of postoperative complications, duration of chest tube placement (days), duration of hospitalization (days), and survival to discharge. Recorded postoperative complications were defined as adverse events that occurred following surgery until a minimum of 14-day follow-up, according to the Cook classification system, based on physical examinations or email correspondence.[22] Minor complications were defined as those that did not require medical or surgical intervention. Major complications required pharmacologic or surgical treatment. Catastrophic complications were those that caused permanent unacceptable function, potentially directly contributing to death or necessitating euthanasia.

2.3 | Procedure description

After owner consent, client-owned animals presenting for scheduled or emergency lung lobectomy underwent general anesthesia. Perioperative antibiotics were administered at the discretion of the attending surgeon. For total stapled lung lobectomy, the TA stapler (TA 30 V3, TA 55, or TA 90; Medtronic, Minneapolis, Minnesota) was used as described by Cronin et al.[12] The staple line encompassed an individual hilus, including the bronchus, artery, and vein, without separation. The lobe was excised distal to the staples using the stapler as a cutting guide. In total lung lobectomy via SLL, two SLLs (Surgitie, Covidien, Minneapolis, Minnesota) were placed around an individual lung lobe and tightened onto the hilus, including the bronchus, artery, and vein, without separation.[12] Although a spacing of approximately 5 mm between SLLs was attempted, the SLL ligations frequently ended up positioned on top of each other. For masses larger than 8 cm in diameter, the exposed suture loop diameter was expanded as described by Goodman and Casale.[15] Following loop tightening, the lung was excised 5–10 mm distal to the ligatures, leaving an appropriate residual stump to decrease the risk of ligature slippage.[12,21] Similar surgical principles were applied for partial lung lobectomies, but the placement of either the SLL or TA occurred predominantly across lung parenchyma via guillotine method.[13,14,21] The second SLL loop was placed within the same crush as the initial SLL loop. All lobectomies were assessed for hemorrhage post-transection and leak tested under saline via manual positive pressure breath hold at 20 cm H_20.

2.4 | Statistical analysis

Data were reported either as frequency (percentage), median (interquartile range), or mean (+/− standard error). Normality was assessed using a Shapiro–Wilk test. Categorical comparisons between surgical technique and variables of interest were performed utilizing a Fisher's exact test. Outcomes evaluated included the incidence of intraoperative complications, such as intraoperative hemorrhage or air leakage from the lobectomy stump, the incidence of postoperative complications, the duration of chest tube placement, the duration of hospitalization, and survival to discharge. Intraoperative complications were assessed for each lobectomy, whereas postoperative complications and outcomes were assessed at the patient level. Univariable logistic regression was utilized to evaluate the association between binary outcomes and variables of interest. Odds ratios and 95% confidence intervals were reported for outcome data when available. When logistic regression was not possible due to perfect prediction, a categorical comparison between the outcome and the variable of interest was performed using Fisher's exact test. Comparisons between surgical technique and nonparametric continuous outcomes were performed using a rank-sum test. Statistical significance was set at $p < .05$. Sample size was calculated utilizing a likelihood-ratio two-sample proportions test. All statistical calculations were performed with commercial software (version 15.1; StataCorp).

3 | RESULTS

3.1 | Case demographics, evaluation, and surgical procedure

A total of 135 partial or total lung lobectomies from 113 dogs and cats were identified from 2003 to 2023. A total of 26 cases, with 34 lung lobectomies, were excluded due to incomplete medical records or nonexclusive surgical techniques. No cases that used an SLL alone for a lung lobectomy were excluded. Therefore, 87 cases with 101 lung lobectomies were evaluated.

Among dogs undergoing lung lobectomy, 39/72 (54.2%) were male and 33/72 (45.8%) were female, with 32/72 (44.4%) being mixed breed. Two male dogs and three female dogs were intact at the time of surgery, the remainder were sterilized. No other breed represented greater than 5% of the population. The median age of dogs at the time of surgery was 10 years (7–11, $n = 72$), with a median weight of 26.3 kg (10.8–35, $n = 69$). Of cats undergoing lung lobectomy, 10/15 were domestic shorthair, 4/15 were domestic long hair, and one was a Siberian. Ten cats were spayed females, and five cats were castrated males. The mean age of cats at the time of surgery was 9.8 years (+/− 1.13, $n = 15$), with a mean weight of 4.8 kg (+/−0.35, $n = 15$).

Cases were assessed for surgical candidacy and approach utilizing CT +/−thoracic radiographs in 81/87 cases (93.1%) and thoracic radiographs alone in 6/87 cases (6.9%). The surgical approach included lateral thoracotomy in 73/87 cases (83.9%), median sternotomy in 12/87 cases (13.8%), or thoracoscopy in 2/87 cases (2.3%). A total lung lobectomy was performed in 92/101 instances (91.1%). The distribution of lung lobe resections and lobectomy type is outlined in Table 1.

Thoracoabdominal staplers were used in 70/87 cases (80.5%), 11 of which were cats, and 83/101 lung lobectomies (82.2%) overall. A TA 30 V3 stapler was used in 73/83 lung lobectomies (88.0%). More than one staple cartridge was required in 11/83 lung lobectomies (13.2%). Self-ligating loops were used in 17/87 cases (19.5%), four of which were cats, and 18/101 lung lobectomies (17.8%) overall. All SLLs were performed after 2020. No difference was noted between SLL use and species ($p = .548$), age ($p = .256$), or weight ($p = .802$).

3.2 | Outcome data

Intraoperative complications occurred in 14/101 lung lobectomies (13.9%); all intraoperative complications occurred during stapled lung lobectomies. Intraoperative hemorrhage occurred in 12/101 lobectomies (11.8%). Leak test failure was encountered in 2/101 lung lobectomies (2.0%). There was no difference in intraoperative complication rates between TA stapler and SLL lung lobectomies ($p = .069$). No other variables were found to be associated with intraoperative complications (Table 2).

Postoperative complications occurred in 12/87 cases (13.8%); all postoperative complications occurred in

TABLE 1 Distribution of lung lobectomy location and lobectomy type.

Lung lobectomy location	Location ($n = 101$)	Total lobectomy ($n = 92$)	Partial lung lobectomy ($n = 9$)
Right cranial	19	16	3
Right middle	14	12	2
Right caudal	14	13	1
Accessory	2	2	0
Left cranial	31	28	3
Left caudal	21	21	0

cases with exclusively stapled lung lobectomies. These were categorized as catastrophic in 4/87 cases (4.6%), major in 5/87 cases (5.8%), and minor in 3/87 cases (3.4%). Details of postoperative complications are found in Table 3. There was no difference in postoperative complication rates between TA stapler and SLL lung lobectomies ($p = .112$). No other variables were found to be associated with postoperative complications (Table 4).

All cases underwent intraoperative chest tube placement. The median duration of chest tube placement was one day (1, 2). The median duration of hospitalization was two days (2, 3). Additionally, 82/87 cases (94.3%) survived to discharge. The lobectomy technique was not

TABLE 2 Univariable logistic regression of intraoperative complications and variables of interest.

Variable	n	Complication incidence by variable	OR	95% CI	p-value
Weight (kg)	98	–	1.02	0.98–1.07	.245
Age (years)	101	–	1.02	0.87–1.20	.798
Species (cat)	101	0/19	–	–	.066[a]
Median sternotomy	101	0/16	–	–	.118
Use of SLL	101	0/18	–	–	.069[a]
Use of TA 30 V3 cartridge	83	12/73	0.79	0.15–4.17	.778
Partial lung lobectomy	101	1/9	0.76	0.09–6.57	.803
Caudal lung lobectomy location	101	7/37	1.9	0.61–5.92	.269

[a]Logistical regression not possible. A Fisher's exact test was utilized to generate a p-value.
Abbreviations: CI, confidence interval; OR, odds ratio; SLL, self-ligating loop; TA, thoracoabdominal stapler.

TABLE 3 Classification of postoperative complications encountered following lung lobectomy.

Postoperative complication	Species	Technique	Classification	Treatment
Cardiopulmonary arrest immediately postoperatively	Cat	TA 30 V3	Catastrophic	Unsuccessful cardiopulmonary resuscitation
Cardiopulmonary arrest immediately postoperatively	Cat	TA 30 V3	Catastrophic	Unsuccessful cardiopulmonary resuscitation
Cardiopulmonary arrest immediately postoperatively	Dog	TA 30 V3	Catastrophic	Unsuccessful cardiopulmonary resuscitation
Cardiopulmonary arrest 1 day postoperatively	Dog	TA 30 V3	Catastrophic	Unsuccessful cardiopulmonary resuscitation
Atrial fibrillation	Dog	TA 30 V3	Major	Anti-arrhythmic medication
Hemothorax	Dog	TA 90	Major	Auto-transfusion
Pulmonary hypertension	Dog	TA 55	Major	Sildenafil administration
Recurrent pneumothorax 8 days postoperatively	Dog	TA 30 V3	Major	Blood pleurodesis
Incisional dehiscence	Dog	TA 30 V3	Major	Primary surgical repair
Chest tube abscessation	Dog	TA 30 V3	Minor	None
Left iliac vein thrombosis, 7 days postoperatively	Dog	TA 30 V3	Minor	None
Minor incisional dehiscence	Dog	TA 30 V3	Minor	None

Note: Each complication occurred in a distinct animal.
Abbreviation: TA, thoracoabdominal stapler.

TABLE 4 Univariable logistic regression of postoperative complications and variables of interest.

Variable	*n*	Complication incidence by variable	OR	95% CI	*p*-value
Weight (kg)	84	21.9 [6.5–32.75]	1.00	0.95–1.04	.844
Age	87	10 [7–12]	1.18	0.96–1.46	.120
Species (cat)	87	2/15	0.95	0.19–4.87	.955
Median sternotomy	87	3/12	2.44	0.56–10.75	.237
Use of SLL	87	0/17	–	–	.112[a]
Partial lung lobectomy	87	2/9	1.94	0.35–10.70	.445
Caudal lung lobectomy location	87	7/36	2.22	0.64–7.66	.207
>1 lung lobectomy	87	0/13	–	–	.199[a]

Abbreviations: CI, confidence interval; OR, odds ratio; SLL, self-ligating loop; TA, thoracoabdominal stapler.
[a]Logistical regression not possible. A Fisher's exact test was utilized to generate a *p*-value.

associated with either chest tube placement duration ($p = .950$), duration of hospitalization ($p = .058$), or survival to discharge ($p = .578$). The median follow-up duration was 76 days (19–370).

Common histopathological findings included pulmonary carcinoma in 47/87 cases (54.0%), pulmonary bulla in 9/87 cases (10.3%), lung lobe torsion in 9/87 cases (10.3%), and pneumonia in 5/87 cases (5.8%).

3.3 | Sample size calculation

Assuming a 16.9% intraoperative complication rate for stapled lung lobectomies and 5% for SLL lung lobectomies, a sample size of 103 lobectomies per technique group would be required for appropriate evaluation. This assumes equal enrollment, 80% power, and a statistical significance level of .05.

4 | DISCUSSION

We observed low catastrophic and major complication rates in dogs and cats undergoing lung lobectomy using either a TA stapler or SLL. While the intra- and postoperative complication rates were lower for SLLs than TA staplers, our focus was not on establishing technique superiority but on reporting complication rates to inform future study designs. Nonetheless, the results suggest that SLLs are comparable in safety and efficacy to TA staplers for partial and total lung lobectomies in this population.

Intraoperative complications secondary to occlusion failure were encountered in 13.9% of lobectomies, surpassing rates reported in previous human (1.19%) and veterinary literature (6.7%).[9,23] While no association with intraoperative complications were identified, our findings, combined with previous cadaveric research, suggest the need for further investigation into whether SLLs offer improved occlusion security. When compared to an endoscopic stapling device, self-ligating loop lung lobectomies have higher airway leakage pressures (40 cm H_20 vs. 28 cm H_20) for patients undergoing lung biopsy 3 cm from the pulmonary edge.[21] When comparing the TX30V stapler (Ethicon, Somerville, New Jersey) to SLL lung lobectomies, only TX30V stapled ligations had airway leakage at less than 80 mmHg, with one stapled ligation leakage occurring at physiological pressures of 5 mmHg.[12]

The SLLs improved resistance to airway leakage likely correlates with improved resistance to hemorrhage. This is supported by the results of an in situ pulsatile perfusion partial hepatectomy model, where greater time until hemorrhage and less leakage overall were observed for hepatectomies performed by SLL compared to thoracoabdominal stapler.[20] This prior research may lend support to why our population exhibited a higher rate of intraoperative hemorrhage compared to airway leakage, considering that the median arterial pressure of most dogs and cats undergoing lung lobectomy exceeds physiological airway pressures.[3,4,24]

To properly compare lung lobectomy techniques in a prospective study, 103 lobectomies per treatment group would be required based on sample size calculation. This calculation was based on the intraoperative complication rate, as vascular/bronchial occlusion security is likely most influenced by surgical technique. Apart from two postoperative complications (hemothorax, pneumothorax), the complications observed in this study were considered non-specific to the type of lung lobectomy employed. Additionally, differences noted in postoperative complication rates may be confounded by improved postoperative care management over the study period and the exclusive use of SLLs after 2020.

When conducting the sample size calculation, we assumed a 5% intraoperative complication rate for SLL lung lobectomy. This assumption was based on the chance of encountering a single intraoperative complication in the next two lobectomy cases and the recognition that a 0% complication rate in larger sample sizes is unrealistic. Due to the limited sample size for SLLs, this assumption may either overestimate or underestimate the true intraoperative complication incidence. However, in conjunction with a previous report on SLL lung lobectomy cases, the sample size calculation serves as a reasonable target for informing a properly powered technique superiority study.[12] A multi-institutional study may be necessary to achieve sufficient patient recruitment.

Our findings suggest that SLLs may serve as a viable alternative to stapling devices for minimally invasive surgery, as demonstrated by the two dogs who underwent thoracoscopic lung lobectomy via SLL. The use of SLLs may potentially offer an incisional size benefit, as observed in human pediatric patients.[17] Unlike the Endo GIA (Medtronic, Minneapolis, Minnesota) which requires a 12 mm port, the SLL can be utilized within a 5 mm port. Furthermore, an SLL costs only 1/4th-to-1/16th of stapling equipment in our hospital setting. Further assessment of these potential benefits is warranted.

This study had several limitations. The retrospective nature of the study increases the likelihood of misclassification bias as related to outcomes. The limited number of SLL lung lobectomies introduces cognitive bias, as the small sample size may not accurately represent a larger population and may misinform the sample size calculation. The lack of technique randomization introduces confounding factors affecting outcomes, such as surgeon preference, year performed, lesion location, and postoperative management. Although not the primary objective of our study, our sample size was underpowered to reach any definitive conclusions regarding technique superiority. Therefore, future trials will be necessary to confidently answer a hypothesis-driven research question focused on technique superiority. Finally, our study was limited to the evaluation of short-term intra- and postoperative complications. Long-term complications and survival times were not assessed.

In conclusion, successful outcomes can be obtained for dogs or cats undergoing lung lobectomy using either a TA stapler or SLL. Additionally, our findings underscore the need for an appropriately powered randomized prospective study to evaluate technique superiority.

AUTHOR CONTRIBUTIONS

Sandoval D, VMD: Study design, record identification, data acquisition and evaluation, and manuscript preparation. Stobie D, DVM, DACVS: Study conception, study design, performed surgical procedures, and manuscript preparation. Valenzano D, DVM, DACVS (Small Animal): Study design, performed surgical procedures, and manuscript preparation. Zuendt GF, DVM (Small Animal): Study design, performed surgical procedures, and manuscript preparation. Lopez D, DVM, DACVS (Small Animal): Study design, data evaluation and statistical analysis, and manuscript preparation.

CONFLICT OF INTEREST STATEMENT

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

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