Received: 31 August 2022 | Revised: 10 January 2023 | Accepted: 14 January 2023

DOI: 10.1111/vsu.13941

CLINICAL RESEARCH

WILEY

Association between divisional location and short-term outcome of liver mass resection in 124 dogs

Vaughan W. Moore BVSc, MANZCVS |
Joanna White BVSc, MVS (Epi), PhD, DACVIM |
Andrew Malcolm Marchevsky BVSc, MVS, FANZCVS

Small Animal Specialist Hospital, Sydney, New South Wales, Australia

Correspondence
Vaughan W. Moore, Small Animal Specialist Hospital, Sydney, NSW, Australia.
Email: vmoore@sashvets.com

Abstract

Objective: To evaluate the association between divisional location of liver masses on short-term outcomes after surgical excision.

Study design: Retrospective case series.

Animals: Client-owned dogs ($n = 124$).

Methods: Records were reviewed for demographics, surgical findings, and outcomes. The associations between mass location and mortality, intraoperative complications, and postoperative complications were tested with multivariable logistic regression models.

Results: Liver masses (124) were more common in the left (72) division than the central (34) and right (18) divisions. Median follow up was 286 (range: 14 to 2043) days. Intraoperative complications occurred in 14/124 dogs (11.3%) and postoperative complications in 35/122 dogs (28.7%). No association was detected between mass location and mortality in 8/124 dogs (6.5%). Postoperative complications were more likely if the incision extended to the thorax ($P < .001$), which was more common during resection of right divisional masses ($P = .020$). Postoperative complications were less likely when surgery was performed with a thoracoabdominal (TA) stapler ($P = .005$), by a specialist surgeon ($P = .033$), and in heavier dogs ($P = .027$). The odds of intraoperative complications were 19 times higher when surgery was performed without a TA stapler ($P = .006$). Intraoperative complications were less commonly associated with left ($P = .007$), but not central ($P = .0504$) divisional masses than right divisional masses.

Conclusion: Right divisional masses were prone to intraoperative but not postoperative complications.

Clinical significance: Clinicians should anticipate an increased risk of intraoperative complications when planning treatment of right divisional masses.

1 | INTRODUCTION

Primary liver tumors account for 0.6% to 1.3% of all canine neoplasms, and are categorized morphologically

---

Abbreviations: AUC, area under the curve; CI, confidence intervals; CT, computed tomography; HCA, hepatocellular adenoma; HCC, hepatocellular carcinoma; MAP, mean arterial pressure; MST, median survival time; OR, odds ratio; ROC, receiver operating characteristics; TA, thoracoabdominal.

as massive, nodular, and diffuse.[1,2] Massive liver tumors are large, solitary masses originating from a single lobe with or without encroachment of neighboring lobes. Nodular tumors are discrete, multifocal nodules involving several lobes whereas diffuse tumors permeate part of, or the entire liver parenchyma.[1] Hepatocellular carcinoma (HCC) and hepatocellular adenoma (HCA) are the most common primary liver tumors in dogs. Malignant hepatobiliary neoplasms, such as biliary duct carcinomas, carcinoids, and sarcomas, are also reported.[1,2] Surgical resection via liver lobectomy is the current recommendation for the management of solitary liver masses.[3,4] Long-term outcomes for dogs treated surgically for solitary liver masses depends on histopathological diagnosis. Surgical excision of HCC and HCA is associated with excellent long-term outcomes, with median survival times (MST) for surgically treated HCC not reached after 1460 to 1836 days.[3,5–7] The MSTs for HCA have not been reported but are expected to be long, due to the benign nature of this tumor.[6]

Reported poor prognostic indicators of short-term outcomes for liver lobectomies include hilar dissection technique, perioperative anemia, preoperative lethargy, and tumor location.[3,7,8] Anatomically, right divisional liver lobectomies provide an additional surgical challenge due to the close proximity to the caudal vena cava.[9] The resection of right divisional HCCs is reported to have a higher mortality rate than the resection of HCCs located elsewhere, often due to marked intraoperative hemorrhage.[3] Since this observation, right divisional masses have been associated with a poorer prognosis than masses located elsewhere without further investigation.[3,10] From our clinical experience, we hypothesized that right divisional solitary liver masses were not associated with an increased risk of mortality. Hence, the objective of this study was to evaluate the association between divisional location of liver masses on outcomes within 2 weeks of surgical excision.

2 | METHODS AND MATERIALS

2.1 | Study design

Electronic medical records at the Small Animal Specialist Hospital, North Ryde, between February 2008 and January 2020 were reviewed retrospectively. Dogs with the diagnosis of solitary liver masses, and with surgical treatment for them, were included. Dogs with septic peritonitis were excluded, as were dogs that had concurrent adrenalectomies or thoracotomies for reasons other than to improve surgical access. Dogs whose medical records failed to include mass location or with less than 14 days postoperative follow up were also excluded. Follow-up data were collected from medical records at the Small Animal Specialist Hospital. If at least 14 days follow up was not available, the referring veterinary clinic records were reviewed. Data were collated on potential predictors of outcome, which included breed, age at time of surgery, weight, sex, location of solitary liver mass, technique for resection, size of the mass, whether other surgical procedures were performed, and extension of the incision to the thorax. Additional information collected included the degree of hepatic resection, number of lobes excised, and histopathological diagnosis. The divisional location of dogs presenting with liver masses during the study period that did not receive surgery was analyzed. The proportion of right divisional masses (compared to left and central) among nonsurgical cases was compared with the proportion of right divisional masses among surgical cases.

Liver mass location was defined as either left (left medial, lateral or the papillary process of the caudate lobe), central (quadrate or right medial lobes), or right divisional (right lateral and caudate process of the caudate lobe).[3] When a dog had a mass in both the left and central division, it was defined as a central divisional mass. A combination of central and right division masses was defined as a right divisional mass. Complete hepatic resection was defined as a lobectomy, where the lobe was amputated at the hilus, compared to a partial lobectomy, where the lobe was amputated through the parenchyma. Size of the mass was measured in cubic centimeters, and was determined from imaging records. Imaging records were preferred because size was inconsistently documented on surgical records. Computed tomography (CT) was preferred but if it was not available measurements were obtained from ultrasound reports. When imaging records did not include at least 2 dimensions of the size of the mass, histopathology records were reviewed for the size of the mass. When only 2 dimensions were recorded, cubic size was estimated by multiplying these 2 dimensions by their mean value. The surgical resection technique was defined as use of a thoracoabdominal (TA) stapling device, hilar dissection, or "other," which included circumferential ligature and vessel sealing device. Incision extension into the thorax was recorded if a median sternotomy or diaphragmotomy was performed to aid with surgical access. A surgeon could be a specialist or nonspecialist.

Outcome measures included mortality, intraoperative complications, and postoperative complications within 14 days. Intraoperative complications were defined as intraoperative hemorrhage requiring blood product transfusion, or injury to surrounding structures during attempted mass resection. Postoperative complications were defined as any adverse event or surgical complication up to 14 days after surgery. Pyrexia was defined as a body temperature of 103 °F or greater on more than 1 occasion. Gastrointestinal complications were defined as 2 or more vomiting or regurgitation episodes. Hypoglycemia was defined as a blood glucose less than 3.3 mmol/L. Hypoproteinemia was defined as serum total protein less than 5.8 g/dL, hyperlactatemia as a blood lactate greater than 2.5 mmol/L. Hypotension was defined as a mean arterial pressure (MAP) less than 60 mmHg measured with noninvasive blood pressure. Aspiration pneumonia, or pleural space disease, was confirmed with radiography, and cardiac arrhythmias were diagnosed with electrocardiogram evaluation. Pancreatitis was defined by clinical suspicion correlated with sonographic evidence.

2.2 | Statistical analysis

Data from dogs with left divisional masses were compared with those from dogs with right divisional masses, and dogs with central divisional masses were compared with dogs with right divisional masses. The surgical excision technique was combined into hilar dissection and "other" for comparison with the TA stapler.

Descriptive data were stratified by mass location and compared with Fisher's exact test for categorical data and the Kruskal-Wallis test for continuous data. Outcomes were stratified by mass location and compared with a Fisher's exact test (https://www.socscistatistics.com/tests/fisher/default2.aspx). Dogs that did not receive surgery were stratified by mass location and compared with the surgical population using a Fisher's exact test to assess for any bias in selection of patients for surgery.

Three separate multivariable regression models were created to evaluate the potential relationship between the explanatory variables while accounting for potential confounding factors. Univariable logistic regression analysis was used initially to assess predictive factors for mortality, intraoperative complications, or postoperative complications. Predictive valuables included in the statistical analysis were age, sex, weight, size of mass, excision technique, mass location, surgeon, incision extension, and presence or absence of other procedures. All variables were initially assessed in a univariable binary logistic regression model, and potential explanatory variables with an initial $P < 0.5$ were entered into a multivariable logistic regression model. A stepwise backwards selection protocol was followed. Nested models were compared using an ANOVA. Explanatory variables that were not statistically significant were removed from the model, one at a time, beginning with the least significant, until the estimated regression coefficients for the retained variables were significant ($P \leq .05$).

The results of the final model are reported in terms of adjusted odds ratios (OR) for each explanatory variable. The discriminatory ability of the final models was assessed by the calculation of the area under the curve (AUC) of a receiver operating characteristic (ROC) curve.

3 | RESULTS

3.1 | Signalment

A total of 124 dogs (age median 11.5, Q1-Q3 10.2 to 13.1 years; weight median 14.0, Q1-Q3 7.4 to 24.9 kg) had surgical resection of liver lobe masses between 2008 and 2020 (Table 1). There were 57 male (8 intact, 49 neutered), and 67 female (4 intact, 63 neutered) dogs. Median follow up was 286 (range: 14 to 2043) days.

3.2 | Liver mass

Masses included a single lobe (96 dogs), 2 lobes (24 dogs), 3 lobes (2 dogs), and 4 lobes (1 dog). Information regarding mass size (median 379.5, [Q1-Q3 98.2 to 843] cm^3) was available for 90 dogs.

3.3 | Surgery

Liver lobectomy involved the left lateral lobe (51 dogs), left medial lobe (33 dogs), quadrate lobe (25 dogs), right medial lobe (23 dogs), right lateral lobe (11 dogs), the caudate process of the caudate lobe (9 dogs), and the papillary process of the caudate lobe (2 dogs). Location of liver lobectomy was defined as left divisional in 72, central divisional in 34, and right divisional in 18 dogs. A complete liver lobectomy was performed in 98 dogs, and a partial lobectomy in 26 dogs – depending on the mass location and at the discretion of the attending surgeon.

A ventral midline abdominal approach to the liver was made in all dogs. Incision extension into the thorax was performed in 27 dogs at the discretion of the attending surgeon; 13 via a median sternotomy, and 14 by diaphragmotomy. Extension of the surgical incision to the thorax occurred more often with surgical resection of right rather than left divisional masses ($P = .020$, Table 1).

Other procedures were performed in 56 dogs, including splenectomy (22 dogs), cholecystectomy (12 dogs), abdominal lymph node extirpation (6 dogs), subcutaneous/cutaneous mass excision (5 dogs), pancreatic biopsy (5 dogs), enterotomy or gastrotomy (4 dogs), gastropexy (4 dogs), desexing (3 dogs), gastrointestinal biopsies (3 dogs), and cystotomy, artificial urethral sphincter

TABLE 1 Data collected on 124 dogs undergoing liver lobe resection stratified by mass location

Variable	Right	Central	Left
Age median (years) (Q1–Q3)	11.75 (11.00–13.05)	11.30 (10.10–13.28)	11.45 (11.00–13.05)
Weight median (kg) (Q1–Q3)	17.00 (7.10–30.15)	12.50 (7.20–20.82)	13.58 (8.12–26.08)
Sex (male: female)	8: 10	17: 17	32: 40
Size median (cm^3) (Q1–Q3)	561.0 (370.0–803.0)	222.0 (84.0–857.0)	343.0 (95.3–738.0)
Incision extension into the thorax	8/18 (44.4%)*	8/34 (23.5%)	11/72 (15.3%)*
Cases performed by a specialist	16/18 (88.9%)	31/34 (91.2%)	63/72 (87.5%)
Cases performed using a TA stapler	8/18 (44.4%)	15/34 (44.1%)	42/71 (59.2%)

*Statistically significant; ($P = .0195$).

TABLE 2 Surgical outcomes stratified by mass location

Surgical outcomes	Right (18)	Central (34)	Left (72)
Mortality	2/18 (11.1%)	4/34 (11.8%)	2/72 (2.8%)
Morbidity	8/17 (47.1%)	10/33 (30.3%)	17/72 (23.6%)
Intraoperative complications	6/18* (33.3%)	4/34 (11.8%)	4/72* (5.6%)

*Statistically significant ($P = .0037$).

placement and removal of an abdominal mass in 1 dog each. No inadvertent injury to the extrahepatic biliary tract was noted, and all cholecystectomies were performed due to close association between the mass and the gall bladder in 11 dogs and primary gall bladder pathology in 1. Surgery was performed by a Board-certified specialist surgeon in 110 dogs, and nonspecialist surgeon in 14 dogs. There was a total of eight different specialist and four different nonspecialist surgeons. The liver lobectomy was performed with a stapling device (TA stapler; Infiniti Medical, Redwood City, California, USA) (65 dogs), hilar dissection with individual ligation of vessels (51 dogs), bipolar vessel sealing device (Caimen; B. Braun Pty Ltd Australia, Bella Vista, Australia) (6 dogs), circumferential ligature (1 dog), and was not recorded in 1 dog. The histopathological diagnosis was available for 122 dogs. Histopathological diagnosis was HCC (75 dogs); HCA (25 dogs); hemangiosarcoma (7 dogs); hepatic nodular hyperplasia or vacuolation (6 dogs); histiocytic sarcoma (2 dogs); biliary carcinoma (2 dogs); and hematoma, carcinoid, metastatic adenocarcinoma, polycystic liver disease, and hepatocellular adenoma with metastatic mast cells in 1 dog each.

3.4 | Surgical outcomes

3.4.1 | Mortality

Eight of 124 dogs died (6.5%), including 2 dogs with lobectomies of the right division and 6 of the left or central division (Table 2). One dog died intraoperatively from exsanguination during surgical manipulation of a right divisional tumor. Two dogs suffered cardiopulmonary arrest during recovery from anesthesia within hours after surgery. Two dogs were euthanized 5 days postoperatively; 1 due to the development of *Klebsiella pneumoniae* septic peritonitis and the other following the development of multiple organ dysfunction syndrome. Individual dogs died from presumed pulmonary thromboembolism, acute respiratory distress syndrome, and sepsis.

In the final multivariate model, no variable was a statistically significant predictor of mortality. Age was the last potential predictor within the model ($P = .068$, OR 1.4, CI 0.99-2.01). There was no increase in mortality when resecting right divisional masses when compared to resecting masses in the left or central divisions (Table 3).

3.4.2 | Intraoperative complications

Intraoperative complications were seen in 14/124 dogs (11.3%) (Table 2). Blood products were administered to 33/124 dogs (26.6%). Whole blood was administered to 29 dogs, packed red blood cells to 3 and plasma to 8, 7 of which had both plasma and whole blood. Blood products were administered preoperatively (6 dogs), intraoperatively (17 dogs), and postoperatively (13 dogs). Hemorrhage requiring an intraoperative or postoperative blood transfusion occurred in 7 dogs and injury to major blood vessel requiring direct repair occurred in 11 dogs. All other blood transfusions were given perioperatively, as a result of the disease process rather than as a result of

TABLE 3 Association between liver mass location and mortality in 124 dogs: Regression coefficients and standard errors from bivariate logistic regression

Variable	Coefficient	*P* value	OR (95% CI)
Age	0.0005	.065	1.001 (0.099–1.002)
Sex	0.754	.621	0.689 (0.136–2.939)
Weight	0.029	.374	1.026 (0.965–1.085)
Location			
Left versus right	1.038	.155	0.229 (0.026–2.020)
Central versus right	0.920	.944	1.067 (0.186–8.295)
Technique (TA stapler versus other)	0.754	.376	1.950 (0.457–9.865)
Surgeon (specialist versus nonspecialist)	1.109	.911	0.883 (0.140–17.20)
Size (cm^3)	0.0005	.711	1.0002 (1.000–1.001)
Incision extension into thorax	0.847	.819	1.213 (0.171–5.646)
Additional procedures performed	0.754	.654	0.713 (0.163–3.125)

Note: Age was the final potential predictor within the multivariable model and was not significant ($P = .0683$, OR 1.383, CI 0.992-2.010).
Abbreviations: CI, confidence interval; OR, odds ratio.

TABLE 4 Association between liver mass location and intraoperative complication in 124: Regression coefficients and standard errors from bivariate logistic regression

Variable	Coefficient	*P* value	OR (95% CI)
Age	0.131	.129	1.212 (0.951–1.596)
Sex	0.590	.417	0.620 (0.181–1.913)
Weight	0.023	.114	1.037 (0.990–1.084)
Location			
Left versus right	0.718	**.0029**	0.118 (0.026–0.470)
Central versus right	0.730	.0703	0.267 (0.059–1.094)
Technique (TA stapler versus other)	1.057	**.0057**	18.489 (3.494–341.871)
Surgeon (specialist versus nonspecialist)	1.080	.607	1.742 (0.306–32.936)
Size (cm^3)	0.0005	.992	1.00 (0.999–1.001)
Incision extension into thorax	0.589	**.011**	4.500 (1.398–14.600)
Additional procedures performed	0.622	.194	0.446 (0.117–1.422)

Note: Bold values are statistically significant ($p < .05$). In the final multivariable analysis, the technique of excision ($P = .007$, OR 19.003, CI 3.379-361.656) increased the odds of intraoperative complication. Right divisional masses increased the odds of intraoperative complication when compared with left ($P = .007$, OR 0.118, CI 0.023-0.539). When compared with right divisional masses, central divisional masses were close to significant but not significant ($P = .0504$, OR 0.204, CI 0.038-0.964).
Abbreviations: CI, confidence interval; OR, odds ratio.

attempted surgical removal of the liver mass. Major vessels injured included the caudal vena cava (6 dogs), adjacent hepatic vein (4 dogs), and the splenic vein in 1 dog. Inadvertent injury to the diaphragm occurred in 1 dog.

In the final multivariable analysis, technique of excision ($P = .006$, OR 19.00, CI 3.38-361.66) was associated with an increased likelihood of intraoperative complications. Hilar dissection, use of a bipolar vessel sealing device, or use of a circumferential ligature, was associated with a 19 fold increase in the odds of an intraoperative complication compared to use of a TA stapler. The likelihood of intraoperative complications differed by location: left divisional masses were associated with fewer intraoperative complications ($P = .007$, OR 0.12, CI 0.02-0.54). Central divisional masses, when compared to right, were close to, but not a significant predictor of intraoperative complication ($P = .0504$, OR 0.20, CI 0.04-0.96) (Table 4).

3.4.3 | Postoperative complications

Postoperative complication data were available for 122 dogs. Complications occurred in 35/122 dogs (28.7%) (Table 2). The most common complications involved

TABLE 5 Association between liver mass location and postoperative complication in 122 dogs: Regression coefficients and standard errors from bivariate logistic regression

Variable	Coefficient	*P* value	OR (95% CI)
Age	0.091	.090	1.168 (0.980–1.406)
Sex	0.416	.105	0.510 (0.220–1.136)
Weight	0.020	.239	0.977 (0.939–1.014)
Location			
Left versus right	0.560	.059	0.348 (0.115–1.056)
Central versus right	0.616	.246	0.489 (0.143–1.643)
Technique (TA stapler versus other)	0.448	**.0005**	4.774 (2.045–12.006)
Surgeon (specialist versus nonspecialist)	0.597	.149	0.423 (0.130–1.411)
Size (cm^3)	0.0003	.768	1.000 (0.999–1.001)
Incision extension into thorax	0.488	**.00002**	8.185 (3.223–22.168)
Additional procedures performed	0.410	.265	0.633 (0.278–1.401)

Note: Bold values are statistically significant ($p < .05$). In the final multivariate model; incision extension ($P = 0.00009$, OR 9.064, CI 3.135-28.884) and technique of excision ($P = .005$, OR 4.352, CI 1.622-12.755) were associated with an increased odds of postoperative complication. Specialist surgeon ($P = .033$, OR 0.174, CI 0.033-0.877) and increasing weight ($P = .027$, OR 0.941, CI 0.888-0.990) decreased the odds of morbidity.

Abbreviations: CI, confidence interval; OR, odds ratio.

gastrointestinal signs (21 dogs), followed by pyrexia (12 dogs), the need for oxygen therapy (12 dogs), hypoproteinemia (5 dogs), readmission to hospital following discharge (4 dogs), hyperlactatemia (4 dogs), hypoglycemia (3 dogs), hypotension (3 dogs), cardiac arrhythmias (3 dogs), aspiration pneumonia (3 dogs), neurological signs (2 dogs), wound complications (2 dogs), pancreatitis (2 dogs), and pyothorax and septic peritonitis in 1 dog each.

In the final multivariable analysis, extending the surgical incision to the thorax was associated with a 9.1 fold ($P < .001$, OR 9.06, CI 3.14-28.88) increase in the chance of developing a postoperative complication. Technique of excision ($P = .005$, OR 4.35, CI 1.62-12.76) was associated with an increased likelihood of postoperative complications. Hilar dissection, use of a bipolar vessel sealing device, or use of a circumferential ligature was associated with a 4.4-fold increase in the odds of a postoperative complication compared with the use of a TA stapler. Surgery performed by a specialist surgeon ($P = .033$, OR 0.17, CI 0.03-0.88) and increasing weight ($P = .027$, OR 0.94, CI 0.89-0.99) were associated with lower likelihood of postoperative complications (Table 5).

3.4.4 | Nonsurgical cases

A total of 22 dogs with complete medical and imaging records documenting a solitary liver mass and its location that did not receive surgery were included. Of these dogs, liver masses were identified in the left division (12 dogs), central division (6 dogs) and right division (4 dogs). The proportion of right division to other division was not statistically significant between the nonsurgical and surgical groups ($P = .746$).

4 | DISCUSSION

The surgical management of dogs with right divisional liver masses was not associated with a higher mortality or increase in postoperative complications than in left and central masses. However, they were associated with an increase in intraoperative complications compared with masses located in the left division. In this study population, intraoperative complications occurred in 11.3% of patients. In comparison with masses within the left division, resection of a right divisional mass was associated with an 88% higher chance of an intraoperative complication – which is in line with previous studies.[3] An increased risk of intraoperative hemorrhage during right divisional lobectomies is likely a reflection of the intimate association of the right divisional liver lobes with the caudal vena cava.[9] In relation to the central division and risk of intraoperative complications, Linden and colleagues recently published a paper on the outcomes for central liver lobectomies. They identified a relatively high rate (32.8%) of intraoperative hemorrhage, prompting the authors to conclude an increased technical challenge of central divisional lobectomies when compared with those on the left.[7] In the present study, injury to the caudal vena cava occurred in surgery involving both central and right divisional lobectomies, but not the left. This may suggest a similar technical challenge for both central and right divisional lobectomies as distinct from left divisional lobectomies. When compared in the multivariable analysis, there was no significant difference between right and central divisional lobectomies with regards to the risk of intraoperative complications. Given that intraoperative complications occurred in only 14 dogs, it is possible that more case numbers would make this association clearer.

Our intraoperative complication rate of 11.3% was similar to some studies[7] but was lower than other reported intraoperative complication rates.[3,7] Quantifying intraoperative hemorrhage as an outcome variable was challenging. In this study, intraoperative complications were defined as intraoperative hemorrhage requiring blood product transfusion or injury to surrounding structures during attempted mass resection, including injury to a major blood vessel. It is possible that intraoperative hemorrhage was understated and, in future studies, it should preferably be measured prospectively using objective criteria. Injury to and repair of surrounding vasculature, however, would have been consistently reported in surgery reports, and remains an important inclusion in definition of intraoperative complications.

Mass location was not associated with mortality. In our study, 6.5% of dogs undergoing liver lobectomy died perioperatively. This is comparable with previous studies, where mortality rates ranged from 4.8% to 11%.[3,6–8] Two dogs with right divisional masses died, 1 from exsanguination intraoperatively and the second from a cardiopulmonary arrest during recovery from anesthesia. In the study by Liptak et al. (2004), 2 of 5 dogs with right-sided liver masses exsanguinated intraoperatively as a result of trauma to the caudal vena cava during attempted resection.[3] In our study population, mortality rates were not significantly different between locations. The reason for this difference may be explained by this study's larger sample size.

Perioperative complications in the current literature range from 13% to 32.7%.[3,6,8] In this study, excision technique was a significant predictor for both intraoperative and postoperative complications. Liver lobectomies can be performed using a number of techniques, including hilar dissection, which involves the identification and ligation of individual vessels, surgical staplers, vascular sealing devices, and loop suture.[11] The use of a TA stapler and its association with reduced complications has been reported previously,[7] and is consistent with our finding that excision by hilar dissection or other method increased the odds of intraoperative and postoperative complications by 19 and 4.4 times, respectively, when compared with the use of a TA stapler. This is likely a reflection on the ease of tumor removal. More extensive dissection is likely required for less accessible tumors or tumors involving the hilus. There was also a significant association between increasing weight and reduced postoperative complications. Larger patients may provide an improved surgical access and ease of surgical dissection.

Right divisional masses were not directly associated with an increase in postoperative complications but they may be indirectly related to an increased postoperative complication via their relationship with incision extension into the thorax. Right divisional masses were more likely to require an incision extension into the thorax when compared with masses within the left division. This increased incident of incision extension is again likely a reflection upon the anatomical challenge of right divisional lobectomies. Dean et al. were the first to report on the use of diaphragmotomy to aid with hepatobiliary surgery.[12] In that paper, dogs that received a diaphragmotomy suffered a 68% postoperative complication rate. Median sternotomy incisions to aid with the exposure of hepatobiliary surgery have also been reported by Linden and colleagues, with the postoperative morbidity of this procedure being well reported.[13,14] In our population, extension of incision into the thorax, either by diaphragmotomy or median sternotomy, increased the odds of a postoperative complication by 9.1 times. Despite demonstrating a higher risk of postoperative complications, the improved exposure for mass dissection gained from incision extension should not be underestimated. It is possible that the morbidity or mortality cost of not performing an incision extension for challenging masses may outweigh the morbidity risk of this procedure.

Dogs diagnosed with preoperative septic peritonitis, or those that received concurrent adrenalectomies or thoracotomies for reasons other than to improve surgical access, were excluded from the study population. Complications associated with septic peritonitis and these other procedures are well documented, and inclusion of these dogs may preclude any conclusion as to source of the morbidity or mortality.[13,15,16] Dogs with other procedures performed at the same time as the liver lobectomy were included. Procedures such as splenectomy, abdominal lymph node extirpation and gastropexy would commonly be performed in association with liver lobectomies, and inclusion of these dogs may better reflect the clinical scenario. To investigate whether these procedures may have influenced outcomes, dogs with other procedures were included in the statistical analyses but having other procedures was not found to have had a significant effect in any of the 3 models.

There are limitations inherent in the retrospective nature of this study. The first is the low proportion of right divisional masses when compared with central and left, divisional masses. Despite the right division accounting for 28% of total liver volume,[17] a low proportion of right divisional masses is consistent with other studies in which right divisional tumors account for between 12.2% and 20% of all liver masses.[1,3,6,8] The reason is unclear. Selection bias may be one explanation for the low proportion of right sided lobectomies; however, we measured the prevalence of right-sided masses in our surgical and nonsurgical patients and found no significant difference. As this is a population from a referral hospital, it is possible that a selection bias may have existed in our referring practices, although this is considered unlikely. Despite having a low proportion of right divisional masses, this population includes the most right divisional masses yet reported.

In conclusion, the surgical resection of right divisional masses was associated with increased intraoperative hemorrhage or injury to greater vessels when compared with left divisional lobectomies. Although location was not associated with an increase in postoperative complication, there may be an indirect association with morbidity, due to the increased likelihood of needing to extend the surgical incision into the thorax when performing right lobectomies. Divisional location was not associated with risk of mortality.

ACKNOWLEDGMENTS

Author Contributions: Moore VW, BVSc, MANZCVS: Contributed to study design and definitions of potential predictors and outcome variables. Collected all retrospective data, assisted in statistical processing, and wrote and edited final manuscript. White J, BVSc, MVS (Epi), PhD, DACVIM: Contributed to study design and definitions of potential predictors and outcome variables. Provided statistical analysis and suggestions to statistical study design. Assisted with final manuscript preparation and editing. Marchevsky AM, BVSc, MVS, FANZCVS: Contributed to study design and definitions of potential predictors and outcome variables. Provided study idea and hypotheses. Assisted with final manuscript preparation and editing.

CONFLICT OF INTEREST

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

REFERENCES

1. Patnaik AK, Hurvitz AI, Lieberman PH. Canine hepatic neoplasms: a clinicopathologic study. *Vet Pathol*. 1980;17(5):553-564.
2. Trigo FJ, Thompson H, Breeze RG, Nash AS. The pathology of liver tumours in the dog. *J Comp Pathol*. 1982;92(1):21-39.
3. Liptak JM, Dernell WS, Monnet E, et al. Massive hepatocellular carcinoma in dogs: 48 cases (1992–2002). *J Am Vet Med Assoc*. 2004;225(8):1225-1230.
4. Selmic LE. Hepatobiliary neoplasia. *Vet Clin North Am Small Anim Pract*. 2017;47(3):725-735.
5. Matsuyama A, Takagi S, Hosoya K, et al. Impact of surgical margins on survival of 37 dogs with massive hepatocellular carcinoma. *N Z Vet J*. 2017;65(5):227-231.
6. Kinsey JR, Gilson SD, Hauptman J, Mehler SJ, May LR. Factors associated with long-term survival in dogs undergoing liver lobectomy as treatment for liver masses. *Can Vet J*. 2015;56(6):598-604.
7. Linden DS, Liptak JM, Vinayak A, et al. Outcomes and prognostic variables associated with central division hepatic lobectomies: 61 dogs. *Vet Surg*. 2019;48(3):309-314.
8. Hanson KR, Pigott AM, Linklater AK. Incidence of blood transfusion requirement and factors associated with transfusion following liver lobectomy in dogs and cats: 72 cases (2007–2015). *J Am Vet Med Assoc*. 2017;251(8):929-934.
9. Evans HE. In: Evans HE, ed. *Miller's Anatomy of the Dog*. 3rd ed. WB Saunders Co; 1993:698-699.
10. Liptak JM. Cancer of the gastrointestinal tract. In: Vail DM, Thamm DH, Liptak JM, eds. *Withrow & MacEwen's Small Animal Clinical Oncology*. 6th ed. Elsevier; 2020:459.
11. Risselada M, Ellison GW, Bacon NJ, et al. Comparison of 5 surgical techniques for partial liver lobectomy in the dog for intraoperative blood loss and surgical time. *Vet Surg*. 2010;39(7):856-862.
12. Dean B, Anderson T, Garcia-Pertierra S, et al. Diaphragmotomy to aid exposure during hepatobiliary surgery: a multicentre retrospective review of 31 dogs. *J Small Anim Pract*. 2020;61(5):278-284.
13. Bleakley S, Phipps K, Petrovsky B, Monnet E. Median sternotomy versus intercostal thoracotomy for lung lobectomy: a comparison of short-term outcome in 134 dogs. *Vet Surg*. 2018;47(1):104-113.
14. Burton CA, White RN. Review of the technique and complications of median sternotomy in the dog and cat. *J Small Anim Pract*. 1996;37(11):516-522.
15. Bentley AM, Otto CM, Shofer FS. Comparison of dogs with septic peritonitis: 1988–1993 versus 1999–2003. *J Vet Emerg Crit Care*. 2007;17(4):391-398.
16. Cavalcanti JVJ, Skinner OT, Mayhew PD, Colee JC, Boston SE. Outcome in dogs undergoing adrenalectomy for small adrenal gland tumours without vascular invasion. *Vet Comp Oncol*. 2020;18(4):599-606.
17. Francavilla A, Porter KA, Benichou J, Jones AF, Starzl TE. Liver regeneration in dogs: morphologic and chemical changes. *J Surg Res*. 1978;25(5):409-419.

How to cite this article: Moore VW, White J, Marchevsky AM. Association between divisional location and short-term outcome of liver mass resection in 124 dogs. *Veterinary Surgery*. 2023;52(4):513-520. doi:10.1111/vsu.13941