Analysis of risk factors associated with complications following mandibulectomy and maxillectomy in dogs

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OBJECTIVE
To provide information about complication rates and the risk factors for complications with mandibulectomy and maxillectomy procedures in dogs.

ANIMALS
459 client-owned dogs that underwent a mandibulectomy or maxillectomy between January 1, 2007, and January 1, 2018.

PROCEDURES
Inclusion criteria included a complete medical record that contained an anesthesia record, surgical report, available histopathology results, and results of CBC and serum biochemical analysis before surgery. A minimum follow-up of 90 days after surgery was required.

RESULTS
271 complications occurred in 171 of 459 (37.3%) dogs. Eighteen complications were not given a severity description. Of the remaining 253 complications, most were considered minor (157/253 [62.1%]). Multivariable logistic regression analysis revealed that only increased surgical time had a significant (OR, 1.36; 95% CI, 1.12 to 1.54) association with the occurrence of ≥ 1 complication. For each additional hour of surgery, the odds of complications increased by 36%. Preoperative radiation therapy or chemotherapy increased the odds of incisional dehiscence or oral fistula formation (OR, 3.0; 95% CI, 1.3 to 7.2). Additionally, undergoing maxillectomy, compared with mandibulectomy, increased the odds of incisional dehiscence or oral fistula formation (OR, 1.8; 95% CI, 1.1 to 3.1). Two hundred forty-four of 271 (90.0%) complications occurred in the perioperative period (0 to 3 months after surgery).

CONCLUSIONS AND CLINICAL RELEVANCE
Compared with mandibulectomy, performing maxillectomy increased the risk for incisional dehiscence or oral fistula formation. Mandibulectomy and maxillectomy had a moderate risk for a complication. (*J Am Vet Med Assoc* 2021;259:265–274)

Mandibulectomy and maxillectomy are most commonly indicated for the treatment of oral tumors.[1–3] Additional indications for these procedures include severe trauma, osteomyelitis, lock jaw syndrome, open-mouth lower jaw locking, and dentigerous cysts.[4–8] Many of the reports[9–11] on mandibulectomy and maxillectomy have focused on reporting oncological outcomes following these surgical procedures (and not on complications from the procedures themselves). Surgical complications that have been associated with these procedures include hemorrhage,[11,12] aspiration pneumonia,[11,13,14] incisional dehiscence,[1–3,11–13,15–17] mandibular drift and malocclusion,[11,13,15,17,18] ranula formation,[11,13,18] anorexia,[11,17] nasal discharge or epistaxis,[11] difficulty prehending,[2,11,14] implant migration,[11,14] oronasal fistula formation,[11] and death.[16] Additional complications, although not secondary to the procedure itself, have included tumor recurrence and metastasis.[2,3,11,12,14,16,18]

Risk factors for complications associated with maxillectomy and mandibulectomy have been investigated to a limited extent. A recent study[9] that evaluated complications in dogs undergoing partial maxillectomy revealed that tumor size, location (ie, caudal locations), and surgical approach were significantly associated with severe intraoperative hemorrhage requiring blood transfusion. This was the first study[9] in veterinary medicine to focus on possible complications following orofacial surgery. However, the study[9] had some limitations because it represented affected dogs from a specialized surgical oncology center, its focus was solely on maxillectomy, and a high percentage of affected dogs underwent a complete or caudal maxillectomy (51.8%). Some smaller studies[12,13,16,18] have speculated possible risk factors for potential surgical complications. For instance, in a study[2] that evaluated partial maxillectomy as a treatment for oral cancer in 61 dogs, the authors determined that caudal maxillectomy resulted in higher rates of partial wound dehiscence, compared with dogs that underwent rostral resections. One study[9] cited that 40% of dogs that underwent a caudal maxillectomy received a blood transfusion. In contrast, another study[19] cited that only 25% of dogs that underwent a caudal maxillectomy received a blood transfusion. Additionally, specific complications may be identified, but only rarely is the overall complication rate reported. This may be due to a low overall number of patients in these studies.[13,14,16,17]

In a study,[20] complications following orthognathic surgery (corrective jaw surgery) are reported to occur in 19.2% of human patients. These complications include postoperative malocclusion, hemorrhage, inferior alveolar nerve injury, bad split (unfavorable fracture at osteotomy site), and infection. In that study,[20] complications were more common in men and associated with the increasing duration of surgery, increasing number of surgeries, surgical site involved, and type of osteotomy performed. Surgical site infection and aspiration pneumonia are other examples of common complications following oral surgery in humans.[21,22] One study[22] documented hypoalbuminemia and increasing surgical time as important risk factors for postoperative complications following oral surgery. In patients with head and neck cancer, the rate of surgical site infection ranges from 10% to 45%, with previous chemotherapy, performance of a tracheotomy, free flap reconstruction, blood loss volume, and hypoalbuminemia found as risk factors.[23–27] This type of investigation is recommended in veterinary medicine to inform both surgeons and pet owners of possible complications and risk factors for complications following these surgical procedures.

The purpose of the study reported here was to provide contemporary information about the complication rates and risk factors for complications following mandibulectomy and maxillectomy in dogs. Our hypotheses were that maxillectomies, specifically caudal procedures, would result in a greater risk of severe hemorrhage requiring a blood transfusion and carry a higher risk for incisional dehiscence or oral fistula formation. Additionally, we hypothesized a larger mass size would result in an increased risk of complications associated with both mandibulectomy and maxillectomy.

Materials and Methods

Case selection criteria

Participating institutions were contacted to search their medical record databases for dogs that underwent a mandibulectomy or maxillectomy procedure for any reason between January 1, 2007, and January 1, 2018. Inclusion criteria were a complete medical record that contained an anesthesia record, surgical report, histopathology results if applicable, and results of a CBC and serum biochemical analysis before surgery. A minimum follow-up of 90 days after surgery was required to be recorded in the medical records as communication with the owner, primary care veterinarian, or both.

Medical records review

For each dog included in the study, specific information was extracted from the medical record. The type of surgery was recorded and defined for the mandibulectomy procedure as rostral unilateral (confinement to the rostral mandible; not crossing the midline), rostral bilateral (confinement to rostral mandibles crossing the symphysis), segmental (confined to midhorizontal ramus), ramus (confined to the vertical ramus), rim (involving a portion of the mandible while preserving the ventral cortex), or complete unilateral (removal of the horizontal ramus in entirety).[28] The surgery for the maxillectomy procedure was defined as rostral unilateral (confined to the rostral hard palate on 1 side), rostral bilateral (confined to the rostral hard palate crossing the midline), segmental (confined to the midmaxillary region cranial to the fourth premolar tooth), caudal (confined to the area caudal to the fourth premolar tooth), or complete unilateral (removal of the maxilla in its entirety).[28]

A surgical complication was defined as any adverse event attributed to surgical intervention.[29] For each dog included in the study, the following complications were recorded: aspiration pneumonia, dehiscence, infection, need for blood transfusion, mandibular drift and malocclusion, ranula formation, anorexia for > 3 days, difficulty prehending, implant migration, oral fistula formation, and other complications. Other complications that occurred included gastric dilatation-volvulus, hip joint luxation during recovery, both corneal and oral mucosa ulcer formation, epistaxis, rhinitis, respiratory arrest, urinary tract infection, regurgitation, facial paralysis, facial swelling, tongue trauma, seroma formation, suspect mast cell degranulation, subcutaneous emphysema, neuropathy of the hypoglossal nerve, and hypocalcemia. Anorexia of > 3 days' duration was considered as a severe or medically important event, but not immediately life-threatening.[30] The definition of a surgical site infection was that used by the CDC as an infection that occurs after surgery in a part of the body where the surgery took place.[31] A wound was considered infected if purulent material was present. A microbial culture was not needed for diagnosis.[31] A diagnosis of aspiration pneumonia was made on the basis of a predominately alveolar or interstitial pattern observed with thoracic radiography. A ranula was defined as a swelling that developed on the floor of the mouth. Confirmation of a true ranula was not required; therefore, these complications could also be considered as pseudoranula; however, for the present study, the term ranula was used. Also, both orocutaneous and oronasal fistulas were classified as an oral fistula.

For each complication, a time frame was requested as established by Cook et al[32] as follows: perioperative, 0 to 3 months after surgery; short-term, 3 to 6 months after surgery; midterm, 6 to 12 months after surgery; and long-term, > 12 months after surgery.[32] The severity of each complication was classified as catastrophic, major, or minor at the discretion of the contributing author on the basis of guidelines.[32] A catastrophic complication caused permanently unacceptable dysfunction, was directly related to death, or was a cause for euthanasia. A major complication required further treatment, either surgical or medical, on the basis of the current standard of care. A minor complication did not require additional surgical or medical treatment to resolve.[32]

Data analysis

Continuous data were evaluated for normality by use of skewness, kurtosis, and Shapiro-Wilk tests. Normally distributed data were reported as mean ± SD, and nonnormally distributed data were reported as median and range. Categorical variables were presented as frequencies and percentages. Both median follow-up time and range of follow-up time were calculated.

Univariable logistic regression analysis was used to evaluate for variable associations with the occurrence of ≥ 1 complication, severe hemorrhage requiring a blood transfusion, dehiscence or oral fistula formation, and tumor recurrence.

Variables evaluated for the occurrence of ≥ 1 complication included institution, age, sex and neuter status, body weight, body condition score, largest tumor dimension, margin status, surgery and anesthesia times, preoperative serum albumin concentration, and whether the tumor crossed the midline, a mandibulectomy or maxillectomy was performed, the resection involved excision of the caudal aspect of the mandible or maxilla, tooth roots were removed, perioperative and postoperative antimicrobials were administered, the diagnosis was neoplasia, the patient received preoperative radiation therapy or chemotherapy, a feeding tube was placed, an endocrinopathy was present, and the patient was receiving immunosuppressive medication.

Variables assessed for associations with severe hemorrhage requiring blood transfusion included institution, body weight, largest tumor dimension, tumor crossing the midline, maxillectomy versus mandibulectomy, and caudal resection.

Variables assessed for associations with dehiscence or oral fistula formation included the largest tumor dimension, tumor crossing the midline, maxillectomy versus mandibulectomy, caudal tumor location, postoperative antimicrobial administration, preoperative radiation therapy or chemotherapy, and presence of endocrinopathies.

Variables assessed for associations with tumor recurrence included institution, age, sex and neuter status, body weight, body condition score, presence of endocrinopathies, tumor type, whether the lesion was malignant or benign, margin status, largest tumor dimension, whether tumor crossed the midline, mandibulectomy versus maxillectomy, caudal location of tumor, anesthesia and surgery times, preoperative radiation therapy or chemotherapy, and use of immunosuppressive medication.

Multivariable logistic regression analysis was performed to assess variable associations with the following outcome variables: development of complications, incisional dehiscence or oral fistula formation, and tumor recurrence. Models were built by use of backward selection with variables that had values of $P < 0.2$ in univariable analysis and were not correlated with each other. Variables with values of $P < 0.05$ were retained in the model. Multivariable logistic regression analysis was not performed for severe hemorrhage necessitating blood transfusion because of low event numbers.

Statistical analysis was performed with commercially available software.[a] Values of $P < 0.05$ were considered significant.

Results

Animals

Four hundred fifty-nine dogs met the inclusion criteria. Baseline characteristics and treatment details of the study population are summarized **(Table 1)**. Median age of dogs at the time of surgery was 9.0 years (range, 0.3 to 17.0 years). Median body weight was 29.8 kg (65.6 lb) with a range of 1.8 to 76.6 kg (4.0 to 168.5 lb). On a scale of 1 (very thin) to 9 (morbidly obese), median body condition score was 6.0 (range, 3.0 to 9.0). The most commonly reported type of dog was mixed breed (92/459 [20%]).

Treatment

The mandibulectomy or maxillectomy was performed by a surgical service for 432 of 459 (94.1%) dogs, dentistry service for 26 (5.7%) dogs, and both services for 1 (0.2%) dog. The most common histopathologic diagnosis was acanthomatous ameloblastoma (108/459 [23.5%] dogs), followed by squamous cell carcinoma (68/459 [14.8%]) and melanoma (55/459 [12.0%]; **Table 2**). Median follow-up time was 1,070 days (range, 90 to 3,964 days), and 216 of 459 (47.1%) dogs were alive at the time of final follow-up. Long-term follow-up (> 12 months after surgery) was available for 289 dogs, midterm follow-up (6 to 12 months after surgery) for 96 dogs, short-term follow-up (3 to 6 months after surgery) for 51 dogs, and perioperative follow-up (0 to 3 months after surgery) for 23 dogs.

Mandibulectomy—Two hundred seventy-nine of 459 (60.8%) dogs underwent a mandibulectomy

Table 1—Baseline characteristics and treatment details for 459 client-owned dogs in the present study that underwent a mandibulectomy or maxillectomy between January 1, 2007, and January 1, 2018.

Variable	Category	Values
Dog breeds and types (n = 459)*	American Pit Bull Terrier	10 (2.2)
	Beagle	11 (2.4)
	Boxer	12 (2.6)
	German Shepherd Dog	16 (3.5)
	Golden Retriever	47 (10.2)
	Labrador Retriever	90 (19.6)
	Mixed breed	92 (20)
	Other	181 (39.4)
Sex (n = 459)*	Male castrated	214 (46.6)
	Female spayed	206 (44.9)
	Male sexually intact	33 (7.2)
	Female sexually intact	6 (1.3)
Age (years)†	—	9.0 (4.0)
Body weight (kg)†	—	29.8 (19.1)
Body condition score (scale, 1–9)†	—	6.0 (2.0)
Comorbidities (n = 459)*	Endocrinopathy	26 (5.7)
	Preoperative chemotherapy or radiotherapy	26 (5.7)
	Immunosuppressive medications	17 (3.7)
Service performing surgery (n = 459)*	Dentistry	26 (5.7)
	Surgery	432 (94.1)
	Both	1 (0.2)
Surgery type (n = 459)*	Mandibulectomy	279 (60.8)
	Maxillectomy	180 (39.2)
Type of mandibulectomy (n = 279)*	Caudal	7 (2.5)
	Complete unilateral	25 (9.0)
	Rim	1 (0.4)
	Rostral bilateral	112 (40.1)
	Rostral unilateral	65 (23.3)
	Segmental	63 (22.6)
	Vertical ramus	6 (2.2)
Type of maxillectomy (n = 180)*	Caudal	43 (23.9)
	Complete unilateral	2 (1.1)
	Rostral bilateral	39 (21.7)
	Rostral unilateral	46 (25.6)
	Segmental	50 (27.8)
Lesion largest dimension (cm)†	—	2.0 (1.7)
Resection crossed midline (n = 459)*	Yes	162 (35.3)
	No	295 (64.3)
	Unknown	2 (0.4)
Tooth roots removed*	Yes	204 (44.4)
	No	7 (1.5)
	Not applicable	126 (27.5)
	Unknown	122 (26.6)
Perioperative antimicrobials (n = 459)*	Yes	378 (82.4)
	No	74 (16.1)
	Unknown	7 (1.5)
Feeding tube placed (n = 459)*	Yes	13 (2.8)
	No	445 (97.0)
	Previously in place	1 (0.2)
Neoplasia (n = 459)*	Yes	396 (86.3)
	No	63 (13.7)
Tumor type (n = 459)*	Benign	131 (28.5)
	Malignant	287 (62.5)
	Unknown or not applicable	41 (8.9)
Margin status (n = 459)*	Complete	340 (74.1)
	Incomplete	95 (20.7)
	Unknown or not applicable	24 (5.2)
Postoperative antimicrobials (n = 459)*	Yes	271 (59.0)
	No	186 (40.5)
	Unknown	2 (0.4)
Surgery time (min)†	—	95.0 (77.0)
Anesthesia time (min)†	—	190.0 (100.0)
Hospitalization duration (days)†	—	2.0 (1.0)
Time to eating after surgery (days)†	—	1.0 (0.0)

*Values reported as number of dogs (%). †Values reported as median (IQR).
— = An empty cell. IQR = Interquartile range (ie, the difference between the 75th and 25th quartiles).

Table 2—Summary of histopathologic diagnoses for the study population (459 dogs) described in Table 1.

Diagnosis	No. of dogs	Percentage of study population
Acanthomatous ameloblastoma	108	23.5
Squamous cell carcinoma	68	14.8
Melanoma	55	12.0
Fibrosarcoma	49	10.7
Osteosarcoma	39	8.5
Plasma cell tumor	17	3.7
Soft tissue sarcoma	14	3.1
Inflammatory or infectious	12	2.6
Multilobular osteochondrosarcoma	12	2.6
Trauma	10	2.2
Sarcoma	13	2.8
Peripheral odontogenic fibroma	8	1.7
Hyperplasia	8	1.7
Carcinoma	6	1.3
Normal	5	1.1
Open	5	1.1
Fibroma	4	0.9
Mast cell tumor	4	0.9
Neoplasia open	4	0.9
Squamous papilloma	4	0.9
Cyst	3	0.7
Chondrosarcoma	2	0.4
Odontogenic tumor	2	0.4
Osteoma	2	0.4
Granuloma	1	0.2
Hemangiosarcoma	1	0.2
Histiocytic sarcoma	1	0.2
Histiocytoma	1	0.2
Myxoma	1	0.2

(Table 3). The following types of mandibulectomies were performed in 279 dogs: bilateral rostral (112 [40.1%] dogs), unilateral rostral (65 [23.3%]), segmental (63 [22.6%]), complete unilateral (25 [9.0%]), caudal (7 [2.5%]), vertical ramus (6 [2.2%]), and rim excision (1 [0.4%]). Two hundred fifty-one of 279 (90.0%) dogs underwent a mandibulectomy because of an oral tumor. Tumor recurrence occurred in 22 of 279 (7.9%) dogs. Of these 22 dogs, 2 (9.0%) had tumors considered benign and 20 (91%) had tumors considered malignant. Of the same 22 dogs, recurrence occurred following mandibulectomy at 3 to 6 months in 8 (36.4%) dogs, 6 to 12 months in 6 (27.3%) dogs, 0 to 3 months in 5 (22.7%) dogs, and > 12 months in 3 (13.6%) dogs.

Maxillectomy—One hundred eighty of 459 (39.2%) dogs underwent maxillectomy (Table 3). In 180 dogs, the following types of maxillectomies were performed: 50 (27.8%) segmental, 46 (25.6%) rostral unilateral, 43 (23.9%) caudal, 39 (21.7%) rostral bilateral, and 2 (1.1%) complete unilateral. One hundred sixty-four of 180 (91.1%) dogs underwent maxillectomy because of an oral tumor. Tumor recurrence occurred in 30 of 180 (16.7%) dogs and was suspected but not confirmed in 1 (0.6%) dog. Of these 31 dogs, 3 (9.7%) had tumors considered benign and 28 (90.3%) had tumors considered malignant. Tumor recurrence occurred following maxillectomy at 3 to 6 months in 11 dogs (11/31 [35.5%]), 6 to 12 months in 5 dogs (5/31 [16.1%]), 0 to 3 months in 7 dogs (7/31 [22.6%]), and > 12 months in 7 dogs (7/31 [22.6%]). For 1 dog, it was unknown when the recurrence occurred.

Complications

Two hundred seventy-one complications occurred in 171 of 459 (37.3%) dogs. Multiple (> 1) complications occurred in 60 of 459 (13.1%) dogs. The median number of complications was 2 (range, 2 to 6), and these complications often varied in severity. Of 271 complications, 244 (90.0%) occurred in the perioperative period. Eighteen complications were not given a severity description. Of the remaining 253 complications, most were considered minor (157/253 [62.1%]) and the others were major (78/253 [30.8%]). Eighteen complications (18/253 [7.1%]) were considered catastrophic, although only 4 patients died in the perioperative period. Cause of death included euthanasia at the time of surgery, deterioration of health status following surgery requiring euthanasia, cardiovascular arrest, and euthanasia following femoral fracture secondary to hip joint luxation during hospitalization. Catastrophic complications that occurred after surgery up until the last follow-up included euthanasia because of deteriorating health status, respiratory arrest, development of blindness, and development of laryngeal paralysis.

Mandibulectomy—One hundred six of 279 (38.0%) patients that underwent a mandibulectomy developed ≥ 1 complication. The most common complications in 279 dogs were mandibular drift and maloc-

Table 3—Summary of outcome and complications for the study population (459 dogs) described in Table 1.

Variable	Category	Mandibulectomy (n = 279)		Maxillectomy (n = 180)	
		No. of dogs	Percentage	No. of dogs	Percentage
Complications	—				
	Yes	106	38.0	65	36.1
	No	173	62.0	115	63.9
Multiple complications	—	—	—	—	—
	Yes	38	13.6	22	12.2
	No	241	86.4	158	87.8
Perioperative complications (0–3 mo)	—	—	—	—	—
	Hemorrhage needing transfusion	4	1.4	12	6.7
	Aspiration pneumonia	4	1.4	2	1.1
	Dehiscence	34	12.2	28	15.6
	Infection	4	1.4	10	5.6
	Mandibular drift and malocclusion	31	11.1	1	0.6
	Ranula formation	22	7.9	0	0.0
	Anorexia > 3 days	6	2.2	3	1.7
	Difficulty prehending	18	6.5	2	1.1
	Oronasal fistula	3	1.1	18	10.0
	Other	14	5.0	28	15.5
Short-term complications (3–6 mo)	—	—	—	—	—
	Mandibular drift and malocclusion	4	1.4	0	0.0
	Ranula formation	3	1.1	0	0.0
	Anorexia > 3 days	1	0.4	0	0.0
	Difficulty prehending	1	0.4	0	0.0
	Oronasal fistula	0	0.0	1	0.6
	Other	3	1.1	0	0.0
Midterm complications (6–12 mo)	—	—	—	—	—
	Mandibular drift and malocclusion	1	0.4	0	0.0
	Ranula formation	3	1.1	0	0.0
	Difficulty prehending	1	0.4	0	0.0
	Other	2	0.7	0	0.0
Long-term complications (> 12 mo)	—	—	—	—	—
	Infection	1	0.4	0	0.0
	Mandibular drift and malocclusion	3	1.1	0	0.0
	Ranula formation	1	0.4	0	0.0
	Other	1	0.4	1	0.6
Tumor recurrence	—	—	—	—	—
	Yes	22	7.9	30	16.7
	Suspected not confirmed	0	0.0	1	0.6
	No	255	91.4	151	83.9
Status at follow-up	—	—	—	—	—
	Alive	133	47.7	83	46.1
	Dead	146	52.3	97	53.9

Median follow-up time was 1,070 days (95% CI, 905 to 1,192 days).
— = An empty cell.

clusion in 39 (14.0%), incisional dehiscence or oral fistula formation in 37 (13.3%), and ranula formation in 29 (10.4%; Table 3). Of the 158 complications following a mandibulectomy, 110 (69.6%) were considered minor, 41 (25.9%) were considered major, and 7 (4.4%) were considered catastrophic.

Maxillectomy—Sixty-five of 180 (36.1%) patients that underwent maxillectomy developed ≥ 1 complication. The most common complications in 180 dogs were incisional dehiscence or oral fistula formation in 47 (26.1%), complications classified as other in 29 (16.1%), and severe hemorrhage requiring a transfusion in 12 (6.7%; Table 3). Complications that were classified as other included corneal or oral mucosal ulcer formation, rhinitis, epistaxis, and facial swelling. Of the 95 complications following maxillectomy, 47 (49.5%) were considered minor, 37 (38.9%) were considered major, and 11 (11.6%) were considered catastrophic.

Univariable logistic regression analysis

Univariable logistic regression analysis revealed that lesion size ($P = 0.01$), whether the resection crossed the midline ($P = 0.04$), whether perioperative antimicrobials were administered ($P = 0.002$), surgery time ($P = 0.004$), and anesthesia time ($P = 0.02$) had a significant association with the occurrence of a complication. Preoperative chemotherapy or radiotherapy ($P = 0.01$) and mandibulectomy versus maxillectomy surgery type ($P = 0.02$) had a significant association with the occurrence of incisional dehiscence or oral fistula formation. Age ($P = 0.03$), body weight ($P = 0.004$), preoperative chemotherapy or radiotherapy ($P = 0.02$), mandibulectomy versus maxillectomy ($P = 0.005$), lesion size ($P = 0.006$), whether resection crossed the midline ($P = 0.006$), whether neoplasia was present ($P = 0.0001$), benign versus malignant tumor type ($P = 0.003$), margin status ($P < 0.0001$), surgery time ($P = 0.003$), and anesthesia time ($P = 0.003$) had a significant association with tumor recurrence.

Multivariable logistic regression analysis

Multivariable logistic regression analysis revealed that only increased surgical time had a significant (OR, 1.36; 95% CI, 1.12 to 1.54; $P = 0.03$) association with the occurrence of ≥ 1 complication. For each additional hour of surgery, the odds of complications increased by 36%.

Severe hemorrhage requiring a transfusion

The largest tumor dimension, type of surgery (mandibulectomy vs maxillectomy), and whether a caudal resection was performed were significantly associated with severe hemorrhage resulting in the need for transfusion in the univariable analysis **(Table 4)**.

Incisional dehiscence or oral fistula formation

Preoperative radiation therapy or chemotherapy increased the odds of incisional dehiscence or oral fistula formation (OR, 3.0; 95% CI, 1.3 to 7.2; $P = 0.01$). Additionally, undergoing maxillectomy, compared with mandibulectomy, increased the odds of incisional dehiscence or oral fistula formation (OR, 1.8; 95% CI, 1.1 to 3.1; $P = 0.02$) in the multivariable analysis even when adjusted for whether the dog received preoperative radiation therapy or chemotherapy.

Tumor recurrence

Whether the tumor was malignant or benign and the largest tumor dimension had significant independent associations with tumor recurrence. Lesions that reoccurred included acanthomatous ameloblastoma (4/108), cyst (1/3), fibrosarcoma (9/49), hyperplasia (1/8), melanoma (15/55), multilobular osteochondrosarcoma (2/12), osteosarcoma (5/39), peripheral odontogenic fibroma (1/8), sarcoma (5/13), soft tissue sarcoma (5/13), squamous cell carcinoma (6/68), and carcinoma (1/6). The recurrent cyst was classified as an odontogenic keratocyst, and the recurrent hyperplasia was classified as granulomatous hyperplasia. Malignant tumors, compared with benign tumors, increased the odds of tumor recurrence (OR, 3.09; 95% CI, 1.16 to 8.20; $P = 0.02$) with adjustment for the largest tumor dimension. Increasing the largest tumor dimension was associated with increased odds of tumor recurrence (OR, 1.18; 95% CI, 1.01 to 1.37; $P = 0.04$); for each 1-cm increase in tumor dimension, there was an 18% increase in odds of tumor recurrence.

Discussion

Findings in the present study indicated that there was a moderate risk of complication following mandibulectomy or maxillectomy, with 37.3% (171/459) of patients experiencing ≥ 1 complication. Of 271 total complications, 18 (7%) were considered catastrophic. In most studies that evaluated mandibulectomy and maxillectomy in veterinary medicine, specific complications are identified, but the overall complication rate is rarely reported. One study[3] that examined mandibular resection as a treatment for oral cancer in dogs had an overall complication rate of 22%. Because performing mandibulectomy is often less technically challenging than maxillectomy, a lower complication rate may be expected. Interestingly, in the present study, both procedures had a similar overall complication rate in patients (mandibulectomy, 38% [106/279]; maxillectomy, 36.1% [65/180]). However, many of the complications associated with mandibulectomy were considered minor overall and therefore self-limiting (69.6% [110/158]). The maxillectomy procedure had fewer minor complications (49.5% [47/95]) and slightly more major and catastrophic complications (38.9% [37/95] and 11.6% [11/95], respectively). In a study[11] of curative-intent surgery for oral tumors in dogs, there was an overall complica-

Table 4—Results of a univariable logistic regression model assessing the relationship of variables with transfusion and severe hemorrhage for the study population (459 dogs) described in Table 1.

Variable	Category	OR	95% CI	*P* value*
Institution	—	—	—	0.850
Body weight	—	1	1.0–1.0	0.57
Largest tumor dimension	—	1.3	1.1–1.6	0.007
Crosses midline				
	Yes	2.4	0.7–8.7	0.16
	No	Referent	—	—
Type of surgery				
	Maxillectomy	4.9	1.6–15.5	0.007
	Mandibulectomy	Referent	—	—
Caudal resection				
	Yes	6.5	2.4–18.1	> 0.001
	No	Referent	—	—

*Values of $P < 0.05$ are significant. — An empty cell.

tion rate of 16.2%. However, that study did not have a follow-up requirement, which could have led to an underestimation of the occurrence of surgical complications, compared with that of the present study. Another study[4] of 8 dogs evaluated the occurrence of complications following partial maxillectomy for the treatment of oral tumors; there was a 100% complication rate within the first 48 hours after surgery and an 85% complication rate from 48 hours to 4 weeks after surgery. This was substantially higher than the complication rate for dogs (37.3% [171/459]) of the present study; this could be explained by the fact that a greater proportion of the maxillectomy procedures in the other study[4] involved a caudal approach. Also, the other study[4] recorded complications that were not reported in the present study, such as facial pawing and epiphora. These complications could not be included in the present study because of the retrospective nature and institutional variability in reporting. However, both studies did record many of the same complications, including epistaxis, facial swelling, orofacial fistula formation, incisional dehiscence, infection, and hemorrhage.

Contrary to our hypothesis, the size of a tumor was not associated with the occurrence of a complication on the basis of multivariable analysis findings. The surgical complexity required is expected to increase with larger tumor size, but this did not result in an increased risk of complications, including hemorrhage. An association between tumor size and excessive surgical bleeding followed by a blood transfusion has been reported in a previous study.[9] It is important to keep in mind that the complexity of a lesion on the basis of size would also be affected by the size and breed of the dog. On multivariable analysis, only surgical time was independently associated with the occurrence of ≥ 1 complication. This finding is suspected to be secondary to an increase in surgical complexity, as resection or reconstruction could take longer. However, higher inherent risks such as hemorrhage or hemorrhage occurring persistently over a longer period could also extend surgical time. Prolonged surgical time has been associated with an increased risk of complications for oral surgery in human medicine.[23] To the authors' knowledge, no previous study evaluating mandibulectomy or maxillectomy procedures in veterinary medicine has demonstrated an increased risk of complications with surgical time.

Incisional dehiscence or oral fistula was the most common surgical complication in the present study, as demonstrated in previous studies.[3,11,13] Given the retrospective nature of the present study, these complications were combined because it was difficult to determine what was an actual fistula versus incisional dehiscence that resulted in a fistula. Three dogs developed orofacial fistulas following mandibulectomy. This finding was unexpected because oral fistulas are more commonly associated with maxillectomy procedures. For these dogs, it was difficult to discern whether the fistula formation was secondary to the surgical procedure itself, the underlying disease process, or the use of adjunctive treatment such as radiation treatment. Performing maxillectomy, as well as a procedure in the caudal aspect of the oral cavity, were both associated with an increased risk for occurrence of an incisional dehiscence or oral fistula in the univariable analysis. Only the maxillectomy procedure was confirmed on multivariable analysis as being associated with an increased risk for incisional dehiscence or oral fistula occurrence. It has been postulated that an increase in surgical site dehiscence of a maxillectomy procedure may be the result of an increased tumor size before detection by the owner or veterinarian, resulting in a more complex resection. However, this contradicts our finding that tumor size was not associated with an occurrence of a complication. Incisional dehiscence is suspected to be more common with caudal maxillectomy; however, this was not confirmed with multivariable analysis in the present study. This may be the result of a type II error, as only 43 of 459 (9.4%) dogs underwent caudal maxillectomy. In 1 study,[2] 80% of the dogs that developed wound dehiscence following partial maxillectomy had dehiscence that occurred caudally to the canine teeth. In the present study, a caudal procedure was defined as being performed caudal to the fourth premolar tooth.[15] Our results may have been altered if the anatomic landmark for a caudal procedure had been different, making wound dehiscence a more frequent complication for caudal procedures. Most of the complications in the present study were minor (157/253 [62.0%]); therefore, surgical or medical intervention was not needed. However, dehiscence in the maxillary region is a serious condition because it can result in an oronasal fistula and further complications. Clients should be prepared for these possible complications and potential requirements for surgical revision.

Preoperative radiation therapy, chemotherapy, or both were also associated with an increased risk of surgical site dehiscence or oral fistula formation. To the authors' knowledge, the present study was the first to document this finding with veterinary orofacial surgery. However, this has been documented for humans who have undergone head and neck surgery and received preoperative chemotherapy.[27] In 1 study[33] of dogs with tumors, the risk of complications following cutaneous or mucosal flap surgery is higher for dogs that underwent preoperative radiation therapy. In the present study, it is also possible that neoadjuvant therapy was attempted in dogs with more advanced disease before surgical management, resulting in a selection bias. Radiation damage to healthy tissues (eg, stem cells, blood vessels, and others) can be progressive and permanent.[28] Both chemotherapy and radiation therapy can impede wound healing.[28] It is therefore important to consider the optimal timing for surgery following these treatments. It has been recommended that if radiation therapy is given preoperatively, surgery should be performed after acute radiation reactions have resolved (ie, generally 3 to

4 weeks, depending on the protocol).[28] The optimal timing of surgery following chemotherapy has not been assessed.

In the present study, univariate analysis revealed that a maxillectomy procedure and caudal resection were also associated with an increased risk of severe hemorrhage requiring blood transfusion. Similarly, MacLellan et al[9] determined that dogs undergoing caudal maxillectomy or complete maxillectomy are significantly more likely to have had excessive surgical bleeding and 3 times as likely to have received a blood transfusion than dogs undergoing other maxillectomy procedures. This finding is suspected to be a result of the more complex vascular anatomy in this region and presence of larger vascular branches.[9] Additional preparations could be made in these instances, such as determination of blood type, placement of multiple IV catheters for fluid or blood administration, and having both fluid volume support and blood products available. Temporary occlusion of the carotid artery on the side of resection could be considered, but this technique was not assessed in the present study.

Although tumor recurrence was not considered a surgical complication, risk factors were evaluated for tumor recurrence, given that a large proportion of patients were undergoing surgery for tumor removal (415/459 [90.4%]). Overall recurrence in the present study was low over a prolonged follow-up period (median follow-up time of 1,070 days), with only 54 (11.8%) dogs developing tumor recurrence and 1 (0.2%) dog with suspected but not confirmed tumor recurrence. In the multivariable logistic regression analysis, whether the tumor was malignant or benign and the largest tumor dimension were independently associated with tumor recurrence. As the tumor dimension increased, there was an increased risk of recurrence. This finding is similar to results of previous studies. Sarowitz et al[11] determined that a smaller tumor size (< 2 cm in diameter) is associated with a longer disease-free interval following curative-intent surgery. In the present study, malignant tumors were associated with increased odds of recurrence, compared with benign tumors, which follows what has been found in other studies.[11,12] Preoperative radiation therapy or chemotherapy did not decrease the likelihood of recurrence in the multivariable analysis. This finding may have been a result of the small number of dogs that received these treatments (n = 26).

Because the present study was a retrospective analysis performed at 8 referral institutions, there were several inherent limitations including variability of completeness of medical record information and a lack of standardization with surgical procedures, as these were performed by different surgeons; postoperative management including analgesia; and adjunctive treatment. Also, specifics regarding surgical treatment, such as the use of Rummel tourniquets or suture patterns used, were not investigated in the present study. A follow-up of 90 days was required; thus, some complications may have occurred after this time, resulting in an underestimation of surgical complications. Although most follow-up information was obtained from an in-hospital examination, a telephone conversation with the client was also sufficient, which could result in an underestimation of surgical complications. It is also possible that an overestimation of complications was made in the present study, as all complications that occurred following the procedure were included. Some of these complications may have been related to the anesthesia or case management versus the surgical procedure itself.

The present study provides new information regarding risk factors for the development of complications and provides veterinarians with contemporary information for patient outcomes when performing these specific procedures. These procedures are safe with a moderate risk for a complication but a low risk for a catastrophic complication. The hypothesis that both a maxillectomy procedure and a caudal resection increased the risk for incisional dehiscence or oral fistula was accepted. These procedures also increased the risk for severe hemorrhage requiring a transfusion. However, although the size of the lesion increased the risk for occurrence of a complication on the basis of univariable analysis, this effect was not confirmed on multivariable analysis. On the basis of our data, a larger mass as well as performing maxillectomy, particularly when involving a caudal resection, may carry an increased risk for complications. When attempting one of the procedures, the authors would recommend careful planning by use of imaging as well as care with reconstruction to minimize tension across the suture line. Blood products should be available for immediate use if necessary. Also, clients should be advised of these potential complications to allow for appropriate expectations.

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Footnotes

a. SAS, version 9.4, SAS Institute Inc, Cary, NC.

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