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Surgical treatment of feline intracranial meningiomas: a retrospective study of 26 cases

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ABSTRACT

Background: Surgical excision is the treatment of choice for feline intracranial meningioma.
Objectives: To report clinical findings, complications, and outcomes following surgery for feline intracranial meningioma.
Methods: Medical records (01/2000–01/2017) of cats that underwent surgical excision of an intracranial meningioma at our institution were reviewed. Patient data included signalment, clinical signs, surgical technique, complications, histopathologic diagnosis, survival time, and owners' answers to a satisfaction questionnaire. Survival was assessed using the Kaplan-Meier method and log-rank test.
Results: Twenty-six cats were included in this study. The exact cause of death was known in 17 cases and was not related to meningioma in 9/17 cases. Overall median survival time was 881 days (95% confidence interval 518; 1248). The age of the cat did not influence survival ($p = 0.94$) or the occurrence of complications ($p = 0.051$). Complications occurred in 13/24 cats, including dramatic complications in 4/24 cats. Most complications appeared in the first 24 hours post-surgery (12/13). Males had more postoperative complications ($p = 0.042$), including more seizures ($p = 0.016$). Cats with cranioplasty had fewer complications ($p = 0.021$). Clinical recurrence was confirmed in 3 out of 17 cats. Recurrence-free survival time was 826 days. Most owners (12/14) were satisfied with the outcome.
Conclusions: Surgical treatment of intracranial meningioma in cats was associated with a long median survival time but also with a high rate of minor and major postoperative complications, including early postoperative seizures. Cranioplasty may reduce complications. Age at the time of surgery had no effect on outcomes.

Keywords: Meningioma; cat; intracranial; surgery; cranioplasty; PMMA; complication

INTRODUCTION

Meningioma is the most frequently reported primary intracranial tumor in cats, representing 58% of brain tumors in this species [1,2]. This slow-growing tumor arises from arachnoid meningeal cells [3]. Meningioma affects adult cats (3–21 years) [1,4-6], and the median age at diagnosis is 11–12 years [2,4,7]. In cats, meningiomas are mostly solitary, but multiple meningiomas are not infrequent and may represent up to 17% of cases [1,8,9]. As feline

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Conflict of Interest
The authors declare no conflicts of interest.

meningioma is frequently located peripherally and is mostly non-invasive and benign (World Health Organization grade I), unlike canine meningiomas [1,3,5], surgical resection, when feasible, is often the treatment of choice. Other treatment options include radiation therapy or palliative therapy with or without chemotherapy [10]. Median survival time (MST) is 14 months [11] after radiation therapy and only 18 days after conservative treatment [1]. Surgery is associated with much higher reported survival rates (between 685 days and 37 months [1,4,7]), although tentorial location is associated with higher rates of recurrence and a less favourable prognosis [8].

Surgical treatment of intracranial tumors in small animals is also associated with relatively high perioperative and postoperative complication rates. Complications following craniotomy or craniectomy in dogs and cats usually occur in the early postoperative period: within 24 h in 35% of cases and between 1 and 10 days post-surgery in 52% of cases [12]. Between 32% and 47% of dogs experience major complications, such as death, seizures, worsening of neurological status and aspiration pneumonia, after surgical removal of intracranial tumors [12-14]. However, there are few reports investigating postoperative complications following meningioma excision in cats, nor reconstruction using cranioplasty. One study reported immediate postoperative complications and long-term recurrence [7], and another study investigated perioperative mortality [13]. A third study reported postoperative complications after brain surgery in dogs and cats [12].

Therefore, the aim of this study was to describe clinical findings, perioperative and postoperative complications, and patient outcomes in cats treated surgically for intracranial meningioma.

MATERIALS AND METHODS

Study population

This study was a single-center retrospective cohort study. Medical records from January 2000 to January 2017 at a single veterinary teaching hospital were reviewed. Cats were included in the study if they underwent surgical resection of an intracranial meningioma (confirmed by histology) and had a minimum follow-up of 4 weeks.

Data retrieved from records included signalment (sex, breed, age, sterilization), clinical signs before surgery, surgical technique and surgical approach, implantation of a polymethyl methacrylate (PMMA) cranial vault prosthesis, postoperative treatment, histopathologic diagnosis, perioperative and postoperative complications, the time between surgery and the occurrence of complications, the time between surgery and recurrence or clinical signs that could be associated with recurrence (symptomatic recurrence in the absence of diagnostic imaging to confirm recurrence) and survival time. Cats that had postoperative radiation therapy were excluded from the survival analysis.

All cats were suspected of having an intracranial meningioma based on computed tomography (CT), magnetic resonance imaging (MRI), or both. Images were acquired after a neurologic examination was performed. Surgery was only performed if tumors were deemed resectable; for example, no brain stem meningioma was treated in our study. There was no tumor size limit to preclude resection. For every case, there was a preoperative surgical consultation with the cat's owner to clearly explain the possible complications, risks, and benefits of surgical treatment, in particular, if the tumor was large, deep, or in close contact with important structures such as sinuses, or if the cat had relevant comorbidities that could compromise the outcome.

Anesthesia

Anesthesia was performed by or under the supervision of a diplomate of the European College of Veterinary Anesthesia and Analgesia (ECVAA), and anesthetic protocols were chosen at the discretion of the attending board-certified anaesthesiologist.

Surgical technique

Anaesthetized cats were placed in sternal recumbency with the head elevated and the mandible parallel to the table, taking care to avoid compression of the jugular veins. All surgeries were performed by a single European College of Veterinary Surgeons (ECVS) diplomate surgeon (PM). The surgical approach was chosen depending on the mass location. A unilateral rostrotentorial approach, a unilateral caudotentorial approach, or a transfrontal approach were all defined as "single" surgical approaches when performed alone. When a bilateral rostrotentorial approach was performed, or when the aforementioned approaches were combined, the surgical approach was defined as "combined." Craniectomy was performed using a surgical burr to remove all the calvarium potentially in contact with the tumor. Haemostasis was performed using bipolar cautery, bone wax, or an absorbable hemostat (Surgicel, Ethicon, France). A durectomy was performed and the meningioma was dissected away from the healthy brain parenchyma. After careful hemostasis, the dura mater was closed with fascia muscle or with a dural substitute (Neuropatch, B Braun Medical, France). In most cases, cranioplasty was then performed with PMMA secured to the intact calvarium. Muscle, subcutaneous tissue, and skin layers were then routinely closed.

Postoperative care

All cats recovered from surgery and anesthesia in the intensive care unit (ICU) of our hospital. Once stable, they were transferred to the wards and examined at least twice daily until discharge.

Classification of complications

Complications were classified as minor, major, or dramatic [14]. Minor complications did not require additional medical or surgical treatment (e.g., seroma, hypothermia). Major complications were those manageable with standard medical or surgical treatment. A dramatic complication was defined as causing the death of a patient, motivating euthanasia, or resulting in an intolerable permanent condition (e.g., cardiorespiratory arrest, tetraplegia).

Follow-up

Long-term follow-up was based on review of medical records, a telephone interview with the owner or referring veterinarian (CP performed all interviews), and a feedback questionnaire to assess owner satisfaction with the surgery, results, and postoperative recovery.

Statistical analysis

Descriptive statistics (median, mean, SD, range, and frequency) were used to report patient characteristics. Statistical analysis was performed with R software (The R foundation; stats, base, and graphics packages). Data normality was tested with a Shapiro–Wilk normality test. Fisher's exact test or chi-square test was used. For survival analysis, the inclusion date in the study was the date of surgery, and study endpoints included progression-free survival (PFS) and overall survival (OS). PFS time was defined as the time in days from surgery to recurrence (confirmed with diagnostic imaging) or death of any cause. OS time was defined as the time in days from surgical excision to death of any cause. The Kaplan-Meier method was used to evaluate survival time and complication occurrence. The log-rank test was used to compare Kaplan-Meier curves.

For all analyses, a *p*-value less than 0.05 was considered significant.

RESULTS

Patient characteristics, clinical signs, and diagnosis

Twenty-nine cats underwent surgical resection of an intracranial meningioma at our institution during the study period. However, three cats had an incomplete medical record and were excluded from the study. Therefore, a total of 26 cats with complete medical records and a histopathologic diagnosis of meningioma were included in this study. Median age at the time of surgery was 11.2 years (range 4.2–18.1 years; first quartile 7.3 years, third quartile 13.5 years). The study cohort comprised 14/26 (54%) male and 12/26 (46%) female cats (male:female ratio = 1.1), including 22/26 (85%) domestic shorthair, 3/26 (11%) Norwegian and 1/26 (4%) Maine Coon cats. Of these, 19/26 (73%) cats were neutered, and 7/26 (27%) were intact.

A precise description of clinical signs was available for 24 cats. The most frequent clinical signs were weakness (17/24, 71%), behavior change (13/24, 54%), ataxia (11/24, 46%), altered consciousness (10/24, 42%), circling (9/24, 37.5%), dysorexia (9/24, 37.5%), visual impairment (8/24, 33%: 6 had bilateral amaurosis and 2 had unilateral amaurosis), seizures (4/24, 17%), nystagmus (3/24, 12.5%), head tilt (3/24, 12.5%), anorexia (1/24, 4%) and head pressing (1/24, 4%).

Diagnosis of meningioma was based on CT in 11 cats, MRI in 14 cats and, CT and MRI in one cat.

Surgery

The surgical approach was precisely described in 24/26 surgical reports. A single surgical approach was used more frequently (21/24, 88%) than a combined approach (rostrotentorial and caudotentorial together in 3/24 cats, 12%). Overall, the unilateral rostrotentorial approach was most frequently used (16/24, 67%), followed by the transfrontal approach (4/24, 17%) and the caudotentorial approach (1/24, 4%). Information about cranioplasty was available for 23/26 cats. Cranioplasty with PMMA was performed in 17/23 cats (74%). Six cats had no cranial vault reconstruction (6/23, 26%), and information was not available for three cats. The median postoperative hospitalization time was four days (range 1–11 days).

Histopathology

The histopathologic subtypes of the excised mass were defined in 18/26 cats and included 7/18 transitional, 5/18 psammomatous, 3/18 meningothelial, and 3/18 fibrous meningiomas. The remaining masses (8/26) were described only as “meningiomas.” No malignant meningioma was diagnosed.

Peroperative complications

Major peroperative complications were reported in two cats. One cat had bradycardia, severe hypotension, and respiratory arrest during craniotomy. He was placed under mechanical ventilation, and hypotension was treated by decreasing the inspired fraction of isoflurane and starting an infusion of dobutamine. This cat then recovered from anaesthesia uneventfully.

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The second cat had a large meningioma located at the level of the falx cerebri and severe haemorrhage of the transverse and sagittal sinuses occurred during the surgical approach. Haemostasis was performed with bone wax, and no blood transfusion was needed. No animal died during surgery.

Postoperative complications

The presence or absence of postoperative complications was recorded for 24/26 cats in this study. Complications occurred in 13/24 (54%) cats; 11/24 (46%) cats had no postoperative complications. Among the 24 cats with complications, 6/24 (25%) had minor complications, 9/24 (37.5%) had major complications and 4/24 (17%) had dramatic complications.

Minor complications included transient hypothermia (1/24) or hyperthermia (1/24) within 24 h after surgery, depression (2/24), and non-reactive mydriasis (1/24, self-limiting after four days). Thoracic radiographs were performed for the hyperthermic cat to rule out aspiration pneumonia.

Major complications included postoperative seizures (6/24), signs of intracranial hypertension managed with a bolus of mannitol (1/24), pneumocephalus (1/24), and episodes of ventricular tachycardia managed with lidocaine infusion (1/24). Seizures were initially treated with midazolam or diazepam and an anticonvulsant drug (phenobarbital), then controlled with phenobarbital on a long-term basis (5/24, discontinued after one year for four cats).

Dramatic complications occurred in four cats, among which three experienced a cardiorespiratory arrest. Cardiopulmonary resuscitation was successful for one of these cats, with the return of spontaneous circulation. Two of the cats died after cardiorespiratory arrest, including one that had significant sinus bleeding during surgery. The fourth cat had a surgical site infection with bacterial encephalitis, which was diagnosed 17 days after surgery. The surgical site infection was managed via surgical lavage revision of the PMMA prosthesis using PMMA with gentamicin and broad-spectrum antibiotic therapy. However, this cat died 48 h after surgical revision.

Most complications occurred within 24 h following the surgical procedure (12/13). Postoperative seizures were the most frequent complication (6/24, 25%). All seizures (between one and three episodes) occurred in male cats and within the first 24 h after surgery. Among the six cats that had postoperative seizures, two had had preoperative seizures. The rate of postoperative seizures ($p = 0.016$) and the overall complication rate ($p = 0.042$) were significantly higher in males than in females.

Cats that underwent cranioplasty with PMMA had fewer complications than those that did not ($p = 0.020$), but the only case of postoperative infection in this study occurred in a cat that underwent cranioplasty (1/17 cats with cranioplasty). Complications occurred in all three cats that underwent a “combined” surgical approach and in 9/20 cats that underwent a “single” surgical approach. “Combined” surgical approaches were associated with more complications ($p = 0.029$) than “single” surgical approaches. Breed, age, and neutering status had no effect on complication rate.

Patient outcomes

A total of 3/26 cats died before discharge, all of which had forebrain meningioma; one underwent a unilateral rostrotentorial approach, one a transnasal approach (frontal meningioma) and one a bilateral rostrotentorial approach (meningioma of the falx).

Therefore, the perioperative mortality rate was 11.5%, and the survival to discharge was 88.5%. Six cats were excluded from further survival analysis because the precise date of death was not available for three cats, and the other three cats had postoperative radiation therapy. Among the twenty patients included in the survival analysis, four were still alive when this retrospective study was conducted. The postoperative MST was 881 days (95% confidence interval [CI], 518–1,248) in all cats and 1053 days (95% CI, 700–1,431) for the 16 cats still alive one month after surgery (**Fig. 1**). The cause of death was known for 17 cats. Death was not associated with meningioma in 9/17 (53%) cats and was related to other chronic disease (chronic renal disease [3/9], cardiac disease [2/9], decline in general health [2/9] and systemic neoplasia [2/9]). The age at the time of surgery had no influence on survival time (p = 0.94) or on complication rate (p = 0.051).

PFS (826 days) was similar to MST (881 days). Clinical recurrence occurred in 5/17 (29%) cats for which long-term follow-up was available (19–37 months after surgery). However, this was confirmed by imaging (MRI or CT) in only three cats (19–22 and 37 months after surgery). No delayed complication other than clinical signs consistent with tumor recurrence was reported by owners and referring vets.

Among the 14 owners who answered the study questionnaire, 12 were satisfied with the clinical outcome of their cat. Of these 14 cats, seven had complications (two had cardiorespiratory arrest—one died and the other was resuscitated, two had seizures, one had signs of intracranial hypertension, one was depressed and one had non-reactive mydriasis). One of these cats died three days post-operatively before discharge, another died 99 days after surgery, and the other 12 cats survived long-term (between 508 and 2,515 days post-surgery). Thirteen out of fourteen owners were ready to accept a surgical treatment again. The owner of the cat that lived for 99 days was not willing to consent to a future surgical treatment. Eleven of 14 owners found postoperative care at home easy or acceptable. Twelve of 14 owners described their cats as completely normal one month after surgery. The owner of the cat that was paraplegic before surgery reported a persistent lameness in one pelvic limb.

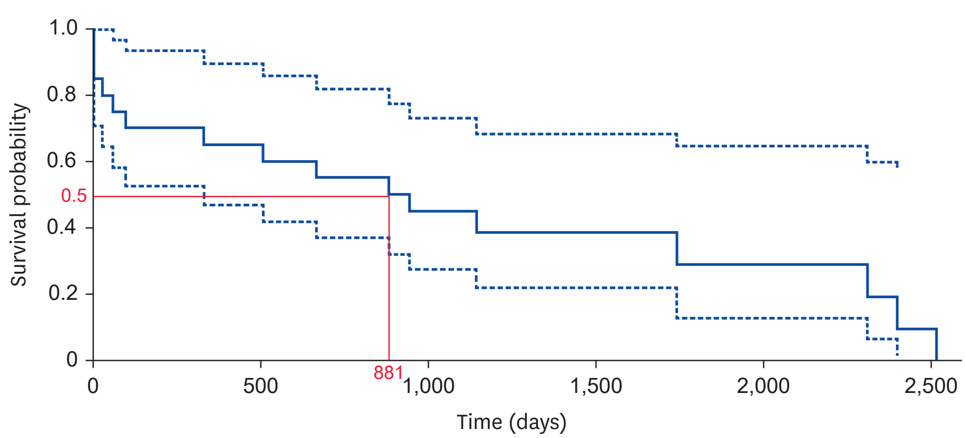

Fig. 1. Kaplan–Meier survival for death due to all causes in 20 cats that underwent surgical excision of intracranial meningiomas (bold blue line).
The dotted blue lines represent the 95% confidence interval.

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DISCUSSION

This retrospective study provides data about outcomes and complications after surgical resection of intracranial meningioma in 26 cats. In our retrospective study, MST of the whole study cohort was 881 days and was superior to the MST of one study [7] (655 days) but inferior to the MST of another study (1,113 days) [4]. However, the MST of cats that were still alive one month after surgery in our study was close to that found in another study (1,153 days vs. 1,143 days, respectively) [4]. No sex predilection was found in our study, contrary to what has been previously reported (1.1:1 vs. 1.8:1 [4] and 1.5:1 [1]). This could be explained by our small study population. Moreover, in our study, age was not associated with survival time, which is consistent with previously reported data [4,7]. Therefore, surgical treatment should be considered in cats with intracranial meningioma regardless of age.

The peroperative mortality (0%) in our study was comparable to that of a previous report (2 of 121 cats) [4]. Death before discharge (11.5%) was lower than that reported in three previous studies, 18% [13], 19% [7], 17% [8], but higher than that of one study (6%) [4]. These discrepancies could be explained by variation in tumor location, which can complexify the surgical approach (among the three cats that died before discharge in our study, one had a combined approach) and differences in population size (type II error). Another contributing factor for our relatively lower rate of death before discharge may be the quality of postoperative care in the ICU between the study of Gordon et al. [7] and ours.

Meningioma recurrence is reported in 11%–39% of cats and occurs 3–60 months postoperatively [4,7,13]. Our results are consistent with these previous reports; in our study, 18% of cats had confirmed recurrence 19–37 months postoperatively.

The most common histologic subtypes identified in our study (transitional 39% and psammomatous 28%) were the same as those in other studies [4,8]. However, fibrous and transitional meningiomas were more commonly reported in a previous study [5]. In our study, we did not examine the effect of meningioma subtype on outcome because all meningiomas were benign, and most of the cats still alive one month postoperatively died of causes unrelated to meningioma. Furthermore, no atypical or anaplastic meningioma was diagnosed in the cats in our study. High grade meningiomas are rare in cats. In previous studies, only five grade II and one grade III tumors were diagnosed histologically in 45 cases of feline meningioma (tumor obtained after surgery or necropsy) [5], and only one (anaplastic) meningioma was identified in 101 cases analysed after surgical excision [4].

Complications were not uncommon in our study (13/24, 54%). This complication rate is higher than those previously reported. In a previous study, 31% of cats had anaemia, 24% had no improvement or worsened neurological status, 14% had anorexia, and 10% had incisional drainage [7]. However, the overall complication rate was not reported in that study, and it is not clear whether some patients had multiple complications. In our study, complications occurred within 24 h after surgery in 92% (12/13) of cats with complications. Therefore, increased monitoring in the ICU (such as frequent clinical and neurological examination, Glasgow coma scale if relevant, continuous ECG, pulse oximetry, and invasive or non-invasive arterial pressure measurement) is highly recommended, at least for the first 24 h post-surgery to detect and manage possible complications and improve postoperative care. The only long-term complications reported in our study were consistent with tumor

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recurrence (altered consciousness (3/5), ataxia (2/5), weakness (2/5), circling (1/5)), which is similar to the results of a previous report of long-term complications in 10/33 cats [7].

Our study is the first to describe seizures as the most frequent complication in cats after meningioma resection (6/24; all male). Previous reports described anaemia as the most frequent complication following meningioma resection [7]. Seizures are a frequent complication after craniotomy or craniectomy in humans and dogs and may be related, among other causes, to manipulation or retraction of the brain parenchyma [15] and/or the presence of brain oedema [16,17]. Meningioma size may also play a role in complication rate (and seizure occurrence). Increased manipulation of brain parenchyma may be needed to remove large meningiomas, despite the relative ease of dissection of feline meningiomas, compared with canine meningiomas. However, the size of the excised meningiomas was not always recorded in our study, and therefore, we could not analyse this factor.

A recent study reported early postoperative seizures (EPS) in 12.8% of neurosurgical surgeries and in 18.2% of dogs with rostrotentorial brain tumors after intracranial surgery [17]. The timing of EPS in that study is similar to the timing of postoperative seizures in the cats in our study (within 24 h after surgery). In human medicine, the incidence of EPS after supratentorial craniotomy for non-traumatic pathology is estimated to be 1%–18% [18]. In a human study investigating EPS after brain tumor surgery, meningioma patients had the highest rate of EPS (10% vs. 5% for other types); in approximately 80% of these patients, a likely cause of the seizures, such as haemorrhage, increased oedema or meningitis, was identified on MRI. However, in human patients with meningioma, no correlation was found between tumor size (patients with postoperative seizures had bigger tumors but this difference was not significant), extra-axial haematoma, brain contusion, resection cavity haematoma, pneumocephalus and EPS [19]. In our study, no postoperative MRI or CT was performed in the cats that had postoperative seizures.

The relationship between EPS and preoperative seizures is unclear. While a study in dogs found no association between preoperative seizures and EPS [17], an association between the two has been found in human medicine [16]. In human patients undergoing resection of supratentorial meningioma, 22% had preoperative seizures. In this cohort, EPS occurred in 6% of patients during hospitalisation and seizures occurred in 14% of patients after discharge [16].

Tumor location may also be associated with post-surgical seizures. In veterinary medicine, rostrotentorial tumors [20,21], especially within the frontal lobes, marked enhancement with gadolinium and subtentorial and/or subfalcine hernia were associated with seizures.

Moreover, sex has an influence on the incidence of seizures after meningioma surgery. In our study, the overall complication rate and the incidence of seizures after intracranial meningioma resection were significantly higher in male cats compared with female cats. In the humans, male sex is also associated with higher rates of seizures after meningioma resection [16] and higher rates of surgical site infections after craniotomy for tumor resection [22]. Despite this association, the role of sex hormones in the mechanism of postoperative seizures is still unknown. We were unable to elucidate the mechanism for this association in our study because we had a small study population, which may have resulted in a type II error, and four of the six male cats that had postoperative seizures were neutered. Therefore, this association warrants further investigation.

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Postoperative anemia was not reported as a complication in our study. However, postoperative packed cell volumes were not recorded for all cats. Blood tests were not systematically performed if cats had no significant bleeding during surgery, were clinically alert and showed no sign of anaemia. Furthermore, no cat required blood transfusion before, during, or after surgery. However, this complication may have been underestimated, or information may have been lost because of the retrospective nature of this study. For example, one of the cats that died in immediate postoperative period had sinus bleeding during surgery and may have been anaemic.

In our study, only one septic complication was reported in a cat that had a cranioplasty. In humans, septic complications occur in around 8%–12% of cranioplasties [23,24], and surgical site infection is the most common complication [24,25]. However, in human medicine, cranioplasty is more often performed for decompressive surgery after stroke or traumatic brain injury (contaminated or bruised wound) than after an intracranial tumor resection. The use of an autologous bone flap is widely used for skull defect reconstruction in humans and the most frequent complications associated with these techniques are aseptic bone flap resorption and septic complications [26]. Synthetic materials, such as PMMA, hydroxyapatite, polyetheretherketone (PEEK), or titanium plates, are also used. These alloplastic materials are recommended because they are associated with less resorption and less infection [27]. PMMA is the most cost-effective synthetic material but is also associated with a greater infection rate than other synthetic implants. This is most likely because irregularities may promote bacterial adhesion, and biofilm formation and PMMA does not facilitate revascularisation [28].

In human patients undergoing tumor resection, cranioplasty is performed with an allograft or with synthetic biomaterial to avoid tumor recurrence when the tumor is in contact with or infiltrates the calvarium. Infiltration of the calvarium by feline meningioma is rare [29,30], and hyperostosis is a frequent finding (up to 73%) [30]. However, in the authors' experience, meningioma and the adjacent dura mater frequently adheres to the calvarium in cats. In a study of 48 human patients who underwent cranioplasty after tumor removal, eight (16.8%) had implant removal due to infection (surgical site infection in four, empyema in three and one with bacteraemia of unknown origin). The association between PMMA cranial vault prosthesis and surgical site infection needs to be investigated in small animals. In our study, cranioplasty was associated with a lower rate of complications. This may be because cranioplasty protects the brain parenchyma against external injury such as shock and against secondary compression by extracranial muscles, muscular bleeding or adherence formation. The physical barrier is not the only advantage of cranioplasty; it also helps to preserve cerebrospinal fluid and cerebral blood flow [31,32]. However, this association may also be related to the fact that if an animal is not stable during surgery, the surgeon will decide to close the patient quickly and will not realise a cranioplasty.

In a previous study of dogs that underwent intracranial surgery (for brain biopsy, tumor removal or decompression after brain injury) only 2/50 had a cranioplasty with PMMA and 23/49 (47%) dogs had postoperative complications, including early postoperative neurological deterioration in 22/49 (45%) dogs [33]. Postoperative neurological degradation was not reported in our study, which may be because meningioma in cats is generally easier to resect than in dogs and may need less brain retraction and manipulation [3]. Cranioplasty may also have played a role in limiting this complication. However, postoperative neurological degradation may have occurred in cats that died in the immediate postoperative period and also may have been missed during recovery from anaesthesia. There also may have been a loss of information due to the retrospective nature of this study.

For the cats in our study, craniectomy site and surgical approach was chosen before surgery depending on tumor location and size. Measurements were taken on MRI or CT images to plan the surgical approach. Combined surgical approaches (a combination of at least two approaches that necessitates the occlusion of transverse venous sinuses or other large veins) were associated with more complications. In our study, one cat had transverse and sagittal sinus haemorrhage during surgery and died postoperatively after a bilateral rostrotentorial approach. Complex surgical approaches are more invasive, longer and harder to perform but may be required to remove large or invasive tumors. With the recent development of 3D preoperative planning, patient specific models and cutting guides, those complex approaches may become safer to perform [9]. Moreover, the use of neuronavigation may also reduce perioperative complications, but this was not available at our institution [34]. The use of operative microscope or endoscope assisted surgery may also help tumor dissection, limit local trauma to brain parenchyma and obtain clean tumor margins [35].

In our study a single surgeon performed all surgeries at a single centre, which may have limited the variability in patient outcomes and complications related to the surgeon. A surgeon's experience can affect patient outcomes. For example, in human medicine, an association between surgeon technical skills and patient outcomes (complication rate, unplanned reoperation, death, or serious morbidity) has been reported in colectomy surgeries [36].

The main limitations of this study are the small patient population and the retrospective nature. As it was a retrospective study, we relied on the quality of existing medical records and therefore, complications may have been missed or underestimated. Nevertheless, it is unlikely that major perioperative and early postoperative complications were unrecognized because short-term follow-up was available in all cats. No cat had multiple meningioma in this study, which may represent a selection bias because those cats were less likely to undergo surgery. As multiple meningiomas represent approximately 17% of meningioma cases in cats [1], the lack of multiple meningiomas in our study may be due to the small patient population. A prospective study with a larger population is necessary to validate our results and increase the statistical power. However, the results of this study are similar to published data and provide further information regarding postoperative complications in cats after meningioma resection with or without cranioplasty.

This study confirms the benefits of surgical treatment of feline intracranial meningioma when tumor location permits resection. This treatment results in a long MST, and age at the time of surgery has no influence on outcomes. While complications were frequent, and the most common complication was EPS, complications may be limited by reconstruction with calvarial prosthesis. This information must be communicated to owners prior to surgery.

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