

## Surgical Resection of Twenty-Three Cases of Brain Meningioma

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**ABSTRACT.** The aim of this study was to report the effectiveness of MRI scanning during brain meningioma resection surgery in the canine and feline. The subjects were 23 cases from 2006 to 2008 in canines and feline diagnosed with meningioma. All were between 8 and 16 years of ages. There were 12 males and 11 females. An appropriate craniotomy was performed for each case according to the initial MRI taken to diagnose meningioma prior to the surgery. Once the dura mater was exposed, an MRI biopsy needle was placed in the tumor as a guide. The first MRI sequence during the surgery was performed with this needle to confirm the location of the tumor. This MRI image was also processed and displayed by multi planar reconstruction to reveal the tumor extent in three dimensions. A Sonopet was applied to the middle of the tumor to destroy the inner part and release pressure from the entire tumor. Creating some space between the brain tissue and tumor, we treated blood vessels and carefully resected them. This procedure was repeated until complete removal of the tumor was confirmed by MRI. Sixteen of the 23 cases survived for more than 2 years postoperatively. The other seven died due to other disorders within 2 years. Our method with MRI navigation during the surgery improved our surgical performance and contributed to a prolonged survival time for the patients. In order to perform multiple MRI procedures smoothly during the surgery, it is necessary to have skillful assistants.

**KEY WORDS:** canine, feline, magnetic resonance imaging (MRI), meningioma, neurosurgery.

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Meningioma is the most common primary intracranial tumor in dogs and cats [9]. The clinical symptoms are associated with the space occupied by the lesion, which causes local pressure on the brain tissue and leads to intracranial hypertension. Surgical resection is considered the best treatment to release such pressure and prevent recurrence. The median survival time for dogs and cats treated with surgery alone is 6 to 7 months [1, 8]. Complete surgical removal of a tumor is considered very difficult due to the poorly defined border between the anatomical location and tumor margin [4]. When tumor recurrence is seen postoperatively, a poor prognosis is usually reported [5]. Therefore, many special instruments and advanced surgical techniques are required to increase the efficacy of surgery.

One of these techniques is the introduction of a navigation system, which is likely to provide major benefits. The system can help verify the presence and position of any remaining tumor and help avoid risk factors, such as damage

to major blood vessels. Both of these features can result in the improvement of surgical safety and accuracy. Medical ultrasonography would be the first choice for the navigation system [10], however, ultrasound is often limited by bone and air. The poor contrast also makes the surgical resection procedure difficult, if ultrasonography is used in the brain. In contrast, magnetic resonance imaging (MRI) provides excellent definition of the surrounding anatomy.

In human medicine, many surgical procedures to remove intracranial tumors have been performed using MRI during surgery. This has resulted in improved surgical performances [3, 6]. In our clinic, we have been aggressively trying to improve our skills and the outcomes for our canine and feline patients. An open MRI machine was introduced into the operating room 6 years ago that allows us to take MRI scans during surgery. In this report, we present our surgical experience with 23 cases of meningioma treated with surgical removal only and the prognoses of the cases.

### MATERIALS AND METHODS

The cases included 22 canines and 1 feline that were diagnosed with meningioma between 2006 and 2008. All were between 8 and 16 years old (average age of 11, median age of 11). There were 12 males and 11 females. Nine of the canine cases were golden retrievers, while the other cases included small dogs, such as a Chihuahua and a Maltese. The one feline case was an American shorthair.

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Fig. 1. a) Our operating room. b) Surgical bed can rotate towards the MRI table. c) Smooth transfer of a patient between the table and MRI stage.

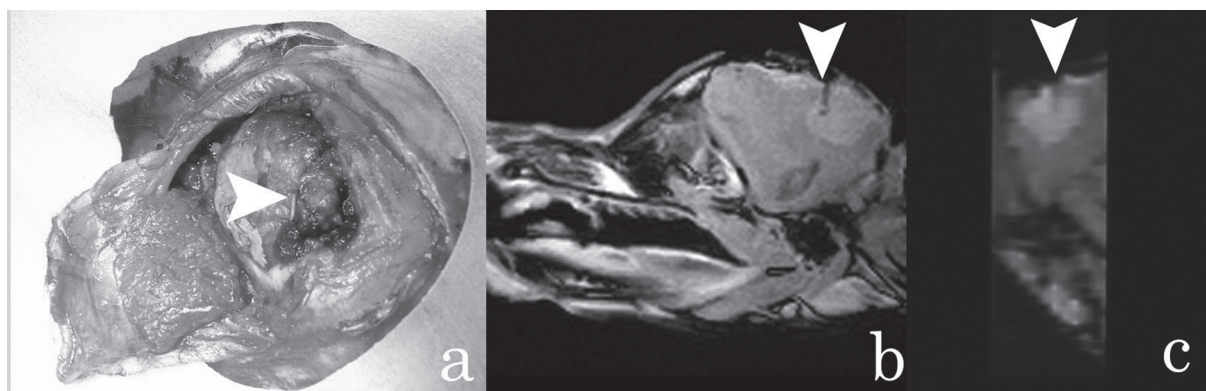


Fig. 2. Each arrow shows the location of the guidance needle. a) Shortly after craniotomy. b) Gd-enhanced T1-weighted image, sagittal section. c) Gd-enhanced T1-weighted image after MPR, transverse image.

Their clinical symptoms ranged from only epilepsy to visual defects, depression of postural reflexes with asymmetry or severe ataxia of gait. MRI was used as a diagnostic imaging tool. Computed tomography (CT) (Asteion Super4, Toshiba Medical Systems, Tochigi, Japan) and digital subtraction angiography examinations were also performed for other diagnostic measurements, and the location of the tumor and its feeding blood vessels were confirmed.

The MRI machine was a 0.3 tesla open type (AIRIS II Comfort, Hitachi Medical Corporation, Tokyo, Japan). In our operating room, we set a rotary surgical bed and the necessary instruments for the surgery outside of the 5 gauss magnetic field of the MRI machine (Fig. 1). The entire room was disinfected and rendered sterile of any contamination. This setup allowed us to transfer a patient between the bed and MRI stage smoothly. We were able to use magnetically intolerant instruments and other machines only when the MRI was not being used. All the power switches for the machines were located in one spot. MRI was performed within a short time with Gd-enhanced T1-weighted and 3D gradient echo sequences (1.0 mm slice thickness). Furthermore, multi

planar reconstruction (MPR) was applied to the image, and the location of the tumor was confirmed in three dimensions. For craniotomy, a round bar was used. For the removal of the tumor, a bipolar, a surgical microscope (OME-500, Olympus, Tokyo, Japan) and microinstruments were employed. An ultrasonic aspirator (Sonopet, Stryker, Tokyo, Japan) was applied to stop hemorrhage from the tumor.

The decision to perform surgery was made in consultation with the owners, and informed consent was obtained before all surgeries were performed. Before craniotomy, mannitol (1 g/kg/TID/IV), methylprednisolone sodium succinate (15–30 mg/kg/SID/IV) and phenobarbital (2 mg/kg/BID/IM) were administered to reduce brain edema and to stabilize the animal. We performed transfrontal sinus craniotomy for tumors close to the frontal lobe, rostral tentorium craniotomy for partial lobe tumors, zygomatic arch excision craniotomy for temporal lobe tumors, caudal tentorial craniotomy for occipital lobe tumors or a mixture of each based on the best approach determined by the preoperative MRI examination.

Once we exposed the dura mater, we placed an MRI biopsy 24 G needle in the middle of the tumor and performed

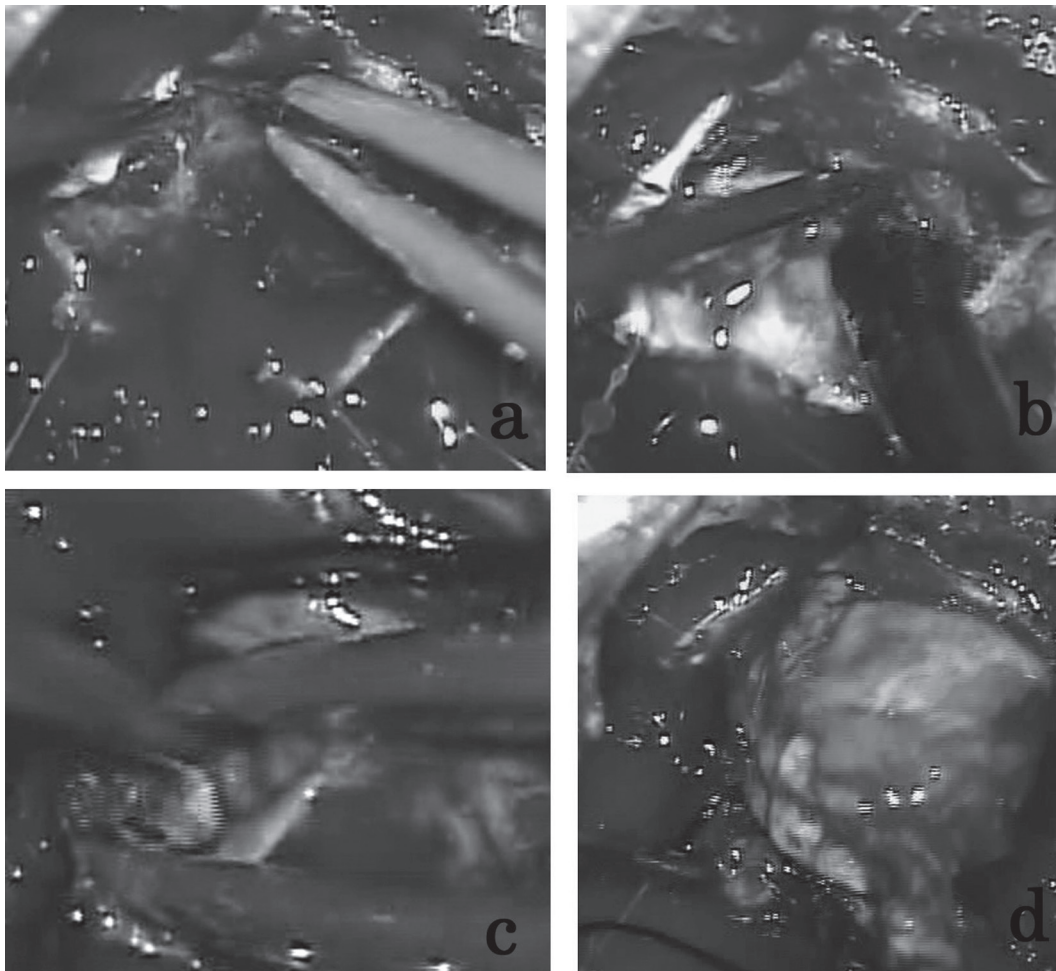


Fig. 3. Surgical procedure (under a surgical microscope). a) The dura mater was opened to expose a tumor. b) An ultrasonic aspirator machine was used to destroy the inner part of the tumor and reduce the pressure. c) After creation of some space between the brain tissue and tumor, the blood vessels going to the tumor were cauterized and resected. d) The procedure in c) was repeated all around the tumor, and the entire tumor was removed.

MRI to confirm the location of the tumor (Fig. 2). The scanned image was displayed on MPR to show the tumor extent in three dimensions. Then, we started the resection surgery under a surgical microscope, referring to the initial MRI. We placed the Sonopet ultrasonic aspirator machine in the middle of the tumor to destroy the inner part and released pressure from the entire tumor. Once we created some space between the brain tissue and tumor, we treated blood vessels and confirmed the supplies going to the tumor, and carefully resected them. We repeated this procedure all around the tumor and finally took out the entire tumor (Fig. 3). We took multiple MRI with Gd-enhanced T1 weighted images during the surgery to check for any residual tumor and for bleeding at any time (Fig. 4). We transplanted cutaneous muscle to suture back the dura mater and then applied suture glue (Bolheal; Kaketsuken Kumamoto, Japan) to prevent any leakage of cerebrospinal fluid. We repaired the skull and sutured back the muscle and skin for closure. Propofol was

given intravenously to calm the patient down and to decrease the brain pressure for 12 hr following the surgery, which was also considered to relieve the stress associated with the operation. After that, we administered glycerin (0.5 g/kg/BID/IV), methylprednisolone sodium succinate (15 mg/kg/SID/IV) and zonisamide (3 mg/kg/BID/PO) for 3 days postoperatively to prevent brain edema.

## RESULTS

Twenty-two of the lesions originated from the cerebrum fornix and the arachnoid cells of the falx cerebri, 18 cases were found on the frontal lobe, 2 cases were found on the temporal lobe, 2 cases were found on the parietal lobe, 1 case was found on the tentorium cerebella, and 1 case was found on a brain ventricle (Fig. 5). In case 6, the intraventricular tumor, the nutrient vessels from the internal carotid artery were detected by a CT scan (Fig. 6). The average length of

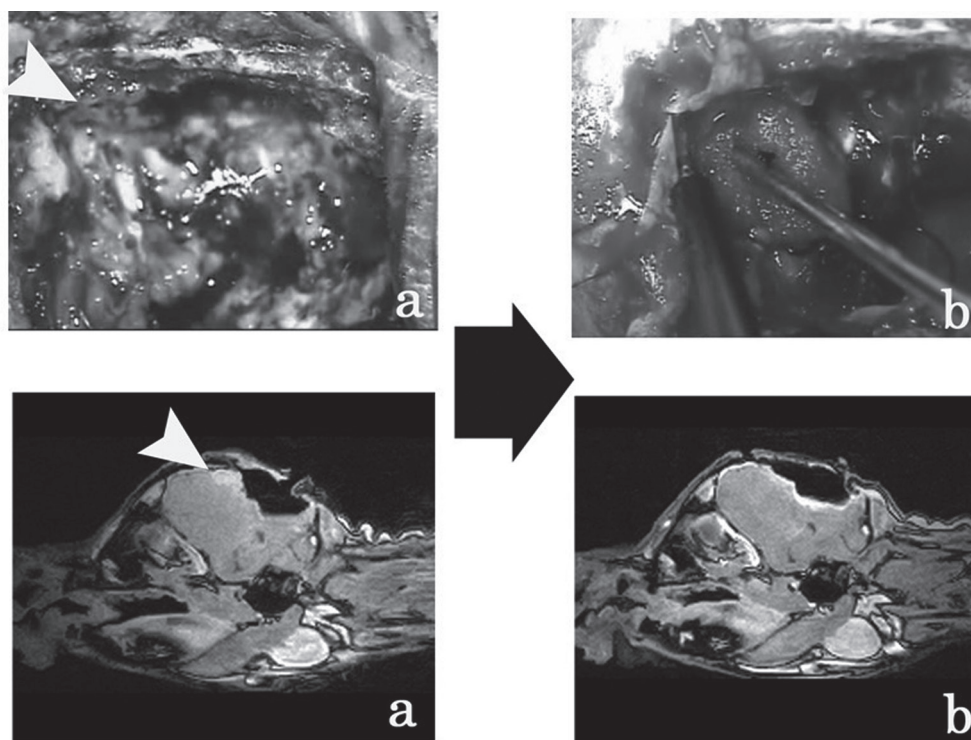


Fig. 4. Top: Findings under a surgical microscope. Bottom: Gd-enhanced T1-weighted image (sagittal section). a) 2nd MRI during surgery. b) Final MRI during surgery. Each white arrow shows the remaining tumors. Panel b) shows that there is no residue after removal.

Table 1. Case summary and survival durations

| Case number | Breed                   | Sex    | Age (years old) | Affected lobe | Survival durations                                 |
|-------------|-------------------------|--------|-----------------|---------------|--|
| 1           | Maltese                 | Male   | 14              | Parietal      | Died from encephalitis at 1.5 years post-op        |
| 2           | Mixed breed dog         | Male   | 12              | Frontal       | 3-year survival                                    |
| 3           | Mixed breed dog         | Female | 10              | Cerebellum    | Died from recurrence at 2 years post-op            |
| 4           | Mixed breed dog         | Female | 10              | Frontal       | 3-year survival                                    |
| 5           | Mixed breed dog         | Male   | 12              | Frontal       | 2-year survival                                    |
| 6           | Shetland Sheepdog       | Female | 9               | Temporal      | Died from pneumonia at 7 days post-op              |
| 7           | Golden retriever        | Female | 9               | Temporal      | 4-year survival                                    |
| 8           | Golden retriever        | Female | 9               | Frontal       | Died from arrhythmia at 7 days post-op             |
| 9           | Golden retriever        | Female | 9               | Frontal       | 2-year survival                                    |
| 10          | Golden retriever        | Male   | 8               | Frontal       | 2-year survival                                    |
| 11          | Golden retriever        | Female | 10              | Frontal       | 2-year survival                                    |
| 12          | Golden retriever        | Male   | 16              | Frontal       | Died from GDV at 8 months post-op                  |
| 13          | Golden retriever        | Female | 12              | Frontal       | 2-year survival                                    |
| 14          | Golden retriever        | Male   | 10              | Frontal       | 3-year survival                                    |
| 15          | Golden retriever        | Male   | 9               | Frontal       | Died from GDV at 4 months post-op                  |
| 16          | Labrador retriever      | Male   | 16              | Frontal       | 8-month survival                                   |
| 17          | Labrador retriever      | Male   | 10              | Frontal       | 2-year survival                                    |
| 18          | German shepherd         | Female | 8               | Frontal       | 3-year survival                                    |
| 19          | Shih tzu                | Male   | 9               | Frontal       | 2-year survival                                    |
| 20          | Yorkshire terrier       | Male   | 13              | Frontal       | Died from aspiration pneumonia at 6 months post-op |
| 21          | American cocker spaniel | Female | 11              | Frontal       | Died from renal diciency at 2 years post-op        |
| 22          | Chihuahua               | Female | 8               | Frontal       | 2-year survival                                    |
| 23          | American shorthair      | Male   | 11              | Parietal      | 7-year survival                                    |

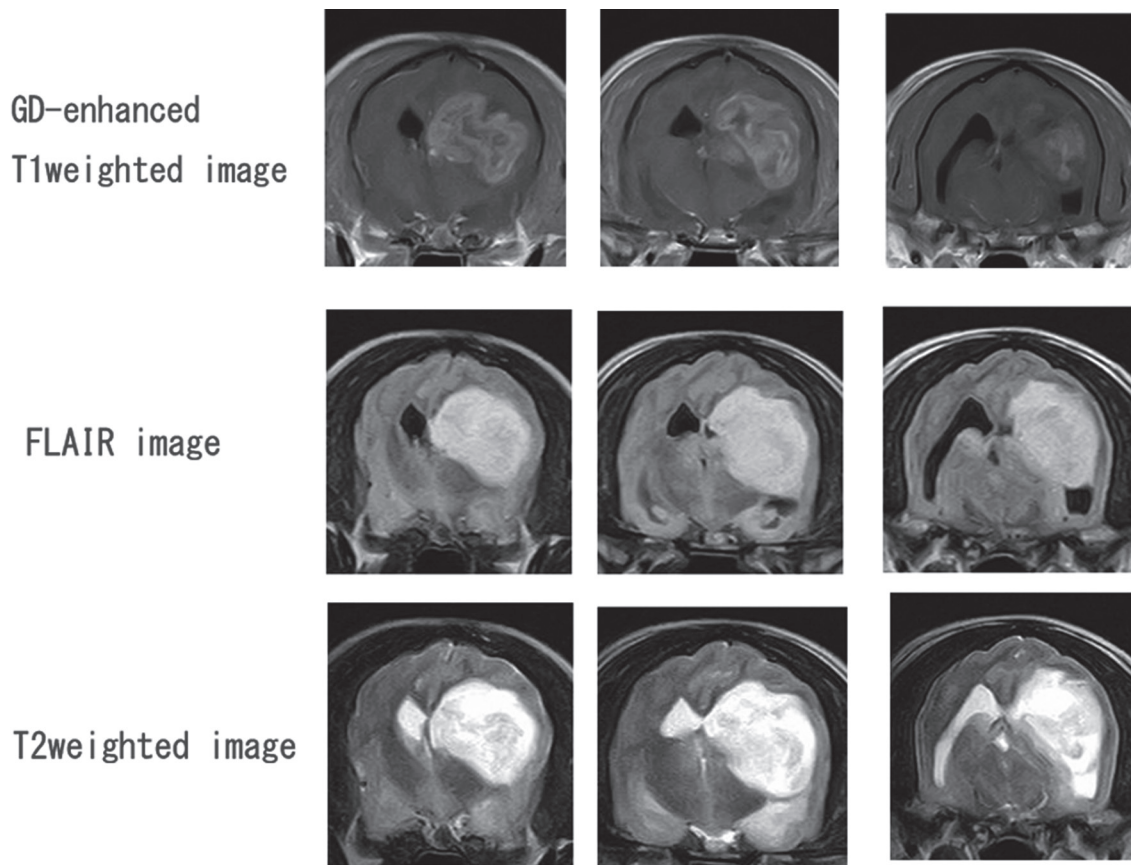


Fig. 5. Intraventricular meningioma (MRI) in case 6.

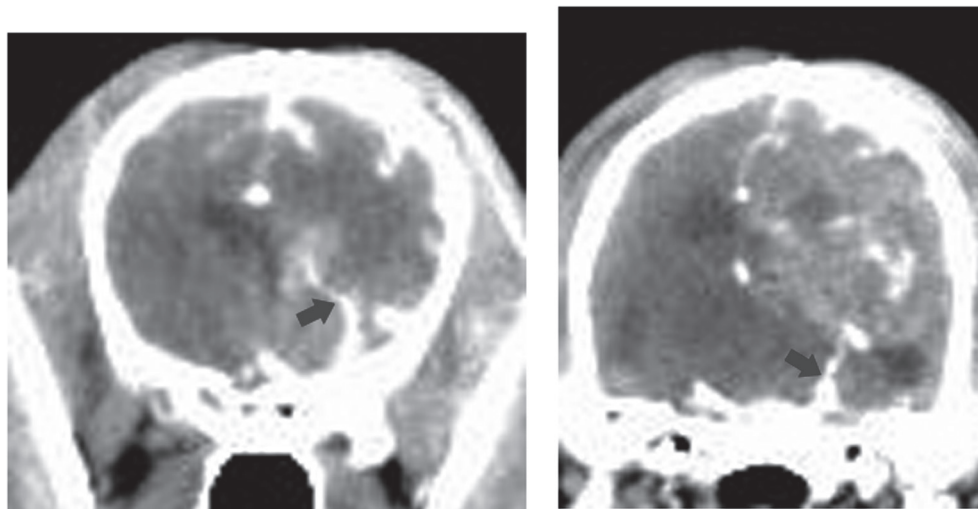


Fig. 6. Contrast-enhanced CT image in case 6. The image shows feeding vessels from the internal carotid artery.

surgery was 5 hr. We did not have any patient deaths during surgery, and 16 of the 23 cases lived for more than 2 years after the procedure.

We had to monitor the patients closely for 7 days post-

operatively, because of the risk of intracranial hypertension. Two patients with widespread brain edema died due to arrhythmia and aspiration pneumonia after surgery. The rest of the patients lived for more than 7 days without any com-

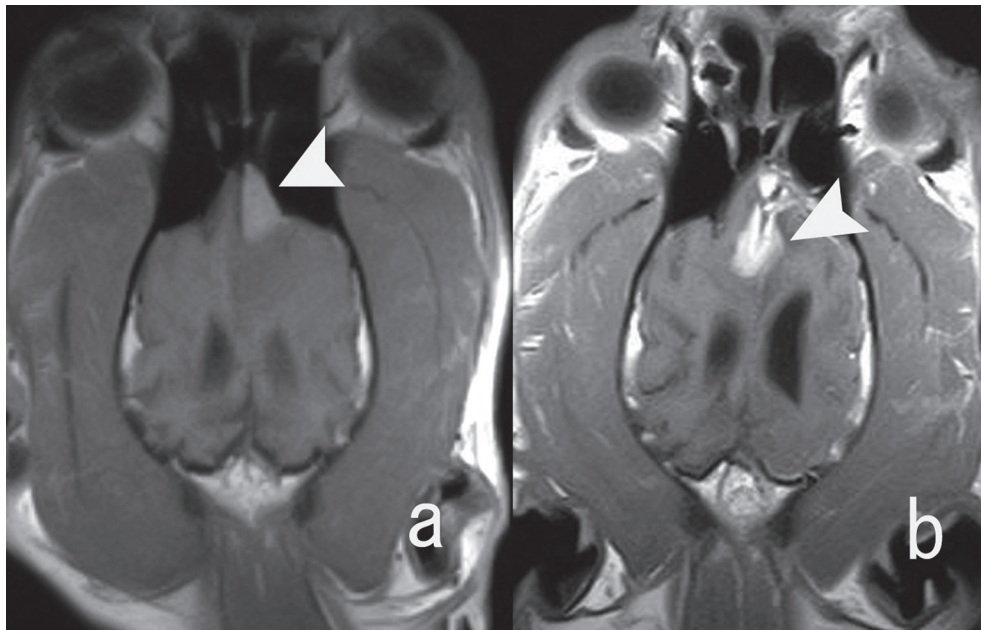


Fig. 7. MRI, Gd-enhanced T1-weighted image (coronal section) in case 2. a) Pre-op. b) Three years post-op. White arrows show the tumor. This patient was doing well after the surgery; however, epileptic seizure occurred 3 years postoperatively. MRI was performed and showed a recurrent tumor posterior to the removal site.

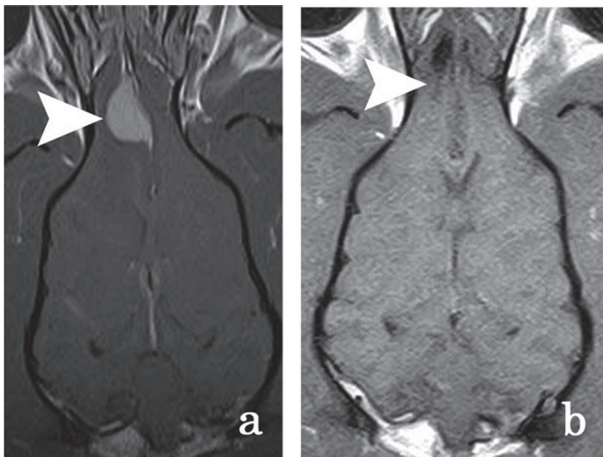


Fig. 8. MRI, Gd-enhanced T1-weighted image (coronal section) in case 15. a) Pre-op. b) Three years post-op. White arrows show the site of tumor formation. No recurrence of tumor was confirmed.

plications. In case 16, the patient was 16 years old and had a cerebral hernia. The patient survived 10 months postoperatively after emergency surgery for the brain hernia. Another 4 cases died within 2 years of gastric dilatation volvulus or other diseases due to their old ages. None of the patients died from intracranial hypertension caused by recurrence of meningioma within 2 years (Table 1). The longest survival time was 4 years, and this patient is still alive. In case 2, recurrence of meningioma was seen 3 years postoperatively. A large recurrent tumor occurred in the dura mater away



Fig. 9. MRI, Gd-enhanced T1-weighted image (transverse section) in case 13. A high-intensity signal tumor lesion was confirmed. In addition, the cyst image, dural tail sign and cystic wall extending from the surface of the tumor were confirmed.

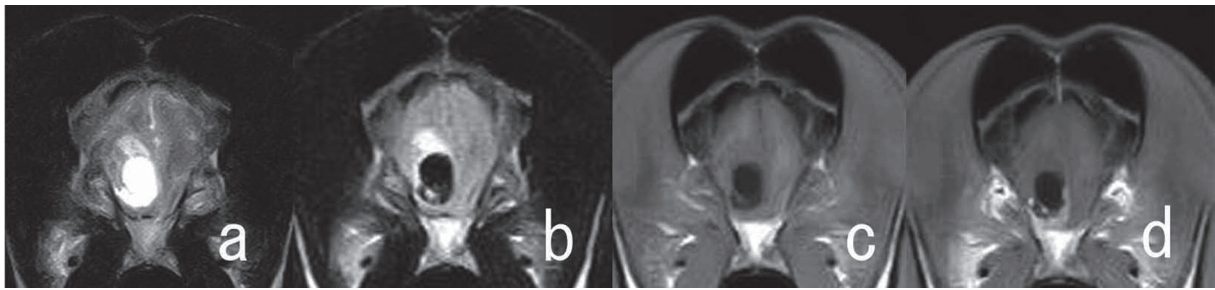


Fig. 10. MRI transverse image in Case 5. a) T2-weighted image. b) T2 FLAIR image. c) T1-weighted cyst image. d) Gd-enhanced T1-weighted image. The cyst image and high-intensity signal tumor lesion of the mass volume were seen from the basilar portion to cerebral falx. The cystic wall was not visualized, which led to the determination that the cyst was outside of the tumor.

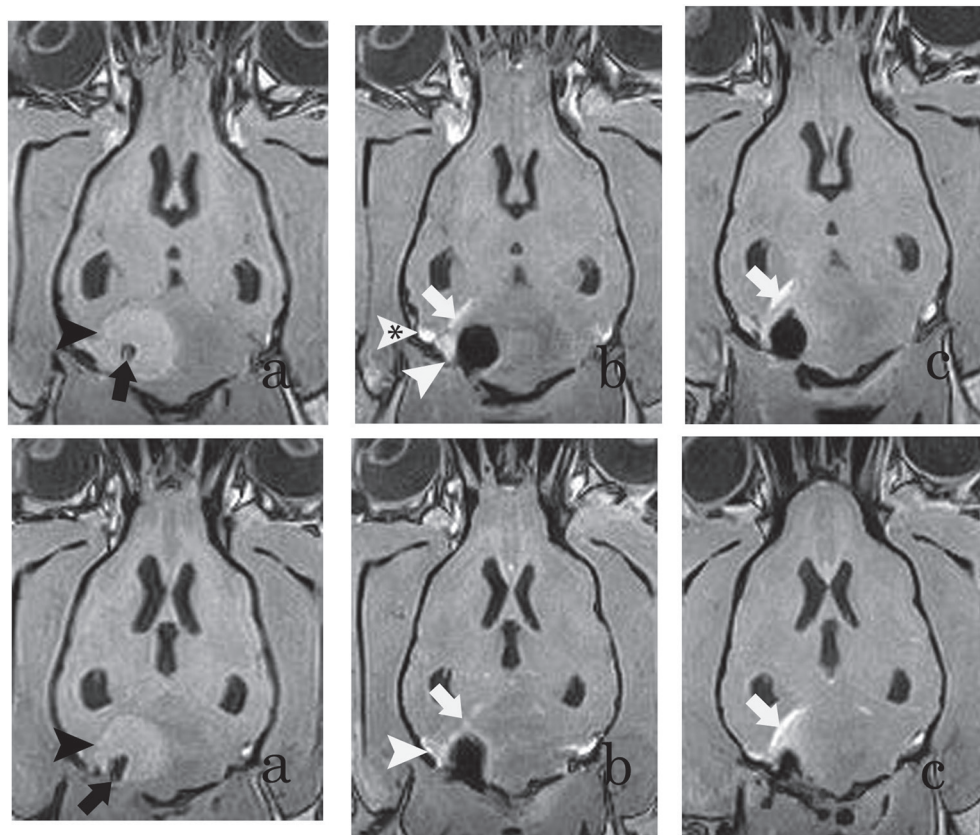


Fig. 11. Gd-enhanced T1-weighted image (coronal section) in case 3. a) First MRI during the surgery. b) Second MRI during the surgery. c) Final MRI during the surgery. Black arrowheads show the tumor. White arrowheads show the remaining tumors. Black arrows show the guidance needles. White arrows show the blood clots. The asterisk (\*) on the white arrowhead shows the sigmoid sinus.

from the removal site, whereas a small recurrent tumor was found at the removal site (Fig. 7). In case 15, no recurrent tumor was seen for more than 3 years postoperatively, likely because we had performed complete removal of a large portion of the falx cerebri (Fig. 8).

Several cases had cystic meningioma of Nauta classification [2, 7] type 2 (Case 13, Fig. 9) and type 3 (Case 5, Fig. 10). In case 14, which was type 2 cystic meningioma, we tried to remove the tumor including the cyst wall, as

shown on enhanced T1-weighted images and kept resecting tissue until no residue was observed during MRI. In case 5, we removed a parenchymal tumor in the same way. As a result, no recurrent cyst was seen on the 6 month follow-up MRI for case 5 or the 2 year follow-up MRI of case 14 after surgery.

The MRIs taken during surgery showed a tumorous lesion with a high signal intensity on Gd-enhanced T1-weighted images and extensive edema on a T2-weighted image and

fluid-attenuated inversion recovery (FLAIR) images. MRI provided relatively wide-range images and the anatomical location of the tumor. T1-weighted images revealed the exact location of blood vessels running around the tumor. Especially when a surgical approach around sinus veins was needed, MRI was very informative to avoid massive bleeding. It is possible that artifacts might occur when bleeding is confirmed as a high-intensity signal and could cause unclear tumor images on MRI; however, it was still possible to distinguish these areas by examining the differences of enhancing effects and by microscopic examination (Fig. 11).

## DISCUSSION

The use of MRI scanning during surgery as a navigation system improved our surgical performance and contributed to a prolonged survival time for the patients [3, 6]. MRI was able to show the exact location of the tumor before the resection. Performing microsurgery under a surgical microscope was also helpful to obtain good results for canine meningioma, which generally has poorly defined tumor margins [4]. These techniques minimized the trauma to the subarachnoid tissue. In one case where the border of the tumor was not identified visibly, multiple MRIs taken during surgery helped us to confirm the exact location of the tumor and reduce the risk of damaging healthy brain tissue. Additionally, the presence of remnant tumor tissue is generally dependent on the location of the tumor and skills of the surgeons, but MRI scans during surgery can allow for better localization of a tumor and therefore more accurate resection. Our techniques can also prevent the rise of a mass effect and intracranial hypertension. However, it was impossible to take MRI scans during surgery for confirmation of the site of tumor recurrence on the dura mater and falx cerebri. Therefore, the portion of the dura mater invaded by the tumor needed to be more widely resected, but this resulted in the prevention of tumor recurrence. In case 9, relapse was confirmed at 6 years post operation. The tumor developed at the same location and grew to about the same size as the original tumor. The subtype of this new tumor was diagnosed as a transitional histologic tumor type. In 2006, Greco *et al.* reported that the median survival time of patients with the transitional histologic tumor type of brain meningioma was 1,254 days when using a surgical aspirator [4]. Except for that fact that they performed radiation and chemotherapy together as well, their team and our both employed an ultrasonic aspirator for meningioma excision surgery. However, our case 9 patient survived longer, and relapse was slower than in any of their patients as a result. Therefore, we would like to suggest that MRI during surgery allowed us more precisely excise the

tumor.

The major problems associated with taking MRI scans during surgery would be the patient transfer to the MRI stage and the MRI scanning time. However, our surgical setup allowed us to transfer the patient between the surgical bed and MRI stage smoothly with only 2 assistants. Draping the patient also helped to prevent infections. Gradient echo sequences with MPR took only about 10 min, which did not interfere with the surgery. We believe that surgeries are not only affected by surgeons. In order to perform multiple MRI procedures smoothly during surgery, it is necessary to have skillful assistants. Creation of an excellent team with skilled members is necessary to achieve even more accurate treatments and ensure integration of the MRI data in surgical planning and performance.

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