POST-OPERATIVE COMPUTED TOMOGRAPHY IN TWO DOGS WITH CEREBRAL MENINGIOMA

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Post-operative computed tomography (CT) has been described as a technique for diagnosing incomplete resection or recurrence of cerebral neoplasms in humans. The characteristics of immediate post-operative CT images in dogs with intracranial pathology are unknown. This report describes findings from preoperative, immediate post-operative, and 4 week to 9 month follow-up CT examinations in two dogs with histologically-confirmed cerebral meningiomas. In images of one dog after surgery there was mild contrast enhancement of the tissue surrounding the surgical site. This enhancement had resolved in later images and was probably the result of surgically induced trauma. In post operative images of the other dog there was significant hyperattenuation of the tissues around the surgical site. In post contrast images there was increased enhancement that was evident in later images. These findings, although not supported by necropsy, probably indicate incomplete excision of the tumor. *Veterinary Radiology & Ultrasound, Vol. 41, No. 5, 2000, pp 425–432.*

Key words: CT Brain, post-operative period, craniectomy, dog, meningioma.

Introduction

CRANIECTOMY HAS BECOME an accepted means for diagnosis and therapy of intracranial neoplasia in the dog.[1] However, determining the extent of a lesion at the time of surgery can be challenging due to ill-defined tumor margins. Intravenous, contrast-enhanced computed tomography (CT) is a sensitive technique for identifying locations in which there is a breakdown in the blood-brain-barrier.[1,2] In humans, CT is also used post-operatively to document residual neoplastic tissue or complications such as hemorrhage or infection.[3–11] The CT characteristics of the normal dog brain a few days after surgery have been described.[12] However, no description of the appearance of the dog brain on CT images immediately after surgery for intracranial pathology could be found. In this study, the immediate post-operative CT findings from two dogs with a histologically-confirmed cerebral meningioma are described. Pre-operative and follow-up CT characteristics are also reported.

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Methods

Dogs

Dog 1 was a 13-year-old, neutered male, 7.9 kg, Miniature Poodle. The dog had a 9-month history of generalized seizures that were increasing in frequency despite appropriate anticonvulsant therapy. On physical exam the dog had a grade III/VI systolic murmur, most prominent over the mitral valve. Results of a neurologic examination were normal. There was a thrombocytosis (671,000/μl 179,000–473,000/μl), an increase in alanine aminotransferase (263 U/L, 13–100 U/L) and an increase in alkaline phosphatase (234 U/L, 20–167). The serum phenobarbital level was within the therapeutic range. Thoracic radiographs were negative for metastatic neoplasia or cardiac disease.

Dog 2 was a 10-year-old, neutered female, 3.4 kg, mixed-breed dog. The dog had episodes of circling to the right and seizures, and was being treated with phenobarbital at the time of admission. There was a grade III/VI systolic murmur, heard best over the mitral valve. An inducible cough was present upon tracheal palpation and there was severe dental disease. Neurologically there was a mild left hemiparesis, consistent with a right forebrain lesion. Complete blood count and serum chemistry tests were within normal limits. In thoracic radiographs there was mild left heart enlargement and echocardiographically there was moderate mitral regurgitation.

Scanning Protocol

All CT scans were performed using a fourth generation scanner.* Dogs were under general anesthesia and positioned on the CT table in sternal recumbency. The head was placed in an extension cradle and supported with radiolucent positioning sponges. Pre-contrast and post-contrast transverse 2–4 mm CT images were obtained at 2–3 mm slice intervals perpendicular to the hard palate, from the level of the cribriform plate to the foramen magnum. CT imaging was repeated immediately following a rapid bolus, intravenous injection of nonionic, iodinated contrast medium.† For each dog, post-operative and follow-up CT scanning protocols were the same as those used pre-operatively. Transverse and reformatted images were viewed on a remote CT workstation.‡ Post-operative images were compared to pre-operative images using similar window/level settings.

Surgical Procedure

A rostrotentorial craniectomy, with extension into the frontal sinus was performed in dog 1 (Fig. 1a).[13] In dog 2, a rostrotentoral craniectomy was performed caudal to the frontal sinus (Fig. 1b). For both dogs, intraoperative ultrasonography was used to assist tumor localization and excision.[14] A 7 MHz probe, with sterile probe cover and gel was used to scan the cerebrum through the craniectomy site. All tissues removed during surgery were submitted for histopathologic examination.

Results

Dog 1

In initial, pre-contrast CT images there was a hypoattenuating mass in the right rostral fossa (Fig. 2a). The rostral horn of the right lateral ventricle was compressed and displaced caudally. In post-contrast CT images a sharply-marginated, 2.1 cm × 3.0 cm × 1.7 cm, ring-enhancing mass was seen involving the right olfactory bulb, frontal and temporal lobes (Fig. 2b). There was marked deviation of the falx cerebri to the left, and mild peritumoral edema. In sagittal and dorsal planar images, the mass appeared to be broad-based along the inner margin of the cribriform plate. No distortion or disruption of the cribriform plate could be identified. The frontal sinuses and caudal nasal cavity appeared normal. The CT diagnosis was a cavitary, extra-axial mass involving the right rostral cerebrum. Differential diagnoses included cystic meningioma, subacute hematoma, or abscess.

At surgery, the mass appeared as a 2–3 cm, spherical, cystic structure in the right rostral cerebrum. There was no indication of bone involvement and it was not possible to clearly define communication with the ventricles. Sonographically the mass was 2 cm in diameter, cavitated, and well encapsulated with echogenic strands running through it. The cyst was drained with the aid of ultrasound and the lining of the structure surgically removed. The fluid was clear and resembled cerebrospinal fluid. The lining of the cystic structure was thin and translucent. The mass appeared to be completely removed on gross inspection, but margins were difficult to assess rostral to the craniectomy defect. After resection there was no sonographic evidence of the lesion. Gross hemorrhage was not visible after the mass was removed.

A CT scan of the brain was repeated immediately after surgery. The rectangular craniectomy defect could be seen in the right rostrodorsal calvarium and dorsolateral frontal bone. (Fig. 2c) In pre-contrast images the hypoattenuating mass was no longer evident. Patchy areas of hyperattenuating tissue occupied the surgical site. Some gas pockets were also evident. In post-contrast images, the tissue in the surgical site exhibited moderate, heterogenous enhancement, with ill-defined margination. (Fig. 2d) Deviation of the falx cerebri and right ventricular compression were less severe than in pre-operative images. The dog recovered from anesthesia with minor left-sided postural reaction deficits and a tendency to circle to the right. The owners declined radiation therapy and the dog was treated with anticonvulsants. The histologic diagnosis for the excised mass was meningioma.

Five weeks after surgery, the dog appeared to be clinically improved. There had been no more seizures and the only neurologic abnormality was the tendency to circle right. In pre-contrast CT images at this time there were patchy areas of hypo- and hyperattenuating tissue in the right rostral fossa. (Fig. 2e) The craniectomy defect appeared unchanged. The previous intracranial gas opacities were no longer evident. In post-contrast images, a recurrent ring-enhancing lesion was identified in the right rostral fossa. (Fig. 2f) There was continued deviation of the falx cerebri to the left. Patchy enhancement was also seen in the ventral portion of the olfactory bulb. A rim of enhancement occurred along the dorsal cerebral margin.

Nine months after surgery, the dog's clinical signs had worsened. The dog was more lethargic and having seizures every 4–6 weeks. The owner reported one recent episode of cluster seizures. Both the phenobarbital and potassium bromide dose had been increased. In pre-contrast CT images at this time there was hyperattenuating tissue in the right rostral fossa. (Fig. 2g) In post-contrast images there was a markedly-enhancing, sharply-marginated, 1.5 cm × 1.2 cm mass involving the right olfactory bulb and frontal lobe. (Fig. 2h) There was mild deviation of the falx cerebri to the left. The owners declined further surgery and the dog was

*IQ/Xtra, Picker International, Cleveland, Ohio.

†Iohexol. 240 mg I/cc, 2 cc/kg. Omnipaque, Nycomed Inc., Princeton, NJ.

‡Voxel Q Visualization System, Picker International, Cleveland, Ohio.

A

B

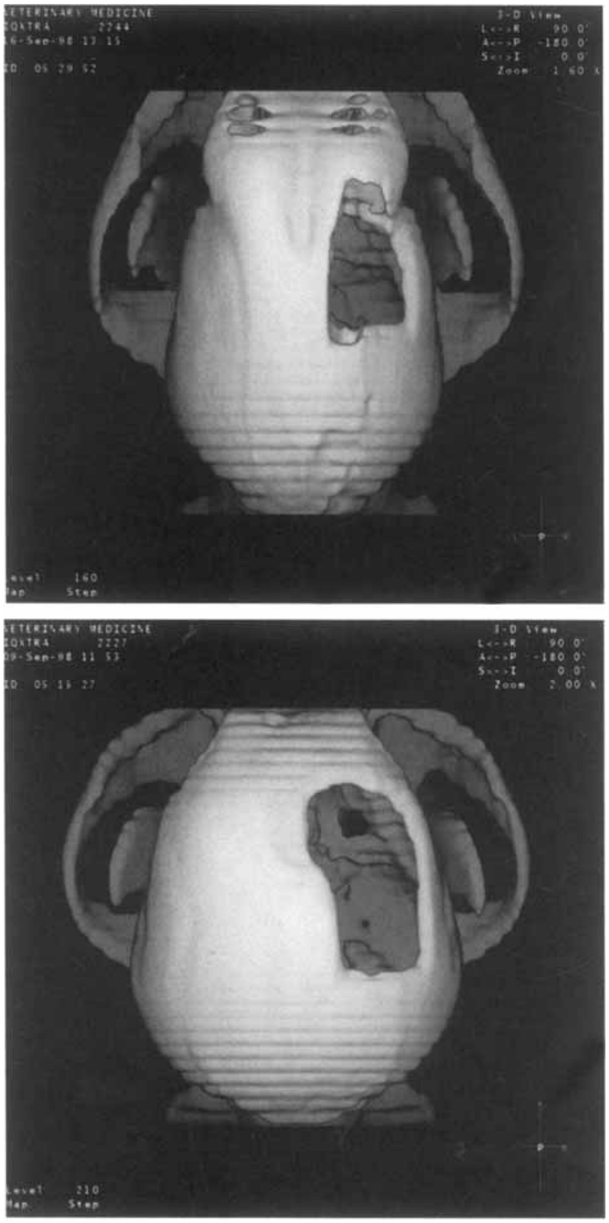

FIG. 1. Dorsal, three-dimensional CT images of (a) dog 1 and (b) dog 2.

discharged with steroid therapy.§ In a phone conversation the owner indicated that the dog had died one year from the time of surgery due to complications of pneumonia. No post-mortem brain examination was performed.

Dog 2

In initial pre-contrast CT images there were patchy hyperattenuating areas in the right rostral fossa. (Fig. 3a) In post-contrast images, a 1.7 cm × 1.7 cm × 2.1 cm, markedly-enhancing mass involved the right frontal, temporal, and parietal lobes. (Fig. 3b) The mass appeared broad-based along the margins of the falx cerebri and dorsal cerebrum. There was moderate displacement of the falx cerebri to the left, moderate to severe peritumoral edema, and moderate compression of the right lateral ventricle. No bone changes or other mass lesions were identified. The CT diagnosis was an extra-axial mass involving the right rostrodorsal cerebrum. Differential diagnoses included falcal meningioma or granuloma.

At surgery a 3 cm lobular mass was evident in the rostral portion of the right cerebral hemisphere. There did not appear to be bone involvement. Sonographically there was a well-demarcated focal hypoechoic mass, approximately 3 cm in diameter. It was thought that the entire mass had been removed and there was no gross hemorrhage at the time of closure. After surgery the dog recovered without complications. Phenobarbital was continued at the same dose as before. The histologic diagnosis for the excised mass was angioblastic meningioma.

In immediate post-operative CT images the rectangular craniectomy defect was clearly evident in the right dorsal calvarium. (Fig. 3c) A hyperattenuating rim of tissue was visible in the rostroventral portion of the surgical site. The rostral aspect of the right frontal lobe appeared more radiopaque than the left. The right lateral ventricle appeared less compressed than in the preoperative examination. Gas pockets around the surgical site were noted. In post-contrast images, the previously described right cerebral mass was absent. (Fig. 3d) There was resolution of the falx cerebri deviation. Mild enhancement of the rostral, ventral and medial margins of the surgical site was seen.

Six weeks after surgery, the dog was clinically improved and there had been no seizures. She continued to have slight left-sided postural reaction deficits with a tendency to circle to the right. In pre-contrast CT images at this time there was resolution of the previous subcutaneous and intracranial gas pockets. (Fig. 3e) The craniectomy defect appeared unchanged in size and margination. The dorsolateral margin of the brain partially protruded into the craniectomy defect. Hypoattenuating tissue occupied the previous surgery site. The right lateral ventricle was slightly larger than seen previously. In post-contrast images there was moderate enhancement of the rostrodorsal portion of the falx cerebri and the margin of the dura adjacent to the craniotomy defect. (Fig. 3f) The falx cerebri was displaced to the right at the level of the parietal lobes.

Six months after surgery, the owner reported the dog's death due to an episode of status epilepticus. The brain was removed and submitted for histopathologic examination. A large area of leukomalacia was identified in the right rostral cerebrum. This was characterized by increased vascularity, loss of normal white matter architecture, glial proliferation including large gemistocytic astrocytes and perivascular accumulation of macrophages with abundant granular eosin-

§Prednisone 5 mg QD.


2a
2b
2c
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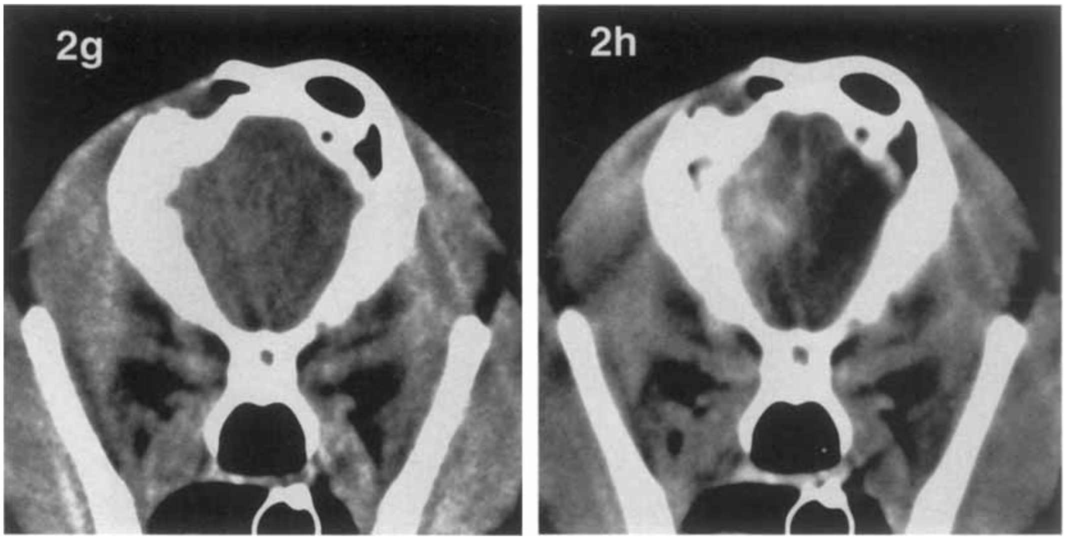

FIG. 2. Transverse, pre-contrast (a, c, e, g) and post-contrast (b, d, f, h) CT images obtained at the level of the rostral fossa in dog 1. In pre-operative images (a, b) there is a hypoattenuating, rim-enhancing mass involving the right cerebrum. In immediate post-operative images (c, d) the cranioectomy defect, gas pockets and absence of the cerebral mass can be seen. Patchy, heterogenously-enhancing tissue occupies the surgical site. In images obtained 5 weeks post-operatively there has been resolution of the gas pockets. Mixed opacity, rim-enhancing tissue is present in the previous surgery site. In images obtained 9 months post-operatively (g, h) there is hyperattenuating, markedly-enhancing tissue in the previous surgery site.

ophilic material in the cytoplasm (myelin). No evidence of tumor recurrence was found.

Discussion

Contrast enhancement that occurs following post-operative CT scans can be affected by many different mechanisms including breakdown of the blood-brain barrier, hypervascularization or neovascularization, and luxury perfusion, an increased volume of blood flow to tissues resulting from a pathologic process.[15–17] Blood brain barrier disruption may be due to tissue manipulation, infarction, infection, or synthetic hemostatic materials.[18] Using intra-operative CT, it has been suggested that edge enhancement seen following contrast medium administration may be due to the breakdown of the blood-brain barrier as a direct result of surgical trauma.[19] The author also reported remote tissue enhancement, thought to be related to disruption of the white matter blood-brain barrier caused by brain retraction. After about seven days, neovascularization may also result in contrast enhancement even when there is no residual neoplastic tissue.[12]

In a series of 11 normal dogs, a partial resection of the parietoccipital region was performed.[12] In these dogs there was no contrast enhancement visible in CT images acquired before the first week. Enhancement was absent after four weeks. Histologically, CT contrast enhancement appeared to be directly related to reactive vascular changes in the tissue. Proliferation of blood vessels along the margins of the surgically resected site of the canine brain was evident by two weeks and declined by four weeks. A ring enhancement of the surgical margins on the immediate post-operative image was also described. It has been suggested that there may be a difference in the human and canine brain with regard to the response to surgical injury, and that the optimal time to scan after surgery may be different.[16]

The best time to perform initial post-operative CT imaging is controversial and may ultimately be decided by the degree of contrast enhancement and amount of artifact present.[16] Imaging has been advocated as early as immediately following surgery and as late as 30 days after surgery. Earliest, i.e., within the first few days, may be best because in later images there may be changes that look like infection or neoplasia due to blood-brain barrier damage, gliosis and scarring.[10] In humans, it has been concluded that post-operative CT imaging should be done no earlier than one month because this is the time when surgical artifacts and edema will be minimized.[16] However, others argue for scanning sooner after surgery. For example, in a group of patients imaged 3 days after surgical removal of an intracerebral hematoma, there was no post-operative contrast enhancement. There was enhancement present by day seven. This increase in contrast enhancement was thought to be related to an increase in vascularity. Another proposed mechanism was contrast medium leaking from new blood vessels in the region.[3] Earlier imaging, around day three or four, has been advocated.[15] Contrast enhancement at day three, before neovascularization, may result from residual tumor and associated leakage of contrast medium into the parenchyma. This occurs because residual tumor vasculature lacks a normal blood-brain barrier.

Another argument against later imaging is that waiting 30 days may be too long, based on rate of regrowth of some

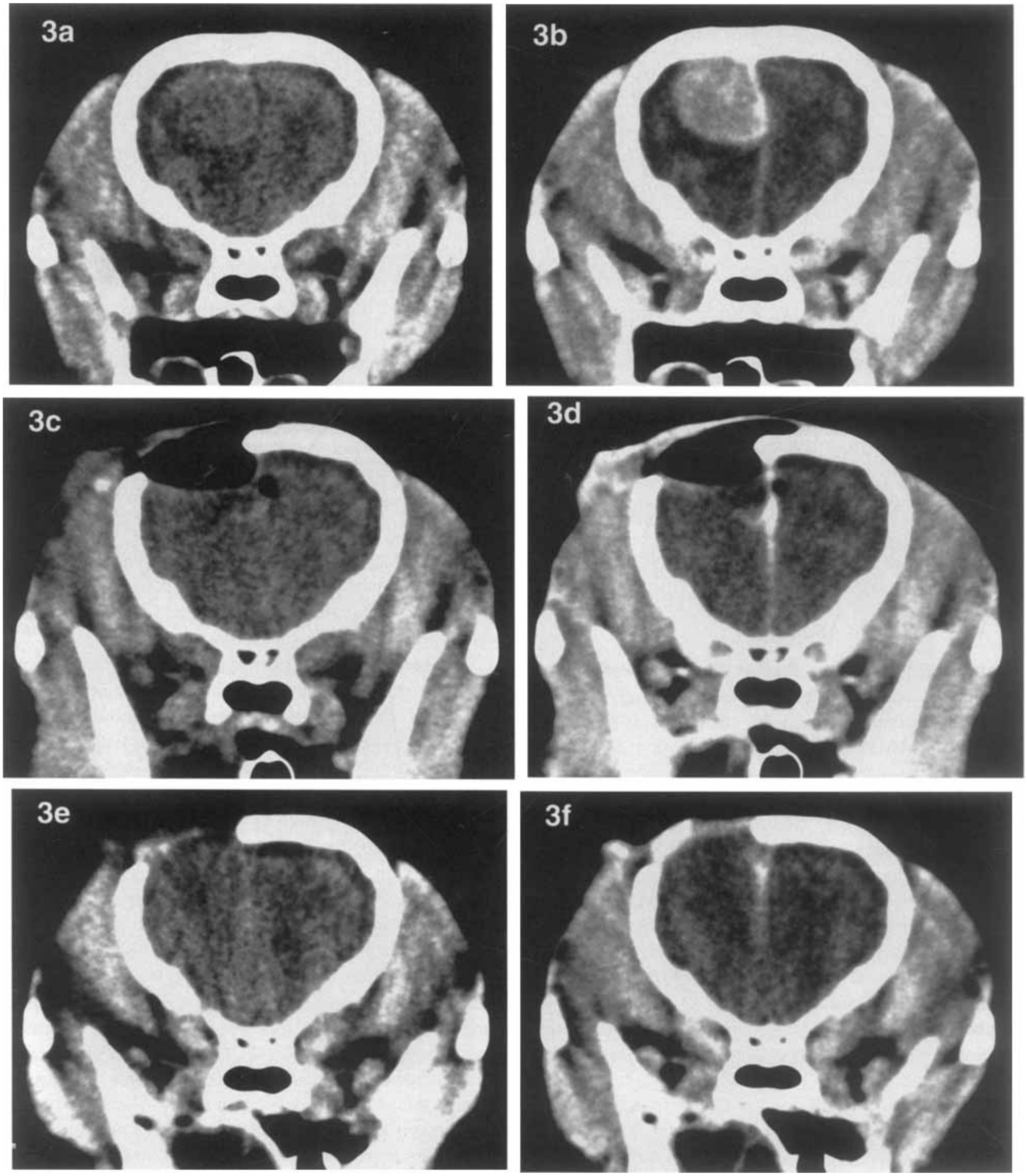

FIG. 3. Transverse, pre-contrast (a, c, e) and post-contrast (b, d, f) CT images obtained at the level of the rostral fossa in dog 2. In pre-operative images (a, b) there is a mixed-opacity, markedly-enhancing mass involving the right cerebrum. In immediate post-operative images (c, d) demonstrate the craniectomy defect, gas pockets, and absence of the cerebral mass are apparent. A rim of hyperattenuating, mildly-enhancing tissue is present in the rostral falx cerebri and on the dorsal margin of the surgical site. In images obtained 6 weeks post-operatively (e, f) resolution of the gas pockets and mild bulging of the brain margin into the craniectomy defect can be seen. There is a persistent rim of enhancing tissue in the rostral falx cerebri and on the dorsal margin of the surgery site. Patchy, hypoattenuating, non-enhancing tissue occupies the previous surgery site.

tumors.[20] Imaging before 72 hours may be needed to institute additional therapies.[8] After surgery, ring enhancement similar to a resolving intracerebral hematoma has been noted in a small series of patients with both benign and neoplastic lesions. Such enhancement may be present between days 6 and 56 after surgery.[6] This may necessitate delayed and sequential CT imaging. Early imaging may also help provide a baseline and differentiate post-operative granulation tissue from recurrent tumor tissue seen in later CT images.[21]

In dog one, increased opacity at the surgery site made assessment of contrast enhancement difficult. This may have been due to post-operative hemorrhage in the resection area. Five weeks after the surgery, the hyperattenuating tissue was largely resolved. There was continued contrast enhancement around the site of the surgery. (Fig. 2f) This could have been caused by neovascularization or residual neoplastic tissue.[3,11] Ring enhancement can be a nonspecific finding and is not necessarily associated with neoplasia.[22,23] Nine months following surgery, the CT images were characterized by progressive enhancement of tissue rostral to the surgical site. The distinction between neoplastic tissue and scar tissue could not be made because no postmortem examination was performed.

The immediate post-operative CT images in dog 2 were considerably different than in dog 1. A rim of hyperattenuating tissue was visible in the rostroventral margin of the surgical site. The right rostral aspect of the frontal lobe appeared more radiopaque overall than the left. The immediate post-operative contrast enhancement appeared to resolve over time. This may be comparable to the exudation described immediately following CT imaging in both humans after surgery and experimentally in animals.[10,24] This phenomenon has been theorized to result from blood-brain barrier breakdown caused by surgical tissue disruption allowing contrast medium to leak into the extravascular space. Another cause for the changes could be ongoing bleeding from small vessels along areas of resection, although these changes should have been evident in precontrast images.[10,24] This may have contributed to the focal enhancement of the dura and falx cerebri in dog 2. At necropsy no neoplastic tissue was found, which supports complete tumor removal. The leukomalacia found at necropsy may have been the result of surgical trauma, CT images of this may show regions of decreased density and possibly cavitation.[25] It is difficult to correlate the regions of malacia with the CT images.

In both cases, the pre-contrast images demonstrated evidence of hemorrhage. Blood initially appears as an area of hyperattenuation on CT images due to a high protein content.[25] In the present cases, hemorrhage is suspected due to the resolution of the regions of hyperattenuation along the surgical margins in later images. It has been stated that hemorrhage is identified by CT imaging as a markedly hyperattenuating regions. This effect resolves within a few days as the free blood in the tissues is metabolized. The identification of areas of suspected hemorrhage may serve to help identify post-operative complications such as hematoma formation.

Corticosteroid use may also affect the appearance of post-operative CT images.[15,26] Both dogs in this report received corticosteroids after the initial CT imaging. A steroid-induced pseudoresponse has been reported in people and may cause a reduction in the visible tumor volume.[18] The dose and duration required to cause these changes are unknown.

The CT changes found immediately post-surgery were similar to those described in humans. Immediate post-operative CT images may be beneficial in determining removal of neoplastic tissue. However, hemorrhage associated with surgery, evident in pre-contrast post-surgical CT images of dog 1, can obscure interpretation of contrast enhancement of residual neoplastic tissue. Disruption of the blood-brain-barrier at surgery may also cause immediate post surgical contrast enhancement that mimics residual neoplasia, as seen in dog 2, since contrast enhancement was not seen in subsequent images. Also, interpreting later images without the benefit of immediate post-operative CT may be difficult since neovascularization can resemble neoplasia. In conclusion, a single post-surgical CT examination may not be accurate for identifying residual neoplastic tissue. Demonstration of progressive disease in sequential imaging may be a better indicator. Future studies of different tumor types are needed to more clearly define the role of post-operative CT for treatment planning and prognosis in dogs with intracranial neoplasia. The comparison of CT to magnetic resonance imaging (MRI) may also provide insights to help optimize post-operative care.

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