

Analysis of Blood Flow in a Third Ventricular Ependymoma and an Olfactory Bulb Meningioma by using Perfusion Computed Tomography

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ABSTRACT. Brain perfusion computed tomography (CT) scanning was performed in a mongrel dog and a golden retriever that were diagnosed with third ventricular tumor and olfactory bulb tumor, respectively, by contrast-enhanced CT. The tumors were pathologically diagnosed as ependymoma and meningioma, respectively. Perfusion CT results revealed that the ependymoma in this study had a lower blood flow, higher blood volume, and greater transit time of blood than the adjacent brain tissue. Further, the meningioma in this study had a higher blood flow, higher blood volume, and greater transit time of blood than the adjacent brain tissue. Perfusion CT can potentially be used for the grading of brain tumors and narrowing differential diagnosis, provided the perfusion CT data of animals are accumulated.

KEY WORDS: brain tumor, canine, perfusion CT.

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Perfusion computed tomography (CT) is a method for assessing essential tissue functions by evaluating the blood flow in capillary tissues [10, 13]. An iodinated contrast medium is used as the tracer. The analysis of time variations in contrast enhancement in the time-density curve obtained from each pixel by dynamic image acquisition enables the assessment of tissue hemodynamics: cerebral blood flow (CBF, ml/100 g tissue/min), cerebral blood volume (CBV, ml/100 g tissue), and mean transit time (MTT, sec). Recently, attempts have been made to apply the perfusion CT technique for the analysis of human brain tumors [2, 3]; however, perfusion CT blood flow data for clinical cases of canine brain tumor have not been reported. Here, we present a novel finding with regard to the hemodynamics of a spontaneous ependymoma in the third ventricle and an olfactory bulb meningioma obtained by perfusion CT; this finding could not have been obtained by contrast-enhanced CT.

Ependymoma was detected in a female mongrel dog (12 years old, 13.5 kg) who presented with circling and a head tilt to the right side. Neurological examination revealed normal spinal reflexes. Intracranial disease was suspected, and a CT examination was performed. A multidetector-row CT (Asteion Super 4, Toshiba, Tokyo, Japan) was used for image acquisition. Anesthesia was induced by administering 8.0 mg/kg propofol (Rapinovel, Schering-Plough, Tokyo, Japan) and maintained using isoflurane (ISOFLU, Dainippon Sumitomo Pharma Co., Ltd., Osaka, Japan). The contrast medium used was iohexol (Omnipaque 300, Daiichi-Sankyo Co., Ltd., Tokyo, Japan) at a dose of 800 mg/

kg. Contrast-enhanced CT (120 kVp, 150 mA, 0.5-mm slice thickness, and 0.75 sec/rotation) revealed a contrast-enhanced area (Fig. 1a, 22.6 mm × 15.6 mm) in the third ventricle; this area was diagnosed as a third ventricular tumor. There was no evidence of metastasis to any other organs. Choroid plexus papilloma and ependymoma were the differential diagnoses. Perfusion CT was performed on another day at the level of the largest tumor image that was selected from among the contrast-enhanced CT images. The dog was positioned in dorsal recumbency. The head was positioned with the cerebral base perpendicular to the CT table to obtain images similar to transverse images of the human cranium. The anesthesia protocol adopted was identical to that used for the contrast-enhanced CT examination. Iohexol (200 mgI/kg) was injected via a 16-gauge catheter that was inserted into the jugular vein (4.5 ml/sec). The maximum slope method generally employs an injection rate of approximately 10 ml/sec in humans [1]; however, an injection rate of 4.5 ml/sec was employed in this study based on the body surface area and cardiac output of dogs. Dynamic CT scanning was initiated at the time of contrast-medium injection for a period of 40 sec (80 kV, 100 mA, 5.0-mm slice thickness, 1.0 sec/rotation). Simultaneous initiation of scanning and contrast medium injection was employed, because the contrast medium circulation is faster in dogs than in humans, and to obtain reliable CT values of pre-contrast images. The dynamic image data were analyzed using the maximum slope method [6]. The CBF, CBV, and MTT values in our study represented the average value of 3 regions of interest (ROI). An ROI (25 mm³) was carefully positioned to avoid contamination from adjacent different tissues.

The CBF in the tumor area (arrow in Fig. 1b; 68.5 ml/100 g/min) was lower than that in the adjacent brain tissue (Fig.

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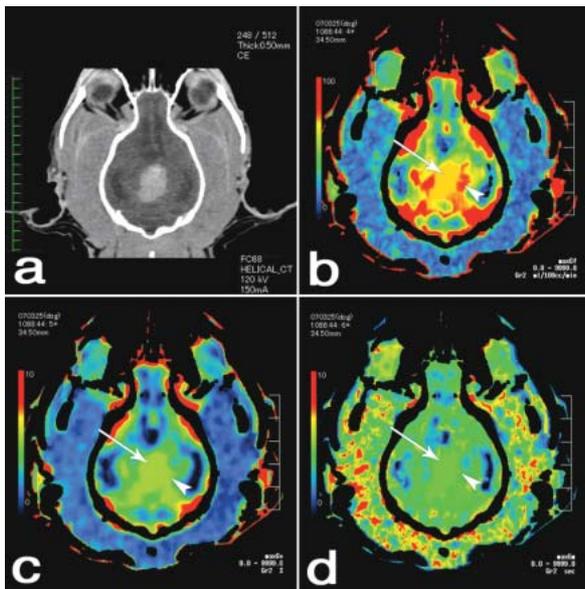


Fig. 1. Contrast-enhanced CT image and perfusion CT images of the ependymoma case. (a) Contrast-enhanced CT image; color maps for (b) CBF, (c) CBV, and (d) MTT. In the perfusion CT color map, areas with high CBF, CBV, and MTT values are indicated by colors close to red, while those with low values are indicated by colors close to purple, as defined by the color scale on the left side of the map (CBF: cerebral blood flow, CBV: cerebral blood volume, MTT: mean transit time).

1b, arrowhead; 76.2 ml/100 g/min). The CBV in the tumor (arrow in Fig. 1c; 5.33 ml/100 g) was higher than that in the brain tissue (arrowhead in Fig. 1c; 4.71 ml/100 g). Further, the MTT of the tumor (arrow in Fig. 1b; 4.67 sec) was greater than that of the brain tissue (arrowhead in Fig. 1d; 3.72 sec). The dog was euthanized at the request of the pet owner. Among the gross findings, the tumor was located in the third ventricle, extending from the anterior part of the thalamus to the anterior end of the mesencephalon. Based on microscopic and immunohistochemical analyses, the tumor was diagnosed as ependymoma. In addition, some malignant features such as local invasion of the brain parenchyma and bizarre nuclei were observed.

Meningioma was detected in a female golden retriever (14 years old, 30.0 kg) who presented with seizure. Contrast-enhanced CT revealed a brain tumor in the olfactory bulb area that was suspected as a meningioma; however, the pet owner did not wish that the dog be subjected to any aggressive treatment such as surgery or radiation treatment. CT examination was performed again to investigate the tumor status. Simultaneously, perfusion CT was performed. The imaging methods of contrast-enhanced CT and perfusion CT were the same as in the ependymoma case. Contrast-enhanced CT revealed a contrast-enhanced area (Fig. 2a, 35.0 mm × 28.8 mm) in the olfactory bulb area. The CBF in the tumor area (arrow in Fig. 2b; 55.9 ml/100 g/min) was higher than that in the adjacent brain tissue (Fig. 2b, arrowhead; 35.8 ml/100 g/min). The CBV in the tumor

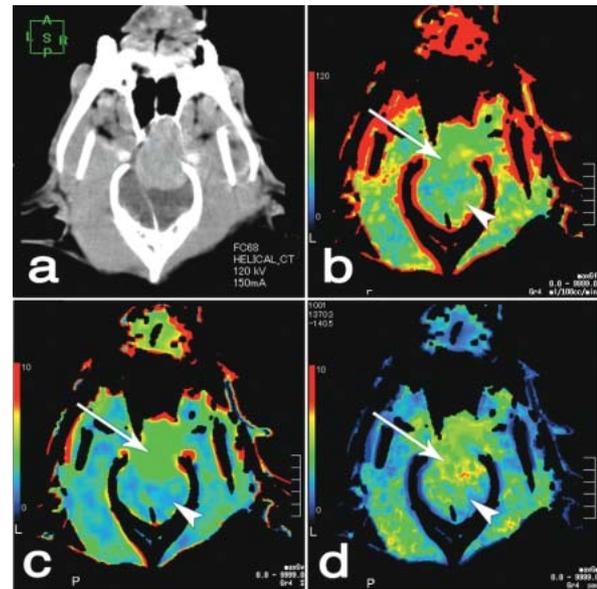


Fig. 2. Contrast-enhanced CT image and perfusion CT images of the meningioma case. (a) Contrast-enhanced CT image; color maps for (b) CBF, (c) CBV, and (d) MTT.

(arrow in Fig. 2c; 3.88 ml/100 g) was also higher than that in the brain tissue (arrowhead in Fig. 2c; 2.41 ml/100 g). Further, the MTT of the tumor (arrow in Fig. 2b; 4.70 sec) was greater than that of the brain tissue (arrowhead in Fig. 2d; 4.05 sec). The dog was euthanized at the request of the pet owner. Among the gross findings, the tumor adhered to the frontal cortex and severely compressed the brain tissue. Based on microscopic analysis, the tumor was diagnosed as a meningioma. In addition, malignant features such as local invasion of the brain parenchyma were observed.

The perfusion parameters of ependymoma suggest that the tumor had 90% blood flow supply and 113% capillary blood volume as compared to the adjacent brain tissue. Furthermore, the greater transit time of the blood suggests the possibility of congestion in the capillary bed of the tumor. The perfusion parameters of meningioma suggest that the tumor received 156% blood flow supply and 161% capillary blood volume as compared to the adjacent brain tissue. Similar to the ependymoma case, the possibility of congestion in the capillary bed of the tumor was suggested by the greater transit time of the blood.

In primary glial tumors, the presence of vascular proliferation and angiogenesis leads to an altered histopathological grade, which commonly corresponds to high-grade areas [5]. Traditionally, the extent of contrast enhancement has been used as a mark of malignancy; however, contrast enhancement itself reflects disruption of the blood-brain barrier and not tumor angiogenesis [11]. On the contrary, perfusion CT reflects the amount of capillary vessels (CBV). The ependymoma in this study had some malignant features. Those findings may have been responsible for the higher CBV than peritumoral area. Noninvasive grading of

glioma will possibly be enabled if more patient data of gliomas are accumulated in future studies [4, 12]. In addition, selecting the higher CBV area (greater tumor vascularity) for the biopsy site may reduce the failure of definitive diagnosis [8].

Meningiomas that are easy to differentiate generally have well-defined borders from the brain parenchyma, exhibit high contrast, and are extra-axially localized. However, 15% of meningiomas can have atypical imaging characteristics such as cystic and necrotic areas, intratumoral hemorrhage, peritumoral edema, and parenchymal invasion [9]. In these cases, differentiation between meningioma and intra-axial tumors is difficult. Meningiomas are generally highly vascularized tumors, and their CBV ratios were found to be higher than the CBV ratios of intra-axial tumors [7]. Accumulation of perfusion patterns of meningioma will lead to the development of perfusion CT as a useful tool for differentiating between meningiomas and intra-axial tumors.

Even magnetic resonance imaging (MRI) may be insufficient for the definitive diagnosis of brain tumors based on their derived location or morphology. In this report, contrast-enhanced CT indicated the presence of the tumor as well as its shape and location. Further, perfusion CT provided data regarding tumor hemodynamics (CBF, CBV, and MTT). In addition, hemodynamic information regarding canine third ventricular ependymoma, which is a relatively rare kind of tumor, is presented in this report. The 2 cases reported here may not represent all the hemodynamic patterns of cerebral ependymoma and meningioma; however, this study demonstrates that perfusion CT can potentially be used for the grading of brain tumors and for arriving at a more specific differential diagnosis for living animals, provided sufficient perfusion CT data on animals are accumulated. This technique is an ideal rapid diagnostic tool for veterinary medicine and a feasible, cost-efficient, and qualitative method for diagnosing brain tumors based on tissue hemodynamics. Perfusion CT has the potential for determining the preferred approach for needle biopsy, for determining the feasibility of surgery, for presurgical and preradiation assessments, and for monitoring during chemoradiotherapy.

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