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Acute irradiation injury of canine brain with pathology control is detected by diffusion-weighted imaging of MRI

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Abstract

To investigate the pathological changes of canine brain after irradiation and evaluate the effect of diffusion-weighted imaging (DWI), 25 healthy dogs were treated with 70 Gy ^{60}Coγ-ray irradiation on right temporal brain. Respectively, the apparent diffusion coefficient (ADC) values of canine alba and ectocinerea were measured by MRI T1 weighted imaging (T1WI), T2 weighted imaging (T2WI), and DWI. Compared with the control group, at every time point after irradiation, the ADC values of canine brain tissue were decreased significantly (P<.05). DWI is a very sensitive imaging technology that detects the changes of water molecule diffusion and microscopic pathological changes after canine brain irradiation.

Keywords: Diffusion-weighted imaging; Canine brain; Animal experiment; Acute irradiation injury

1. Introduction

Radiotherapy, especially stereotactic radiosurgery and stereotactic radiotherapy, is the principal strategy for benign and malignant intracranial tumor treatment [1]. However, radiation damages normal tissues as well as kills tumor cells, and brain injury is one of the most serious complications of radiation therapy. Therefore, it is of great significance to understand the early symptoms caused by radiation and make use of possible techniques for early diagnosis and therapy, which helps reduce the incidence of severe complications [2]. There are two stages in radiation brain injury—endoscopic microdamage and radioencephalopathy (RE). Diffusion of water molecules is an important biophysical process in human tissues.

Functional MRI diffusion-weighted imaging (DWI) technology could be used to map the diffusion process of water molecules in vivo, which is an indication of the pathophysiological state. Generally, apparent diffusion coefficient (ADC) is used to describe the diffusion of water molecules. DWI is a kind of noninvasive MRI functional imaging technique based on the diffusion of water molecules, so it could provide the quantitative information of the organizational structure. Through the DWI technique, we could detect the pathological changes of the microstructure in white matter when it got injured [3]. In this study, we measured brain injury in a canine animal model and tried to preliminarily specify the value of DWI in detecting early radiation brain injury.

2. Material and method

2.1. Animals and groups

Twenty-five dogs aged 1 to 3 years old, 13 of which were male and the others were female, weighing 7.5–15 kg were active and healthy and had bright fur and moist noses. These dogs were divided into two groups: 10 for the control group (CG) before irradiation and 25 for the experimental group (EG) after irradiation. The latter had been divided into five subgroups: 2, 4, 8, 10, and 12 weeks after irradiation (five per subgroup).

2.2. Modeling

We anesthetize the dogs with sodium pentobarbital (30 mg/kg) by hind intravenous injection, then lay the dogs

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on the left side of the treatment bed of the ^{60}Co machine; 70 Gy was used to irradiate at the right temporal part of the dog brain. The beam area was 4×4 cm. The irradiation distance was 65 cm. The irradiation depth was 3 cm.

2.3. MRI

The Siemens Symphony 1.5 T MRI scanner was applied. Anesthetized dog lay on its left side on the MRI examination bed with a standard head coil (Fig. 1 ①). The ADC values of canine brain white and gray matter were measured by MRI T1 weighted imaging (T1WI), T2 weighted imaging (T2WI), and DWI examination before irradiation and 2, 4, 8, 10, and 12 weeks after irradiation, respectively.

2.4. Pathologic sampling

Dogs in each group were killed immediately after MRI examination, and then, the brains were taken out. In each group, three brains were first fixed in formalin solution, then embedded in paraffin and stained with hematoxylin and eosin and, lastly, examined with light microscopy; another two brains were fixed in paraformaldehyde solution and then rinsed with phosphate buffer (0.1 mmol/l, pH 7.4). After the rinse, these tissue blocks were fixed with osmic acid (10 g/l) for 2 h and progressively dehydrated with alcohol and acetone. Again, these tissues were saturated with acetone and pure embedding medium and then embedded with ethoxyline 618 and cut to 50-nm slices. At last, these samples were examined with electron microscopy for histological changes.

2.5. Statistical analysis

Values are expressed as mean±S.E.M. Excel is used to analyze the data. *T* test is performed to compare the measurement data; chi-square test is used to analyze count data.

3. Results

3.1. Animals' responses to irradiation

Animals exposed to irradiation all had reduced appetite and activity, but these animals gradually returned to normal after 2–7 days. Dog hair in the beam area began to fall after 1 month. Some dog hair around the beam area became white and had skin reactions and pigmentation (Fig. 1 ②③④).

3.2. Conventional MRI findings

No significant change appeared at 2 and 4 weeks after irradiation until the 8th week. The side of the brain exposed to irradiation appeared to atrophy with local thinning cortical, widening sulus, and ventricular dilatation. At 12 weeks, cerebral hemispheres were shrinking, but there were no obvious abnormal changes of signal intensity (Fig. 1 ⑤⑥⑦⑧).

3.3. ADC

ADC values are shown in Table 1, which are from the irradiated brain tissue and the normal CG. The trend of ADC

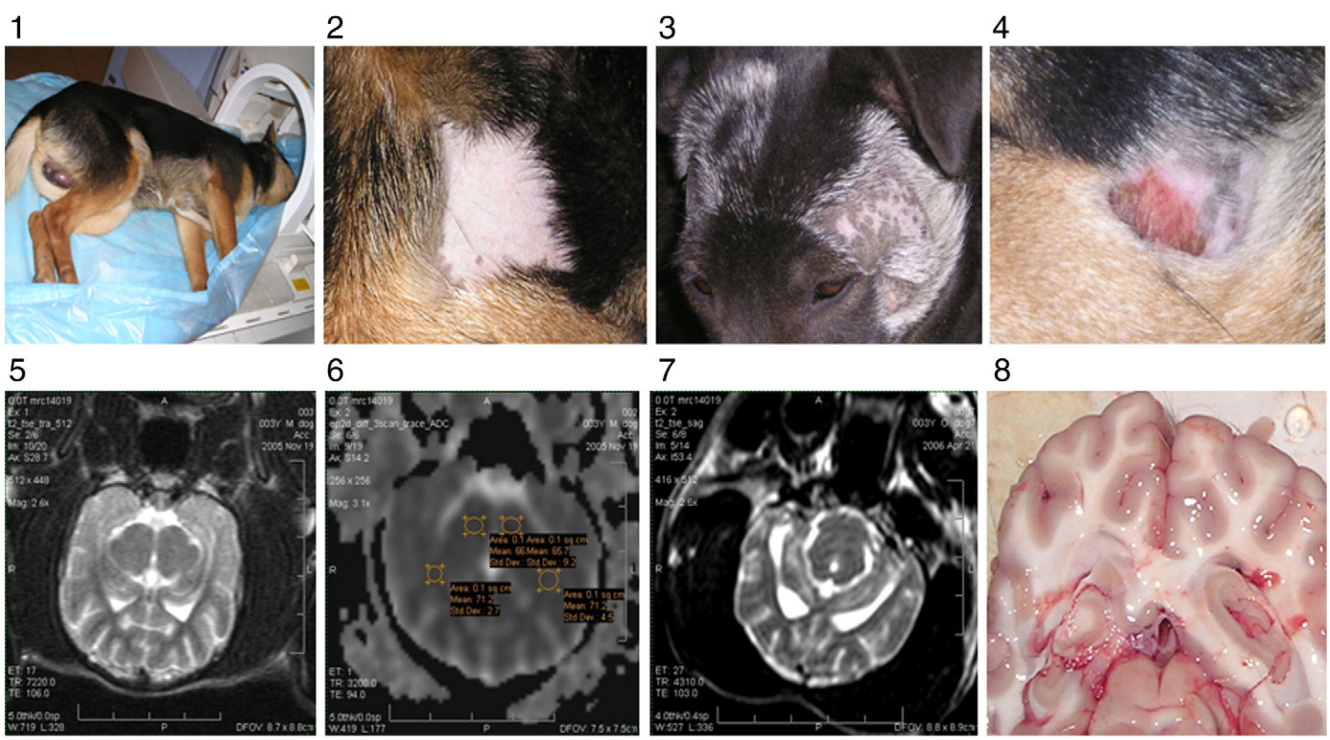

Fig. 1. ① MRI examination; ② dogs' hair loss in beam area; ③ bleaching dog hair; ④ skin reaction; ⑤ normal canine brain image; ⑥ ROI; ⑦ 12 weeks after irradiation, brain atrophy, and lateral brain ventricle dilation; and ⑧ brain ventricular dilatation and local cortical thinness.