

Computed Tomographic Findings of Experimentally Induced Neurogenic Muscular Atrophy in Dogs

Hiromitsu ORIMA and Michio FUJITA

Division of Veterinary Radiology, School of Veterinary Medicine, Nippon Veterinary and Animal Science University, 7-1 Kyonan-cho 1 chome, Musashino-shi, Tokyo 180, Japan

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ABSTRACT. Neurogenic muscular atrophy was examined using computed tomography (CT) in dogs induced by crushing the sciatic nerve. The CT number and cross-sectional area in denervated muscles decreased in 1 to 2 weeks after denervation. Those were significant after 3 weeks. The examination with CT might be useful to diagnose canine neurogenic muscular atrophy. — **KEY WORDS:** canine, CT, muscle atrophy.

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In addition to electromyography and muscle biopsy, X-ray computed tomography (CT) is often used to diagnose muscle disease in humans [1, 2, 3, 5, 7] because morphological changes can be observed noninvasively even in deep muscles [4, 7, 9, 10]. However, CT has not been used to diagnose muscle disease in veterinary medicine. To evaluate its possible application in dogs, we conducted CT scanning in experimentally induced neurogenic muscular atrophy.

Six clinically healthy beagle dogs, 3 to 4 years old, 9 to 12 kg, were used regardless of gender. The dogs were restrained under general anesthesia in a left lateral recumbent position. The right sciatic nerve was approached from the caudal side of the greater trochanter, grasped with mosquito forceps at the caudal site to the sciatic crest. The nerve was crushed five times to induce neurogenic muscular atrophy. Electromyography was used to confirm muscle denervation.

The proprioceptive positioning response and flexor reflex on the manipulated side disappeared immediately after surgery. The dogs showed a knuckling of the legs. Electromyograms were evoked by stimulating the right sciatic nerve and recorded from the ipsilateral interosseus muscle. They showed that the H wave had been eliminated on day 1. The M wave potential had been reduced on day 4, and then completely eliminated on day 7. These findings suggested denervation of muscles innervated by the sciatic nerve. These neurological and electromyographical changes persisted until the end of the experiment.

CT scanning was done under general anesthesia using an Image Max II (Yokogawa Medical Systems Co.). The dogs were held supine. The hind leg was extended to the maximum to make the knee as straight as possible, and the knee joint was immobilized with a belt. The knee joint angle was measured using a lateral scanograph. Knee was carefully placed at the same angle during subsequent CT scans. The gantry angle was vertical to the femoral bone, and the middle of the femoral area was scanned in 5-mm-thick slices. Scanning was conducted serially over a period of 56 days—i.e., before crushing the sciatic nerve, and on day 1, 4, 7, 14, 21, 28, 42, and 56 after crushing.

In order to obtain CT images and data acquisition, the

window level and width were set at 50 HU and 250 HU respectively. CT images were also evaluated under the other conditions in necessary. We observed well-defined biceps, semimembranosus, and semitendinosus, in comparison with the quadriceps innervated by the femoral nerve and the adductor innervated by the obturator nerve as controls. CT numbers were measured at three arbitrarily chosen regions for each muscle, and the mean values were regarded as the CT number for that muscle.

The cross-sectional area of each muscle was measured, using an area-measurement program of CT unit by manually tracing the muscle margin on the CT image. The cross-sectional area of the femoral bone was measured likewise, and the cross-sectional area of a muscle was expressed as its ratio to the cross-sectional area of the femoral bone.

On day 28, the semitendinosus muscle in one dog was taken from a region which would not influence subsequent CT examination. The sample was examined histopathologically.

All procedures were conducted according to the Guidelines for the Care and Use of Laboratory Animals of The Nippon Veterinary and Animal Science University. Within eight months after the end of the experiment, the dogs showed no neurologic abnormality in the affected leg.

CT images showed decreases in CT number and muscle cross-sectional areas (Fig. 1). Before denervation CT numbers (HU) of muscles were 58.4 ± 2.2 for the biceps, 56.0 ± 1.8 for the semimembranosus, 50.0 ± 3.2 for the semitendinosus, 57.8 ± 3.7 for the quadriceps, and 58.7 ± 2.1 for the adductor. The semitendinosus was difficult to be measured accurately because of its small cross-sectional area. In the three muscles innervated by the sciatic nerve CT numbers increased on day 1, and then tended to decrease from day 14 after surgery, continuing to decrease relatively rapidly until day 28. A slight further decrease was observed thereafter with minimum values on day 56 (Fig. 2).

The cross-sectional areas of the muscles were measured on the CT images before denervation. The ratios to the cross-sectional area of the femoral bone were 6.8 ± 1.6 for the biceps, 5.5 ± 1.8 for the semimembranosus, 2.7 ± 1.6 for the semitendinosus, 6.2 ± 1.7 for the quadriceps, and 11.2 ± 3.1 for the adductor. Changes by nerve crushing



Fig. 1. CT images of femoral muscles on day 28 after denervation. Cross-sectional areas and muscle tissue density decreased on the denervated (right) side in comparison to the normal (left) side. B: Biceps, SM: Semimembranosus, ST: Semitendinosus.

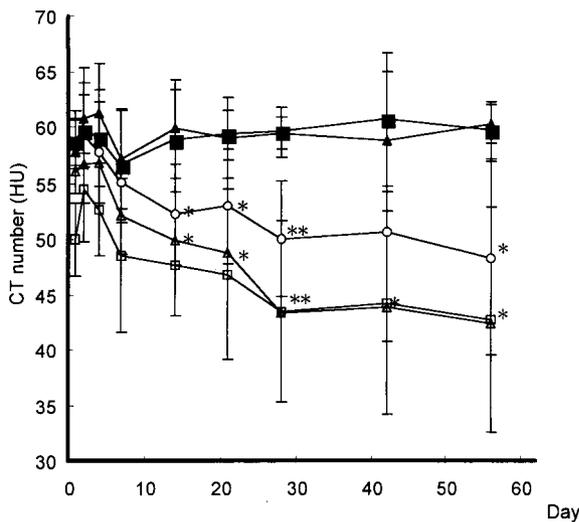


Fig. 2. Changes in CT number for biceps (○), semimembranosus (□), semitendinosus (△), quadriceps (◇), and adductor (▽) following denervation. Points and vertical bars represent mean \pm SD. Significantly different from day 0: * $p<0.05$; ** $p<0.01$.

began to appear on day 14. On day 28 cross-sectional ratios had decreased significantly for the biceps, the semimembranosus, and the semitendinosus. No further decrease was observed thereafter. The cross-sectional areas of the quadriceps and the adductor showed no change during the study (Fig. 3).

On day 28 adipose tissue had infiltrated into the muscle, and muscle fibers had atrophied (Fig. 4).

Rapid atrophy is common in denervated muscles. In humans, atrophy appears in the CT image as a markedly reduced muscle cross-sectional area after denervation. However, CT number do not usually decrease [3, 4]. A decrease in the CT number is preceded by a reduction of

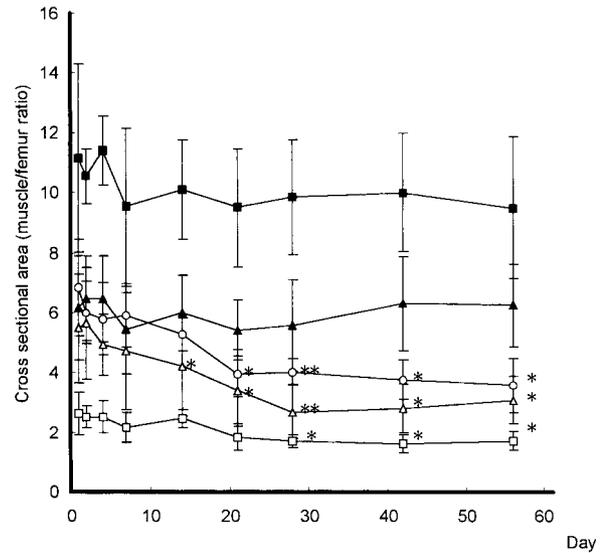


Fig. 3. Changes in cross-sectional muscle/femur area ratio for biceps (○), semimembranosus (□), semitendinosus (△), quadriceps (◇), and adductor (▽) following denervation. Points and vertical bars represent mean \pm SD. Significantly different from day 0: * $p<0.05$; ** $p<0.01$.

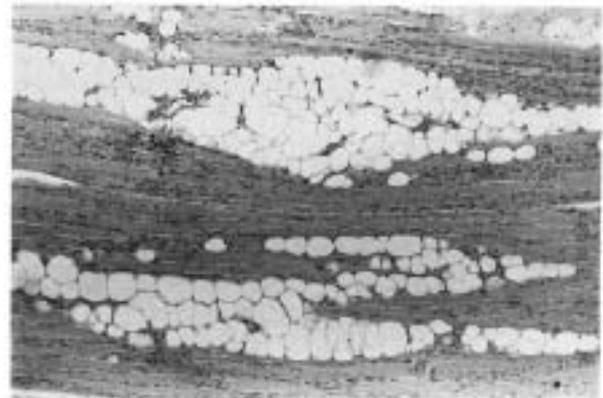


Fig. 4. Semitendinosus muscle on day 28 after denervation. Adipose tissue has infiltrated into the muscle, and muscle fibers have atrophied (HE stain).

cross-sectional area, and the CT number decreases in the final stage of disease [3, 4]. In this study, both the cross-sectional areas and CT number decreased, although the results differed somewhat from those reported in humans. The decrease in CT number is attributed to adipose tissue infiltration [4, 8, 10], and the degree and timing of this infiltration apparently differ between humans and dogs. Transitory increase in CT number on day 1 was clarified, however one possible cause is muscle hyperemia due to the surgical manipulation.

The serial changes in the ratio of the bone muscle cross-sectional area to the femoral bone cross-sectional area were found to decrease with those of the CT number. At first, we had planned to assess the muscle cross-sectional areas by their absolute value. However we finally decided to use

the muscle/femoral bone ratio [4] since this measurement was varied with the size of the dog.

Muscular atrophy is fairly often encountered in clinical cases, and can be diagnosed to some degree by plain X-ray. CT makes muscles observed without interference of overlapping muscles, which contributes to diagnosis of muscle disorder. When a specific group of muscles is involved, as showed in the present study, the condition may be evaluated easily and accurately based on analysis of the CT image and CT number. The entire muscle group at the area of observation may be affected in some cases. CT diagnosis of canine muscles will require the standard muscle area values that was established for typical breeds. Therefore, as we did in this study, it may be useful to adopt ratios to the cross-sectional area of adjacent bone rather than absolute values.

In summary, our study demonstrated that the muscle CT number and the muscle/femor cross-section ratio begin to decrease 1 to 2 weeks after denervation, which are significant after 3 weeks. CT diagnosis may prove to be useful in evaluation of neurogenic muscular atrophy, in order to judge the disease stage and choose biopsy sites in dogs.

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