Can CT Number Predict Micro Morphological Changes of Intervertebral Endplate?

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INTRODUCTION:
The intervertebral endplate is an important structure in maintaining intervertebral disc function. Physiologically, it provides the nutrition of the intervertebral disc, and mechanically it transfers the load between disc and vertebra. The vertebral endplate undergoes degeneration cascade with aging. In the early stage of degeneration, the clefts and fissures are found in the endplate. The lower stiffness and diffusion properties of degenerated endplate increase the risk of nucleus protrusion into the vertebral body. Therefore, Schmorl’s node, fissure, or endplate fracture is created and the degeneration change is accelerated. Following the sustained degeneration, cartilage and bony endplate is overcome by ossification. The ossification results in the less blood supply and decreases the permeability of endplate.

In clinic, many nucleus replacement devices or injectable biomaterials are under development for treating of disc degeneration. Determination of morphological changes of degenerated endplate is helpful for designing treatment protocol for disc or endplate. Computed tomography (CT) is a non-invasive method used in daily clinical examination. In this study, we want to find if the CT scanning can be used to determine the morphological degeneration of endplate.

MATERIALS AND METHODS:
Specimens. Fourteen motion segments from five cadavers (Age: 86±5.3 years) including thoracic spine (T11-T12) and lumbar spine (L1-L5) were examined. The DEXA scanning showed the bone mineral density of the specimens ranged from 0.626 to 1.307 g/cm² (T-score:-3.4~3.2). All specimens were examined by CT scanning first (LightSpeed VCT, GE Healthcare). The thickness of scanning was 2.5 mm. The field of view of CT images was 96 mm. The spacial resolution was 0.1875 mm/pixel.

Specimen Slicing & Photography. After the CT scanning, the vertebra-disc-vertebra construct was sliced at 1 mm thickness. A home made diamond saw apparatus was designed to cut large tissue specimens (up to 5 cm in cube). This apparatus is equipped with a motor, a special designed shaft with aligned bearing that prevent the cutting blade from vibration, linear encoder, and a 5 inch (127 mm) diameter and 0.015 inch (0.38 mm) thick diamond blade (Model: 801-136, Leco Corporation, St. Joseph, MI, USA). The error of sliced thickness was proved to be under 0.1 mm. The sliced samples were photographed using digital camera (Canon 450D, Canon Inc, Japan, sensor size: 22.2 * 14.8 mm, sensor resolution: 4272 * 2848 pixels) with close up micro lens.

Image analysis. The morphological changes of endplate, which determined by the examination of macroscopic photography, were attributed into three groups: intact, cleft, and calcified (Figure 1). The color of intact endplate is close to wheat and the boundary is smooth (Figure 1a). The color of endplate with cleft is lightpink and fissures in the endplate can be found (Figure 1b). The color of calcified endplate is the mixture of red and white. The red is blood and the white is calcified endplate. The boundary of the calcified endplate is zigzag and rocky (Figure 1c). The CT numbers of interested endplate site were analyzed using the ImageJ image processing program (NIMH, NIH, USA). Ten points each site were collected and averaged to minimize the inter-observer error.

Data Analysis. CT numbers of the three groups were analyzed by one-way ANOVA. Post hoc Tukey’s HSD procedure was conducted to compare the difference among groups. The significant level of the experiment was set at p<0.05.

RESULTS:
A total of 16 slices and CT images of endplate from the 14 motion segments were analyzed. Among the 16 specimens, 7 specimens were found to be intact, 6 specimens were with cleft, and 3 specimens were calcified. The CT numbers of intact, cleft and calcified endplate are 886 (SD58), 489 (SD114), and 1190 (SD86) respectively (Figure 2). The CT number reflects the endplate structure significantly (p=0.000). The CT number of intact endplate is greater than endplate with cleft (p=0.000).

DISCUSSION:
The present study showed that the degenerated change can be differentiated by CT number. The CT number of calcified endplate is higher than the intact or cleft endplate. The calcification of endplate may be due to the bony sclerosis, so the irregular shape and brighter endplate shown in CT image. The CT number of cleft group is the smaller than the one of intact endplate. The lesion of endplate in CT images is dark and discontinuous line in CT image. This study found the CT number may be helpful in clinical diagnosis of endplate morphological changes.

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