MRI Visualization Of Cartilage Canal Vessels In Cadaveric Human Epiphyseal Growth Cartilage

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Disclosures:

Introduction: During skeletal maturation in humans and animals, the blood supply to the articular-epiphyseal cartilage complex (AECC), which is the immature joint cartilage at the ends of growing long bones, is confined to channels known as cartilage canals. The importance of these vessels in various diseases including osteochondrosis (1) is well recognized in animals. In children and adolescents, however, their role during skeletal growth and implications for orthopedic disease processes, such as osteochondritis dissecans (OCD) is poorly understood, largely due to the lack of appropriate (in vivo) imaging methods and/or difficulties obtaining cadaveric specimens.

Recently, the use of susceptibility weighted imaging (SWI) was demonstrated for ex vivo and in vivo visualization of the cartilage canal vessels in a porcine animal model (2,3). The purpose of the present study was to apply this method to juvenile human cadaveric specimens of the developing AECC. We hypothesized that the epiphyseal cartilage of the distal femur and proximal tibia of humans would be richly supplied with blood vessels in growing children up to the age of 4 years and that the pattern of vasculature would be similar to that previously described in a porcine animal model.

Methods: Eight cadaveric knees of children 9 months to 4 years old were obtained from Allosource (Centennial, CO, United States) (Acknowledgement Todd Huft, Allosource) frozen at -20 deg C. Specimens were thawed and immersed in saline solution (0.9% NaCl) for imaging. All specimens were imaged at 7.0 Tesla (Magnetom 7 T, Siemens, Erlangen, Germany) using an 8-channel transmit/receive knee coil (Virtumed, LLC Minneapolis, MN) driven by a B1 shimming unit (CPC, Hauppauge, NY) with 8x1 kW amplifiers. Transmit B1 (B1+) shimming (4) was applied within a manually defined region of interest to maximize flip angle homogeneity (5). 3-D multi-echo GRE sequence was used for imaging the specimens, with sequence parameters set similar to SWI acquisition (2): (lowest) bandwidth = 60 Hz/pixel, TR/TE(s) = 45/2.5 - 29.1 ms, matrix size to fit sample with isotropic resolution of 0.32 mm³. For visualization of the cartilage canals, only image-domain average of the echoes was used, without SWI-post-processing. To enhance canal visualization, 2 mm-thick minimum intensity projections (mIP) were calculated for each specimen. For 3-D visualization, distal femora were manually segmented to remove background and the 3-D volume rendering was created using Osirix (Osirix v.5.7 64-bit, http://www.osirix-viewer.com/).

Results: Cartilage canal vessels were visualized in the echo-averaged 3-D GRE datasets of the imaged specimens. To further enhance visualization, 2-mm thick axial minimum intensity projections were calculated at two different locations in the distal femora (Fig. 1). Clear differences between the 9-month-old and 1-year-old specimens and the 4-year-old specimens were seen in the size of the secondary ossification center as well as in the size and number of vessels traversing the AECC. The 3-D structure of the cartilage canals in a specimen from 4-year-old male was demonstrated in the 3-D volume rendering (Fig. 2).

Figure 1. Axial 2-mm thick minimum intensity projections through right knee joint at level of trochlea and mid-condyles.
Discussion: In the present study, high-resolution multi-echo GRE, set up as an SWI scan, enabled visualization of the cartilage canal vessels ex vivo in cadaveric human specimens similar to previous work in an animal model (2,3). The results demonstrated that the distribution of cartilage canal vessels in humans closely matches that reported for an animal model (1,3). The demonstration of cartilage canal blood vessels in cadaveric human specimens is an initial step in mapping the maturation of the AECC in humans and serves as a starting point for future in vivo application of this technique in humans, as has been previously demonstrated in growing pigs (2,3). Previously, in vivo visualization of cartilage canal vessels was only possible using Gadolinium contrast media (6); however, the method described in the present abstract has excellent potential to provide a non-invasive, in vivo tool for investigating the blood supply of the AECC. Future research will likely allow investigation of the role of the blood supply of the AECC in orthopedic diseases of the developing skeleton.

Significance: This study has demonstrated, for the first time, visualization of cartilage canal vessels in cadaveric human specimens using a non-invasive high-resolution MRI method that lends itself to in vivo use. This is the first step towards mapping the maturation of the blood supply in AECC in humans and serves as a starting point for future in vivo investigations.

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