Epiphyseal Cartilage Vascular Architecture at the Distal Humeral Osteochondritis Dissecans Predilection Site in Juvenile Pigs

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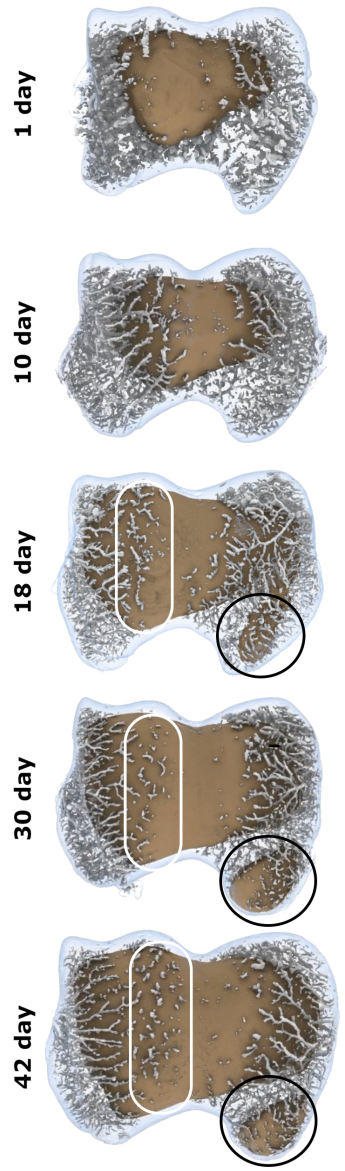
INTRODUCTION: Osteochondritis dissecans (OCD) is a developmental orthopaedic disease affecting children and young animals. It is characterized by formation of osteochondral flaps or fragments in developing joints that cause pain, locking of the joints, and disability. Failure of endochondral ossification due to interruption of the vascular supply to the epiphyseal cartilage is a critical step in the development of OCD. Vascular architecture of the epiphyseal cartilage and its susceptibility to failure have been extensively studied in the distal femur[1], but not the distal humerus. Accordingly, the objective of our study was to describe the three-dimensional vascular architecture of the distal humeral epiphyseal cartilage in developing pigs and identify characteristic features that have been associated with development of OCD in the knee joint across species. We hypothesized that, similar to the distal femoral condyle, the epiphyseal vascular architecture at the distal humeral OCD predilection sites would be comprised of elongated vessels traveling parallel with the articular surface, and that OCD precursor lesions would be identified in these regions.

METHODS: Unilateral distal humeral specimens were harvested from n=5 pigs, aged=1, 10, 18, 30 and 42 days old that were presented to the veterinary diagnostic laboratory for diagnostic necropsy for causes unrelated to the musculoskeletal system (thus, no IACUC approval was necessary). Soft tissues were sharply excised and distal humeri were immersed in perfluoropolyether for a clean background and to avoid artifacts at tissue-air interfaces during MRI. Data were acquired using a 3D gradient recalled echo (GRE) sequence in a preclinical 9.4 T MRI scanner that yielded an isotropic spatial resolution of 78 µm (specimen ages 1 and 10 days, field-of-view =30 mm^3) or 100 µm (specimen ages of 18-42 days, field-of-view =38.4 mm^3). The MRI data were processed using a quantitative susceptibility mapping (QSM) pipeline to visualize the vascular architecture.[1] Specimens were also evaluated histologically to identify the presence of OCD precursor lesions, including osteochondrosis (OC)-latens lesions (areas of ischemic epiphyseal cartilage necrosis) and OC-manifesta lesions (areas of failure of endochondral ossification associated with ischemic chondronecrosis).

RESULTS: The QSM data enabled visualization of two distinct vascular beds arising from the perichondrium at the lateral and medial aspects of the distal humeral epiphysis. Elongated vessels originating from these beds coursed axially to supply the lateral and medial thirds of epiphyseal cartilage. At 18 days of age and older, a shift from perichondrial to transosseous blood supply was noted axially, which appeared more pronounced on the lateral side. This shift coincided with histologic identification of OC-latens (30- and 42-day-old specimens) and OC-manifesta (18- and 42-day-old specimens) lesions in the corresponding regions.

DISCUSSION: Vessels arising from the perichondrium covering the medial and lateral aspects of the distal humeral epiphysis gave origin to elongated branches coursing parallel with the articular surface in the axial direction. These elongated vessels terminated before reaching the mid-portion of the joint, creating an area devoid of vasculature resembling a 'watershed' region. This vascular architecture is nearly identical to that of the femoral condylar epiphyseal cartilage, the primary OCD predilection site in the pelvic limb in children and pigs, where the vascular supply also originates from the axial and abaxial portions of each condyle, courses axially and terminates before reaching the mid-portion of the femoral condyles. Our study has several limitations. While our sample size is small, with only one animal imaged at each time point, it is known from previous studies conducted in pigs[2] and horses[3] that the blood supply to the epiphyseal growth cartilage is highly consistent in a given species at a specific age and location. Also, our findings are qualitative in nature, making their rigorous evaluation difficult. Nevertheless, consistent features of the vascular architecture present across individual pigs (i.e., the presence of elongated vessels arising from the perichondrium) along with progressive changes occurring over time (i.e., a shift to transosseous blood supply in the axial segments) remain important observations with potential clinical significance.

SIGNIFICANCE/CLINICAL RELEVANCE: The vascular anatomy and its evolution at the distal humeral epiphysis closely resembles that implicated in the pathogenesis of knee OCD, suggesting a shared pathophysiology between the knee and elbow joints.



3D reconstructions of the secondary ossification center, epiphyseal cartilage, and the epiphyseal vasculature, depicting the vascular architecture to the distal humeral epiphyseal cartilage in pigs aged 1 to 42 days. Elongated vessels, arising abaxially from the perichondrium, supply the lateral and medial third of the joint. At 18 days of age and later, at the lateral portion of the distal humerus, blood supply to the axial segment has shifted from vessels originating from the perichondrium to vessels traversing the ossification front (white ellipses). Black circles mark the secondary ossification center of the medial epicondyle.

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