HISTOLOGIC AND MAGNETIC RESONANCE IMAGING CORRELATIONS IN PIGLET FEMORAL HEAD AVASCULAR NECROSIS

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INTRODUCTION:

Induction of ischemia and avascular necrosis in the immature piglet femoral head by intracapsular surgical ligation around the base of the neck plus cutting of the ligamentum teres has proven to be an excellent model for creating Legg-Perthes like changes. We have utilized this model effectively by operating 3 week old piglets and describe here studies outlining the three-dimensional shape changes in the femoral head, the dynamic and changing pattern of magnetic resonance imaging (MRI) findings, and the histologic appearance of the femoral head over an 8 week time-frame.

MATERIALS AND METHODS:

Operation was performed under general anesthesia using sterile technique in 9 piglets. Ischemia was induced by a doubled silk ligature placed circumferentially and tied tightly around the base of the femoral neck within the hip joint capsule along with cutting of the ligamentum teres. MR imaging was performed at 1.5 Tesla (GE Medical Systems, Milwaukee, WI). In all animals, conventional MR images including T1, T2 and spoiled gradient recalled echo images were obtained. An intravenous contrast agent (OptiMARK;ema, Wayne, NJ) was also used. MRI was performed post-surgery under general anesthesia at 48 hours and 1, 2, 4, and 8 weeks. Sacrifice was performed at 2 weeks in 1 and 8 weeks in 8 piglets. Structural studies at sacrifice involved gross photographs of proximal femurs, specimen radiographs, photographs of coronal plane hemi-sections after decalcification, and light microscopy after preparation by paraffin embedding and plastic JB4 embedding techniques. The non-operated side in each piglet served as a control. The experiments had IRB approval.

RESULTS:

Growth abnormalities of the proximal femoral head and neck occurred in each instance (Fig 2). The deformity was mild in one instance and severe in the other 7, although an exact deformity of the head and neck was never reproduced in each animal. Measurements from the top of the articular surface of the femoral head to the distal femoral articular surface revealed a 0.4 centimeter shortness in the femur whose growth was least affected while those most severely involved to gross examination showed the greatest length discrepancies of 1.4 cm, 1.5 cm, and 1.8 cm. The abnormal operated and normal control sides are shown in gross photographs (Fig 2), specimen radiographs, and coronal plane hemi-section photographs (Figs 3, 4, 6, 7).

The shortened head and neck with persisting normal trochanteric growth led to coxa vara. There were no instances of subluxation or dislocation of the femoral head. The deformed head was flattened to oval in shape (as distinct from the normal round appearance), wider than normal, and often developed an uneven surface shape. The femoral neck was invariably widened and shortened. The articular surface was always intact but areas of localized depression were often seen.

Immediate complete femoral head ischemia was documented in all operated animals at the first imaging session at 48 hours (Fig 1). Re-perfusion began at the periphery of the femoral head in most at the 2 week session, with some at one week and a few not until 4 weeks. Necrosis in the secondary ossification center from 4 weeks onward was concentrated centrally. The lateral femoral head cartilage enhanced on imaging earliest and was always most pronounced (Fig 7). Changes in shape of the femoral head were seen as early as 2 weeks and in all by 4 weeks. Trochanteric growth and imaging characteristics remained normal in all. MRI studies at 8 weeks showed widening and flattening of the femoral head in all (Fig 5). The physes were always irregular in conformation (irregularly undulating) with many small transphyseal bridges seen in some. The articular cartilage was always thickened compared to the normal contra-lateral side.

Histology at 8 weeks showed that the thickened cartilage by MRI was articular cartilage plus persisting epiphyseal cartilage that had not ossified (Fig 9). The findings contrasted markedly with the normal (Fig 8). Blood vessels were prominent at the lateral aspect of the articular and epiphyseal cartilage area. Non-ossified trabeculae of cartilage persisted in both the secondary ossification center and metaphysis with excellent MRI correlation. Transphyseal bone and fibro-vascular bridges were seen. Areas of marked necrosis of secondary center bone were seen histologically corresponding to the absent perfusion on MRI (Fig 5 and 6). Both intramembranous and endochondral bone repair was seen (Fig 9).

DISCUSSION:

The model induces ischemia and subsequent AVN/Legg-Perthes well. This longitudinal MRI study with end-stage histologic correlation shows that head deformations begins as early as 2 weeks post surgery, that re-perfusion from the periphery is relatively rapid but non-uniform, that the central areas are the last to re-perfuse and the first to deform, and that the fragmentation seen by plain radiographs can be anticipated by several weeks by non-uniform imaging densities in the secondary center within several days of lesion creation.

The study demonstrates that deformity appears to occur early in the process, that MRI provides an excellent demonstration of the underlying dynamic events, that the articular cartilage can often show chondrocyte irregularities such as cloning and necrosis, and that spontaneous repair occurs, but in an asymmetric fashion and with differing bone pathways.

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**Figure 1**  **Figure 2**  **Figure 3**
**Figure 4**  **Figure 5**  **Figure 6**
**Figure 7**  **Figure 8**  **Figure 9**