Development of a Large Animal Model of Local Non-Weight-Bearing to Study its Effects on Musculoskeletal Conditions

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Introduction: In orthopedic practice, local non-weight-bearing (NWB) using crutches or walkers is commonly prescribed for conditions such as femoral head osteonecrosis, hip joint inflammation, and after musculoskeletal injuries such as fracture or dislocation. However, the amount of clinical evidence supporting the beneficial effects of NWB is limited, largely due to the difficulty in studying its effects and documenting compliance during prescribed NWB treatments. Availability of a large animal model of NWB would provide a clinically useful method to study the effects of NWB on bone healing. The purpose of this study was to determine (1) whether it is feasible to develop a large animal model of local non-weight-bearing to study its effects on a hip disorder (femoral head osteonecrosis), and (2) what are the complications associated with the models. We investigated two separate techniques to institute local non-weight-bearing (NWB) in a large animal model of ischemic femoral head osteonecrosis.

Methods: Twenty piglets were induced with osteonecrosis on one hind limb by surgically placing a ligature tightly around the femoral neck to disrupt the blood flow to the femoral head [1] and a second procedure was performed during the same setting to induce local non-weight bearing. Two types of procedures were performed and compared. Less invasive tendon release surgeries such as patellar tenotomy and/or Achilles tenotomy were compared to a below or above knee amputation surgery. Two piglets received a patellar tenotomy, one pig received Achilles tenotomy, and one received a combination of patellar and Achilles tenotomies on the osteonecrosis limb. Eight piglets received a below knee amputation (BKA) and/or above knee amputation (AKA) on the osteonecrosis limb. The remaining eight were used as weight-bearing controls (WB). The contralateral, unoperated femoral heads of WB animals was used as normal controls. The animals were assessed daily for pain, mobility, hip movement, weight-bearing on the treated limb, wound healing, and weekly for weight-gain for eight weeks postoperatively. Femoral heads were retrieved at 8 weeks after the induction of osteonecrosis and assessed using radiography, CT, and histology for femoral head deformity. A one-way ANOVA was used for all statistical analysis.

Results: All animals that underwent surgery had mobility, active hip motion, and similar weight gain as the controls. The need for postoperative analgesia was similar. Initially, animals receiving patellar and/or Achilles tenotomy exhibited signs of reduced weight bearing on the affected limb, such as toe-touch or partial weight bearing on the affected limb when standing and walking. However, by four weeks post-op, they resumed full weight bearing of the operated limb, as confirmed by pressure mat testing. Seven animals were initially treated with a BKA. Of the seven, three were found to weight-bear on the residual limb and developed a small pressure sore. Conversion to an AKA prevented weight-bearing and no pressure sore developed. Non-weight bearing was also observed in one animal that received AKA as a primary procedure. All pigs undergoing amputation exhibited bony overgrowth (exostosis) from the
distal end of residual bone. At eight weeks after osteonecrosis surgery, AP and lateral radiographs and histological assessment revealed greater flattening and epiphyseal fragmentation of both WB and patellar tenotomy treated femoral heads (Fig 1). The trabecular bone of the femoral heads were crushed and densely compacted. One animal treated with Achilles tenotomy showed no deformity. The epiphyseal quotient (a ratio of femoral head height to diameter) based on a mid-coronal CT image was used to quantify the amount of femoral head collapse. The epiphyseal quotient of the amputation group was significantly higher (0.45±.04) compared to both the WB group (0.27±.05) and the tenotomy group (0.31±.13) (p<0.01) showing the amputation group had significantly less deformity (Fig 2). No significant difference was observed in the epiphyseal quotient between the amputation group and normal control group.

**Discussion:** The development of a large animal model of NWB of the femoral head and hip joint can be used to study how this type of treatment affects the healing of hip conditions, including femoral head osteonecrosis [2], hip fractures, and hip joint inflammation. In this study, we examined the feasibility of soft tissue and bony techniques to create a reproducible NWB model. Our findings show that above knee amputation most consistently eliminates weight-bearing during ambulation while still allowing an active hip motion. Tendon release procedures did produce toe-touch to partial weight-bearing for a limited duration and may be used if the duration need for a partial weight-bearing is short (<4 weeks). These results show that femoral head deformity following ischemic osteonecrosis can be significantly decreased by limiting the mechanical force placed on the femoral head during healing.

**Significance:** We developed a large animal model of local NWB which can be used to study its effects on bone healing in hip disorders such as ischemic osteonecrosis of the femoral head.
Figure 2: Epiphyseal quotient was used to quantify femoral head deformity on mid-coronal CT slices illustrated. The (*) signifies p<0.01 when comparing weight-bearing or tenotomy to normal and amputation groups.

ORS 2015 Annual Meeting
Poster No: 0845