Electroarthrography, a Non-invasive Streaming Potential-based Method, Measures Cartilage Quality in Live Horses

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Introduction

1. Degenerative joint diseases, like osteoarthritis, are characterized by progressive cartilage degeneration, which can lead to pain and loss of mobility1-3.
2. Low-grade cartilage deterioration occurs early in disease progression and may be treatable2.
3. However, current clinical assessment methodologies, including physical exam, synovial fluid analysis and imaging, may not be sensitive enough to detect early degenerative changes4-6.
4. Electroarthrography (EAG) is a new technology capable of measuring streaming potentials produced by cartilage during compression through electrodes applied to skin surrounding an articulating joint1,7-8.
5. Streaming potentials arise from interactions among constituents of the cartilage extracellular matrix during load bearing and provide a sensitive measure of cartilage degeneration2-4.
6. Consequently, EAG may provide a sensitive, non-invasive method for detecting low-grade cartilage degeneration. In this study, a methodology for assessing EAG in the fetlock joints of five horses was developed, and externally-measured EAG was compared to direct measurements of cartilage streaming potentials.

Methods

1. Three horses (n=3)
   - Horses aged 7, 9 and 16 years.
   - All underwent comprehensive lameness examinations & radiographic assessment.
   - The 16 year old former racehorse was subsequently euthanized for unrelated reasons. The fetlocks were available for in vitro EAG assessment and direct measurements of streaming potentials.

2. In Vitro EAG during Simulated Standing
   - Fetlocks from 16 year old horse mounted in a mechanical tester (Instron 8000) and aligned with the axes of a depth of freedom load cell.
   - Gold-plated electrodes (10 mm diameter) attached to prepared skin at the same sites used for in vivo EAG assessment.
   - Load sequences consisted of 10 cycles. Each cycle, a displacement of 15 mm, which approximates 1.9 (n=561) in the phalanx and cannon, respectively.
   - EAG signals were acquired at 600 Hz with a wireless data acquisition system (CleveMed Biobio E150).

3. In Vitro EAG during Standing Simulated
   - Fetlocks from 16 year old horse disarticulated and cartilage appearance assessed with India ink.
   - Direct measurements of cartilage streaming potentials made with the Arthro-BST device (Fig. 4) at 250 sites on the cannon and phalanx joint surfaces.

4. Data & Statistical Analyses
   - EAG coefficients (μV/kg): Determined by fitting EAG signals to measured axial loads for each electrode. EAG coefficients for load cycles 5-10 were averaged.
   - Quadrature Parameter (QP): Calculated by the Arthro-BST and corresponds to the number of micromicroelectrodes in contact with cartilage when the sum of streaming potentials reaches 100 mV.
   - Statistical Analyses (Statistica 8.0): Pearson’s correlation calculated between EAG coefficients obtained during in vivo and in vitro EAG.

Results & Discussion

1. EAG, which captures cartilage streaming potentials externally during joint loading, can be used to assess the fetlock joints of live horses.
2. Externally-measured EAG reflects direct measurements of cartilage quality.

Conclusions & Significance

1. This study demonstrated the application of EAG, a novel, non-invasive cartilage assessment method, in a clinical setting.
2. EAG may be more sensitive to early cartilage degeneration than radiography and may contribute an objective measure of cartilage quality that could enhance a typical lameness examination.

What are Streaming Potentials?

1. During cartilage compression, positive mobile ions in the interstitial fluid are displaced relative to the fixed negatively-charged proteoglycan molecules, which are immobilized in the collagen network (Fig. 8A).
   - In osteoarthritic cartilage (Fig. 8B), the collagen network is degraded and there is a loss of proteoglycans, leading to abnormal streaming potentials.