Non-invasive Electroarthrography Correlates to Direct Measurements of Cartilage Streaming Potentials in Weight Bearing Regions of Equine Metacarpophalangeal (Fetlock) Joints

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Introduction

- Degenerative joint diseases, like osteoarthritis, are characterized by progressive cartilage degeneration, which can lead to pain and loss of mobility1-3.
- Low-grade cartilage deterioration occurs early in disease progression and may be treatable2.
- However, current clinical assessment methodologies, including physical exam, synovial fluid analysis and imaging, may not be sensitive enough to detect early degenerative changes4-6.
- Electroarthrography (EAG) is a new technology capable of measuring streaming potentials produced by cartilage during compression through electrodes applied to skin surrounding an articual joint7-8.
- Streaming potentials arise from interactions among constituents of the cartilage extracellular matrix during load bearing and provide a sensitive measure of cartilage degeneration6.11.
- Consequently, EAG may provide a sensitive, non-invasive method for detecting low-grade cartilage degeneration. The relationship between EAG and direct measurements of cartilage streaming potentials was explored here in equine fetlock joints.

Hypotheses

- EAG, which assesses streaming potentials externally, correlates to direct measurements of streaming potentials in weight bearing cartilage.
- EAG can distinguish between fetlocks obtained from a horse with a clinical history of joint disease and those of young, normal horses.

Methods

1. Equine Fetlock Joint Explants (n=6)
- 13 year old horse (n=2): History of forelimb joint disease.
- 3 year old horses (n=4): Racehorses with no reported musculoskeletal issues.

2. EAG during Simulated Standing & Walking
- Each fetlock mounted in a mechanical tester (Instron 8000) and aligned with the axes of a six degree of freedom load cell.
- 10 gold-plated electrodes (10 mm diameter) attached to skin at 6 sites around the fetlock and at negative reference and ground sites (Fig. 2).
- Sites identified by palpation and prepared by removing hair, lightly abrading skin and cleaning with alcohol.
- Standing and walking loads12 were approximated with displacements of 15 mm and 25 mm, respectively.
- Load sequences consisted of 10 cycles. During each cycle, displacement was applied at 5 mm/s, held for 5 s, and unloaded at 5 mm/s.
- EAG signals were acquired at 600 Hz with a wireless data acquisition system (Clevemed Bioradio 150).

3. Direct Assessment of Cartilage Streaming Potentials
- Fetlocks disarticulated and cartilage appearance assessed with India ink.
- Direct measurements of cartilage streaming potentials made with the Arthro-BST device (Fig. 3) at 138 ± 6 (n=6) and 101 ± 7 (n=6) sites on the cannon and phalanx, respectively.

4. Data & Statistical Analyses
- EAG coefficients (μV/kg): Determined by fitting EAG signals to measured axial loads for each electrode. EAG coefficients from load cycles 6-10 were averaged.
- Quantitative Parameter (QP): Calculated by the Arthro-BST and corresponds to the number of microelectrodes in contact with cartilage when the sum of streaming potentials reaches 100 mV.
- Weight Bearing Areas: QP grouped according to weight bearing areas identified from reported load distribution patterns13-15 (Fig. 5).
- Statistical Analyses (Statistics 8.0): Pearson’s correlations calculated between EAG coefficients and QP in weight bearing areas. Normal and degraded fetlocks compared with a one-way ANOVA and Tukey’s HSD.

What are Streaming Potentials?

- 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. 4A).
- In osteoarthritic cartilage (Fig. 4B), the collagen network is degraded and there is a loss of proteoglycans, leading to abnormal streaming potentials.

Results & Discussion

- Degraded fetlocks exhibited lower (p<0.05) EAG coefficients at anterior (EAG1, EAG2) and medio-lateral (EAG3, EAG4) electrodes (Fig. 7), as well as higher QP (p<0.05) measured directly in corresponding weight bearing areas of the anterior phalanx and central cannon (Fig. 5 & Fig. 6).
- EAG and QP changes were less consistent at the cannon/sesamoid interface. EAG coefficients in degraded fetlocks were determined by fitting EAG signals to measured axial loads for each electrode.

Conclusions & Significance

- EAG, which assesses streaming potentials externally, correlates to direct measurements of streaming potentials in weight bearing cartilage.
- EAG can distinguish between fetlocks obtained from a horse with a clinical history of joint disease and those of young, normal horses.

References: