BIOMECHANICAL PROPERTIES OF THE CERVICAL FACET JOINT CAPSULE IN AN *IN-VIVO* CAPRINE MODEL

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INTRODUCTION

The cervical facet joint capsule (FJC) experiences significant deformation during a whiplash-like perturbation (Pearson et al., 2004). The FJC is richly innervated with mechanoreceptors involved in both proprioception and nociception (McLain, 1994). Overstretching the FJC damages the embedded mechanoreceptors and nerve endings, resulting in various neurophysiological manifestations. Persistent afterdischarge from Group III and IV afferent fibers in goat cervical FJCs were evident at capsule strains of approximately 45 % (Lu et al., 2005a). Unpublished data from our group suggests capsule strains of approximately 32% result in muscle afterdischarge, and may affect muscular recruitment patterns.

Currently available FJC injury tolerance data were mainly derived from cadaveric tissue specimens (Winkelstein et al., 2000; Siegmund et al., 2001). The use of cadaveric tissue does not take into account the effects of active physiologic and neuromuscular systems on FJC biomechanics. In-vivo rat FJC biomechanical data is available (Lee et al., 2006), and although the ratio of FJC tensile force at failure to force at sub-failure was similar to this ratio in human FJCs, the scaling relationship between the two species remains undefined (Lee et al., 2006).

Goats have been used as a human surrogate in many cervical spine studies (Baisden et al., 1999; Pintar et al., 2000; Lu et al., 2005a,b). The goat has an upright head-neck position which axially loads the cervical spine similarly to humans (Pintar et al., 2000). Goat and human cervical spines are also similar in terms of size, morphology and alignment of facet joints (Baisden et al., 1999).

Therefore, the purpose of this study was to examine the biomechanical properties of the caprine cervical FJC in-vivo, subjected to an incremental tensile stretch paradigm.

METHODS AND PROCEDURES

Five adult female Lamancha goats (39-63 kg) were utilized in this study. Anesthesia was induced and maintained throughout surgical preparations by inhalation of isoflurane (1-3.0%) and oxygen (2 L/min). Once surgical preparations were complete, α-chloralose was administered (60 mg/kg) and maintained (10-15 mg/kg) throughout the test procedures. The goats were positioned in a test fixture which accommodated a spine fixator, a load cell-actuator system and stereoimaging system to measure capsular strain (Lu et al., 2005a). The left C5-C6 FJC was surgically isolated from its bony attachments and connected to the load cell-actuator system. The FJC underwent a series of controlled uniaxial stretch tests in 4 mm increments at a rate of 0.5 mm/s until the capsule ruptured. Each test had a trapezoidal loading pattern consisting of a load ramp to a specified displacement, a 10 second hold, and a release ramp back to the original position. Oxidized brass spheres applied to the FJC were tracked via stereoimaging to obtain 3D capsular strain. Load, actuator motion, and video data were collected synchronously.

Strain histories of each mesh element were obtained to determine maximum principal Lagrangian strain. *Failure strain* was defined as the maximum principal strain at which FJC tears were first visible, whether partial or complete. Since tears on the ventral surface of the FJC would not have been visible, and micro tears occurring in the lower test increments could lower the yield point of the FJC in subsequent tests, *failure load* for a given FJC was defined as the highest load observed in that FJC test series.

RESULTS

Measurements of the C5-C6 FJC in two goats showed rostral-caudal lengths of 17.5 ± 3.5 mm and widths of 18.0 ± 1.4 mm. Due to spine translation, FJC stretch was on average 49.5% of the actuator displacement (range = 31.3-72.6%). When pooled by test increment, maximum principal strains and peak capsule loads (N) increased with increasing FJC displacement. Strains in the 12 mm test and below (41.9 ± 13.3 %) did not produce any apparent tissue damage. The average failure strain was 77.5 ± 65.1 %, and the average failure load was 105.1 ± 60.2 N. Toe regions were estimated to account for 2.0 ± 3.5 % strain.

DISCUSSION

Four of the five goats showed visible partial FJC tears prior to complete rupture. Failures beyond the first visible FJC tear were not quantified. Thus, “failure” in this study corresponds more closely to the definition of sub-failure (decrease in capsule load with a continued increase in displacement) adopted by others (Winkelstein et al., 2000; Siegmund et al., 2001). The failure strain and load reported here were larger than the sub-failure strains (~35-65 %) and loads (~45-84 N) reported previously (Winkelstein et al., 2000; Siegmund et al., 2001). In these studies, sub-failures may have been apparent in the load trace before they were visible macroscopically, which may account for the differences in failure loads between studies. Differences could also be due to applied FJC stretch rates; facet size differences between species; or differences in mechanical properties between in vitro cadaveric specimens and the in vivo goat specimens used here.

SUMMARY

This study examined the in-vivo biomechanical properties of cervical FJC to low-rate loading (0.5 mm/s). Failure strains and loads were larger than previously reported cervical FJC injury thresholds (Winkelstein et al., 2000; Siegmund et al., 2001). The strain rates observed in this study (~1-2 %/s) are representative of physiologic strain rates in cervical spine movements of daily living (Lu et al., 2005b). Studies of the in-vivo biomechanical properties of cervical FJC to dynamic strains, which more accurately represent strains observed under impact conditions, are underway.

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