Joint Motion Remains Altered Following Remobilization in an Animal Model of Post-Traumatic Elbow Contracture

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Introduction: INTRODUCTION: Traumatic elbow injuries are a challenging clinical problem, and often lead to long-term joint stiffness and contracture [1-3]. While both extrinsic and intrinsic factors have been reported as contributors [1], the etiology of elbow stiffness remains poorly understood. Recently, we developed an animal model of post-traumatic stiffness of the elbow using Long-Evans rats [4]. Following a surgically induced injury and six-weeks of joint immobilization, elbow joints exhibited decreased range of motion (ROM) and increased stiffness throughout normal flexion/extension motion, thereby mimicking common symptoms of the human condition [4]. However, it is unknown if the altered biomechanical properties induced by this protocol persist long term or if they are transient effects apparent shortly after immobilization. Therefore, the purpose of this study was to evaluate if joint function remains altered following remobilization in our rat model of post-traumatic joint stiffness, which has implications for the usefulness and validity of this animal model.

Methods: METHODS: In this IACUC approved study, 22 Long-Evans rats (300-343g) were randomized into two injury groups (n=6 per group), a sham group (n=4), and control group (n=6). Surgical Procedure. Under sterile conditions, one of two clinically relevant elbow injuries was surgically created. The elbow was exposed laterally and an anterior capsulotomy was performed (“Injury I”) or an anterior capsulotomy combined with transection of the lateral collateral ligament (LCL) was performed (“Injury II”). These injury protocols were performed in order to replicate common soft tissue injuries seen clinically in elbow subluxations/dislocations. For the “Sham” group the left elbow was exposed laterally, but there was no injury induced. Contralateral (CL) limbs were not injured and served as uninjured comparisons. After skin closure, injured limbs were wrapped using tubular elastic nets and Vetrap bandaging to immobilize the joint for a six-week period. After three-weeks of immobilization (i.e., halfway point) x-rays were taken to quantify the position at which injured limbs were immobilized to ensure maintenance of a flexed position. Following the immobilization period, injured limbs were unwrapped and animals were allowed unrestricted cage activity for a six-week remobilization period. Age-matched “Control” animals were left uninjured and allowed unrestricted cage activity for the duration of the study. Sample preparation and testing. Following sacrifice, forelimbs were detached at the shoulder joint and skin removed. The humeral head and paw were secured in plastic tubes filled with hardening putty. A custom mechanical test system for loading rat elbows in flexion and extension was used to quantify joint stiffness and ROM. The device utilizes one actuator of a planar biaxial mechanical test system (TestResources, Shakopee, MN) to apply linear displacement and measure force. A rack and pinion gear converts linear displacement to rotational motion and allows for load-controlled cyclic testing of the rat elbow in flexion-extension. After positioning joints in the mechanical test system, cyclic loading to ±0.75-N (corresponding to ±11.25-Nmm of torque) was applied for five cycles. A digital camera mounted above the test system captured images at maximum and minimum angles of rotation.
Data analysis. Force and displacement data from the first cycle were converted to torque and angular position, and the resulting loading curves were analyzed for total ROM (angular rotation between maximum and minimum torques), neutral zone (NZ) stiffness (slope of loading curve corresponding to stiffness of joint in functional range), and NZ length (angular size of functional range) using a Matlab code. Paired and unpaired t-tests were used to compare injured/immobilized limbs to CL and control joints, respectively.

Results: RESULTS: Following dissection, right and left forelimbs appeared relatively similar, with some injured/immobilized limbs exhibiting more flexed resting positions compared to contralateral limbs (Fig.1A). Mechanical testing analysis demonstrated decreased total ROM for all treated joints, which were significantly different from both CL and control limbs (Fig.1B). The length of the NZ was significantly smaller for Sham and Injury II limbs compared to CL (Fig.1C). There were no differences in NZ stiffness, with small values measured for all groups.

Discussion: DISCUSSION: We demonstrated that remobilization following elbow injury and immobilization does not completely restore joint mechanics in a clinically relevant animal model of elbow trauma. In our previous study [4], an injury and immobilization protocol led to dramatic changes in joint contracture and stiffness in rat elbows at the conclusion of the immobilization period. In addition, the magnitude of these changes correlated with injury severity, with Injury II exhibiting the most altered joint motion. The purpose of the present study was to determine whether these observed changes were transient effects or whether they would persist following joint remobilization. Compared to control and CL limbs, injured limbs were more contracted as assessed via biomechanical joint testing (Fig.1). Surprisingly, the loss in total ROM was very similar across all three immobilized groups (i.e., Sham, Injury I, Injury II), demonstrating that the amount of joint contracture present following remobilization was not dependent on severity of the injury. Compared to our prior study [4], ROM was increased in this study, indicating that some joint motion was regained during the remobilization period, yet biomechanical parameters remained altered compared to control. Other studies using a rabbit knee model showed that joint motion returns to normal when an immobilized-only joint is remobilized [5]. However, when a soft tissue injury was combined with immobilization, rabbit knees remained contracted long-term at levels (~30°) similar to the present study [6]. Our rat elbow model utilizes more clinically relevant patterns of soft tissue injury, similar to elbow subluxation/dislocation events and is less invasive than similar models of knee injury. The elbow is complex anatomically and functionally, and our rat elbow model is better suited to investigate questions of clinical relevance specific to the highly unique and complex elbow joint. In summary, joint motion remained altered following remobilization in an animal model of elbow stiffness and contracture. Future work will utilize this model to evaluate biological contributors to elbow contracture and the functional impact of joint stiffness.

Significance: SIGNIFICANCE: Post-traumatic elbow stiffness is a common clinical problem, yet the etiology of this condition is poorly understood. We recently developed a clinically relevant animal model of elbow stiffness and contracture; this study evaluated whether the biomechanical deficits induced in this model are permanent. A validated animal model will lead to better understanding of this condition, and help guide treatment plans.
Fig 1. (A) Elbows from injured/immobilized animals appeared similar but slightly more contracted compared to CL joints; (B) injured limbs had decreased ROM compared to CL limbs and controls; (C) the length of the NZ also decreased for injured limbs. (*= significantly different than CL, #= significantly different than control)

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