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ORIGINAL ARTICLE

Persistent motion loss after free joint mobilization in a rat model of post-traumatic elbow contracture

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Background: Post-traumatic joint contracture (PTJC) in the elbow is a challenging clinical problem due to the anatomical and biomechanical complexity of the elbow joint.
Methods: We previously established an animal model to study elbow PTJC, wherein surgically induced soft tissue damage, followed by 6 weeks of unilateral immobilization in Long-Evans rats, led to stiffened and contracted joints that exhibited features similar to the human condition. In this study, after 6 weeks of immobilization, we remobilized the animal (ie, external bandage removed and free cage activity) for an additional 6 weeks, after which the limbs were evaluated mechanically and histologically. The objective of this study was to evaluate whether this decreased joint motion would persist after 6 weeks of free mobilization (FM).
Results: After FM, flexion-extension demonstrated decreased total range of motion (ROM) and neutral zone length, and increased ROM midpoint for injured limbs compared with control and contralateral limbs. Specifically, after FM total ROM demonstrated a significant decrease of approximately 22% and 26% compared with control and contralateral limbs for injury I (anterior capsulotomy) and injury II (anterior capsulotomy with lateral collateral ligament transection), respectively. Histologic evaluation showed increased adhesion, fibrosis, and thickness of the capsule tissue in the injured limbs after FM compared with control and contralateral limbs, which is consistent with patterns previously reported in human tissue.
Conclusion: Even with FM, injured limbs in this model demonstrate persistent joint motion loss and histologic results similar to the human condition. Future work will use this animal model to investigate the mechanisms responsible for PTJC and responses to therapeutic intervention.
Level of evidence: Basic Science Study; *in-vivo* Animal Model
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Keywords: Elbow joint; post-traumatic joint contracture; free mobilization; joint mechanics; range of motion; flexion-extension

The Washington University in St. Louis Institutional Animal Care and Use Committee approved this study.

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Post-traumatic joint contracture (PTJC) as a result of injury to the elbow is a common and challenging clinical problem because the elbow is anatomically and biomechanically one of the most complex joints in the body.[9,18] The highly congruent joint surfaces of the 3 bones that comprise the elbow create a complex articulation that allows precise positioning of the forearm and hand in space.[2] Joint articulation is stabilized by several surrounding periarticular soft tissues (ie, capsule, ligaments, tendons, muscles). Injury to the elbow often disrupts the periarticular structures, potentially causing changes in ligament tension, bone anatomy, or cartilage congruity, and leads to an onset of PTJC. Injury is poorly tolerated in the elbow, such that even a relatively minor injury can result in significant functional impairment affecting routine daily and vocational activities.[7] Because injury severity does not always correlate with the degree of functional deficit, predicting who is at risk for developing PTJC is difficult and presents a significant clinical challenge in managing elbow injuries with contracture. Thus, there is a critical need to study the development of elbow PTJC in a relevant model.

Our group previously developed an animal model of elbow PTJC.[10] We demonstrated that elbow contracture could be induced in Long-Evans rats by surgically creating a soft tissue injury, followed by 6 weeks of immobilization. Our animal model was evaluated biomechanically in flexion-extension (F-E) and histologically and was found to replicate characteristics similar to the human condition, including decreased total range of motion (ROM) and neutral zone (NZ) length as well as increased cellularity, adhesion, and capsule thickness. However, more research is needed to determine whether symptoms of PTJC persist long-term in this animal model. Long-standing contracture would indicate that periarticular joint tissues are permanently altered, which would further validate the use of our rat elbow model for studying PTJC pathophysiology and treatment methodologies. Therefore, the objective of this study was to evaluate whether decreased joint mechanics induced by injury and immobilization resolves after joint free mobilization (FM) in our recently developed rat model of elbow PTJC.

Materials and methods

Animal model

Long-Evans rats (Charles River Laboratories International, Wilmington, MA, USA) were selected and used based on criteria previously described.[10] Briefly, these animals were evaluated based on their (1) anatomical similarities, (2) functional ROM of the joint, and (3) use of their upper extremities. Anatomically, Long-Evans rats exhibit many features that are analogous to the human elbow, in which 3 bones (humerus, radius, and ulna) form a complex articulation. The periarticular structures surrounding the elbow are also similar to human anatomy.

Injury model

Male Long-Evans rats (250-300 g) were randomized into 3 surgical groups (sham, injury I, injury II) and a group of age-matched control animals. The study used 40 rats initially. After 4 samples were excluded because of dissection and testing abnormalities, 36 rats were included (n = 7-10 per group). Clinically relevant elbow injuries were surgically created to replicate varying degrees of soft tissue injury seen in elbow subluxation/dislocation, as described previously.[10] Briefly, the animals in each surgical group were anesthetized, and surgery was performed under sterile conditions on the left limb: sham (superficial lateral incision without violation of joint structures), injury I (anterior capsulotomy), and injury II (anterior capsulotomy combined with lateral collateral ligament transection). Sham animals were used to evaluate the effect of joint immobilization combined with a minor surgical procedure (superficial lateral incision) but no periarticular joint tissue injury. Thus, sham represents the least severe injury (ie, no joint injury with immobilization), and injury II represents the most severe injury (ie, anterior capsulotomy and lateral collateral ligament transection with immobilization). Animals received single doses of antibiotic (7.5 mg/kg enrofloxacin; Bayer Health LLC, Shawnee Mission, KS, USA) and nonsteroidal anti-inflammatory drug (5 mg/kg, carprofen; Pfizer Animal Health, New York, NY, USA) preoperatively via subcutaneous injection and 1 dose of analgesic (0.5 mL of 5 mg/mL bupivacaine; Hospira, Lake Forest, IL, USA) postoperatively via subcutaneous injection under the closed incision. Contralateral (CL) and control limbs were not injured and served as comparisons.

After surgery, operated limbs were immobilized in flexion (151° ± 2°) for 6 weeks. CL limbs and control animals were not immobilized and allowed unrestricted motion. As described previously,[10] the injured limbs were immobilized using tubular elastic netting (Nich Marketers Inc., Gulf Breeze, FL, USA) and self-adhering Vetrap bandaging (3M, St. Paul, MN, USA). An access hole was cut to leave the CL limb unconstrained. During the 6-week immobilization period, animals were evaluated 5 times per week to ensure the injured limb was constrained and to identify any pain or distress. Clean wraps were applied weekly. Additional details regarding animal care and observation during the immobilization period were previously reported.[10] Any time an animal was rewrapped, any sores or cuts caused by scratching or rubbing of the wrap were treated topically with antibiotic powder/cream (nitrofurazone; Neogen Corp., Lexington, KY, USA; or silver sulfadiazine; Dr. Reddy's Laboratories Louisiana, Shreveport, LA, USA) or chafing cream (Prestige Brands, Tarrytown, NY, USA). After 6 weeks, the wrapping restraints were removed and animals were allowed unrestricted cage activity for the remaining 6 weeks to allow mobilization of their left limb. At the conclusion of the FM period, animals were euthanized by CO_2 inhalation and immediately stored in a –20°C freezer.

Mechanical testing

Mechanical testing was performed on the injured and CL limbs for each animal so paired comparisons could be made in addition to comparisons with controls. Forelimbs were prepared for mechanical testing as described previously.[10] To summarize, forelimbs were skinned, the glenohumeral joint was disarticulated, and the paw was removed. The humeral head and distal ulna/radius were secured in test fixtures. In the test setup, the limb was aligned to

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