J Shoulder Elbow Surg (2015) 24, 1243-1248

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Journal of Shoulder and Elbow Surgery

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Hyperosmolar irrigation compared with a standard solution in a canine shoulder arthroscopy model

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Nicholas M. Capito, MD*, Matthew J. Smith, MD, Aaron M. Stoker, PhD, Nikki Werner, James L. Cook, DVM, PhD

Department of Orthopaedics, University of Missouri, Columbia, MO, USA

Background: A hyperosmolar irrigation solution may decrease fluid extravasation during arthroscopic procedures. Demonstrating the safety of a hyperosmolar irrigation solution with respect to chondrocyte viability and cartilage water content was deemed necessary before designing a clinical efficacy study.
Methods: We designed a translational animal model study in which hyperosmolar arthroscopy irrigation fluid (1.8%, 600 mOsm/L) was compared with normal saline (0.9%, 300 mOsm/L). Purpose-bred research dogs (n = 5) underwent bilateral shoulder arthroscopy. Irrigation fluid was delivered to each shoulder joint (n = 10) at 40 mm Hg for 120 minutes using standard ingress and egress portals. The percentage change in shoulder girth was documented at the completion of 120 minutes. Articular cartilage sections from the glenoid and humeral head were harvested from both shoulders. Chondrocyte viability and tissue water content were evaluated. Differences between groups and compared with time 0 controls were determined, with significance set at $P < .05$.
Results: The mean percentage change in shoulder girth was higher in the isotonic control group (13.3%) than in the hyperosmolar group (10.4%). Chondrocyte viability and tissue water content for glenoid and humeral head cartilage were well maintained in both treatment groups, and differences were not statistically significant.
Conclusions: The data from this study suggest that doubling the osmolarity of the standard irrigation solution used for arthroscopy was not associated with any detrimental effects on chondrocyte viability or tissue water content after 2 hours of arthroscopic irrigation. On the basis of potential benefits in conjunction with the safety demonstrated in these data, clinical evaluation of a hyperosmolar solution for irrigation during shoulder arthroscopy appears warranted.
Level of evidence: Basic Science, In Vivo Animal Study.

Keywords: Arthroscopy; hyperosmolar; chondrocyte viability; irrigation solution; extravasation; canine

An isotonic solution, such as saline (0.9%, 300 mOsm/L) or lactated Ringer's (273 mOsm/L), is commonly used for joint irrigation during arthroscopy based on proven safety.[3,7,28,32] The mean osmolarity of human synovial fluid has been reported to be approximately 400 mOsm/L.[4] During arthroscopic surgery, synovial fluid is replaced by

The Institutional Animal Care and Use Committee approved this study (Approval #7469).

*Reprint requests: Nicholas M. Capito, MD, University of Missouri, 1100 Virginia Ave, DC953.00, Columbia, MO 65212, USA.

E-mail address: capiton@health.missouri.edu (N.M. Capito).

1058-2746/$ - see front matter © 2015 Journal of Shoulder and Elbow Surgery Board of Trustees.
http://dx.doi.org/10.1016/j.jse.2014.12.027

the irrigation solution. Thus, chondrocytes are exposed to a relatively low osmolarity environment during the procedure and for as long as it takes the synovial fluid to be re-established. Several studies have provided evidence to suggest that a decrease in the extracellular osmolarity may increase in situ chondrocyte death after a mechanical insult to the articular cartilage.[1,4,8,9] Furthermore, a study using various concentrations of saline solution reported a chondroprotective effect associated with hyperosmolar solutions up to 600 mOsm/L after a mechanical insult.[2] These experiments provide impetus for the use of a hyperosmolar irrigation solution for arthroscopic procedures.

During most arthroscopic procedures, extravasation of irrigation fluid into periarticular tissues is inevitable and may create technical difficulties as well as patient morbidity and complications. In the realm of shoulder arthroscopy, previous investigators have reported complications, including tracheal obstruction, postoperative airway edema, and compromise, which led to prolonged intubation, excess weight gain, neurologic injuries, skin necrosis, and fluid overload associated with excessive fluid extravasation with retention in tissues.[5,6,10,16-20,22,23,25-28,30,31,34] Furthermore, fluid that is accumulated during the operation is slowly released back into the systemic circulation.[33] Although the change in circulating volume is not rapid, there may be implications for elderly patients and those with multiple comorbidities during prolonged arthroscopic surgery.

Aside from closely monitoring pump pressure and minimizing the length of surgery, the other controllable variable that may decrease fluid extravasation and associated problems is the osmolarity of the irrigation solution. Theoretically, according to the principles of osmosis, a hyperosmolar irrigation solution may decrease fluid extravasation during arthroscopic procedures. On the basis of potential benefits with respect to chondrocyte protection and decreased fluid extravasation, use of a hyperosmolar irrigation solution for arthroscopic procedures could have important clinical benefits. However, determining the safety of a hyperosmolar irrigation solution for this intended application is necessary before clinical investigation. As such, we designed a translational animal model study using canines to address the research question.[11,13,21] Our hypothesis was that hyperosmolar arthroscopy irrigation fluid would not be associated with significant loss of chondrocyte viability or alterations in articular cartilage water content compared with standard-of-care isotonic irrigation solution when used for shoulder arthroscopy in dogs. As a secondary objective, we evaluated the change in shoulder girth after completion of the arthroscopy as a measure of fluid extravasation into the periarticular soft tissues.

Materials and methods

On the basis of a prestudy power analysis using data from our previous studies, we used 5 adult (aged 2 to 4 years) purpose-bred research hounds (body weight >20 kg). In conjunction with another study for maximal ethical use of research animals, each dog was given an overdose of pentobarbital/phenytoin and placed on an operating table in dorsal recumbency with both forelimbs suspended for arthroscopic surgery using the hanging limb technique.[12] Both shoulders (n = 10) of each dog were instrumented for arthroscopy using a standard caudal (posterior)-lateral scope (3.0-mm 30o foreoblique arthroscope; Arthrex, Naples, FL, USA) portal and a cranial (anterior)-lateral instrument portal (18-gauge intravenous catheter). As soon as both portals were established, irrigation of the joint was initiated. Normal saline (0.9%, 300 mOsm/L) served as the standard-of-care control and was compared with a hyperosmolar (1.8%, 600 mOsm/L) saline solution. The hyperosmolar solution was created by adding 23.4% saline (115 mL) to a 3-L bag of 0.9% saline.

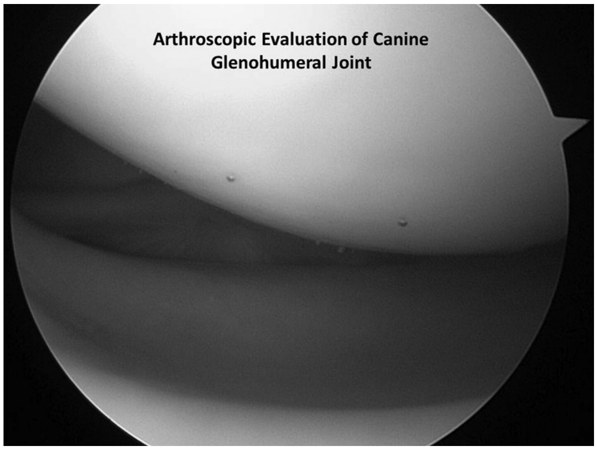

Figure 1 A glenohumeral arthroscopic evaluation confirms a healthy-appearing articular surface.

All joints were assessed arthroscopically to confirm portal placement and to inspect the glenohumeral joint for healthy-appearing articular surfaces, ensuring no pre-existing pathology was present (Fig. 1). The scope portal was used for irrigation solution ingress and the instrument portal was used for egress. For consistency, because no differences were noted between shoulders based on physical examination and arthroscopic assessments, the right shoulder of each dog received the hyperosmolar irrigation solution and the left received the isotonic solution. The solution was delivered to each shoulder for 120 minutes at 40 mm Hg. Irrigation was monitored to ensure constant ingress and egress by direct observation. The amount of fluid delivered to the joint was recorded.

Shoulder girth was measured before instrumentation (time 0) and immediately after discontinuation of irrigation and portal removal (120 minutes). A caliper was used to measure the medial-to-lateral width of the shoulder at the joint level. This was standardized using the acromion as a consistent anatomic landmark and horizontal orientation for caliper placement. One investigator performed all measurements of shoulder girth. Three separate measurements were performed for each shoulder at each time point, and the mean of the 3 measurements was used for comparisons. The percentage change in shoulder girth was calculated using the formula: [(Time 0 caliper distance – Time 120 min caliper distance)/Time 0 caliper distance] × 100.

After shoulder girth measurements were performed, both shoulders of each dog were immediately disarticulated