Effect of Radiofrequency Energy on Glenohumeral Fluid Temperature During Shoulder Arthroscopy

Christopher R. Good, Michael K. Shindle, Matthew H. Griffith, Tony Wanich and Russell F. Warren

This information is current as of February 9, 2009

Effect of Radiofrequency Energy on Glenohumeral Fluid Temperature During Shoulder Arthroscopy

By Christopher R. Good, MD, Michael K. Shindle, MD, Matthew H. Griffith, MD, Tony Wanich, MD, and Russell F. Warren, MD

Investigation performed at the Department of Orthopedic Surgery, Sports Medicine and Shoulder Service, The Hospital for Special Surgery, New York, NY

Background: Reports of glenohumeral chondrolysis following arthroscopy have raised concern about the deleterious effects that thermal devices may have on articular cartilage. The purpose of this study was to investigate the effects of flow and duration of treatment with a thermal device on temperatures within cadaveric glenohumeral joint specimens. It was hypothesized that the use of a thermal device during surgery increases the temperature of fluid within the joint to >45°C, which has been shown to cause chondrocyte death.

Methods: Temperature was measured at four locations within ten cadaver shoulder joints. Eight heating trials were performed on each cadaver shoulder to test three variables: the method of heating (continuous or intermittent), the fluid-pump flow rate (no flow, 50% flow, or 100% flow), and the location of the radiofrequency probe (the radiofrequency energy was either applied directly to anterior capsular tissue in a paintbrush pattern or held adjacent to the glenoid without tissue contact).

Results: Temperatures of >45°C occurred in every trial. The average maximum temperatures in all no-flow conditions were significantly higher than those in the trials with flow. Higher temperatures were measured by the anterior probe in all trials. When the heating had been applied adjacent to the glenoid, without tissue contact, the time needed to cool to a safe temperature was significantly longer in the no-flow states (average, 140.5 seconds) than it was in the 50% flow states (average, 12.5 seconds) or the 100% flow states (average, 8.5 seconds).

Conclusions: Use of a thermal probe during arthroscopy may cause joint fluid temperatures to reach levels high enough to cause chondrocyte death. Maintaining adequate fluid-pump flow rates may help to lower joint fluid temperatures and protect articular cartilage.

Clinical Relevance: The use of radiofrequency devices according to the manufacturer's recommendations in situations similar to clinical scenarios can result in exposure of chondrocytes to temperatures high enough to cause their death (>45°C). While this complication is rare, this study emphasizes that care must be taken when using these devices; precautions include minimization of direct chondrocyte exposure and maintenance of adequate flow rates.

Thermal energy delivered with a radiofrequency or laser device is routinely used during shoulder arthroscopy for débridement, coagulation, thermal capsulorrhaphy, or chondroplasty. When tissues are heated to ≥65°C, the heat-labile collagen cross-links are damaged, which causes collagen polypeptide chains to unwind and shorten. An inflammatory response with collagen fusion then occurs and is followed by a repair response with synovial hyperplasia and fibroblast proliferation[1].

Thermal energy is commonly used in the medical field; however, there have been numerous complications associated with the use of thermal energy in orthopaedic surgery. Thermal capsulorrhaphy has been used for the treatment of shoulder instability but has been associated with a number of complications, including chondrolysis, recurrent instability, axillary nerve damage, and adhesive capsulitis[2-7]. Because of these complications, the initial wave of enthusiasm for thermal capsulorrhaphy has subsided[6].

Thermal chondroplasty has the theoretical benefit of allowing cartilaginous defects to be débrided to a smooth surface without damaging adjacent unaffected cartilage. Turner et al.[8] and Kaplan and Uribe[9] reported that bipolar radiofrequency energy was safe for use on articular cartilage because there was no evidence of chondrocyte death. However, Lu et al.[10] and Edwards et al.[11] later demonstrated that bipolar energy was responsible for chondrocyte death and full-thickness cartilage loss following chondroplasty and cautioned against using radiofrequency energy to treat fibrillated cartilage. As a result of these findings, the enthusiasm for using thermal energy for chondroplasty has also subsided.

There is debate regarding the critical temperature that reduces chondrocyte viability. Voss et al. examined full-thickness cartilage explants from the humeral heads of sheep that were exposed to varying temperatures[12]. They concluded that there is a strong relationship between increasing temperature and cell death, with a sharp increase in chondrocyte death occurring between 50°C and 55°C. The percentage of viable cells decreased significantly for each increase in temperature after 45°C ($p < 0.05$). Kaplan and Uribe demonstrated that the acute response of osteoarthritic cartilage to treatment at 55°C was a decrease in cell viability of 10% at thirty seconds, 40% at one minute, and 50% at three minutes[9]. Although some controversy exists, it is clear that there is a decrease in cell viability at 45°C and most radiofrequency devices used for chondroplasty operate at temperatures exceeding 100°C[12,13].

Despite the complications associated with thermal energy during capsulorrhaphy or chondroplasty, thermal energy is still commonly used during routine shoulder arthroscopy for débridement and coagulation. However, the actual fluid temperatures that are reached in the glenohumeral joint during these procedures are not known. The purpose of this study was to investigate the effects of flow and duration of treatment with a thermal device on temperatures within cadaveric glenohumeral joint specimens. It was hypothesized that the use of a thermal device during surgery increases the temperature of fluid within the joint to >45°C, which has been shown to cause chondrocyte death.

Materials and Methods

Ten fresh-frozen cadaver shoulder joints (six left and four right) were obtained for use in this experiment. All cadaver specimens were harvested in a manner that protected the soft tissues surrounding the shoulder joint. The entire scapula and humerus and all soft-tissue attachments were intact. The average age of the donors at the time of death was seventy-five years (range, sixty-four to eighty years). None of the shoulders had had prior surgery or injury. The shoulders were thawed to room temperature (23°C) in a water bath before use.

Arthroscopy was performed with the shoulder in a simulated beach-chair position, which was obtained by mounting each shoulder with use of a clamp on the scapula. A standard posterior portal to the glenohumeral joint was established with use of a trocar and cannula. The arthroscope was inserted through the posterior portal. An Arthrex Continuous Wave II pump (Arthrex, Naples, Florida) was used with a pressure setting of 30 mm Hg and variable flow. Normal saline solution (0.9%) at room temperature (23°C) was used as the pump irrigant. An anterior portal was established under direct arthroscopic visualization with use of a spinal needle to find the correct entry point just above the subscapularis tendon. All portals were placed through stab incisions in the skin, and care was taken to avoid removing or changing portals once they were placed. Fluid extravasation through portal sites or soft-tissue planes was not encountered during any of the testing trials.

Four custom-built temperature probes (Type-T thermocouple probes; Cannuflow, San Jose, California) were placed under arthroscopic guidance. Three of these probes were placed at the anterior, superior, and posterior margins of the glenoid articular surface with the tip of each probe at the edge of the articular cartilage. A fourth probe was placed in the axillary recess between the inferior articular margin and the capsule overlying the axillary nerve. The shoulder was abducted slightly to allow placement of the axillary probe, and then the shoulder was allowed to return to a fully adducted position for the remainder of the testing. A Mitek VAPR3 radiofrequency system (DePuy Mitek, Raynham, Massachusetts) was used for this study. The radiofrequency probe was inserted into the joint through the anterior cannula and was placed 1 cm inferior to the anterior temperature probe tip at the edge of the glenoid. The radiofrequency probe was used on its default setting (V3-80) for all trials.

Temperatures measured with each of the temperature probes were recorded with use of an Apical multiple-channel type-T thermocouple data-acquisition unit (Apical Instruments, Mountain View, California). This unit records the simultaneous measurements of up to eight temperature probes every 8 msec.

Eight heating trials were performed on each cadaver, with testing of three variables: the method of heating (continuous or intermittent), the pump flow rate (no flow, 50% flow, or 100% flow), and the location of the radiofrequency probe (radiofrequency energy was either applied directly to anterior capsular tissue in a paintbrush pattern or adjacent to the glenoid without tissue contact). For trials with continuous heating, the radiofrequency probe was activated continuously for one minute. For intermittent heating, the radiofrequency probe was turned on for ten seconds and then off for ten seconds, for a total of five on/off cycles. The radiofrequency probe location was varied only by rotating the probe so that its heating surface was either applied to the anterior soft tissue or exposed fully to the fluid within the joint. The flow rate was adjusted by setting the fluid pump to 0, 50%, or 100% for the duration of the trial. After each trial, and before the beginning of the next trial, the pump was set to 100% flow and the joint was irrigated with room-temperature normal saline solution until all probe temperatures returned to the baseline room temperature (23°C). All trials were performed on each cadaver before the investigator moved on to the next specimen to allow consistent temperature probe placement within each shoulder.

TABLE I Results of Experimental Trials				
Trial	Heating	Flow	Max. Temp.* (°C)	Time to Cool* (sec)
1	Continuous, no tissue contact	No	56.85 ± 20.21 (50.4-63.3)	125 ± 49.50 (89.6-160.4)
2	Continuous, no tissue contact	50%	37.40 ± 16.82 (32.0-42.8)	16 ± 10.75 (8.3-23.7)
3	Continuous, no tissue contact	100%	32.35 ± 14.95 (27.6-37.1)	8 ± 4.21 (5.0-11.0)
4	Intermittent, no tissue contact	No	57.75 ± 20.07 (51.3-64.2)	156 ± 38.64 (128.2-183.6)
5	Intermittent, no tissue contact	50%	33.65 ± 14.67 (29.0-38.3)	9 ± 5.68 (4.9-13.1)
6	Intermittent, no tissue contact	100%	33.75 ± 14.10 (29.2-38.3)	9 ± 3.16 (6.7-11.3)
7	Continuous on tissue	No	46.42 ± 16.83 (41.0-51.8)	122 ± 28.98 (101.3-142.7)
8	Continuous on tissue	50%	33.33 ± 12.05 (29.47-37.2)	9 ± 5.68 (4.9-13.1)

*The values are given as the mean and standard deviation with the 95% confidence interval in parentheses.

The temperature measured by each probe was recorded every ten seconds for the first two minutes of testing and then at thirty-second intervals. Each trial was stopped when all probes recorded room temperature or after a maximum of twenty minutes. The average maximum temperature, the time needed to reach 45°C, and the time needed to cool to below 45°C were calculated for each trial.

Analysis of variance was used to compare the effects of the heating method (intermittent or continuous), flow rate (no flow, 50% flow, or 100% flow), and probe location (directly against capsular tissue or held adjacent to the glenoid without tissue contact). When analysis of variance showed a difference in a specific parameter, the Bonferroni method was used to identify that difference. Significance was set as $p < 0.05$.

Source of Funding

Results

Joint fluid temperatures of >45°C were seen at some point during every trial regardless of the flow rate or heat setting that was used. In the first three trials, a continuous method of heating was used, without tissue contact, during no flow, 50% flow, and 100% flow (Table I and Fig. 1). The average maximum temperature (and standard deviation) was 56.85°C ± 20.21°C (95% confidence interval, 50.4°C to 63.3°C) in the no-flow trial, 37.4°C ± 16.82°C (95% confidence interval, 32.0°C to 42.8°C) in the 50% flow trial, and 32.35°C ± 14.95°C (95% confidence interval, 27.6°C to 37.1°C) in the 100% flow trial. Temperatures in the no-flow trial required an average of 125 ± 49.5 seconds (95% confidence interval, 89.6 to 160.4 seconds) to return to a safe level of <45°C, whereas an average of 16 ± 10.75 seconds (95% confidence interval, 8.3 to 23.7 seconds) was required in the 50% flow trial and an average of 8 ± 4.21 seconds (95% confidence interval, 5.0 to 11.0 seconds) was needed in the
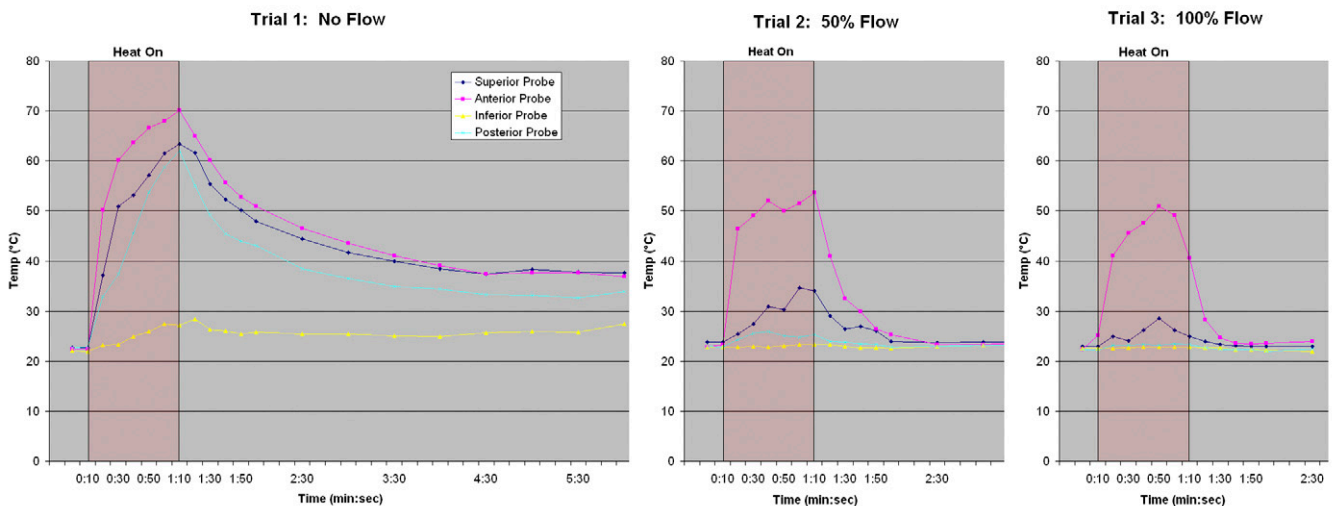

Fig. 1

Summary of temperatures reached during a continuous method of heating with no flow, 50% flow, and 100% flow and the radiofrequency probe held adjacent to the glenoid without tissue contact (trials 1, 2, and 3).

TABLE II Comparisons Revealing Significant Differences			P Value	
Trial Comparison	Heating	Flow	Avg. Max. Temp.	Avg. Time to Cool
1/2	Continuous	No/50%	<0.0001	<0.0001
1/3	Continuous	No/100%	<0.0001	<0.0001
4/5	Intermittent	No/50%	<0.0001	<0.0001
4/6	Intermittent	No/100%	<0.0001	<0.0001

100% flow trial. In the trials with continuous heating, the average maximum temperature and the time needed to return to a safe temperature under the no-flow condition were significantly ($p < 0.0001$) higher and longer, respectively, than they were under either the 50% or the 100% flow condition (Table II). However, no significant difference in the maximum temperature or in the time needed to return to a safe temperature was found between the 50% and 100% flow trials.

In trials 4, 5, and 6, an intermittent method of heating was used, without tissue contact, during no flow, 50% flow, and 100% flow (Table I, Fig. 2). The average maximum temperature was 57.75°C ± 20.07°C (95% confidence interval, 51.3°C to 64.2°C) in the no-flow group, 33.65°C ± 14.67°C (95% confidence interval, 29.0°C to 38.3°C) in the 50% flow group, and 33.75°C ± 14.1°C (95% confidence interval, 29.2°C to 38.3°C) in the 100% flow group. Temperatures in the no-flow trial required an average of 156 ± 38.64 seconds (95% confidence interval, 128.2 to 183.6 seconds) to return to a safe level, whereas an average of 9.0 ± 5.68 seconds (95% confidence interval, 4.9 to 13.1 seconds) was required in the 50% flow trial and an average of 9.0 ± 3.16 seconds (95% confidence interval, 6.7 to 11.3 seconds) was required in the 100% flow trial. The maximum temperature and the time needed to return to a safe temperature under the no-flow conditions were significantly ($p < 0.0001$) higher and longer, respectively, than those with either 50% or

100% flow (Table II). However, no significant difference in the maximum temperature or in the time needed to return to a safe temperature was found between the 50% and 100% flow trials.

No significant difference between the average maximum temperatures or between the average times needed to return to a safe temperature level was found when we compared continuous heating and intermittent heating, regardless of whether the trial involved no flow (trial 1 compared with trial 4), 50% flow (trial 2 compared with trial 5), or 100% flow (trial 3 compared with trial 6).

When the probe was applied continuously and directly to anterior capsular tissue (Table I, Fig. 3), instead of being held adjacent to the glenoid without tissue contact, the average maximum temperature was 46.42°C ± 16.83°C (95% confidence interval, 41.0°C to 51.8°C) with no flow compared with 33.33°C ± 12.05°C (95% confidence interval, 29.47°C to 37.2°C) in the 50% flow trial. Temperatures in the no-flow trial required an average of 122 ± 28.98 seconds (95% confidence interval, 101.3 to 142.7 seconds) to return to a safe level, whereas an average of 9 ± 5.68 seconds (95% confidence interval, 4.9 to 13.1 seconds) was needed in the 50% flow trial.

The average time needed for the temperatures to cool to a safe level in the trials in which the probe had been held adjacent to the glenoid without tissue contact was 140.5 seconds in the no-flow trials, 12.5 seconds in the 50% flow trials, and 8.5 seconds in the 100% flow trial.
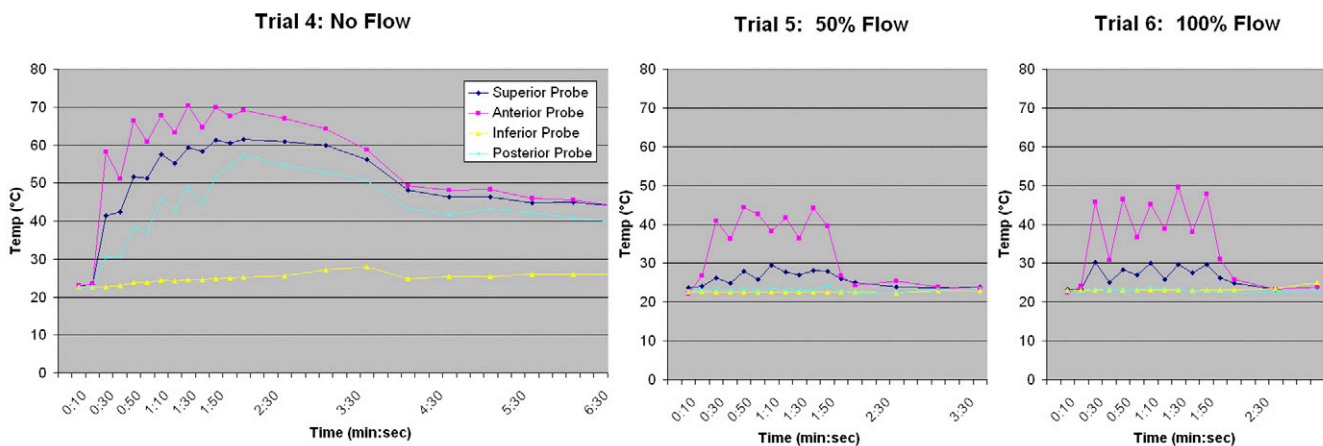

Fig. 2

Summary of temperatures reached during an intermittent method of heating with no flow, 50% flow, and 100% flow and the radiofrequency probe held adjacent to the glenoid without tissue contact (trials 4, 5, and 6).
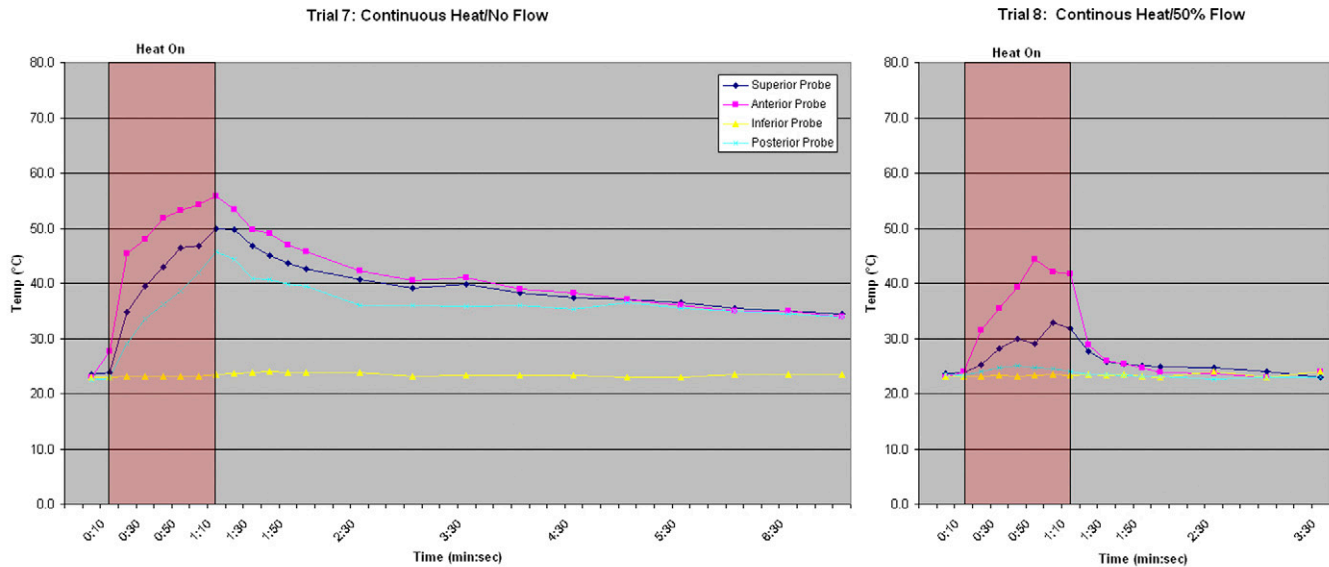
Fig. 3

Summary of temperatures reached during a continuous method of heating with no flow and 50% flow and the radiofrequency probe placed directly on anterior capsular tissue (trials 7 and 8).

Discussion

Chondrolysis is a potentially devastating complication following the use of radiofrequency energy. Several experimental studies and case reports have demonstrated the deleterious effects of radiofrequency energy on chondrocyte viability[7,11,14-18]. In all of the trials in the present study, use of a thermal device during shoulder arthroscopy increased the temperature of fluid within the joint to >45°C at some point.

Radiofrequency energy devices are currently available in either monopolar or bipolar form. Both types of devices create a rapidly alternating electromagnetic field, across which charged particles rapidly move, generating heat in the process. In the case of monopolar devices, the field is located between the end of the probe and the ground, which is the tissue; rapid motion and friction within the tissue itself generate the heat. With bipolar devices, the field is between two points on a probe. Both types of devices are commonly used in shoulder arthroscopy, and they both can result in chondrocyte death below the articular surface[16]. However, the depth of penetration appears to be lower with monopolar devices, along with a lower mean temperature at the tip of the probe[11,16].

The optimal temperature for thermal shoulder capsulorrhaphy has been found to be between 65°C and 75°C[11,14,15]. A temperature in this range is necessary to disrupt the intramolecular collagen bonds resulting in tissue degeneration and capsular shrinkage. At these temperatures, however, there is evidence of decreased biomechanical properties within the treated tissues[11,14]. Cartilage is even more sensitive to heat exposure, with chondrocyte death occurring at temperatures as low as 45°C[11,14,15]. Several radiofrequency devices do not have an operating temperature lower than 45°C. Thus, there may not be a safe operating range for these devices.

For our study, we selected a commercially available radiofrequency probe that has been found to have the highest mean operating temperature[13]. Various operating parameters were utilized in the different trials to simulate clinically relevant conditions. Temperatures of joint fluid that are potentially damaging to chondrocytes (>45°C) were seen at some point in every trial, regardless of the flow rate or heat setting that was used. Approximately the same maximum temperature was achieved regardless of whether the device was utilized continuously or intermittently. Although we expected that using the radiofrequency device directly on tissue would act as a heat sink and reduce the temperature of the surrounding fluid, we found no significant difference in the results of the trials in which the device was used directly on tissue and those of the trials in which it was used in the surrounding fluid. While our findings are consistent with the results reported by Lu et al.[19], they differ from those in a recent study by McKeon et al.[13], who did not find any temperatures of >45°C in their trials.

One possible explanation for the difference between our study and that by McKeon et al.[13] is the difference in the locations of the temperature probes. In our study, the anterior temperature probe, located 1 cm away from the radiofrequency device, consistently displayed the highest temperatures, whereas McKeon et al. found the highest temperatures 3 mm from the end of the radiofrequency probe. We positioned our temperature probes around the perimeter of the glenoid surface to detect regional differences in temperature that may occur as a result of regional topography of the shoulder.

This study had several limitations. First, the temperature of the cadaver specimens was room temperature, rather than a more physiologic temperature. Normal blood flow in living tissue may also act as a heat sink to reduce intracapsular tem-

peratures. Furthermore, the difference in the thermal coefficients between living and cadaveric tissue has not been studied, to our knowledge. Arm position may also have an effect on the temperatures reached in different regions. The axillary probe never reached critical temperatures in any of our trials, but the heat source was only applied anteriorly. It should be noted that, if the radiofrequency probe is used in the axillary pouch, the temperature is likely to be higher, placing the axillary nerve at increased risk for injury[4]. Although the temperatures reached in the joint were high enough to cause chondrocyte death, a causal relationship cannot be established without examining chondrocyte viability. The duration of the exposure is another important factor in determining the impact of elevated temperatures on cartilage. The simulated use of the radiofrequency device in this study may not accurately represent the clinical scenario. In our study, the radiofrequency device remained in the same location in the shoulder throughout a given trial, in contrast to the more widespread or dynamic use in a clinical setting. Despite the limitations of this study, it is still notable that the joint fluid temperature exceeded 45°C in every trial regardless of the flow rate or heat setting that was used. In addition, a reduction in flow from 50% or 100% to no flow resulted in significant increases in the maximum temperature as well as prolonged the time needed for heat dissipation.

We have seen glenohumeral chondrolysis without the use of a radiofrequency device, in cases in which a laser or only a form of thermal ablation was used[20]. If thermal ablation is used to débride areas of synovitis in the glenohumeral joint, there is the potential for additional cartilage injury if the irrigation-fluid flow is lost. This study demonstrated that irrigation-fluid flow, rather than whether the energy source is continuous or intermittent, is critical for maintaining lower joint-fluid temperatures. Thus, having a well-placed exit cannula that does not back out should help to protect the joint.

In summary, the use of radiofrequency devices according to the manufacturer's recommendations in situations similar to clinical scenarios can result in exposure of chondrocytes to fluid temperatures that are high enough to cause cell death (>45°C). While this complication is rare, this study emphasizes that care must be taken when using these devices. Precautions should include minimization of direct chondrocyte contact with the probe and maintenance of adequate flow rates. ∎

NOTE: Ted Kucklick from Cannuflow, Inc., provided the custom-built temperature probes and the data-acquisition device for this study.

Christopher R. Good, MD
Virginia Spine Institute, 1831 Wiehle Avenue, Reston, VA 20190

Michael K. Shindle, MD
Matthew H. Griffith, MD
Tony Wanich, MD
Russell F. Warren, MD
The Hospital for Special Surgery,
535 East 70th Street,
New York, NY 10021.
E-mail address for M.K. Shindle: shindlem@hss.edu

References

1. Abrams JS. Thermal capsulorrhaphy for instability of the shoulder: concerns and applications of the heat probe. Instr Course Lect. 2001;50:29-36.

2. Fanton GS, Wall MS. Thermally-assisted arthroscopic stabilization of the shoulder joint. In: Warren RF, Craig EV, Altchek DW, editors. The unstable shoulder. Philadelphia: Lippincott-Raven; 1999. p 329-43.

3. Gryler EC, Greis PE, Burks RT, West J. Axillary nerve temperatures during radio-frequency capsulorrhaphy of the shoulder. Arthroscopy. 2001;17:567-72.

4. McCarty EC, Warren RF, Deng XH, Craig EV, Potter H. Temperature along the axillary nerve during radiofrequency-induced thermal capsular shrinkage. Am J Sports Med. 2004;32:909-14.

5. Sperling JW, Anderson K, McCarty EC, Warren RF. Complications of thermal capsulorrhaphy. Instr Course Lect. 2001;50:37-41.

6. Levine WN, Bigliani LU, Ahmad CS. Thermal capsulorrhaphy. Orthopedics. 2004;27:823-6.

7. Levine WN, Clark AM Jr, D'Alessandro DF, Yamaguchi K. Chondrolysis following arthroscopic thermal capsulorrhaphy to treat shoulder instability. A report of two cases. J Bone Joint Surg Am. 2005;87:616-21.

8. Turner AS, Tippett JW, Powers BE, Dewell RD, Mallinckrodt CH. Radiofrequency (electrosurgical) ablation of articular cartilage: a study in sheep. Arthroscopy. 1998;14:585-91.

9. Kaplan L, Uribe JW. The acute effects of radiofrequency energy in articular cartilage: an in vitro study. Arthroscopy. 2000;16:2-5.

10. Lu Y, Edwards RB 3rd, Nho S, Cole BJ, Markel MD. Lavage solution temperature influences depth of chondrocyte death and surface contouring during thermal chondroplasty with temperature-controlled monopolar radiofrequency energy. Am J Sports Med. 2002;30:667-73.

11. Edwards RB 3rd, Lu Y, Nho S, Cole BJ, Markel MD. Thermal chondroplasty of chondromalacic human cartilage. An ex vivo comparison of bipolar and monopolar radiofrequency devices. Am J Sports Med. 2002;30:90-7.

12. Voss JR, Lu Y, Edwards RB, Bogdanske JJ, Markel MD. Effects of thermal energy on chondrocyte viability. Am J Vet Res. 2006;67:1708-12.

13. McKeon B, Baltz MS, Curtis A, Scheller A. Fluid temperatures during radio-frequency use in shoulder arthroscopy: a cadaveric study. J Shoulder Elbow Surg. 2007;16:107-11.

14. Edwards RB, Markel MD. Radiofrequency energy treatment effects on articular cartilage. Oper Tech Orthop. 2001;11:96-104.

15. Lu Y, Edwards RB 3rd, Nho S, Heiner JP, Cole BJ, Markel MD. Thermal chondroplasty with bipolar and monopolar radiofrequency energy: effect of treatment time on chondrocyte death and surface contouring. Arthroscopy. 2002;18:779-88.

16. Lu Y, Edwards RB 3rd, Cole BJ, Markel MD. Thermal chondroplasty with radiofrequency energy. An in vitro comparison of bipolar and monopolar radiofrequency devices. Am J Sports Med. 2001;29:42-9.

17. Lu Y, Hayashi K, Edwards RB 3rd, Fanton GS, Thabit G 3rd, Markel MD. The effect of monopolar radiofrequency treatment pattern on joint capsular healing. In vitro and in vivo studies using an ovine model. Am J Sports Med. 2000;28:711-9.

18. Petty DH, Jazrawi LM, Estrada LS, Andrews JR. Glenohumeral chondrolysis after shoulder arthroscopy: case reports and review of the literature. Am J Sports Med. 2004;32:509-15.

19. Lu Y, Bogdanske J, Lopez M, Cole BJ, Markel MD. Effect of simulated shoulder thermal capsulorrhaphy using radiofrequency energy on glenohumeral fluid temperature. Arthroscopy. 2005;21:592-6.

20. Good CR, Shindle MK, Kelly BT, Wanich T, Warren RF. Glenohumeral chondrolysis after shoulder arthroscopy with thermal capsulorrhaphy. Arthroscopy. 2007;23:797.e1-5.