SCIENTIFIC ARTICLE

Temperature in and Around the Scapholunate Ligament During Radiofrequency Shrinkage: A Cadaver Study

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Purpose To investigate whether applied radiofrequency energy (RFE) for shrinkage of the scapholunate interosseus ligament reaches temperatures required for ligament shrinkage while leaving adjacent structures unaffected.

Methods Standard wrist arthroscopy was performed on 7 pairs of cadaveric limbs with continuous saline irrigation and gravity-assisted outflow through an 18-gauge needle. We subjected 14 scapholunate ligaments to treatment with monopolar (n = 7) or bipolar (n = 7) RFE for ligament shrinkage. Temperature was recorded simultaneously inside the dorsal part of the scapholunate interosseus ligament at a depth of 0.9 ± 0.1 mm and at 6 other sites in and around the wrist because thermal shrinkage starts at 60°C to 65°C.

Results We observed an increase in temperature corresponding to the time of energy application. The highest measured peak temperatures at the scapholunate ligament were 43°C (monopolar) and 32°C (bipolar). Mean temperatures at 30 seconds of application were 29°C ± 7°C (monopolar) and 28°C ± 3°C (bipolar).

Conclusions Temperatures sufficiently high to induce ligament shrinkage were not reached with either monopolar or bipolar RFE. We did not monitor temperature levels responsible for damage on adjacent cartilage or immediately adjacent capsular tissue in this setting.

Clinical relevance This study suggests that RFE for capsular shrinkage in the wrist is safe but ineffective. *(J Hand Surg Am. 2015;40(2):259–265. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Temperature, SL ligament, RFE, thermal shrinkage.

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THE SCAPHOLUNATE INTEROSSEUS ligament (SLIL) has a crucial role in the function of the wrist because incompetence of the SLIL causes pain and progressive arthritis.[1,2]

Over the past decade, arthroscopic thermal shrinkage was used to treat patients with ligamentous laxity in various joints, including the scapholunate ligament with partial disruption (Geissler I and II).[3–7]

The SLIL contains primarily type I collagen, which is composed of 3 polypeptide chains and is organized in a triple-helix structure. The 3-dimensional structure is stabilized and maintained by intramolecular cross-links of covalent aldehyde bonds that are heat-labile. The

intramolecular cross-links break down at 60°C to 65°C[8–10] and protein denatures into a random, organized, gel-like state.[11–13] Collagen molecules are able to regain their triple-helical structure as tissues cool.[14] However, denatured collagen is metabolized during the repair mechanism and is replaced with scar tissue.[15,16] This process ultimately accounts for thermal ligament shrinkage.[17] Thermal exposure on collagen has been reported to result in tissue shrinkage depending on the temperature and time.[15,18] Clinical improvement of a patient's symptoms after thermal shrinkage likely results from modified joint stability as a result of the thermally induced contraction of capsules and ligaments.[19–23] Application of radiofrequency (RF) energy (RFE) performed with a monopolar device induces heat in the tissue owing to the frictional resistance of the tissue rather than the probe itself. In contrast, electromagnetic energy between 2 points of a probe (bipolar) requires less current because the current passes through a smaller volume of tissue. Once the critical temperature (60°C to 65°C) is reached, collagen derivatives denature independently of the source of thermal energy.[13]

The objective of this study was to obtain temperature data in and adjacent to the SLIL during arthroscopic thermal shrinkage. Loss of perfusion with the use of a tourniquet results in a lower temperature of the limb during surgery. In addition, the temperature of the irrigation fluid is near that of the operating room (20°C to 22°C). Therefore, to mimic the *in vivo* environment, this study was performed on cadaver wrists with irrigation fluid at 20°C.

Based on the literature, we hypothesized that RFE application might not induce the full collagen degradation of SLIL[24,25] in the wrist because Shellock[24] reported a markedly lower temperature of 50°C at 2 mm depth. Furthermore, we presumed that the maximum temperature varies between bipolar RF energy (bRFE) and monopolar RF energy (mRFE) as a result of the crucially different heat distribution with higher temperatures for the bipolar probe.

MATERIALS AND METHODS

We obtained 14 upper limbs from 7 fresh-frozen cadavers. The limbs were stored at −20°C with no further preservation and were thawed to room temperature before the experiment started. The thawed specimens were screened for room temperature by probes inserted 2 cm into the muscle tissue of the forearm to ensure complete rewarming. Moreover, 8 probes placed at certain locations for subsequent measurement during the experiments confirmed room temperature at all measuring points before the experiment.

We did not perform sample size analysis before this study, but we chose the number of cadaver to be consistent with similar prior studies.[26,27]

Temperature probes containing platinum chip sensors (Pt 1000, TYP PCA, 1.1505.10M JUMO GmbH and Co.KG, Fulda, Germany) were used for all experiments. The probes reported 2 measurements/s with an accuracy of ±0.1°C. Probe 1 served as a reference to monitor the temperature of the irrigation fluid at a room temperature of 20°C. In addition, 6 probes were surgically implanted into separate locations under ×2.5 magnification. Probe 2 was positioned intra-articularly into the radial recess. Probe 3 was placed from the distal midcarpal joint into the dorsal part of the scapholunate ligament at a depth of 0.9 ± 0.1 mm central to the ligament, where the thickness of the SLIL is approximately 3 mm in a dorsal-ventral view.[2] Probe 4 was inserted into a 2-mm hole drilled dorsally and subchondrally just proximal to the center of the lunate fossa of the radius. Probe 5 was placed intra-articularly at the distal radioulnar joint (DRUJ). Probe 6 was placed into the tendon sheath of the 4/5 compartment. Probe 7 was implanted adjacent to the ulnar nerve at the same level as the ulnocarpal joint (Fig. 1). All of these probes were positioned through a skin incision followed by blunt dissection. Probes were fixed with 4−0 suture and the wrist capsule for intra-articular placements was closed.

Afterward, limbs were fixed in a commercially available Arc Wrist Tower (AcuMed, Hillsboro, OR), in which finger traps and maximum distraction were applied. Probe 8 was placed intra-articularly under arthroscopic inspection centrally in the midcarpal joint.

We then performed standard wrist arthroscopy using the 6R portal for the camera and the 3/4 portal to introduce the RF probe. To apply bipolar currency, VAPR II 2.3-mm side-effect electrodes (DePuy Mitek, Westwood, MA) were applied. A monopolar ablator for small joints (45° REF AR-9601SJ-45 OPES Ablator AR-9600; Arthrex, Naples, FL) was used for all monopolar applications.

All wrists were initially flushed with 0.9% saline solution until all temperature probes reached a temperature of 20°C. Irrigation was applied at a pressure of 50 mm Hg with an inflow rate of 50 mL/min. An 18-gauge needle in the 6U portal achieved a gravity-assisted outflow. Temperature was monitored and recorded by an 8-channel, custom-built, simultaneous measuring device.