COMPLICATIONS OF THERMAL CAPSULORRHAPHY OF THE SHOULDER

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Background: The purpose of this study was to evaluate the rate of recurrence and the prevalence of complications related to the use of thermal energy for the treatment of glenohumeral instability.

Methods: A survey was conducted of all members of the American Shoulder and Elbow Surgeons, the Arthroscopy Association of North America, and the American Orthopaedic Society for Sports Medicine. The survey focused on the rate of recurrence, the number of axillary nerve injuries, and the prevalence of capsular insufficiency seen in revision surgery after thermal capsulorrhaphy of the shoulder.

Results: Three hundred and seventy-nine surgeons responded to the survey. Of 236,015 shoulder procedures performed over the last five years, 14,277 (6%) involved the use of thermal energy (1077 involved laser energy; 9013, monopolar radiofrequency; and 4187, bipolar radiofrequency) for the treatment of glenohumeral instability. The rates of recurrent instability after laser, monopolar radiofrequency, and bipolar radiofrequency capsulorrhaphy were 8.4%, 8.3%, and 7.1%, respectively. Of the patients with recurrent instability, 363 (twenty-one treated with laser energy, 220 treated with monopolar radiofrequency, and 122 treated with bipolar radiofrequency) required revision surgery. In this group of patients with revision surgery, seven (33%) of the twenty-one treated primarily with laser energy, thirty-nine (18%) of the 220 treated primarily with monopolar radiofrequency, and twenty-five (20%) of the 122 treated primarily with bipolar radiofrequency exhibited signs of capsular attenuation at the time of the revision. A total of 196 patients (1.4%) (three treated with laser energy; 133, with monopolar radiofrequency; and sixty, with bipolar radiofrequency) had a postoperative axillary neuropathy; 93% of the 196 had a sensory deficit only. Of these patients, 95% recovered completely, with the sensory deficits lasting an average of 2.3 months and the combined deficits, an average of four months.

Conclusions: The use of thermal energy for the treatment of shoulder instability has promising short-term results. The rates of recurrent instability are low. However, when recurrent instability occurs, capsular insufficiency may be present. Axillary nerve injury was reported in 1.4% of the patients, in most of whom it resolved spontaneously.

Case Report

A twenty-eight-year-old right-hand-dominant man sustained an injury of the left shoulder in an automobile accident. He reported persistent shoulder pain and a sense of instability with no history of frank dislocation. After a course of conservative treatment and an arthroscopic acromioplasty failed, he was referred to us for additional evaluation. Anterior shoulder instability was suspected on the basis of the results of the examination. Examination with the patient under anesthesia revealed increased anterior translation with the arm in neutral rotation in the scapular plane, which was blocked with 110° of external rotation compared with 90° on the right. Diagnostic arthroscopy revealed a normal glenohumeral joint except for a positive drive-through sign and a frayed labrum. The anterior band of the inferior glenohumeral ligament was treated with monopolar thermal shrinkage; there were no perioperative complications.

The patient initially did well, but at two months postoperatively, when he was playing basketball against our advice, he sustained an anterior shoulder dislocation that required physician-assisted reduction in the emergency department. Initial treatment consisted of a short period of immobilization followed by strengthening exercises. However, he continued to have recurrent episodes of shoulder dislocation and subluxation. Contrast-medium-enhanced magnetic resonance imaging of the shoulder showed a new Hill-Sachs lesion and a torn, severely attenuated anteroinferior glenohumeral ligament (Figs. 1-A and 1-B). Eighteen months after the initial shoulder dislocation, he underwent arthroscopic repair of a SLAP lesion (superior portion of the labrum, anterior and posterior) and a Bankart and capsular repair (without grafting). Twelve months postoperatively, the shoulder was stable, with minor pain, and the patient was able to play golf at his previous level.

Background

Arthroscopic procedures have become increasingly popular for the treatment of shoulder instability. With the advent of thermal energy as a means to stimulate capsular contraction, there has been tremendous enthusiasm for its use to treat a variety of shoulder problems. Proponents of thermal capsulorrhaphy mention many factors, such as decreased surgical morbidity, shorter hospital stay, less postoperative pain, improved appearance, and the ability to perform an open capsular imbrication procedure if shrinkage fails. In addition, the

Fig. 1-A

Fig. 1-B

Axial (Fig. 1-A) and oblique sagittal (Fig. 1-B) magnetic resonance arthrogram images demonstrate a new Hill-Sachs defect and a torn, attenuated anteroinferior glenohumeral ligament.

complication rate following thermal capsulorrhaphy is relatively low[1]. However, it is likely that the true prevalence of postoperative complications is not known. The purpose of this survey was to identify the types and prevalences of complications encountered after arthroscopic thermal capsulorrhaphy for the treatment of glenohumeral instability.

Mechanism of Thermal Shrinkage

Joint capsule and ligaments are composed primarily of type-I collagen. The collagen molecule is made up of three polypeptide chains, which are stabilized in a triple-helix arrangement by intramolecular cross-links. These molecules are in turn aggregated to form collagen fibrils. This fibrillar arrangement is stabilized by intermolecular cross-links. When collagen tissue is heated to 65°C, the heat-labile intramolecular cross-links are damaged, and the protein goes from an organized structure to a random, gel-like state. It is this unwinding of the triple helix that causes shrinkage to occur initially. Subsequently, the treated tissues undergo a repair response characterized by fibroplasia, neovascularization, and fibrovascular scar formation[2,3].

Modes of Thermal Shrinkage

Laser

The holmium:yttrium-aluminum-garnet (Ho:YAG) laser was the first system used clinically for thermal shrinkage[4]. It is an optical device that can transmit energy in the form of an intense beam of light. This laser light, in turn, is absorbed by the tissues (composed mainly of water), and heat is generated. The energy absorbed by the tissue is controlled by the power density, the spot size, and the duration of application. Power density can be increased by increasing the power output of the laser generator or by decreasing the applied spot size. As a result of the noncontact nature of this device, there is no specific mechanism for precise temperature feedback. It is up to the surgeon to determine the amount of thermal energy applied to the tissue by controlling the duration of application and the spot size. Thus, there is a potential for tissue ablation instead of shrinkage with prolonged heating.

Radiofrequency

Radiofrequency energy is a form of electromagnetic energy[3]. When applied to tissues, the rapidly oscillating electromagnetic field causes movement of charged particles, resulting in heat generation. Frictional or resistive heating of tissue around the probe tip, rather than the probe itself, is the primary source of heat. There are two forms of radiofrequency devices: monopolar and bipolar. Monopolar devices generate heat by applying electromagnetic energy between a single electric probe and a grounding plate; bipolar devices apply energy between two points on the tip of a probe.

Materials and Methods

A survey focusing on the rate of recurrence, the number of axillary nerve injuries, and the prevalence of capsular insufficiency seen in revision surgery after thermal capsulorrhaphy of the shoulder was given to all members of the American Shoulder and Elbow Surgeons, the Arthroscopy Association of North America, and the American Orthopaedic Society for Sports Medicine.

Results

Three hundred and seventy-nine surgeons responded to the survey. Of 236,015 shoulder procedures performed in the last five years, 14,277 (6%) consisted of thermal capsulorrhaphy (Fig. 2). Laser energy was used in 1077 of these procedures; monopolar radiofrequency, in 9013; and bipolar radiofrequency, in 4187. The beach-chair position was used

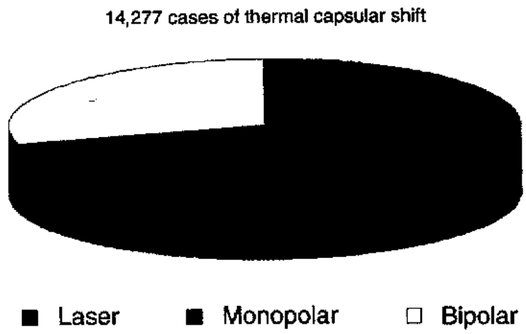

Fig. 2

Pie chart indicating the breakdown of 14,277 cases of thermal capsular shrinkage: 1077 were performed with laser energy; 9013, with monopolar radiofrequency; and 4187, with bipolar radiofrequency.

for 4978 (35%) of the procedures, and the lateral decubitus position was used for 9299 (65%).

Recurrent instability (after variable durations of follow-up) occurred after ninety-one (8.4%) of the laser procedures, 748 (8.3%) of the monopolar radiofrequency procedures, and 298 (7.1%) of the bipolar radiofrequency procedures (Fig. 3). The recurrent instability required revision surgery after twenty-one laser procedures, 220 monopolar radiofrequency procedures, and 122 bipolar radiofrequency procedures. Of the patients undergoing revision surgery, seven (33%) of those treated primarily with laser energy, thirty-nine (18%) of those treated primarily with monopolar radiofrequency, and twenty-five (20%) of those treated primarily with bipolar radiofrequency had signs of capsular attenuation at the revision. In the group of patients with capsular insufficiency at the time of the revision surgery, none of those treated primarily with laser energy, two of those treated primarily with monopolar radiofrequency, and five of those treated primarily with bipolar radiofrequency required the use of a capsular substitute (allograft or autograft). Of the patients who underwent revision surgery, eighteen (86%) of those treated primarily with laser energy, 186 (85%) of those treated primarily with monopolar radiofrequency, and eighty-nine (73%) of those treated primarily with bipolar radiofrequency currently have a stable shoulder.

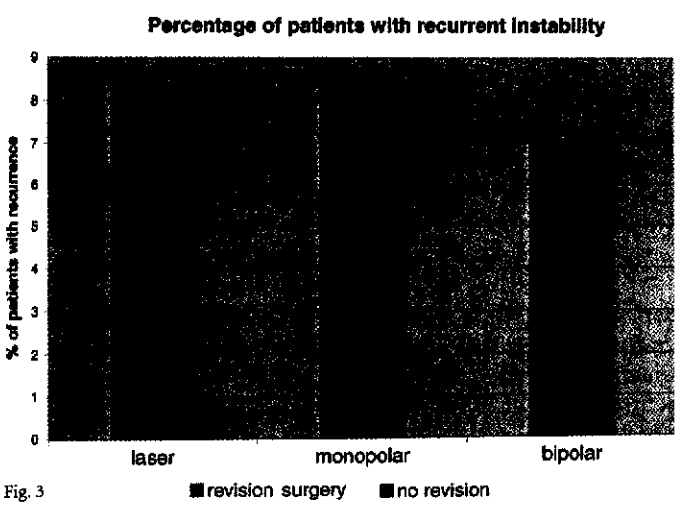

Fig. 3

Percentage of patients with recurrent instability following thermal shrinkage.

Complications

Of the 14,277 cases, 196 (1.4%) had axillary nerve injury (Fig. 4); the rate was three (0.3%) of 1077 after the laser procedures, 133 (1.48%) of 9013 after the monopolar radiofrequency procedures, and sixty (1.43%) of 4187 after the bipolar radiofrequency procedures; 93% of the 196 cases consisted of a sensory deficit only. Axillary nerve injury occurred after eighty-two (1.65%) of the procedures performed in the beach-chair position and after 114 (1.23%) of those performed in the lateral decubitus position. Twenty of the axillary nerve injuries were proved by electromyography. There was complete axillary nerve recovery in 95% of the cases, with the sensory deficits lasting an average of 2.3 months and the combined deficits, an average of four months (Fig. 5).

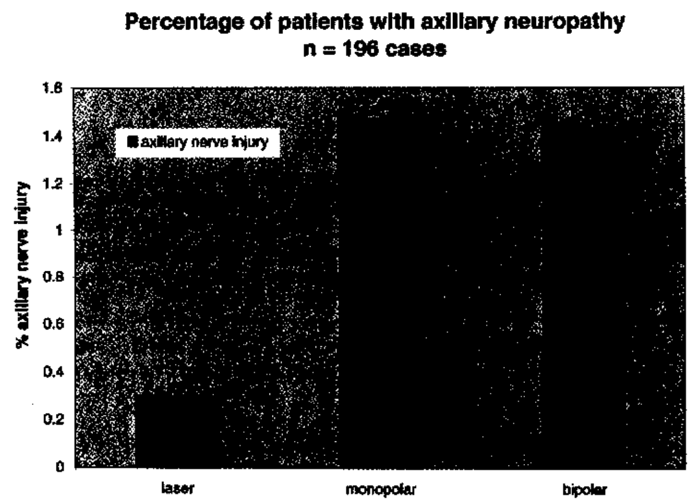

Fig. 4

Percentage of patients with axillary neuropathy following thermal shrinkage as a function of the type of energy delivery.

There was adhesive capsulitis in forty-one cases.

Discussion

There have been few reported complications related to the use of thermal energy for the treatment of shoulder instability. Fanton[1], in 1998, reported on only one patient who had transient axillary neuritis (sensory only) after the use of a monopolar radiofrequency device for the treatment of multidirectional instability. The patient recovered four weeks later, and the result was excellent at two years postoperatively. Recognizing the proximity of the axillary nerve to the inferior aspect of the capsule and the fact that the inferior pouch is sometimes very thin, Fanton suggested reducing the power of the radio-

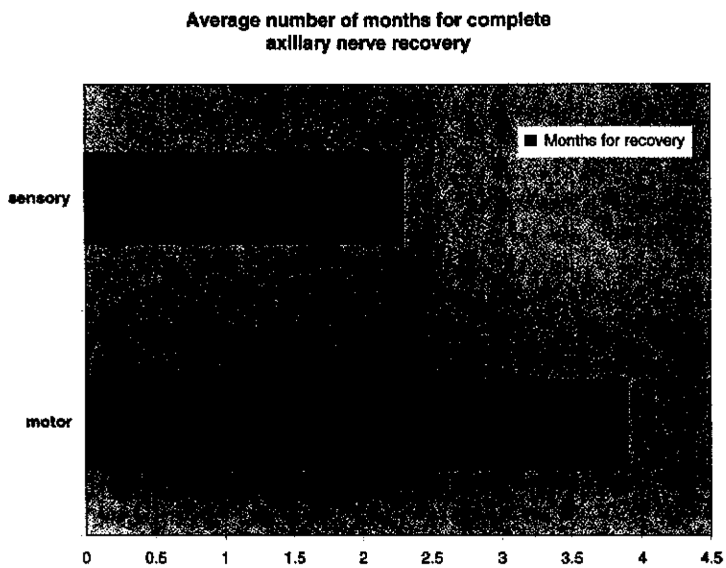

Fig. 5

Average number of months for complete axillary nerve recovery.

frequency device to 20 W in this region. He also recommended avoiding the region between 5 o'clock and 7 o'clock because of the paucity of collagen or glenohumeral ligament structure in that area. The three cases of axillary neuropathy that occurred in our institution (two sensory and one sensory and motor) were associated with the use of an accessory posterior-inferior portal. This portal was established to gain access to the inferiormost aspect of the pouch to shrink the tissue in the 6 o'clock position, especially in patients with a patulous capsule. The patients with only sensory neuropathy had complete recovery in two months. However, the patient with both motor and sensory neuropathy had persistent symptoms.

In an *in vivo* histologic study involving a sheep model, Hecht et al.[2] found a significant and strong correlation between the radiofrequency power setting and the area and depth of the tissue lesion. Histologic analysis of the joint capsule at seven days after treatment revealed thermal damage ("inflammatory cell infiltration, fusion of collagen, pyknosis of fibroblasts, myonecrosis, and vascular thrombosis") at all radiofrequency power settings from 10 to 30 W. Furthermore, an anatomic study of a cadaver model by Bryan et al.[5] demonstrated that the axillary nerve is on average only 3 mm (range, 0 to 8 mm) away from the inferior aspect of the capsule. Since the amount of energy that the axillary nerve can tolerate before irreversible damage occurs and the distance between the distended capsule and the nerve in various arm positions are not known, caution should be exercised when treating areas in which the capsule is known to come into close contact with the nerve.

The reasons for the observed difference in the prevalences of axillary nerve injury associated with different devices are unknown. There are several possibilities. First, the Ho:YAG device is a pulsed laser, and the cooling effects between pulses in a fluid medium greatly limit the tissue damage that occurs[6]. Second, the depth of tissue penetration by the laser could be less than that of radiofrequency devices. However, the depth of tissue penetration and the area of thermal shrinkage are surgeon-dependent. The amount of energy imparted to the capsule is determined by the duration of application, power setting, spot size, and distance from the capsule. There are no feedback mechanisms to control the temperature in the capsule because of the noncontact nature of the laser device. Finally, the relatively small number of respondents (thirty-three surgeons) who used a laser could have biased the result.

Histologic analysis of joint capsular specimens treated with radiofrequency have shown thermal damage characterized by a fused and homogenized appearance of the collagen and fibroblastic nuclear pyknosis[7]. Radiofrequency energy can cause collagen denaturation, cell necrosis, and potentially deleterious mechanical effects in the tissue[8]. Subsequently, under physiologic loading in the early postoperative period, the ligament can restretch and lose its tensile strength. A biomechanical study by Hecht et al.[3] showed that the stiffness and failure strength of the joint capsule were significantly decreased at two weeks after application of radiofrequency energy. The mechanical properties of the treated capsular tissue returned to normal levels between six and twelve weeks later. This study indicates that a regimented rehabilitation program and instructing patients to avoid certain activities in the first twelve weeks are important for a successful outcome.

Another, less well-recognized complication is adhesive capsulitis. In Fanton's study[1], only one patient had postoperative stiffness that required a prolonged course of physical therapy. At twenty-six weeks, the patient regained motion and returned to full unrestricted activity. Although the results of our survey suggest that the prevalence of adhesive capsulitis is low (0.3%), it is important to structure a rehabilitation protocol that will allow early motion to prevent excessive stiffness and at the same time avoid excessive motion that can restretch the capsule.

Conclusions

On short-term follow-up, thermal shrinkage proved effective for the treatment of shoulder instability in the majority of the patients. However, the risks and benefits of the procedure should be recognized and proper patient education is important. Additional investigation is necessary to define the specific patient population that would benefit most from this procedure and to determine the precise rehabilitation protocol. Patients with recurrent shoulder instability after thermal capsulorrhaphy can be managed successfully with either open or arthroscopic revision surgery. It is important to instruct the patient to avoid rigorous activities in the first three months after thermal capsular shrinkage. Although this study demonstrated a higher risk of axillary nerve injury when the procedure is performed with the patient in the beach-chair position, a definitive conclusion cannot be reached since the specific arm position at the time of energy application was not determined. There is a potential for capsular attenuation; the current technique of "striping" the capsule (leaving areas of normal tissue between the treated areas) should decrease the chance of capsular dissolution and should promote faster fibroblastic proliferation from adjacent cells. ■

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