ARTHROSCOPIC THERMAL CAPSULORRHAPHY IN SHOULDER INSTABILITY

ESSAY
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Introduction

The application of heat as a therapeutic modality has evolved from the use of fire to sterilize wounds and control bleeding to the modern day use of hyperthermia to treat various forms of cancer ***(Thabit, 1998)***.

The use of thermal energy has recently been proposed as a technique to shrink redundant or lax connective tissues through the well established mechanism of collagen denaturation ***(Hayashi and Markel, 1998)***.

Basically two different types of energy systems have been used to thermally modify tissues: laser energy and radiofrequency energy ***(Foster and Elman, 1998)***.

The **Laser** (an acronym for **L**ight **A**mplification by the **S**timulated **E**mission of **R**adiation) is an ***Electro optical device*** capable of efficiently transmitting energy in the form of an intense beam of light. The radiant energy of the laser beam can be transformed into heat energy through its interaction with tissues ***(Fanton and Dillingham, 1995)***.

Radiofrequency energy is a form of ***electromagnetic energy***. When applied to tissues, rapid oscillation of electromagnetic fields causes movement of charged particles within the tissue and resultant molecular motion generates heat ***(Shellock, 1999)***.

Shoulder instability spans from occult sublaxation to frank dislocation. It commonly affects between 2% and 8% of the population and represents one third of all shoulder-related emergency department visits ***(Hovelius, 1987)***.

Thermal modification of the unstable shoulder was first described by Hippocrates*. He described the practice of using cautery to cause the shoulder capsule to scar and thus tighten around the joint. He wrote, "Grasp the skin at the armpit between the fingers and draw it in the direction towards which the head of the humerus gets dislocated, then pass the cautery right through the skin thus drawn away" ***(Matsen et al, 1998)***.

Arthroscopic stabilization techniques for the treatment of glenohumeral instability continue to improve. Recently, laser and radiofrequency energy have been used to tighten or shrink the glenohumeral ligaments as well as reduce capsular volume ***(Anderson et al, 1999)***.

**Quoted from Matsen et al, 1998*

Aim of the work

Is to highlight on thermal energy, used in shoulder arthroscopy as a novel therapeutic tool in cases of glenohumeral instability with emphasis on its effect on connective tissues and methods of delivery.

Methods of Delivery of Thermal Energy

1. **Radiofrequency**
   a. **Monopolar**
   b. **Bipolar**
2. **Laser**

(1) Radiofrequency

Radiofrequency is a form of electromagnetic energy. When applied to tissues, rapid oscillation of electromagnetic fields causes movement of charged particles within the tissue and the resultant molecular motion generates heat. The electromagnetic energy can be applied between two points on the tip of a probe (bipolar) or between a single electrode tip and a grounding plate (monopolar). In monopolar radiofrequency device the molecular friction created within the tissues adjacent to the radiofrequency probe produces heat. Thus the actual source of heat is the frictional resistance of the tissue rather than the probe itself. In bipolar radiofrequency probes the electromagnetic energy follows a much shorter path through the conductive irrigating solution, electrolytes, or tissues between the tips of the probe. In bipolar radiofrequency less current is required for a similar effect (compared to monopolar) because the current passes through a much smaller volume of tissues. In addition, the depth of tissue damage (relative to the probe tip) may be less in bipolar applications ***(Schellock, 1999)***.

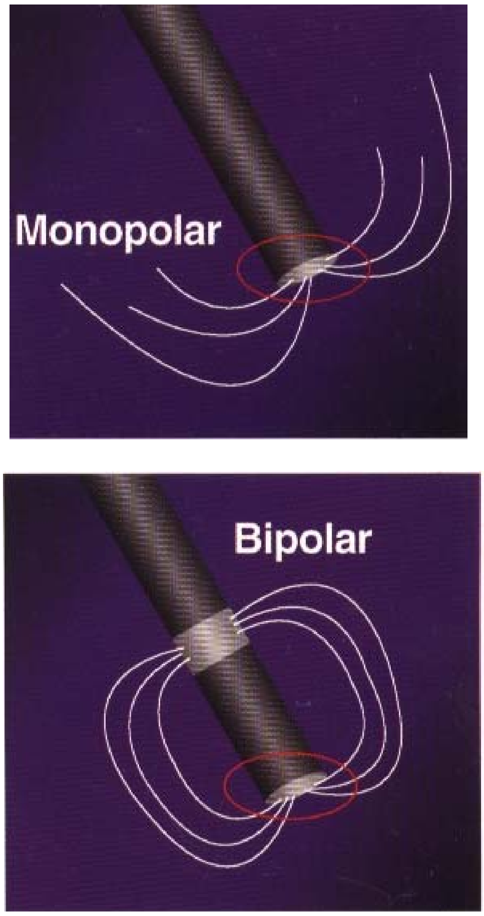


Fig (1): *Monopolar and Bipolar Electrodes (Quoted from Foster and Elman, 1998)*

The alternating current in our homes is electromagnetic energy delivered at the low frequency of 60 Hz. Radiofrequency is found between 1 KHz and 100 MHz on the electromagnetic frequency spectrum. Standard electrosurgical generators in the operating room run at ~460 KHz which is in the middle of the radiofrequency spectrum. Electrosurgical generators in the operating room take the lower frequency current from the wall socket and convert it into a higher frequency waveform in the radiofrequency range. Higher frequency is necessary because it is less apt to cause muscle stimulation i.e. electrocution. All electrosurgical generators, whether used for ablation, coagulation or tissue shrinkage, use electromagnetic energy in the radiofrequency range ***(Hecht et al., 1998)***.

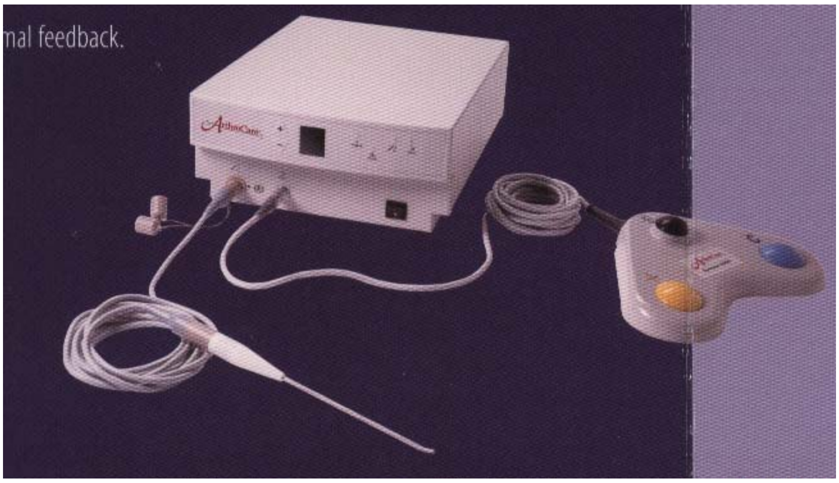


Fig (2): *Standard Electrosurgical Generator (Quoted from Foster and Elman, 1998)*

The thermal effect of radiofrequency energy in tissues is determined by the level of radiofrequency energy (power, impedance), duration of treatment, and nature of the tissues. In addition, electrode type (monopolar or bipolar), size, and shape have an effect ***(Hecht et al., 1998)***.

Some current radiofrequency devices are capable of monitoring and/or controlling the temperature at the tip of the probe. While this is thought to provide the highest margin of safety and efficacy, no data (clinical or experimental) has been published to support this claim. Indeed, the extent of thermal modification with radiofrequency devices is operator dependent and relies on the visual observation of the tissue response. Because the tissue response is both time and heat dependant, the longer a probe is left in one place the greater the resulting tissue damage. In addition, the biologic variables of age, tissue thickness, tissue hydration, and tissue quality all affect the thermal response of tissues ***(Foster and Elman, 1998)***.

The bipolar devices can produce elevated heat transfer along the surface. The heat returns through the probe, making these devices more applicable to tissue ablation as in preparation of an acromioplasty. The monopolar device dissipates heat as it travels to the grounding pad. An elevated temperature is present throughout the entire thickness of the capsule, which may have a greater role in shrinkage ***(Hecht et al., 1999)***.

Mechanisms of Action of Radiofrequency

(A) Thermal Ablation

Orthopedic surgeons were introduced to new electrosurgical tools which were reasonably efficient in removing soft tissue while simultaneously coagulating blood vessels. The term "ablation" describing this process was introduced into the orthopedic vocabulary. A description of the mechanics of ablation is as follows: An electrode connected to an electrosurgical generator is immersed in a conductive fluid such as saline. The electrode is insulated except for the most distal tip. A high frequency electrical current passes from the electrode tip into the saline. The saline at the tip begins to heat and quickly boils changing from a liquid to a vapor phase. A high energy spark discharge spontaneously initiates which by traversing the vapor strikes and vaporizes soft tissue. In the presence of a strong electric field the constituent molecules in the gas are excited to higher energy states and dissociate into

positive and ***negative*** ions. The ions are strongly accelerated in the electric field but quickly collide with other gas molecules, in turn splitting those molecules into ions. This process, called avalanche multiplication, quickly creates an ***"ion cloud"*** which becomes a conductive pathway across which a spark discharge flashes ***(Dillingham, 1998)***.

(B)Thermal Shrinkage

The heating of collagenous tissue occurs when electromagnetic energy is applied to the tissue surface. The alternating current creates an intense oscillation of charge carriers within the tissue causing frictional heating. There are two mechanisms by which the tissue is electrically heated and they are called "ohmic heating" and "dielectric heating". In ohmic heating the movement of charge carriers is translational, back and forth, yet in dielectric heating the movement is rotational, about the poles of the charge carrier. The type of heating that occurs is a function of the frequency of the electricity. At frequencies below 500 MHz heating is ohmic and above 500 MHz the heating is dielectric. Electrosurgical heating in the radiofrequency range is always ohmic and differences in frequency within the range have no effect on the mechanism of tissue heating or the performance of an electrosurgical instrument. Dielectric heating which occurs at frequencies above 500 MHz is illustrated by the microwave oven and does not have an application in electrosurgical technology ***(Hayashi and Markel, 1998)***.

Surgeons are familiar with the number 65°C as a target temperature for tissue shrinkage. It is important to understand that at 65°C it takes a full minute for collagen to shrink maximally. Higher temperatures shrink tissue much more quickly and as a practical issue much higher surface temperatures are required to shrink tissue as quickly as is seen in an arthroscopic procedure. Surgeons should also be aware that thermal injury to nerve will occur if local temperatures rise above 55°C. The heating of the tissue surface is through ohmic heating; however, tissue heating below the surface takes place primarily by conduction of heat into the tissue from the surface ***(Lopez et al, 2003)***.

The rise in surface temperature is primarily due to ohmic heating. This electrical effect is extremely superficial and in fact the effect drops off by the distance from the surface. This would suggest that the primary variable affecting surface heating is electrical power (watts). If the surgeon does not see an adequate tissue response time while performing a shrinkage procedure increasing the wattage is the solution to this problem ***(Hayashi and Markel, 1998)***.

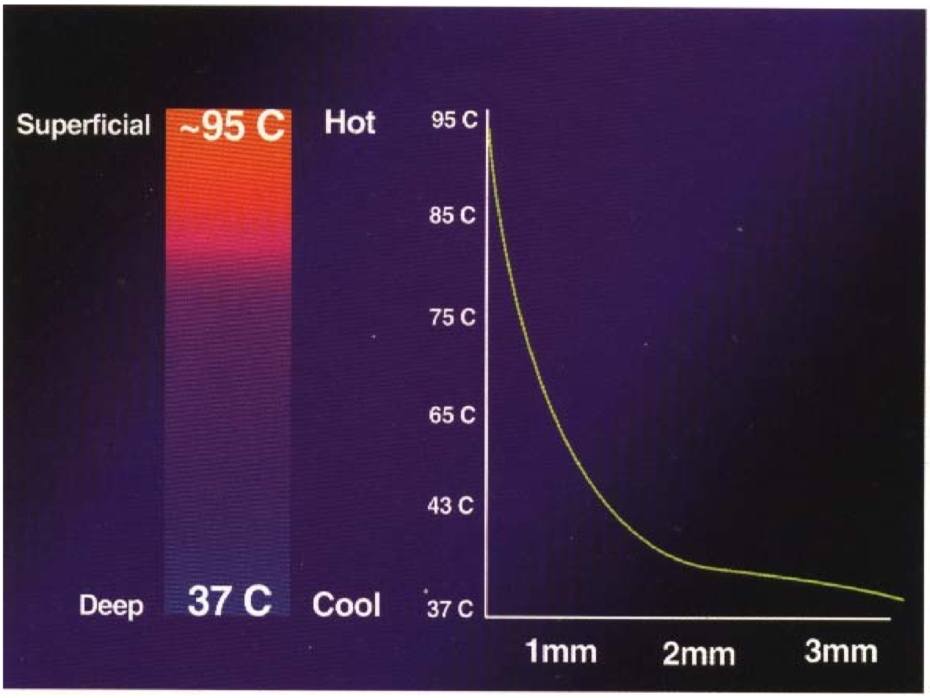
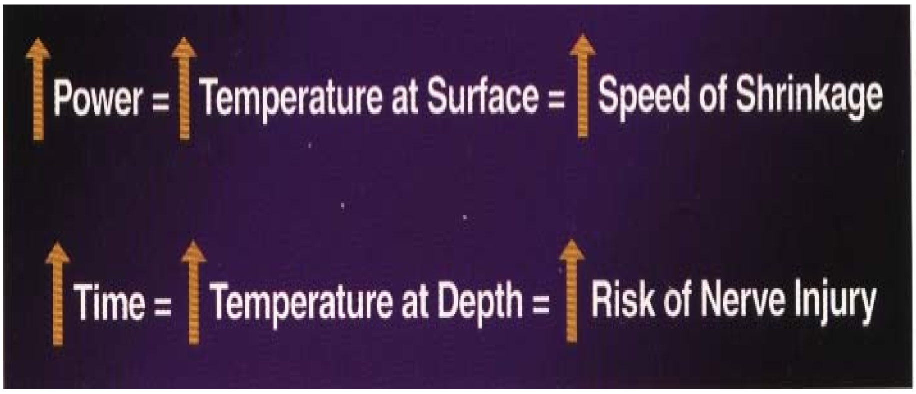


Fig (3): *Thermal Gradient (Quoted from Foster and Elman, 1998)*

Ohmic heating is limited to the immediate surface of tissue and routinely is heated into the region of 100°C. The temperature below the surface however is primarily raised by conductive heating from the surface. Fig (3) shows surface temperature approaching 100°C. There is exponential drop in temperature as the distance from the surface increases. The temperature drops quickly below the threshold of 65°C below which no appreciable tissue shrinkage can occur. Also the 45°C temperature limit is passed before reaching a depth of 2 mm suggesting minimal risk of thermal injury to nerve beyond this depth. Power level is the most important determinant of surface tissue temperature. In contrast, below the surface, the time of probe application to tissue determines the tissue temperature. At the surface the variable of power affects temperature much more strongly than time. At depth however, time predominantly affects tissue temperature even at a significantly lower power levels. The clinical application of this concept is that power relates to the speed of shrinkage whereas time relates to the potential for nerve injury ***(Foster and Elman, 1998)***.



Maximum shrinkage approaches 40-50% of initial length. Given that the temperature in tissue quickly drops off as the distance from the surface increases it can be assumed that the region of maximal shrinkage encompasses only a very superficial lamina of the tissue. Furthermore the percentage shrinkage of tissue will decrease rapidly with increased distance from the surface. As a late healing effect of the thermal injury to the surface, the tissue deep to the surface undergoes remodeling and further contraction yielding a more substantial thickness of contracted tissue ***(Hecht et al, 1998)***.

The shape of the electrode tip can be critical to the efficient performance of a heat shrinkage probe. The flow of electrical current is concentrated around regions of the electrode where edges exist. Increased current density at these edges locally heats saline which easily boils. A spark discharge will then form across the vapor phase at the electrode tip which will ablate tissue. The strategy with heat shrinkage is to modify tissue and avoid the initiation of the spark discharge which would lead to ablation. The ideal geometry, the hemisphere, allows the surgeon the option of operating at higher power levels without risking the development of the ablative discharge ***(Lopez et al, 2003)***.