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Cadaveric Study

The Efficacy of Two Electrodes Radiofrequency Technique: Comparison Study Using a Cadaveric Interspinous Ligament and Temperature Measurement Using Egg White

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Background: One technique in radiofrequency neurotomies uses 2 electrodes that are simultaneously placed to lie parallel to one another. Comparing lesions on cadaveric interspinous ligament tissue and measuring the temperature change in egg white allows us to accurately measure quantitatively the area of the lesion.

Methods: Fresh cadaver spinal tissue and egg white tissue were used. A series of samples were prepared with the electrodes placed 1 to 7 mm apart. Using radiofrequency, the needle electrodes were heated in sequential or simultaneous order and the distance of the escaped lesion area and temperature were measured.

Results: Samples of cadaver interspinous ligament showed sequential heating of the needles limits the placement of the needle electrodes up to 2 mm apart from each other and up to 4 mm apart when heated simultaneously. The temperature at the escaped lesion area decreased according to the distance for egg white. There was a significant difference in temperature at the escaped lesion area up to 6 mm apart and the temperature was above 50 °C up to 5 mm in simultaneous lesion and 3 mm in the sequential lesion.

Limitations:: The limitations of this study include cadaveric experimentation and use of intraspinous ligament rather than medial branch of the dorsal ramus which is difficult to identify.

Conclusion: Heating the 2 electrodes simultaneously appears to coagulate a wider area and potentially produce better results in less time.

Key words: Rhizotomy, radiofrequency neurotomy, 2 needles, facet joint pain, low back pain, cadaveric tissue

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The cause of lower back pain in 15% to 45% of clinical patients (1-7) is alleged to be from the zygapophysial joint, based on an outline established by the International Association for the Study of Pain and others (8-14). Application of medial branch neurotomy is an effective method for intervention of zygapophysial joint pain despite having a limitation with the treatment time (5,6,11-13,15-22). Pain mediated by the medial branch of the lumbar or cervical dorsal ramus is reduced or relieved by coagulating the

nerve to prevent the conduction of nociceptive impulses (17). Subsequently, the nerves can re-develop and the intervention procedure can be repeated (15). It is hypothesized that the relief effect of pains originating from zygapophysial joints and its duration is proportional to the length of the nerve coagulated. Therefore, it is plausible to heat a wide volume of tissue to increase the duration of relief and minimize technical failure due to incomplete coagulation (15,16,23).

For successful nerve coagulation, several aspects need to be considered. For instance, the electrode does not consistently coagulate in a distal direction therefore placing the electrode parallel to the nerve is required to increase the potential for effective coagulation (17). In some instances, multiple lesions are required for sufficient nerve coagulation (17,24,25). The size of the lesion is also known to be proportional to the electrode diameter, so a wider electrode is often used to increase the radius of the coagulating area (10,17,18). This, however, can increase trauma and pain during the insertion process, because the heat is distributed in both directions of the traverse and vertical target nerves, and may cause unnecessary tissue damage. To prevent such a consequence, a lesion parallel to the transverse process (avoiding vertical direction) is often made for effective tissue coagulation.

Alternative methods for the coagulation process are also available such as 2 electrodes simultaneously placed parallel to one another and parallel to the probable area the target nerve is known to traverse. We have previously tested the efficacy of a 2 electrodes technique compared to a one electrode technique (26). Several studies measured the extent of heat dissipation using different media such as egg white, liver and meat (26,27). However, the exact extent of the heated area is difficult to measure visually since these media in vitro have different physical characteristics and conductivity (27). The heat generated spreads differently according to the media and thus distinguishing the coagulated media tissue could be subjective. For example, egg white has been used for the measurement of the heat dissipation, but due to the inconsistent texture of egg white, exact determination of the heat dissipation is difficult.

So far, the reported studies were not tested in human tissue that is comprised of nerves surrounded by bones and ligaments. In order to improve precision in human tissue in clinical treatment, our study investigates the degree and feasibility of nerve coagulation using a a 2 electrodes technique on cadaver interspinous ligament tissue. Lumbar interspinous ligament tissue is surrounded by bone and ligament and is similar to the structure of the medial branch of the the dorsal ramus traverse. We measured the midpoint temperature between the 2 electrodes where incomplete coagulation could occur, the extent of heating using 2 electrodes placed parallel at variable distances from one another, and the degree of tissue coagulation when radiofrequency lesion is made either sequentially or simultaneously.

Methods

Cadaver Interspinous Ligament Measurement

Fresh human cadaver interspinous ligament tissue was selected in this study since the medial branch of the dorsal ramus is difficult to identify and the traverse area is often hidden deep inside the back that is surrounded by bulky muscles and ligaments. The lumbar interspinous ligament was surgically taken and placed in freezer bags for storage at -20°C. The samples were thawed at room temperature 24 hours prior to the study. To the thawed samples 2 rhizotomy electrodes were placed at the covered side of the ligament, so that the electrode end appeared from the open side of the ligaments. A commercially available 20-gauge Teflon coated electrode with 10 mm exposed tip and its companion electrodes were used in this study. The electrodes were connected to the Smith & Nephew® rhizotomy device (Smith & Nephew: 20S Electrothermal® Spine system, Andover, MA, USA).

In the sequential lesion process, the first electrode was positioned perpendicular to the cross section of the spinous process and the second electrode was placed parallel and one mm apart. The first electrode was heated at 80°C for 90 seconds and a resting interval of approximately 60 – 120 seconds was given before the second electrode was heated at 80°C for 90 seconds to minimize the remnant heat effect. Lesion was performed prior to each heating. This process was repeated by placing the electrode 2, 3, 4, 5, 6, 7, 8 and 9 mm apart between the 2 electrodes (Fig. 1).

In the simultaneous lesion process, under the setting described in the sequential process, both electrodes were concurrently heated at 80°C for 90 seconds. After each heating, the size of the coagulated areas was measured visually for both the sequential and simultaneous lesion process (Fig. 1). The white area of the lesion tissue is noted as complete coagulation and pink area as incomplete coagulation. The temperatures of the examined area were also taken.

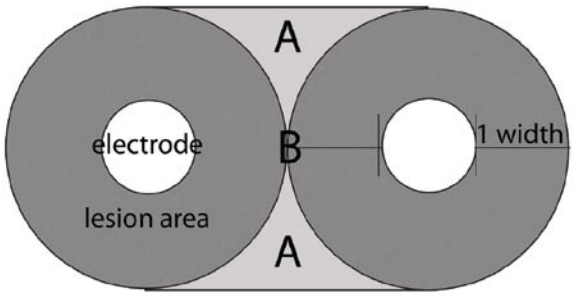


Fig. 1. *Cross-section lay out of the needle placement. Annotations indicate incomplete coagulation or escaped lesion (A) and midpoint of the electrode tip (B).*

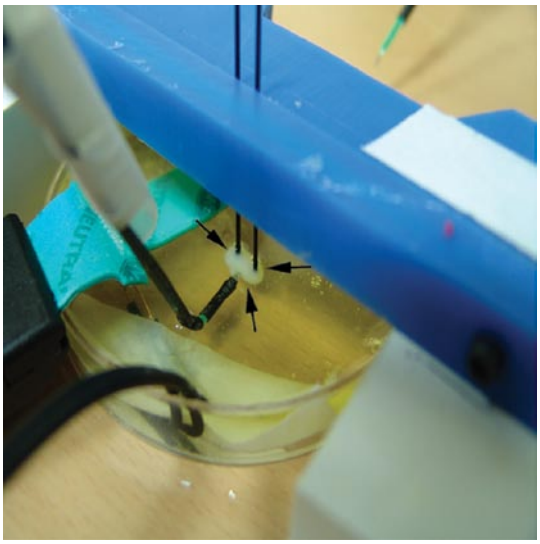


Fig. 2. *Heating of an egg white using 2 electrodes simultaneous lesion. Opaqueness of egg white lesion with continuous strip between the two electrodes was observed. No escaped lesion area was seen (black solid arrows). At the escaped lesion area, the temperatures were monitored with a Radionics® needle temperature sensor.*

Egg White Measurement

Fresh egg white tissue samples were taken and electrodes were placed 1, 2, 3, 4, 5, 6, and 7 mm apart respectively (Figs. 1 & 2). Using the micro-stage device, the electrode tip was fixed at a set distance (Fig. 2). Caution was taken as placing the electrode too far apart may cause escaped tissue lesion because of the circular cross-section of the lesion (10). The tissue temperature at the escaped lesion area (A in Fig. 1) was measured with a Radionics® needle temperature sensor (TCA-2, Radionics Inc. Burlington, MA, USA). The escaped lesion area is identified when 2 needles are heated and the tissue area at the outer margin of the midpoint is not completely coagulated.

The needle temperature sensor was fixed at the escaped lesion area while the distance between 2 electrodes was changed. The samples were heated either sequentially or simultaneously using the same protocol mentioned above and the temperature at the escaped lesion areas was also recorded. The temperature at a given distance was taken 5 times for the electrodes placed 1 to 6 mm apart and once at 7 mm (total 31 times) for quantitative analysis. This was applied for both the simultaneous and sequential lesions.

Results

Cadaver Interspinous Ligament

Sequential Lesion Process

The room temperature and interspinous ligament tissue starting temperature were 23 °C. Our study showed that electrodes placed 1 mm and 2 mm apart between the 2 electrodes completely coagulated the tissue and no escaping of the tissue lesion was found (Fig. 3A). When 2 electrodes were inserted 3 mm apart or greater and heated in succession, some tissue at the outer margin of the midpoint was not fully coagulated particularly in the escaped lesion area (Fig. 3B).

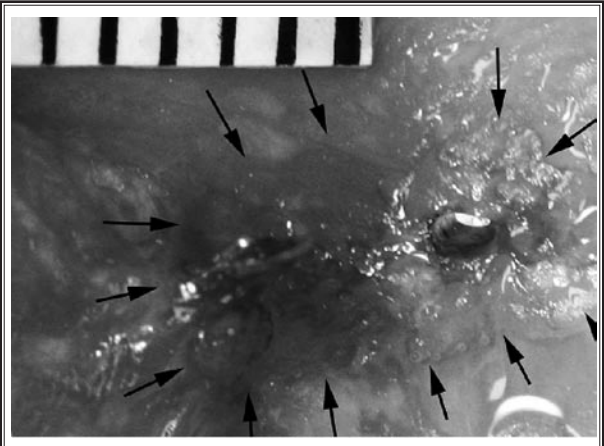
Simultaneous Lesion Process

Our results showed that heating 2 electrodes simultaneously created more extensive lesions of the tissue than those of the sequential lesion process. The tissue was completely coagulated in all samples when the electrodes were placed 1, 2, 3 and 4 mm apart (Fig. 3C) but not so when placed 5, 6, and 7 mm apart where some tissue at the outer margins of the midpoint were not fully coagulated.

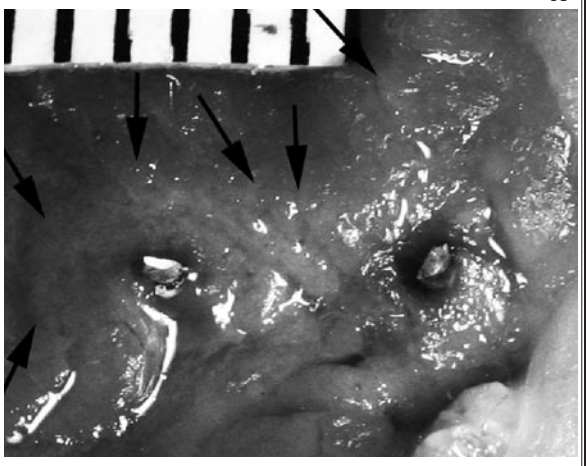
Egg White

Sequential Lesion Process

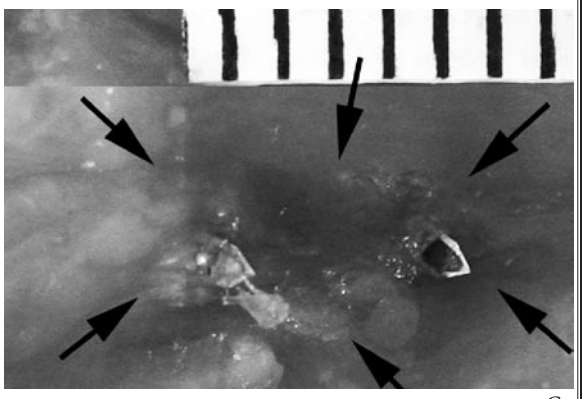
Temperature readings of the escaped lesion area (Fig. 1) for each distance are presented in Figure 4. As the distance increased, the temperature of the escaped



A



B



C.

Fig. 3. *Sequential and simultaneous lesion of interspinous ligament. A. Complete lesion was observed up to 2 mm apart in sequential and simultaneous lesion. The tissue between the 2 electrodes, including escaped lesion, was fully coagulated (black solid arrows). B. Sequential lesion at 4 mm apart in interspinous ligament: incomplete lesion became visible at the escaped lesion area from 3 mm apart. C. Simultaneous lesion at 4 mm apart in the interspinous ligament: complete coagulation of the interspinous tissue including escaped lesion was observed up to 4 mm apart.*

lesion decreased for both the simultaneous and the sequential lesion process. The room temperature and egg white starting temperature were 23 °C. We assigned 50 °C as the limiting temperature as it is suggested that tissue damage occurs above this temperature (22, 23). Temperatures of the escaped lesion were above 50 °C when the 2 electrodes were place 1, 2, and 3 mm apart. From 4, 5, 6 and 7 mm distance apart, the temperature at the escaped lesion was below 50 °C (Fig. 4). The tissue between the 2 electrodes set at 1, 2, 3, and 4 mm apart showed complete coagulation and continuous strip lesion was found at 3 and 4 mm apart.

Simultaneous Lesion Process

The escaped lesion was more than 50° C when the electrodes were set at 1, 2, 3, 4, and 5 mm distance apart. The temperature was below 50 °C when the distance was set at 5, 6, and 7 mm. The tissue between the 2 electrodes was coagulated and continuous strip lesion was observed when the 2 electrodes were set at 1, 2, 3, 4, 5 and 6 mm distance (Figs. 4 & 5).

Discussion

In this study we showed the extent of heating using 2 electrodes placed parallel at variable distances from one another and compared the extent of coagulation when the lesion was made either sequentially or simultaneously. It was shown that simultaneous heating of 2 parallel electrodes was faster and more effective in incorporating a larger volume of coagulated tissue.

Several studies attempted to find the ideal model that has similar characteristics to human tissue where medial branch of the dorsal ramus nerve traverses. We used pig tissue in our previous study while others tried egg white, meat, and liver (27,28). These tissues however have diverse physical characteristics, heat conductivity and distribution (28). Interspinous ligament tissue found around bone is easy to access and was an ideal media for the current study. In pig tissue, the heat dissipated around the electrodes in a circular motion and a similar observation was found for the interspinous tissue.

Measuring temperature at an escaped lesion site is important for definite coagulation where previous research showed temperatures above 45°C to 50°C for 20s or more on tissues damaged cell structures and biomolecules. Our temperature measurements showed electrodes set 5 mm apart in the simultaneous lesion and 3 mm apart in the sequential lesion were ideal for securing the coagulation.

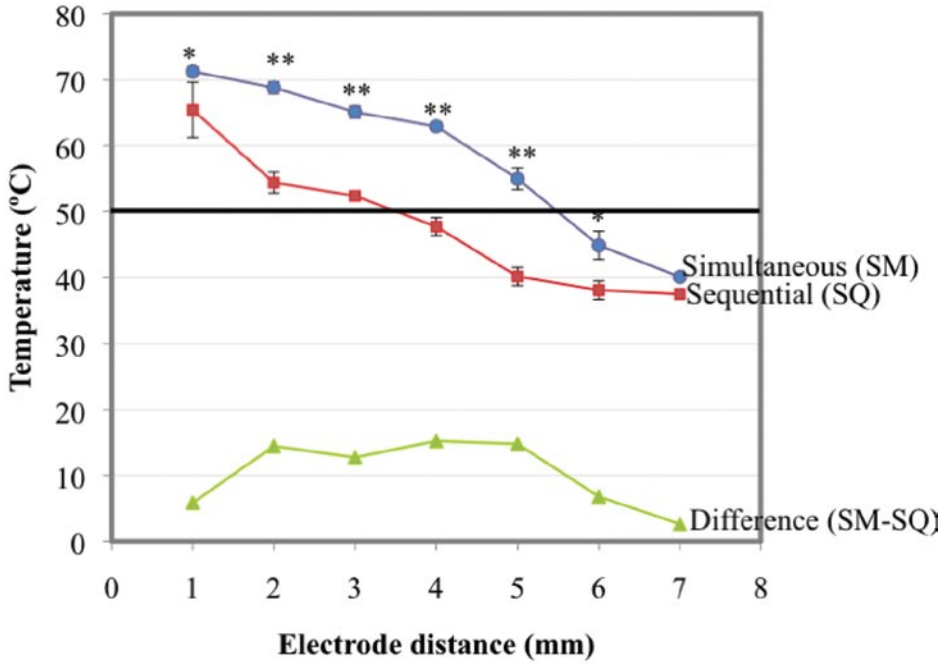


Fig. 4. *Mean temperature change at escaped lesion area in egg white with increasing electrode distance. *P < 0.05 and **P < 0.01 between sequential and simultaneous process at respective distance.*

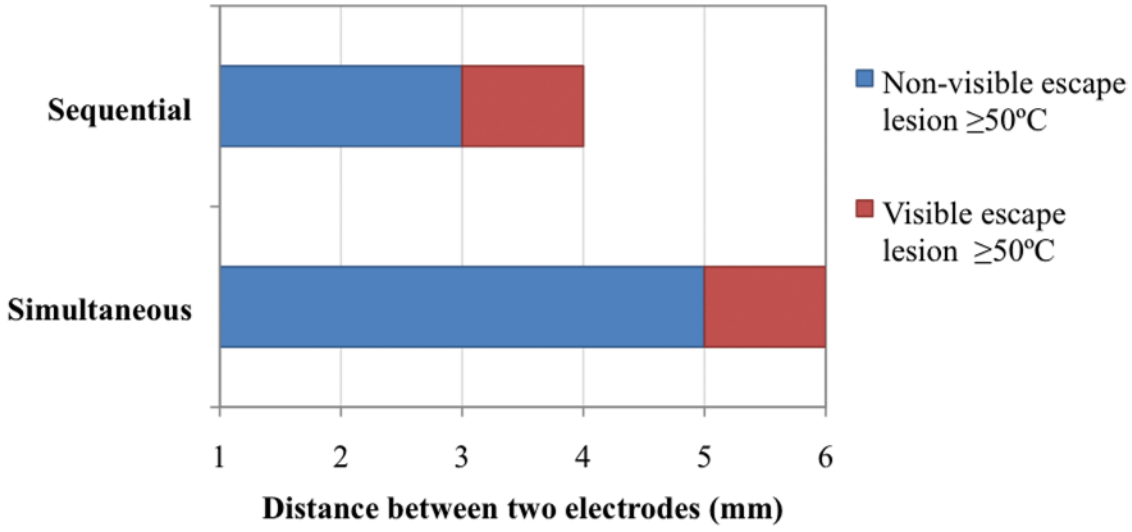


Fig. 5. *Association between visible coagulation of caderveric interspinous tissue and temperature change of escaped lesion area of egg white.*

We observed that 2 electrodes under a simultaneous process could coagulate a wider lesion area without increasing tissue trauma vertically i.e. vertical to the transverse process direction where the 2 electrodes lie. Larger diameter electrodes can distribute heat to larger tissue areas, but have the disadvantage of increasing tissue trauma, and perhaps unnecessary heating in the vertical to the transverse process direction. Another optimal method to coagulate tissue is to perform multiple lesions using side-by-side placement of 2 electrodes. Regardless of the method or technique, if the coagulated tissue area between the 2 lesions does not completely overlap, nerve tissue within this area may not coagulate. Subsequently, even if a lesion is made close to the nerve and if the electrodes are placed too far apart, intervening volumes of tissue may escape coagulation due to the circular and cross-sectional configuration of the lesion area (25).

In practice, when the 2 electrodes are placed parallel to one another at an optimal distance successful coagulation of the intervening tissue could be made and it is also advantageous if the heating parameters are identified. Although previous studies determined that definite coagulation (97.5% confidence level) could occur only when the distance between the first insertion and the second is less than one mm (17), we achieved complete coagulation using two 20 gauge electrodes up to 2 mm apart. When the electrodes were simultaneously heated, the electrode could be placed up to 4 mm apart and the outcome is reliable even when heated from both directions. Moreover, to compensate for potential nerve tissue is damage above 50°C, the electrodes can be placed up to 3 mm apart with sequential lesioning and up to 5 mm apart with simultaneous lesioning. These finding were consistently observed in a series of studies with pig tissue, human interspinous ligament tissue and quantitative study using egg white. Interestingly, in this investigation, using simultaneous lesioning, the 2 electrodes could be placed up to 5 mm apart and still achieve complete coagulation in a very short time without any escaped lesion area.

The limitations of this study include cadaveric experimentation and use of intraspinous ligament rather than medial branch of the dorsal ramus which is difficult to identify.

Conclusion

This study provides data confirming the experimental efficacy of utilizing 2 electrodes technique for medial branch neurotomies in a human cadaver interspinous ligament model. By measuring the temperatures at the escaped lesion area between 2 electrodes, a quantitative and optimal lethal temperature ranges could be acquired.

Parallel simultaneous placement and sequential lesioning of 2 electrodes coagulated a wider area of tissue more accurately then previous studies using only a single electrode. More importantly, simultaneously heating of 2 parallel electrodes was the fastest and most effective method for incorporating a larger volume of coagulated tissue. Although this technique is not currently used clinically, hypothetically, better outcomes could be achieved with this technique compared to other methods.

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