Ex Vivo Comparision of Lesions Created with Cooled Radiofrequency and Protruding Electrode Radiofrequency Probes

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Ex Vivo Comparison of Lesions Created with Cooled Radiofrequency and Protruding Electrode Radiofrequency Probes

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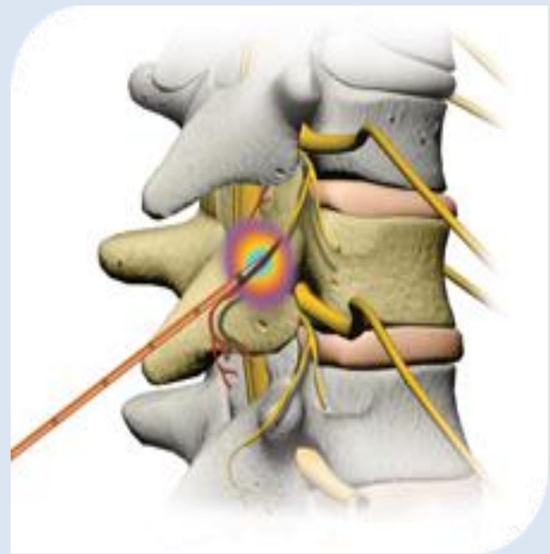
Introduction

Radiofrequency (RF) ablation of nerves is a minimally invasive alternative for the treatment of chronic pain conditions such as facet joint pain, sacroiliac joint pain, discogenic pain and knee pain among others. Positioning of the RF probe and size of the ablation lesion produced are critical factors for the success of the treatment.

Traditionally, RF has been applied using monopolar electrodes that are set to generate lesioning temperatures of 80 °C for 90 seconds. Size of lesion is limited to small volume around the active tip of the RF probe. Alternative designs have been developed to increase the volume of lesion. These include bipolar arrangements, a cooled active tip and a protruding electrode design.

Despite the proven clinical efficiency of RF ablation, there is room for improvement in terms of creating lesion sizes that provide optimum overlap with the affected nerve, while utilizing proper positioning of the probe and minimal effect on surrounding structures. Previous work in our group compared lesion sizes produced by cooled tip RF and bipolar RF (Vallejo et al. *Reg. Anesth. Pain Med.* 2014; 39:312-21).

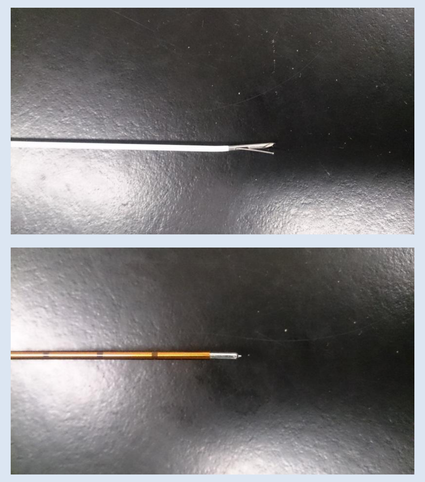
Objective: Here we compare radiofrequency (RF) lesion volumes and shapes produced in an *ex vivo* tissue model by cooled tip RF and protruding electrode RF using commercially available setups.

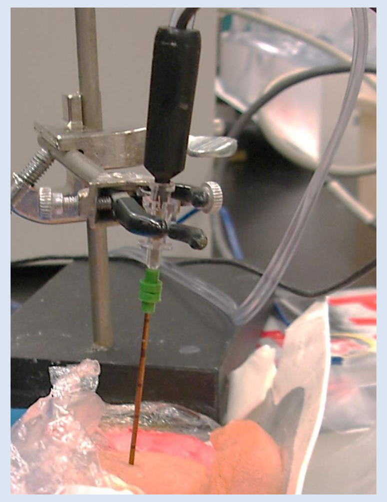


Images courtesy of Kimberly Clark

Materials and Methods

Two systems capable of producing therapeutic lesions were compared in this study. One is based on cooled tip radiofrequency ablation (RFA) (Cooled RF, Kimberly-Clark Corporation, Roswell, GA) and the other one is based on a protruding electrode design (Venom®, Stryker, Kalamazoo. MI). Cooled RFA was performed using a 17 g, cooled tip electrode (4 mm active tip) at 60°C for 150 s via a PMG-115-TD RF generator (Kimberly Clark). In the protruding electrode RFA system, a cannula of 18 g (1.27 mm outer diameter) or of 20 g (0.91 mm outer diameter), each with a 10 mm active tip, was used with a 100 mm electrode to heat at 80°C for 90 s via a Multigen RF generator (Stryker). Lesions were produced in additive-free chicken breast. Measurements of maximum longitudinal, transverse, and depth lesion dimensions were made in each of ten experiments, and were used to calculate lesion volumes. A one-way ANOVA followed by a Holm-Sidak post-hoc test was used to compare average lesion volumes created by cooled RFA and each of the protruding electrode RFA probes. Significant differences were indicated by $p \leq 0.05$. Imaging sequences of lesions produced by each RFA system were obtained using an infrared (IR) camera (i3, FliR Systems, Wilsonville, OR) simultaneously with a visible camera (Cybershot, Sony).





Cross-section of RF lesion caused using a protruding electrode (18 g) at 80 °C for 90 s.

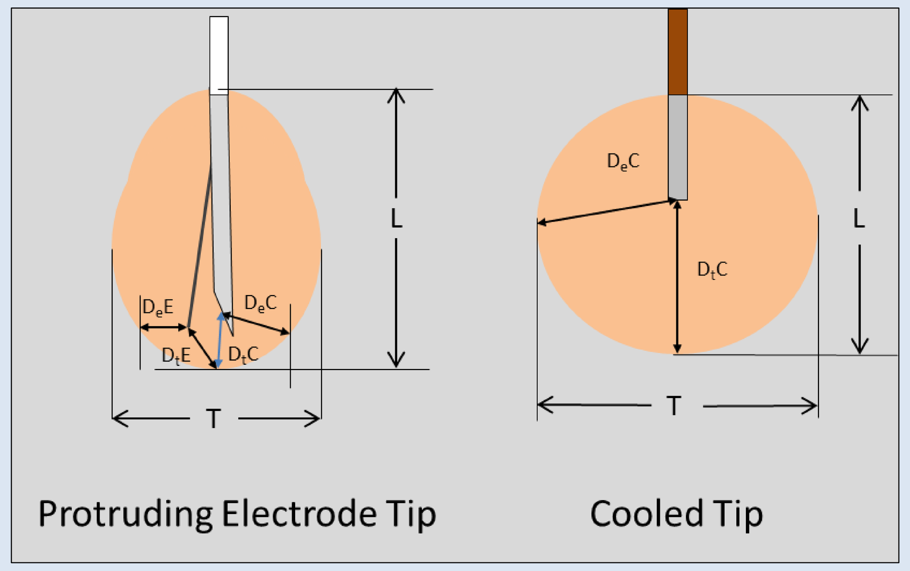
Cross-section of RF lesion caused using a cooled tip at 60 °C for 150 s.

Results

- Mean lesion volume made using cooled RFA was 2.8 times larger than that produced using protruding electrode RFA with an 18 g, 10 mm tip, and 3.4 times larger than that produced with the 20 g, 10 mm tip ($p < 0.001$; Cooled RF vs. each protruding electrode cannula).
- Length of lesion that projects distal to the tip during cooled RFA is 2.3 and 2.6 times larger than those obtained with protruding electrode with 18 g and 20 g cannula respectively.
- For protruding electrode system: an increase in tip diameter from 20 g to 18 g increased lesion volume without statistical significance ($p = 0.324$).
  - Mean transverse lesion length was 0.5 mm longer when using the 18 g cannula, while the mean lesion depth was 0.7 mm longer.
- Cooled RF lesion propagates quasi-spherical lesions with time, while lesions produced by the protruding electrode system are ovoid.
- Protruding electrode design seems to generate heat initially at two "points", which propagates between these two points, similar to a bipolar mode.
- IR images indicate that visual lesions made by the protruding electrode system are formed as early as 13 s into the lesioning period along the longitudinal direction. Additional lesioning time allows for lesion propagation along the transversal and depth directions.
- Lesions produced using a cooled tip probe propagates quasi-spherically with time and are more symmetrical than those obtained with the protruding electrode probe.

Mean lengths (in mm) and Calculated Volume (V, in mm³) of lesions. Standard deviations are indicated in parenthesis (n = 10 for each group).

Method	T	L	D	D_eE	D_eC	D_tE	D_tC	V
Cooled Tip RF (60 °C, 150 s)	11.2 (1.0)	10.7 (1.3)	9.5 (0.8)	---	4.9 (0.6)	---	4.2 (0.9)	595 (112)
Protruding Tip RF 18g (80 °C, 90 s)	6.9 (0.6)	11.7 (0.8)	5.1 (0.6)	1.9 (0.2)	2.5 (0.4)	1.8 (0.3)	1.7 (0.3)	215 (36)
Protruding Tip RF 20g (80 °C, 90 s)	6.4 (1.7)	11.6 (1.1)	4.4 (0.8)	2.1 (0.2)	2.3 (0.3)	1.5 (0.3)	1.6 (0.4)	177 (82)



Protruding Electrode Tip Cooled Tip

$$V = \frac{\pi}{6}(T \times L \times D)$$

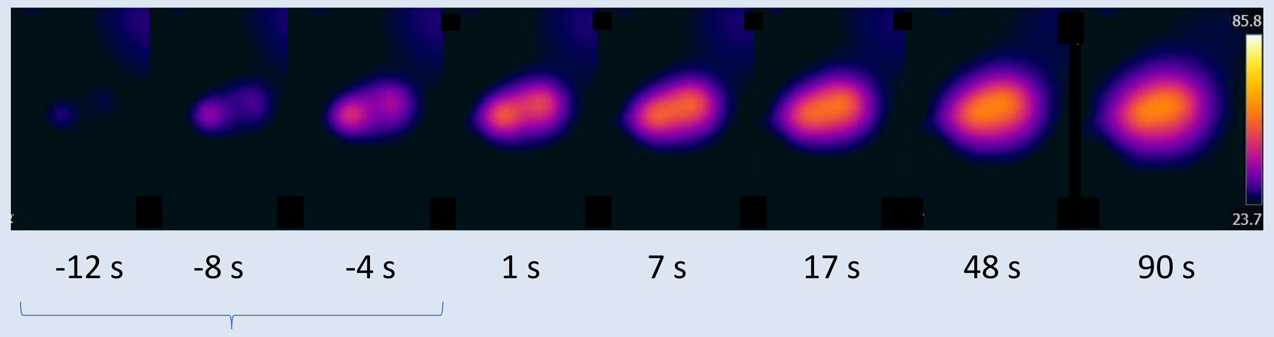
T: Transversal Length

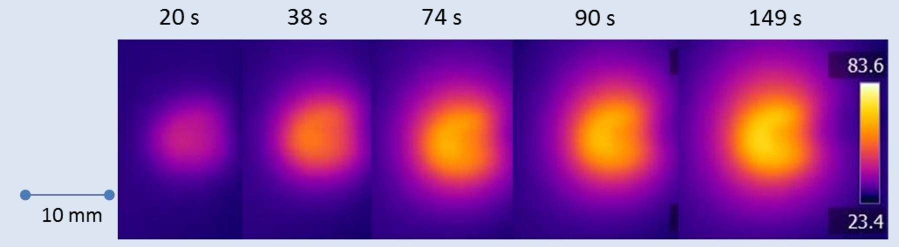
L: Longitudinal Length

D: Depth

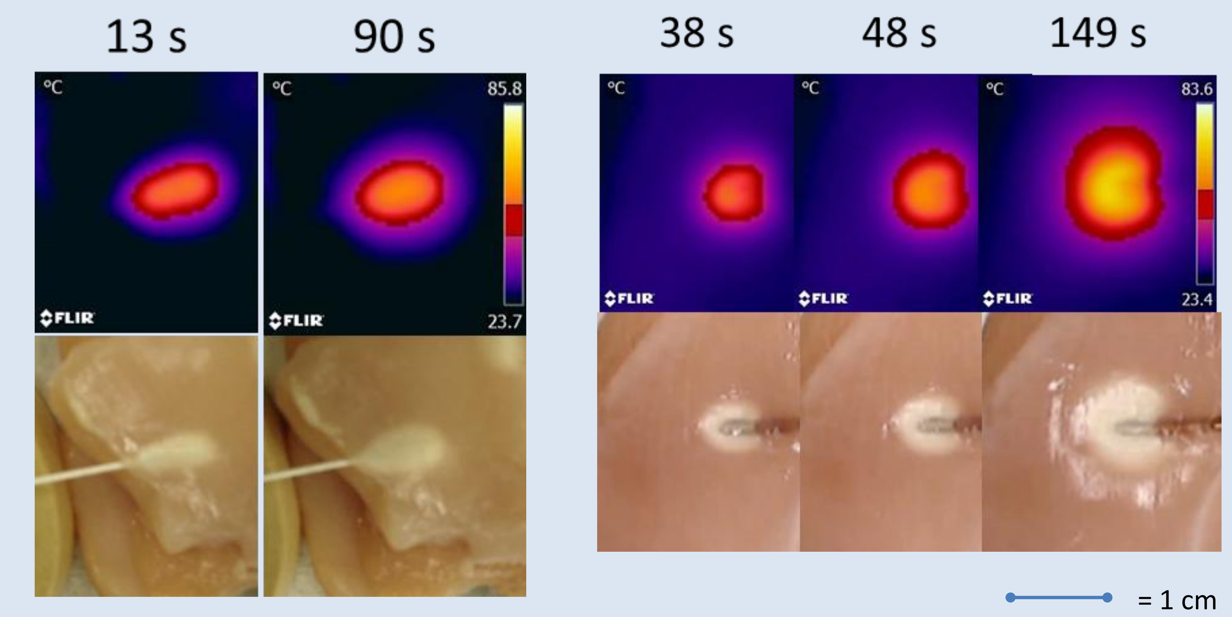
D_i = Distal lenghts to tip

Thermal imaging sequence of lesion evolution from RF ablation using a protruding electrode (top) and cooled tip (bottom)





Comparison of Thermal and Visible Imaging



Red zone indicates temperature range between 45 and 55 °C.

Discussion and Conclusions

- Results of experiments under parameters that resemble those commercially available indicate that the spherically-shaped ablative lesions produced by cooled RF are larger than the ovoid ablative lesions produced by the protruding electrode systems.
- Experiments did not include a study of the effect of tip dimensions (i.e. diameter and length), lesioning time and temperature on lesion size.
- Despite these limitations, it is inferred that larger lesions such as those obtained by cooled RF may increase the probability that a target nerve is captured in the volume of tissue that is heated to neuroablative temperatures.
- This may be beneficial when treating target anatomy with known nerve path complexity and variability such as sacral lateral branches, thoracic and cervical medial branches and the articular sensory branches of the knee and hip joints.
- Cooled RF provides larger distal lesion projection when compared to other systems, which may be an advantage when considering perpendicular approach to the target nerve.
- Larger size and distal projection obtained with cooled RFA may better accommodate any imprecise probe placements made by physicians, because larger lesions predictably have bigger compensatory probe placement error ranges than other systems.

Acknowledgements

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