Soft-Tissue Characterization during Monopolar Electrocautery Procedures

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Background/Problem

Advances in electrosurgical technology have promoted the use of electrocautery in many surgical procedures. Precise modeling of soft tissue deformation during electrocautery with electrosurgical generators can be a valuable tool in training simulators for surgical procedures. Coupling the visualization of electrocautery with the force feedback during an electrocautery process (to maintain optimal current) without causing necrosis is an important learning tool. Realistic simulation will provide surgeon trainees a method to practice electrocautery techniques prior to experimenting on live tissue as well as allow surgeons to gain a feel for electrocautery procedures.

Tools and Methods

The equipment used in the preliminary study of soft tissue electrocautery consists of a one-degree-of freedom device moving only in the horizontal direction (Figure 1) to which an electrosurgical pencil is attached. The setup provides a platform for obtaining the forces imparted on the surgical tool during electrocautery of soft tissue. The device consists of a Maxon motor coupled to a lead screw assembly which provides the accurate, controlled motion of the electrocautery tool through a range of 200 cm at speeds ranging from 0 to 3.81 cm/s [1]. The electrosurgical pencil is attached to a JR3 precision 6-axis force sensor that relays the force and torque data with a resolution of 0.002 N and 0.000025 Nm respectively.

Modern electrosurgical generators provide a vast array of operating modes, each having applications in various types of procedures. The current study will be limited to monopolar electrocautery process in which the cutting power, current profile and cutting speed will be varied. Each variation will be tested individually to determine the specific changes induced during electrocautery. Preliminary tests on pig liver have been completed in which each cut was performed with a speed of 0.1 cm/s with a total length of 6.35 cm. The variation between trials was an adjustment in the cutting power on the electrosurgical generator. Tests were completed while no cutting occurred and at cutting powers of 7, 10, 13, 14, and 16 watts.

Results

The quality of the cut made by an electrosurgical generator depends on the type of electrocautery tool attached, the speed of the cut, the depth of the cut, the tissue properties, the cutting mode used, and the power setting on the generator itself. In this experiment all of these parameters were held constant throughout the trials with the exception of depth of cut and the power setting. The piece of liver used during the trials was selected due to the relatively uniform profile in attempt to minimize the effects that would arise due to different cut depths. The major variable between electrocautery trials was the power setting on the electrosurgical generator.

The force profiles collected for each power setting can be seen in Figure 2. For lower power settings the electrocautery tool operated in a similar manner to a surgical scalpel, i.e. as the electrocautery tool traverses, it builds up forces as the tissue deforms until the point at which the tissue begins to rupture and the tool cuts the liver [1]. This process repeats throughout the entirety of the cut, increasing in magnitude with the depth of the cut. When a sufficient amount of power is supplied to the electrocautery tool the forces imparted on the electrosurgical pencil show a dramatically different profile. In these cases (14 watts and above) there is a slight resistance on the electrocautery blade as it enters the tissue, however, after this point the resistance drops off and very little force is imparted on the tool, regardless of the depth of the electrocautery blade.

Conclusion/Discussion

The data obtained from this experiment validates that unique force profiles can be obtained by altering one parameter at a time between cuts. A new magnetic resonance imaging (MRI) compatible setup is currently being constructed that will allow the experiment to take place in an active 3-T Siemens Magnetron Trio MRI. This will provide two vital advantages. First, it will allow for imaging of the electrocautery blade depth which can be used to normalize the reaction force reducing the error due to variations in the tissue profile. Additionally, the imaging will allow for the use of implanted beads which will provide further information about how the tissue interacts and deforms during the electrocautery process. The beads will also be used to verify any mathematical models that are developed to predict the soft tissue response during electrocautery. Completion of the electrocautery tests within the MRI will provide a foundation for the design and construction of an accurate surgical simulator containing haptic feedback.

References

[1] T. Chanthasopeephan, J. P. Desai, and A. Lau, "Modeling Soft-Tissue Deformation Prior to Cutting for Surgical Simulation: Finite Element Analysis and Study of Cutting Parameters," *IEEE Trans. Bio. Eng,* vol. 54, no. 4, April 2007.

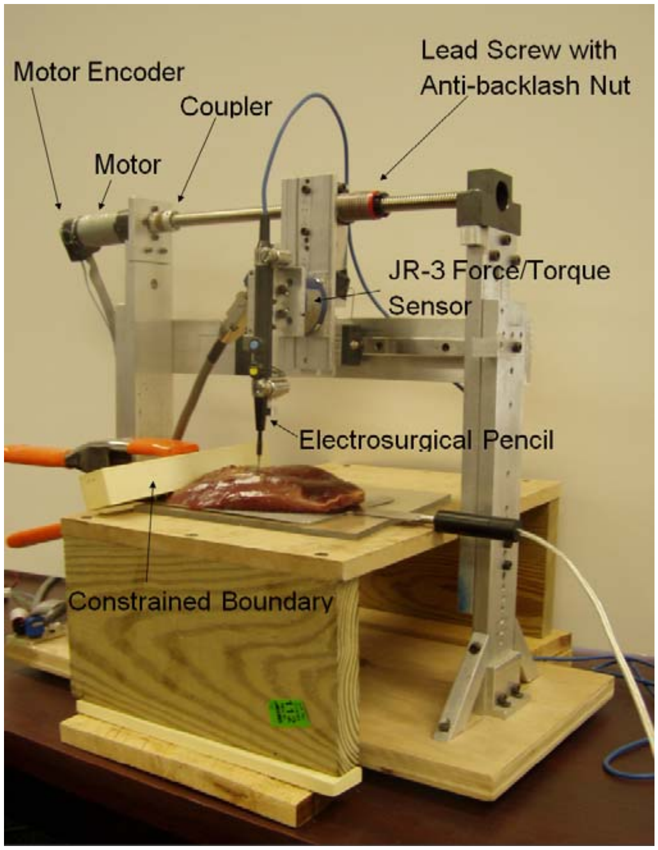

Figure 1: Experimental setup for measuring cutting forces.

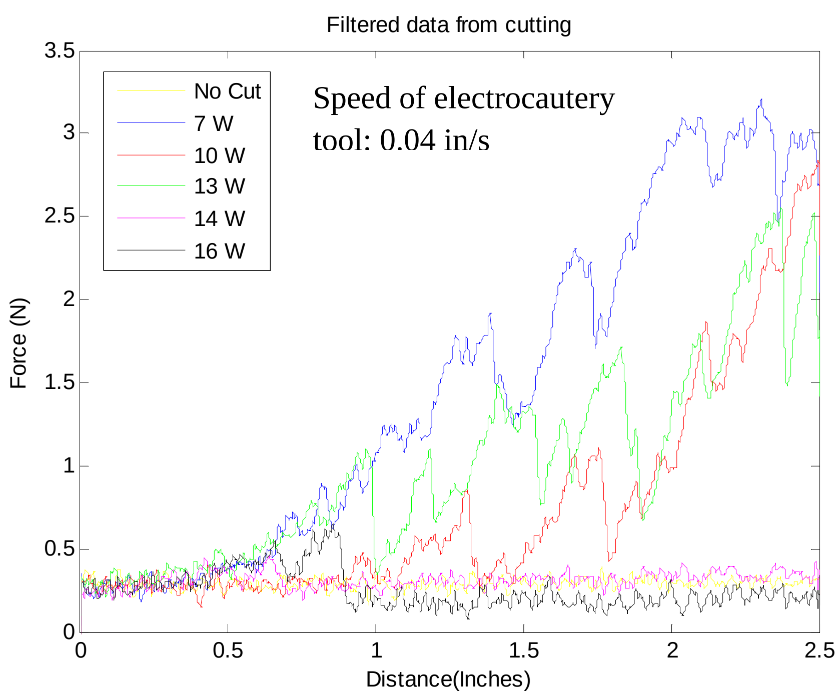

Figure 2: Cutting Force versus Distance profile for various power levels.