Tissue Joining Using Energy Based Surgical Instruments

Research Assistants:
M. Chastagner

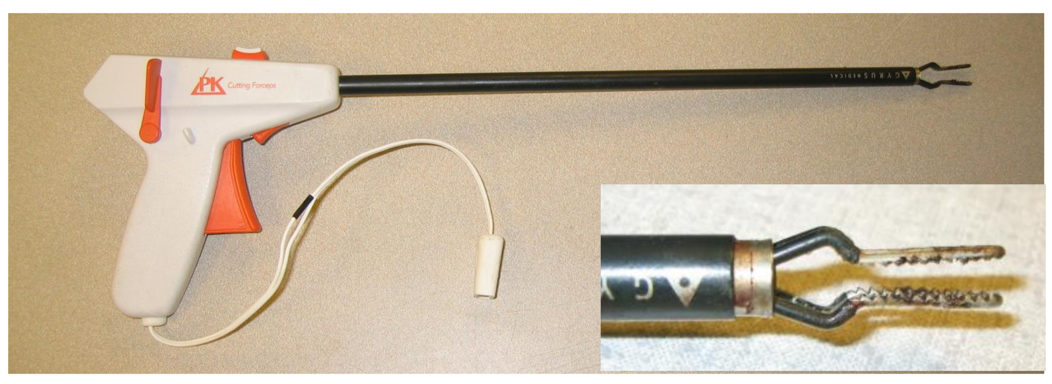
Faculty:
A. Shih

Motivation

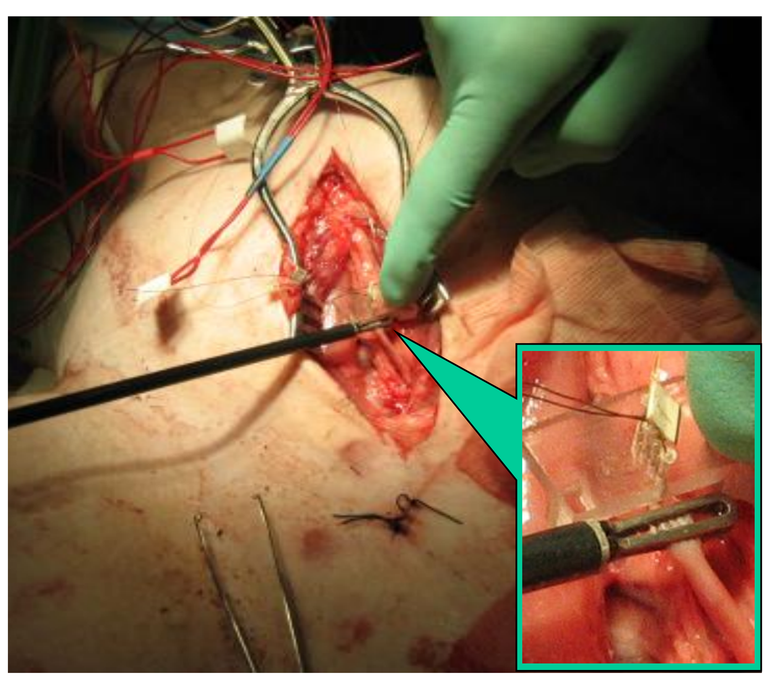
- Almost every time a patient visits the operating room, a cut or wound is made in the tissue during surgery.
- In order for proper patient healing to occur, it is necessary to join the wound back together after the operation with minimal tissue damage.
- With the development of newer minimally invasive surgical (MIS) procedures, the amount of external wound closures has been reduced, however, the need to join tissue during surgery still exists.
- A significant revenue potential exists for the development of a tissue joining process that provides:
  - Minimal tissue damage,
  - Is easy to implement, and
  - Reduces both operating time and patient recovery time.

Objectives

- Develop, compare and test novel methods for tissue joining and anastomosis.
- This will be done through the use of:
  - Experimental analysis of porcine tissue temperature during bipolar, ultrasonic and laser vessel sealing.
  - Creation of a Finite Element Analysis (FEA) model that represents the tissue behavior during each of these joining process.



Bipolar Electrosurgical Instrument with Close Up view of Electrode Tip.



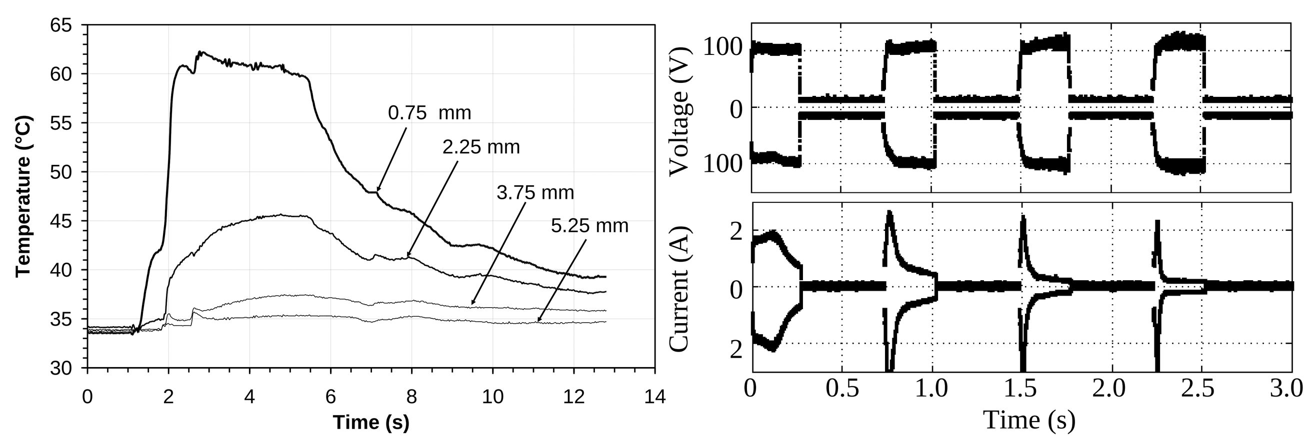
Porcine Animal Model Used for Bipolar Experiment and Close Up View of Experimental Setup to Measure Temperature and Quality of Vessel Seal.

Experimental Results

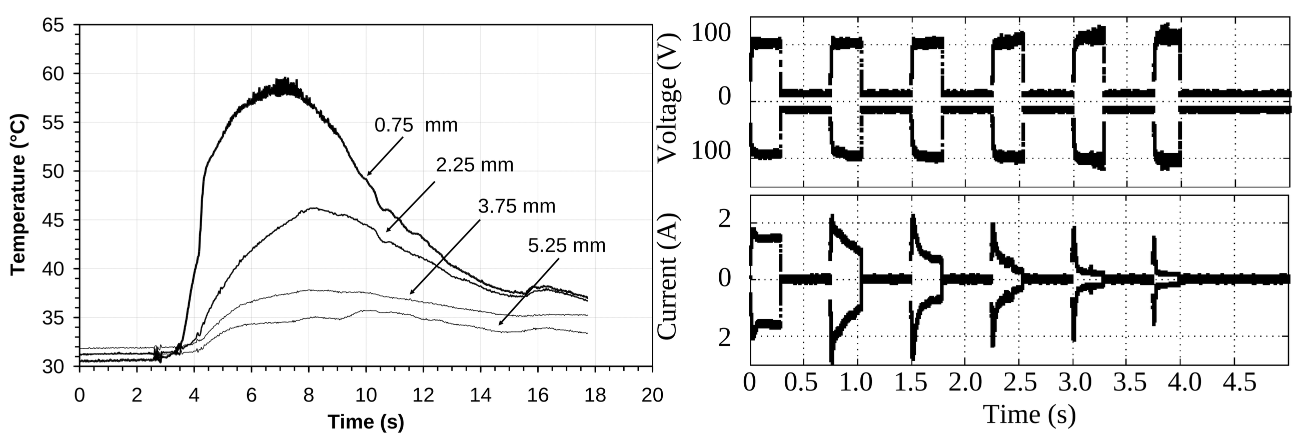
- Initial vessel sealing experiments were conducted using a bipolar electrosurgical device to gain an understanding of the thermal effects during sealing:
  - Experiment I - The sealing of a 4 mm femoral artery was attempted with the 5 mm bipolar device.
  - Experiment II – The sealing of a 8 mm jugular vein was attempted following the same procedure as experiment I.

In-vivo trials

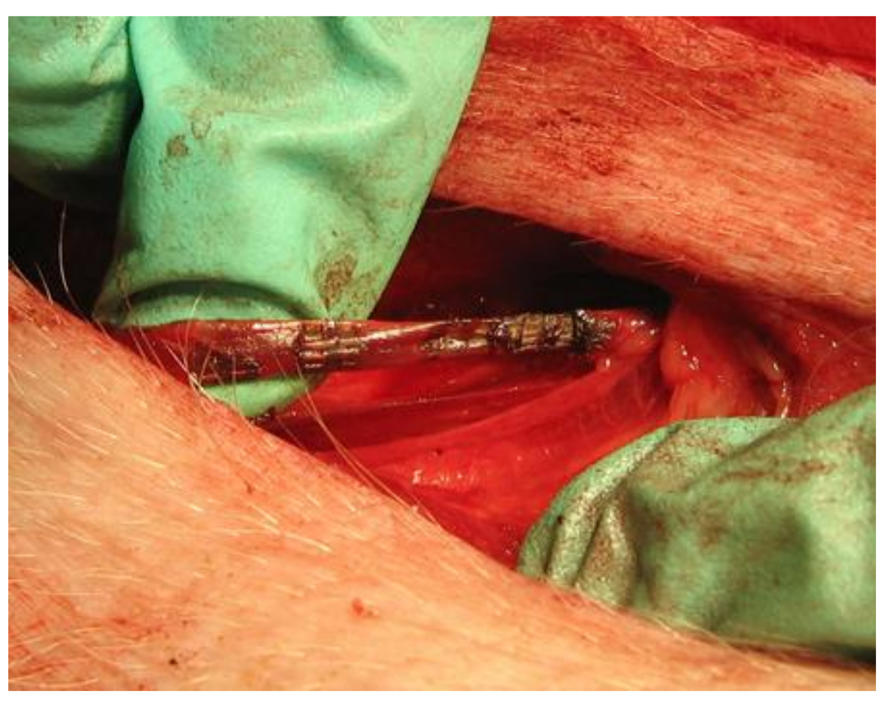
4 mm Femoral Artery



8 mm Femoral Artery



(Left) Temperature Plots During the Vessel Sealing Experiment and (Right) Plot of Electrical Current and Voltage Obtained During Vessel Sealing. (Numerical Values Represent the Location of the Thermistors Relative to the Electrode Edge).



A 4 mm Porcine Femoral Artery Sealed Using a 5 mm Bipolar Electrosurgical Instrument.

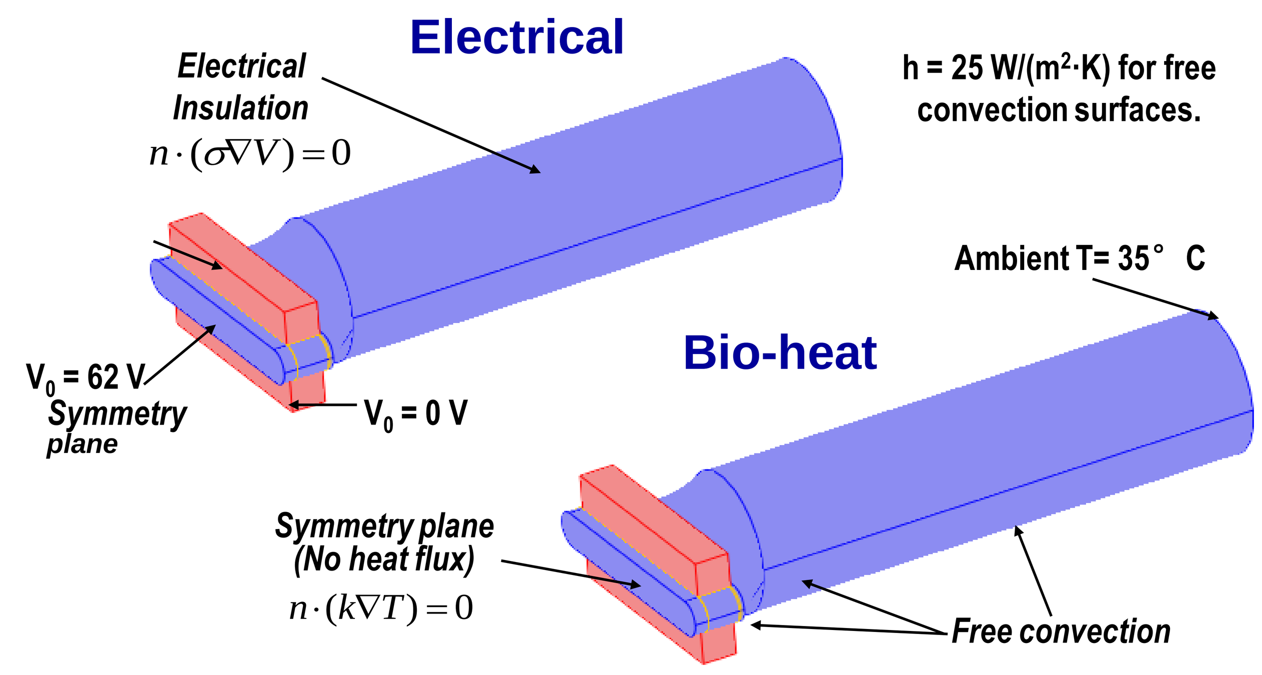
Modeling Results

A mathematical model coupling electrical resistive heating and tissue temperature was developed utilizing thermally dependent conductivities. Heat transfer and electrical equations used in the modeling are, respectively:

$$\rho c \frac{\partial T}{\partial t} = k\nabla^2 T + W_b C_b (T - T_a) + q_m + q_g$$

$$\nabla[\sigma(T)\nabla V] = 0$$

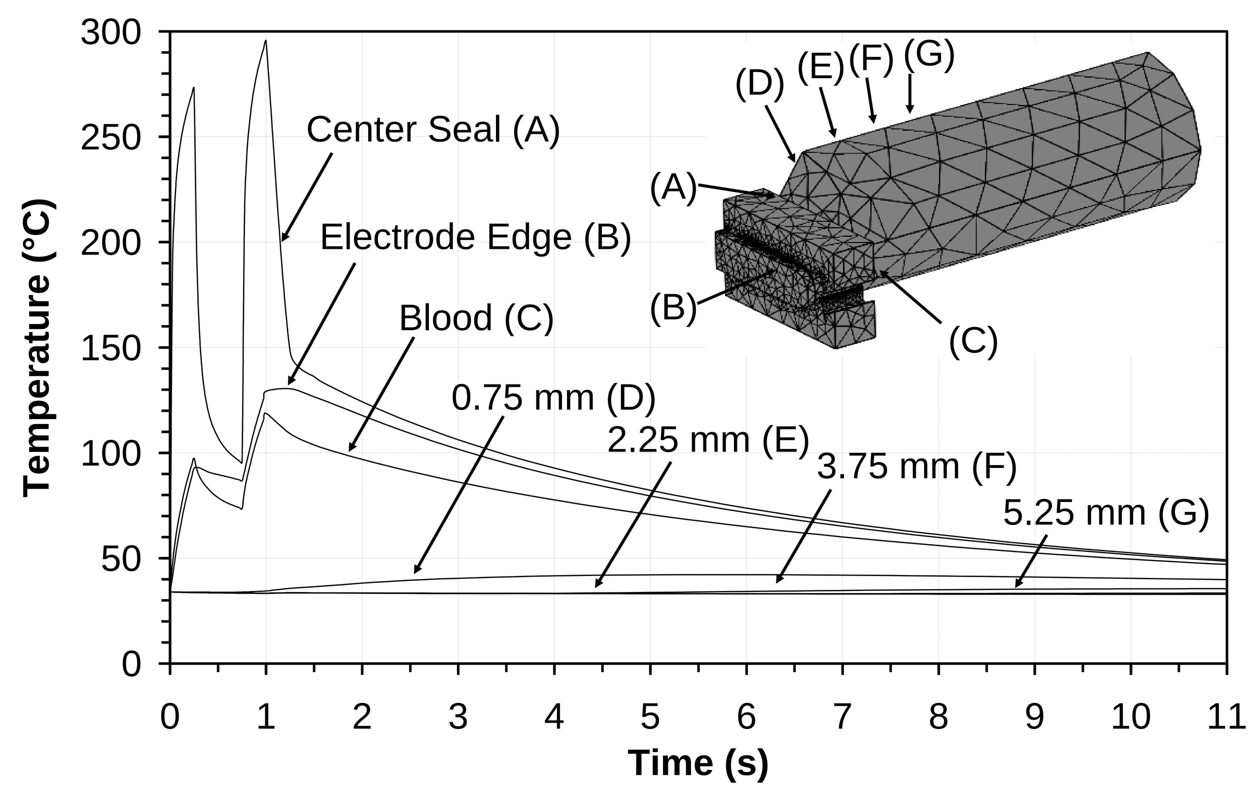
$W_b C_b$ = blood perfusion σ = electrical conductivity
q_m = metabolic heat input V = electric potential
q_g = resistive heat input



Model Boundary Conditions.

Material property	Vessel tissue	Blood	Electrode
Density, ρ (kg/m^3)	1050	1060	6450
Specific heat, C (J/g·K)	3314	3890	840
Thermal conductivity, k (W/m·K)	0.449	0.53	70
Electrical conductivity, σ (S/m)	0.55	0.667	4×10^6
Blood perfusion, ω (kg/m^3·s)	0	--	--

Constants Used in FEA Blood Vessel Model.



Modeling Results of Tissue Temperature at Seven Different Selected Locations (Numerical Values Indicate Distance From Electrode Edge).

Future Work

- Improve the current FEA model with more accurate material properties, fluid interactions, and improved electrode representation.
- Investigate using higher frequency bipolar and ultrasonic based devices to join tissue.
- Design guidelines for new and improved bipolar, ultrasonic and laser based instruments for use in tissue joining and anastomosis.

For more information, contact Prof. A. Shih; Phone: 734-647-1766; Email: shiha@umich.edu