A Novel Surgical Thermal Management System (STMS)

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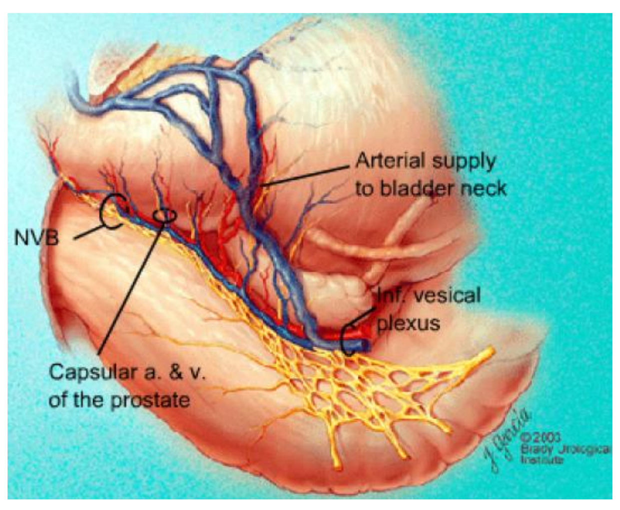
Motivation

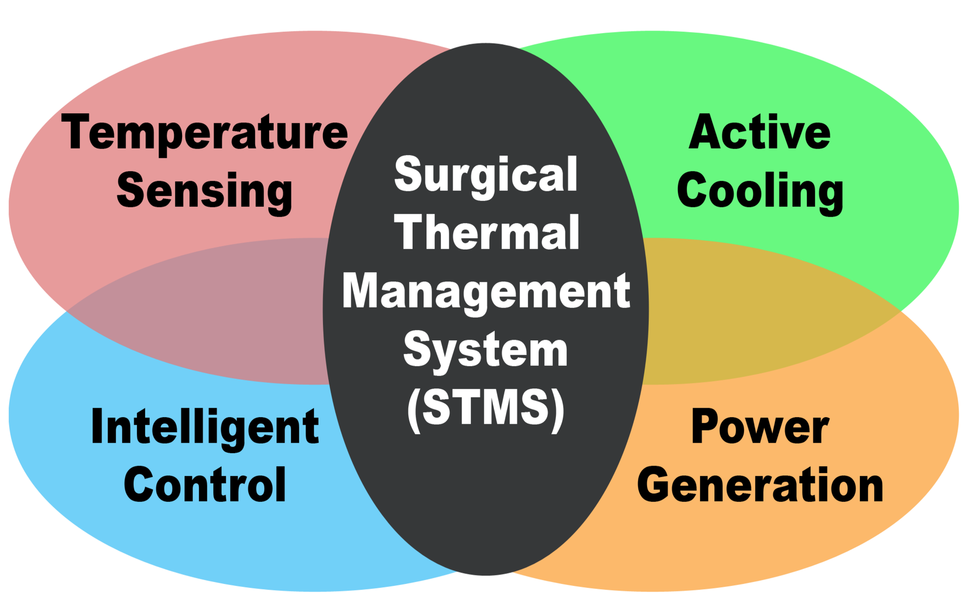
- Over 600,000 hysterectomies and 160,000 prostatectomies are performed each year in the US.
- Current energy-based state-of-the-art laparoscopic instrumentation used in these procedures use monopolar/bipolar electrocautery and ultrasonic energy.
- The thermal spread of these instruments has been linked to post-operative incontinence and potency problems



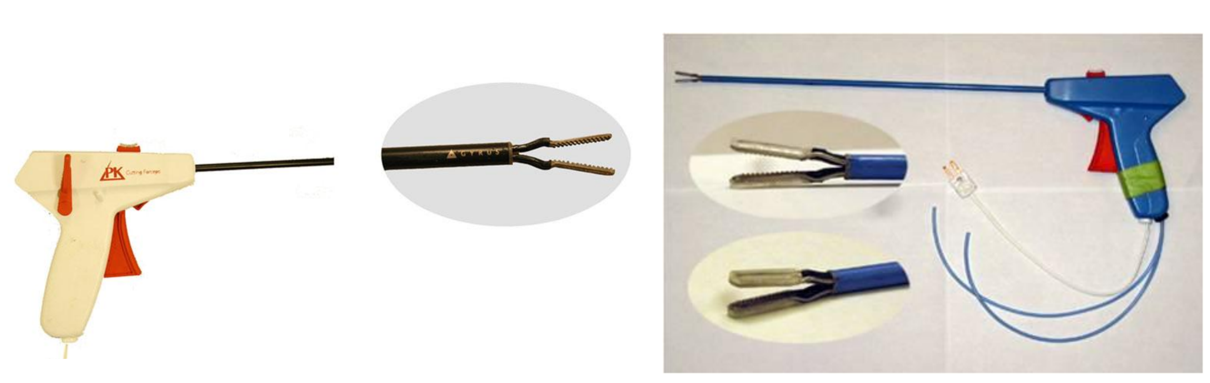
Prostate and the neurovascular bundle (NVB)*

Objectives

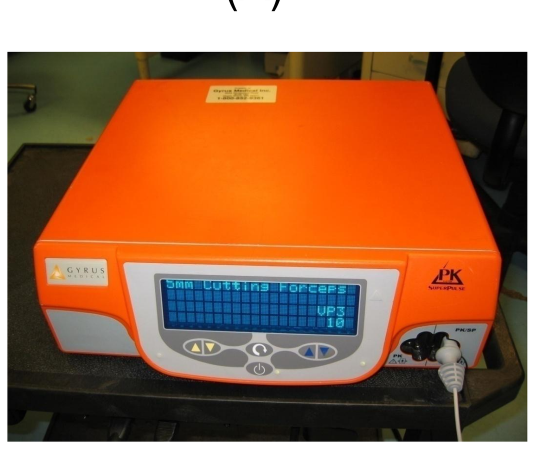
- Develop Surgical Thermal Management System (STMS) to control/eliminate collateral thermal damage.
- Model the bipolar electrocautery technique to predict collateral thermal damage.

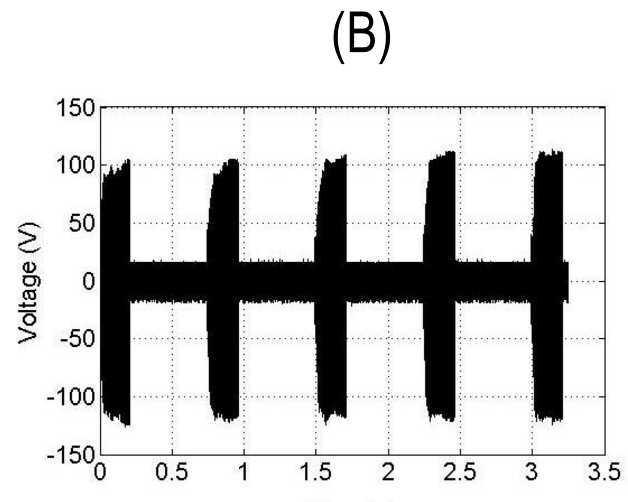


Primary components of proposed STMS



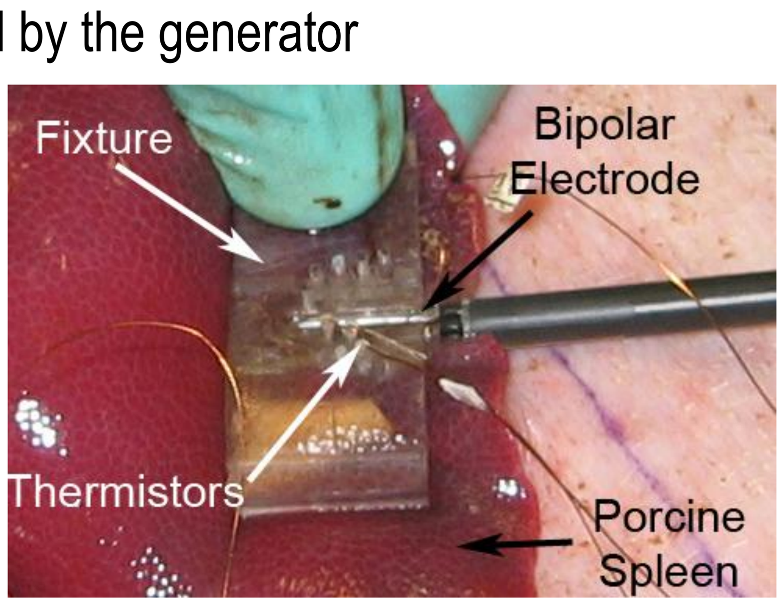
(A) (B)





(C) (D)

(A) Gyrus 5 mm Cutting Forceps, (B) Cutting Forceps with active cooling, with (C) Bipolar Electrosurgical Generator,and (D) measured AC voltage signal produced by the generator

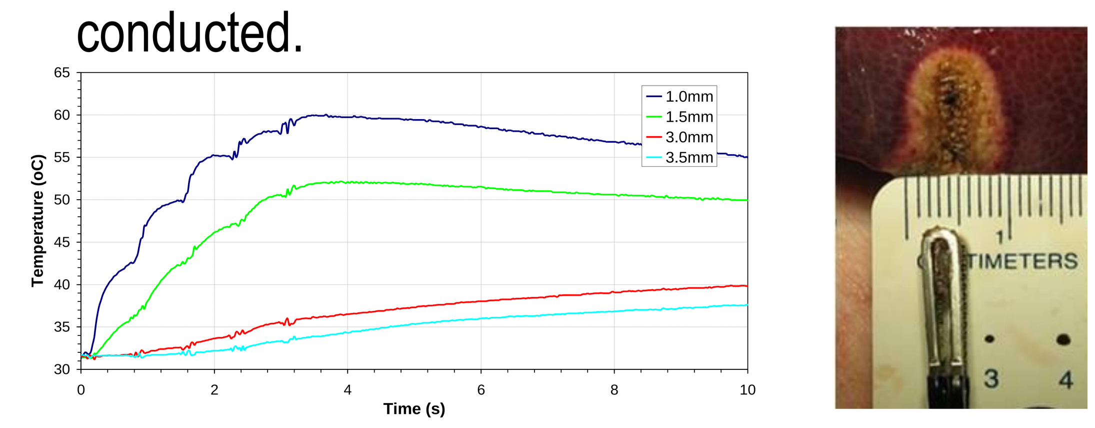


Experimental set-up showing positioning of tissue, electrode, and thermistors.

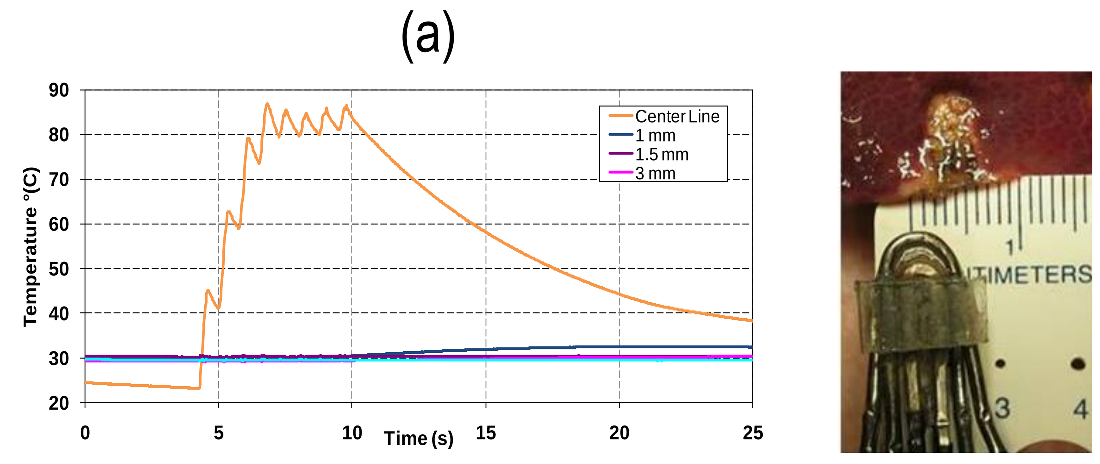
Experimental Results

Comparison to normal bipolar instrumentation

- In-vivo (porcine spleen) thermal profiles during bipolar cautery were experimentally measured.
- Temperature measurements were taken 2 mm below tissue surface using micro-thermistors.
- Both cooled and non-cooled experiments were conducted.

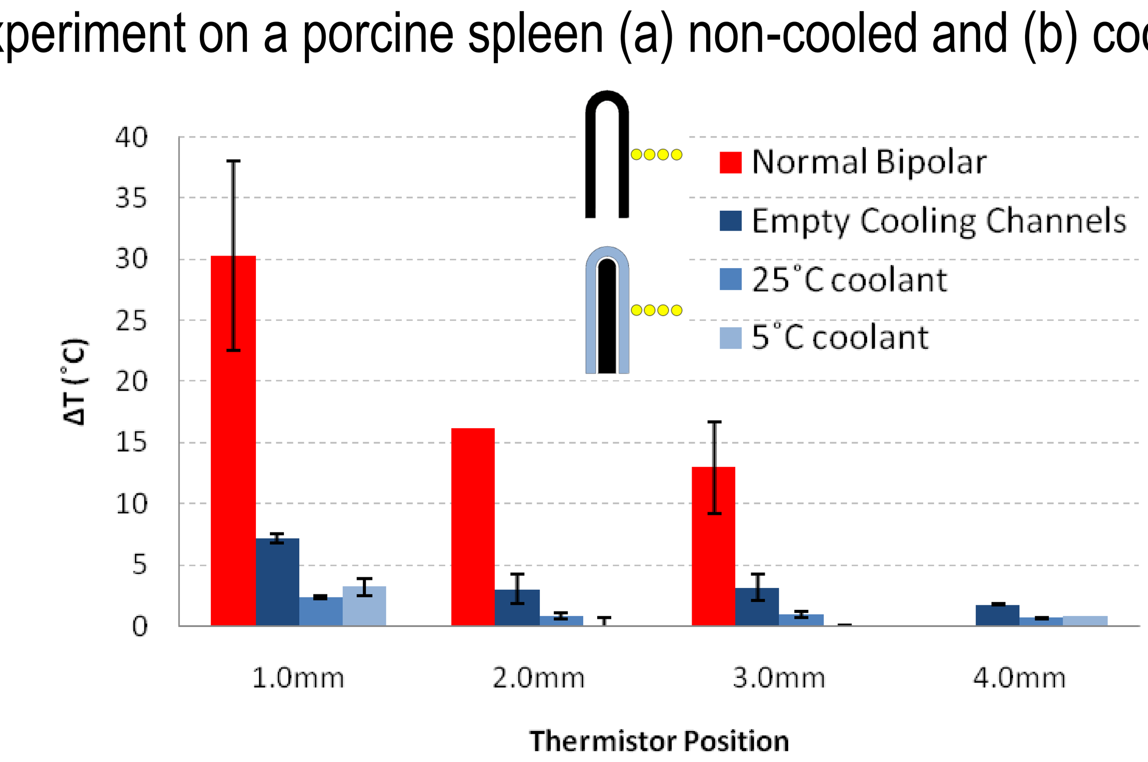


(a)



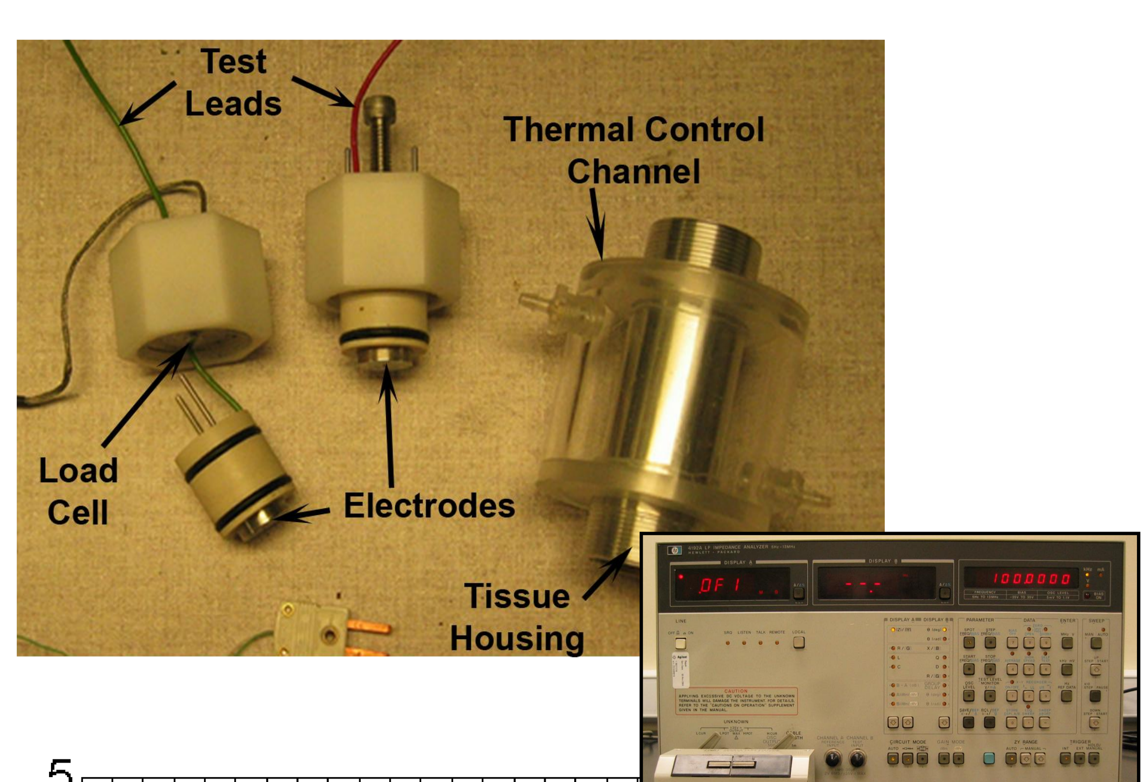
(b)

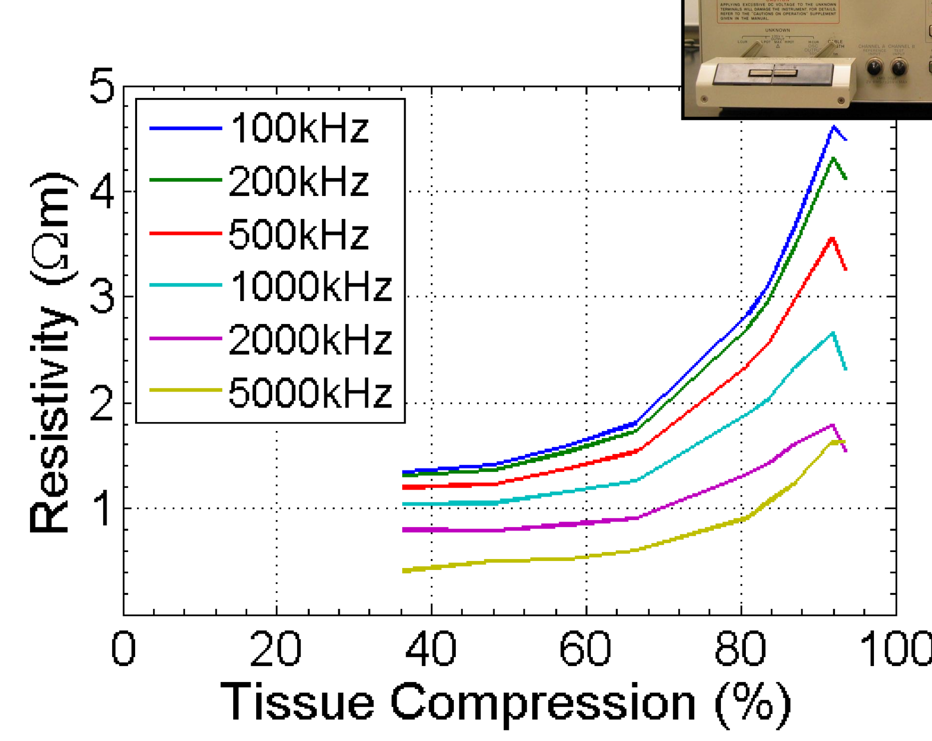
In-vivo trial showing validity of temperature measurement experiment on a porcine spleen (a) non-cooled and (b) cooled.



In-vivo trial results comparing normal bipolar to various temperatures of coolant.

Effect of compression on tissue properties



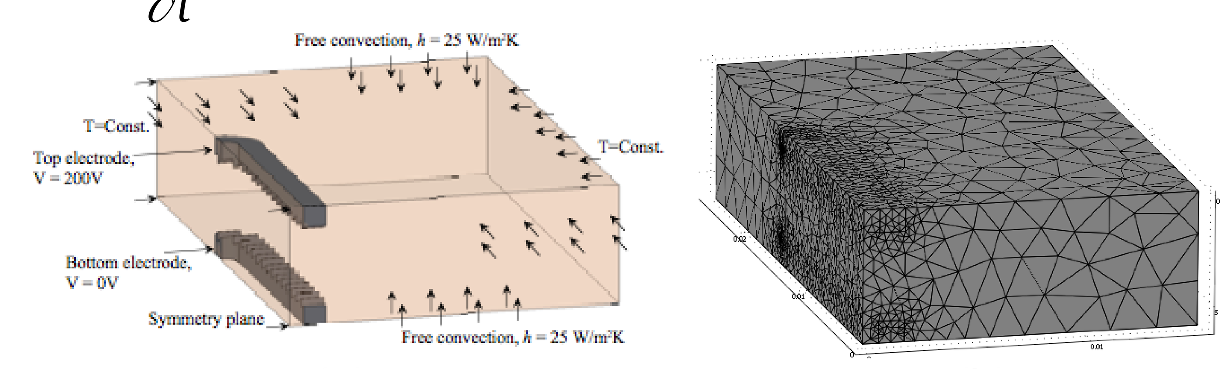


Impact of tissue compression on electrical resistivity. Data collected from experiment set-up (top) via impedance analyzer (middle). Note results show exponential rise in resistivity under higher compressions.

Modeling Results

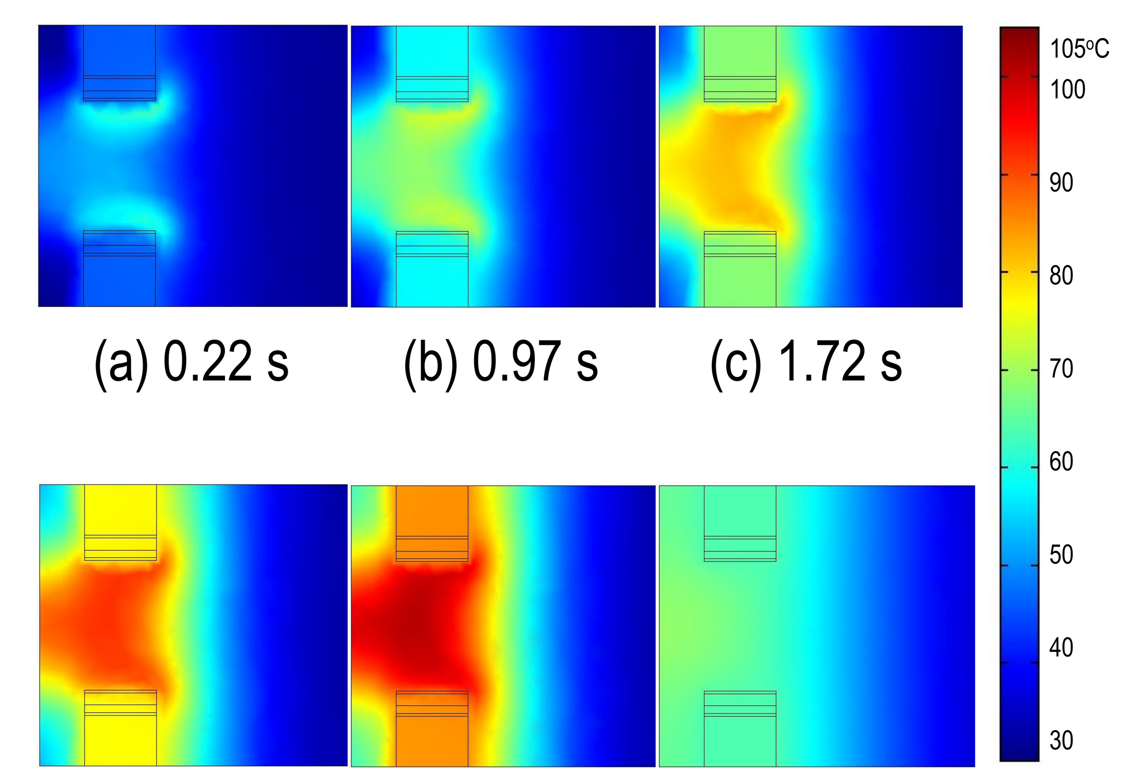
A finite element model (FEM) was developed to predict the temperature of the tissue when including tissue compression. Heat transfer and electrical equations used in the modeling are, respectively:

$$\rho c \frac{\partial T}{\partial t} = k\nabla^2 T + W_b C_b (T - T_a) + q_m + q_g \qquad \nabla[\sigma(T)\nabla V] = 0$$



(a) (b)

Schematic of the FEM model showing (a) the tissue, including boundary conditions and (b) the mesh case.



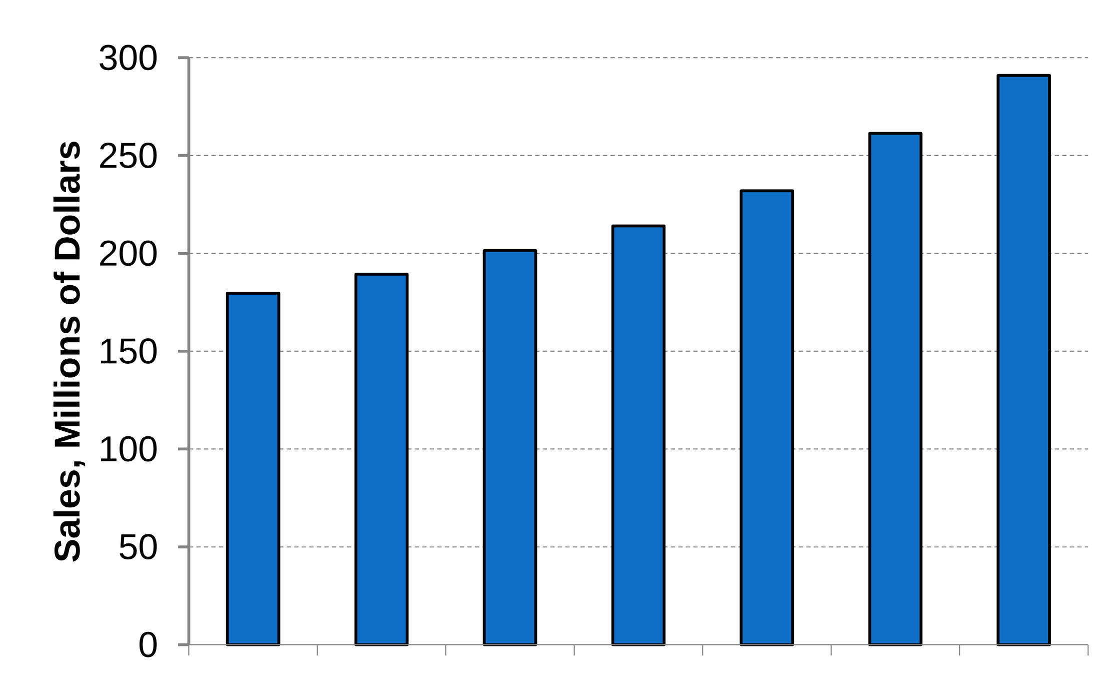
(a) 0.22 s (b) 0.97 s (c) 1.72 s

(d) 2.47 s (e) 3.22 s (f) 10.00 s

Cross-sectional temperature profiles on a plane offset from front plane by 6 mm at various times.

Commercial Information

- Submitted IP covers contained, active cooling as well as applying compression gradient to tissue
- IP submitted 01/2007



Market forecast for laparoscopic/minimally invasive surgical instruments, 2004-2010.

Future Work

- Further develop FEM to incorporate active cooling
- Develop control algorithms to effectively minimize collateral tissue damage
- Market analysis to assess commercial feasibility

Acknowledgements

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* http://urology.jhu.edu/prostate/1.php