In-Vitro Testing and Simulation of Multi-Phase RF Ablation of Heart Tissue

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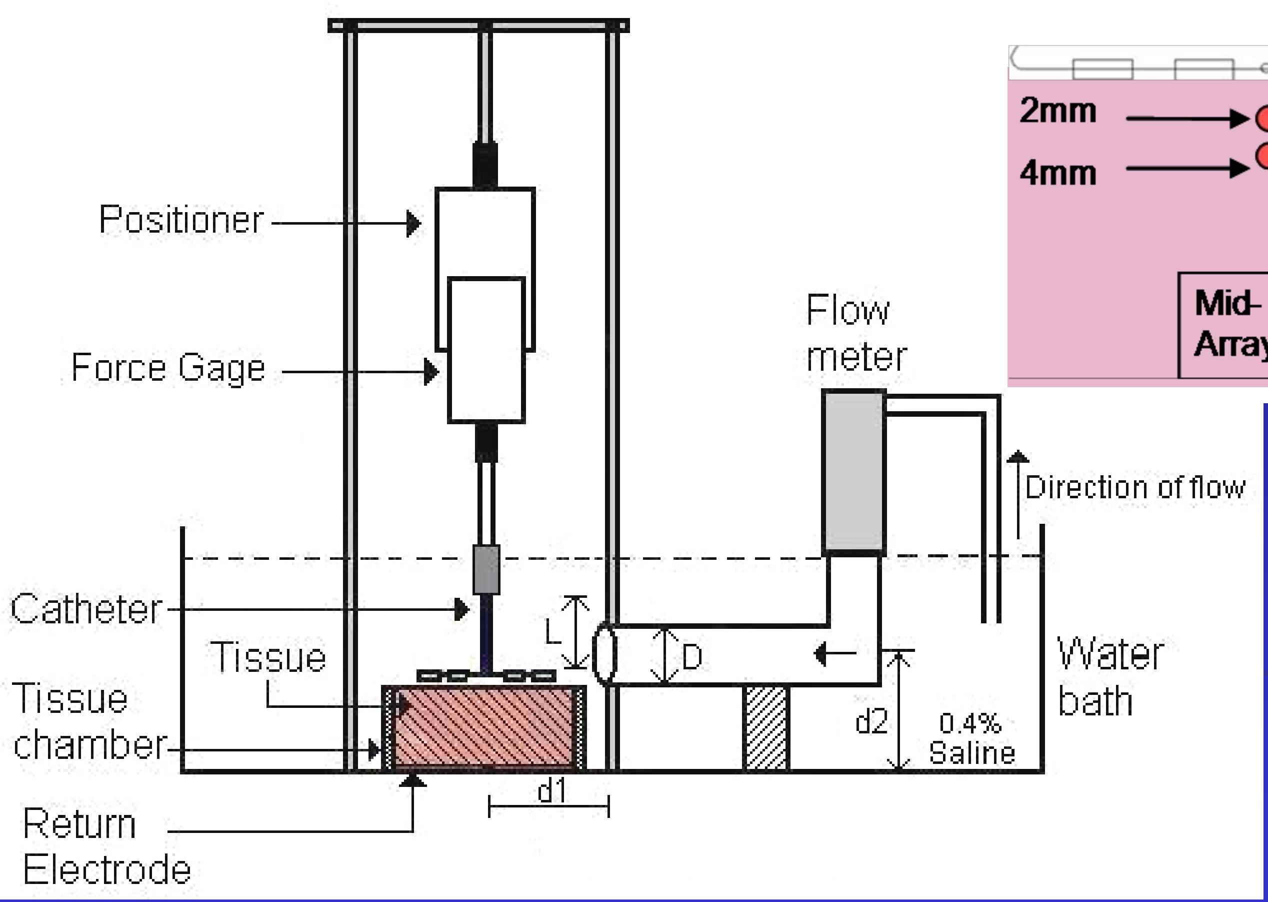
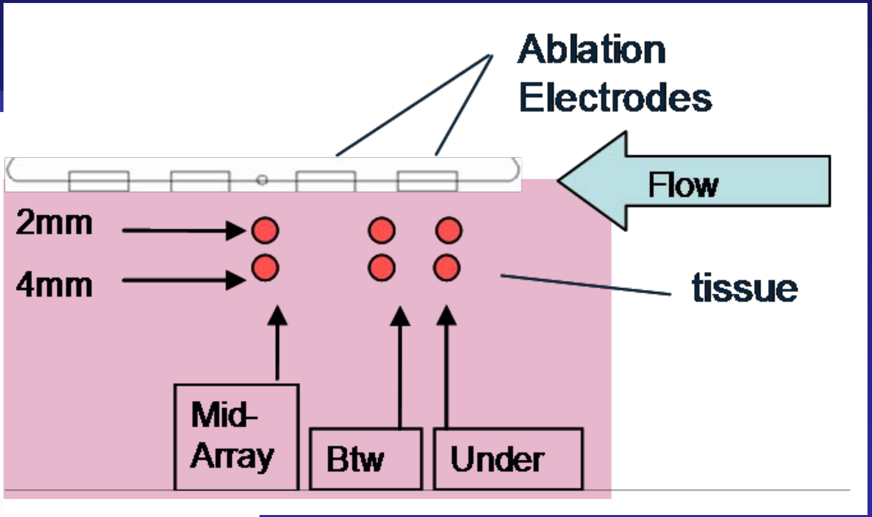
Overview

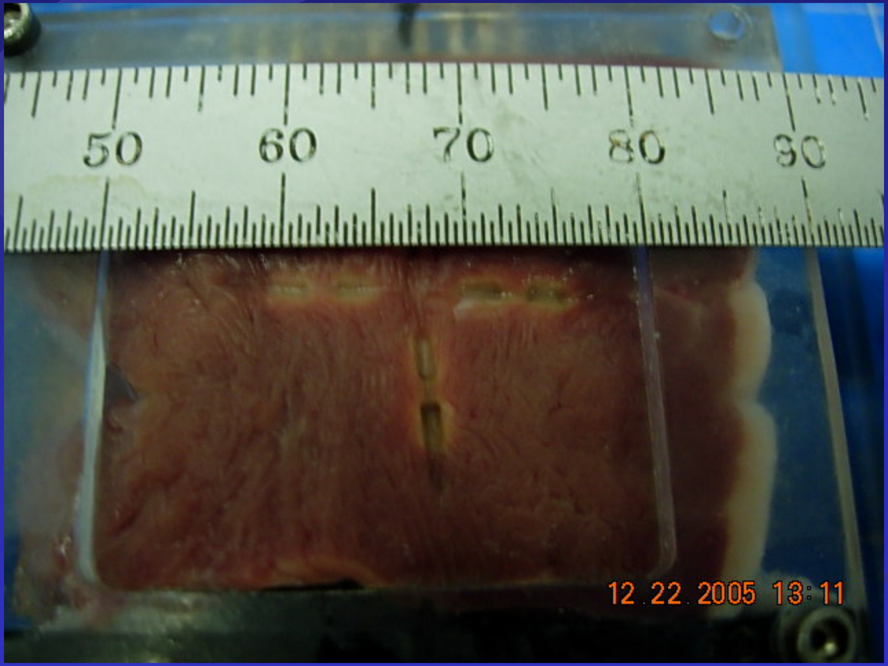
- Radio Frequency (RF) Catheter Ablation is an emerging technique for treatment of some cardiac arrhythmias.
- Understanding lesion size and myocardial tissue temperatures during ablation aids in providing appropriate therapy to the patient based on anatomical location in the heart and avoiding collateral damage to structures such as the esophagus and the phrenic nerve.
- We present results from recent *in-vitro* tests and advanced finite element analysis simulations as an example of a comprehensive and self-consistent engineering methodology for understanding more fully therapeutic applications of RF tissue ablation.

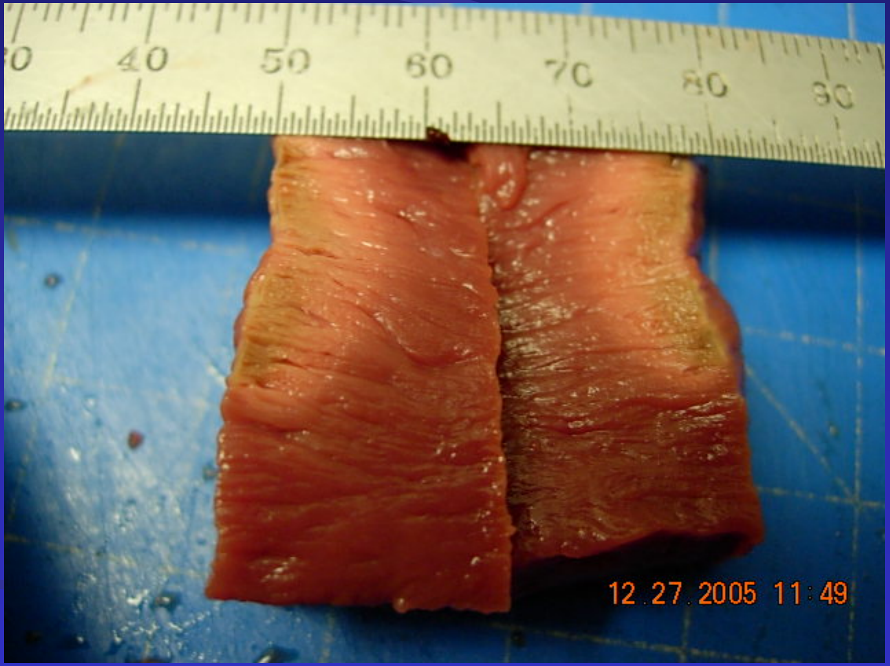
Bench-Top Testing





Lesion Formation





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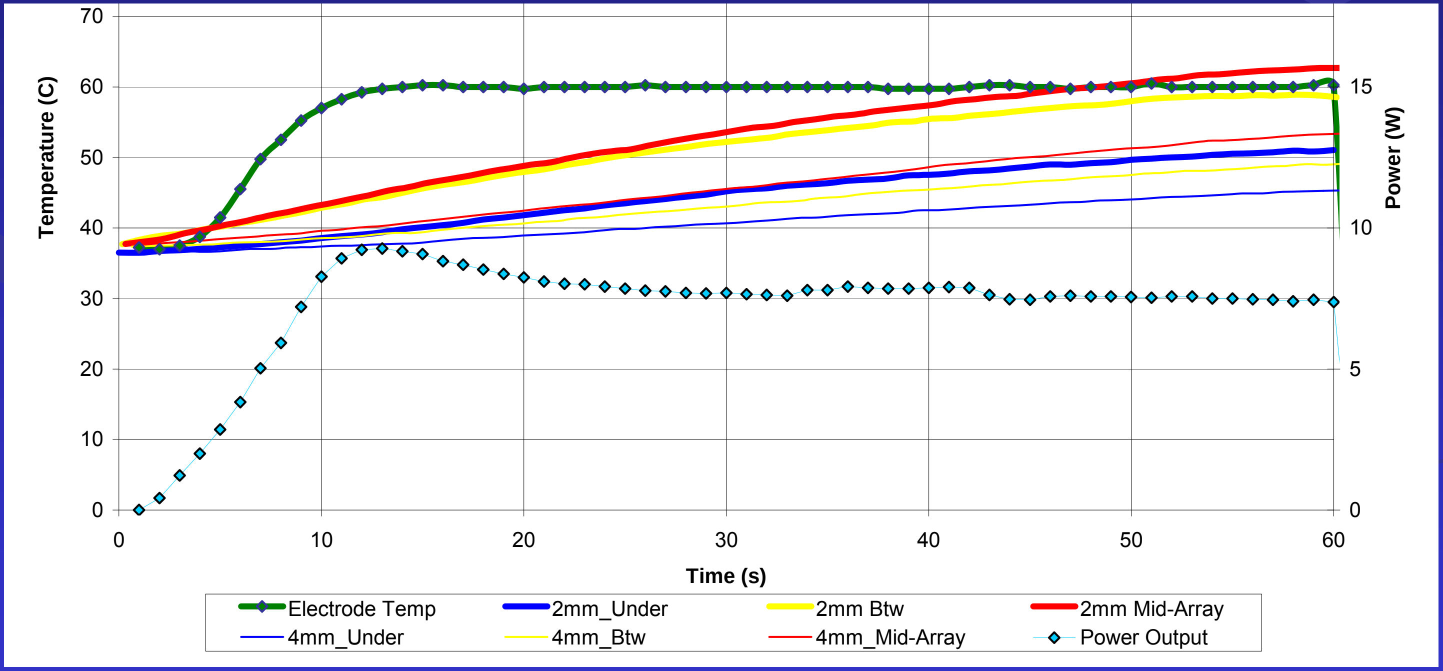
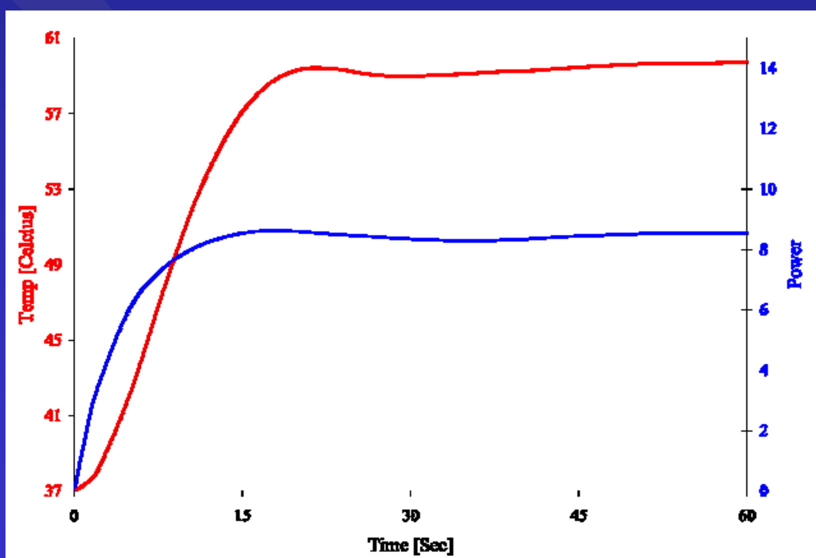
Temperature Measurements

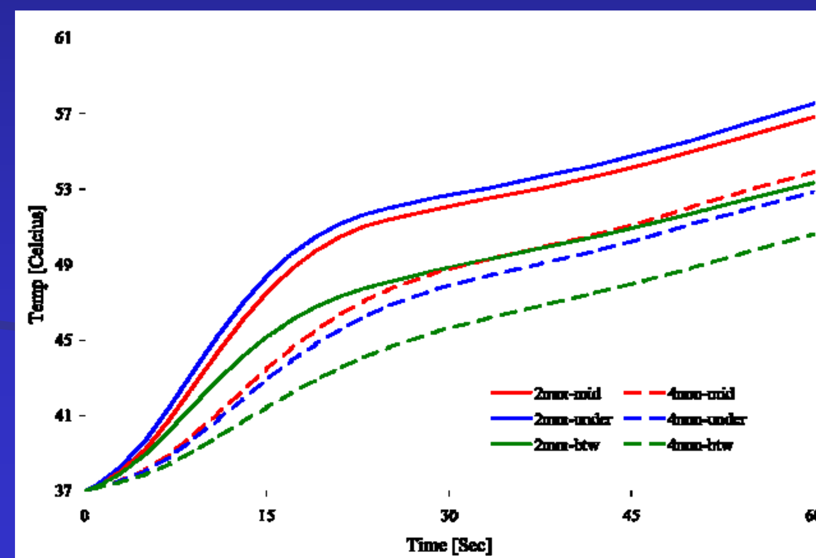


Modeling

- Control mechanism was directly implemented in the FEA model through the use of user subroutines and a PD equation.

$$V = P(T - T\underline{o}0) + D\,d/dt(T - T\underline{o}0) + C$$





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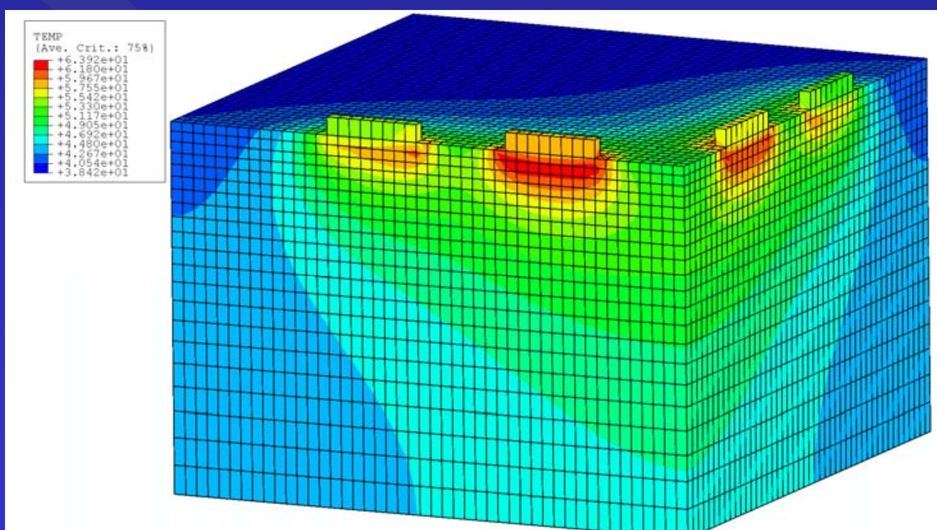
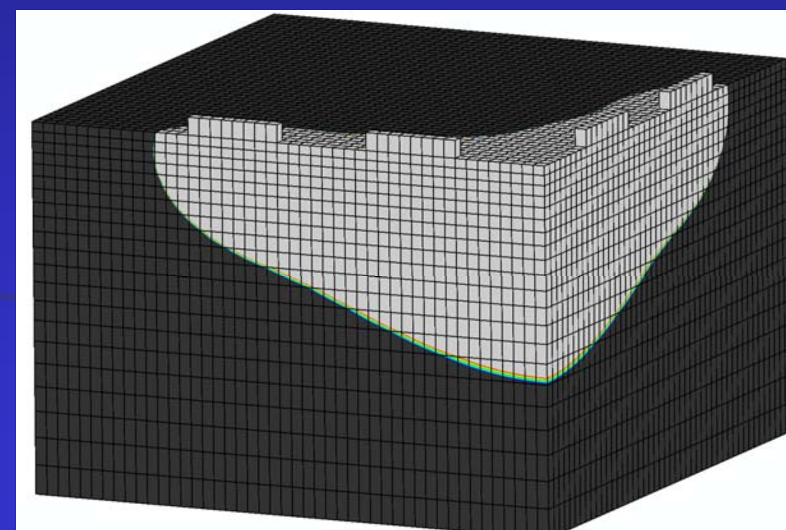
Temperature and Lesion Distribution





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Comparison of Average Lesion Depth

	Unipolar	1:1	2:1	4:1	Bipolar
In-vitro	7.3	5.2	4.5	3.6	2.9
Simulation	5.8	5.1	4.5	4.0	2.5

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Comparison of temperatures at the six thermocouple locations

	2mm under	4mm under	2mm btw	4mm btw	2mm mid	4mm mid
Bipolar						
In-vitro Simulation	42.6 49.6	41.0 45.7	50.1 46.8	42.8 43.8	55.3 49.5	47.4 46.6
4:1						
In-vitro Simulation	46.1 54.9	41.4 50.9	55.2 51.8	43.1 48.9	56.1 54.8	47.2 51.6
2:1						
In-vitro Simulation	51.1 57.5	45.4 52.8	59.5 53.3	49.2 50.6	62.8 56.8	53.4 53.9
1:1						
In-vitro Simulation	55.9 64.1	47.6 58.6	61.7 66.7	54.8 55.0	69.9 63.0	60.3 60.0
Unipolar						
In-vitro Simulation	60.5 66.6	58.7 64.8	72.0 63.8	60.8 60.6	83.0 66.3	66.7 66.2

Discussion

- A comparison of the in-vitro and FEA simulation results shows that the two are reasonably well matched.
- The utility of adopting a comprehensive and self-consistent engineering methodology based on experimental and numerical approaches is that it enables the engineer to quickly explore the effects of influence parameters such as coolant flow and set-point temperature.
- The key benefit is that the simulation allows the extension of the in-vitro results to predict anticipated in-vivo performance.
- Other conditions not easily duplicated or controlled in the bench-top testing such as internal blood flow within the tissue and varying tissue density and properties can be addressed through mindful tweaking of the FEA model.
  - Internal tissue cooling can be simulated by applying convection boundary conditions within volume of the model and can be tuned from location to location to represent actual tissue properties.
- In this fashion, an FEA model, once appropriately calibrated can be adjusted to include patient specific data and provide an effective “real-time” prediction of cardiac arrhythmia treatment using RF Catheter Ablation.