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## Objective

- To characterize the lesions created by the multi-phase RF Generator and a 3-D multi-electrode catheter via *in vitro* testing.
- To model lesion formation by finite element analysis (FEA)

## Cardiac Ablation System

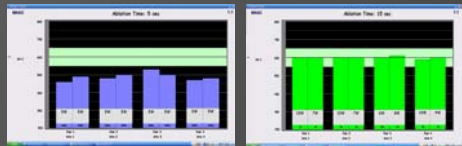
### Multi Array Ablation Catheter (MAAC)

- Composed of eight 2 mm (in length) platinum electrodes
- Designed with fin-like electrode to increase cooling and facilitate efficient RF delivery
- Electrode surface area (9.1 mm<sup>2</sup>); current density (1.84A/cm<sup>2</sup>)



### Multi-channel Generator

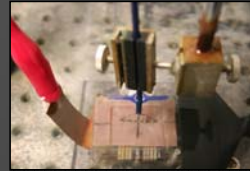
- Multi-phase energy delivery:
  - 0:1 (unipolar only), 1:1, 2:1, 4:1, and 1:0 (bipolar only)
- Temperature controlled
- Thermocouples located directly at electrode-tissue interface
- Power delivery: ~6 -10 watts / electrode
- Duty Cycle:
  - Low power ablations
  - Delivery of high peak powers while providing electrode cooling time during the off cycle
- Accurate temperature acquisition as data can be acquired during the off portion of the duty cycle (RF quiet time).



## Method

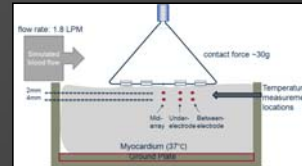
### *In vitro* ablation model

- Flow directed to the electrode using a pump and flow meter at 1.8 L/min
  - Flow meter: Cole Parmer, Vernon Hills, IL
- Constant bath temperature at 37°C ±1°C
- 0.5% saline
- Controlled electrode-tissue contact force (~30 g)
  - Force gauge (DPS-1R; Imada, Northbrook, IL)



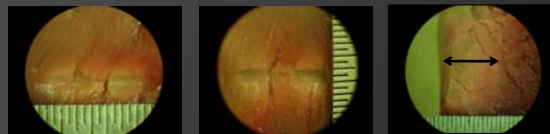
### Tissue Temperature Measurement

- Intramural tissue temperature continuously measured during RF delivery at six locations
- Temperature data acquisition system
  - Thermes USB; 0.01°C resolution; Physitemp, Clifton, NJ
- T-type thermocouples
  - 0.064 mm diameter; measurement accuracy ±0.1°C; time constant 0.1 seconds; Physitemp, Clifton, NJ



### Lesion examination

- Each lesion is photographed and measured under a microscope.



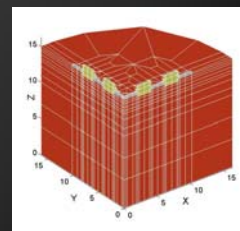
Measured length

Measured width

Measured depth

### Model and Numerical Simulation

- To model the coupled electrical/thermal initial boundary value problem.
- Prescribed voltage at the dispersive electrode, and at each catheter electrode
- Thermal boundary conditions of convective heat transfer to model the heat transfer from the tissue to the saline bath.
- The resulting system of ODEs of the coupled ODE system was integrated in time using an adaptive implicit Euler method.
- The ablation was temperature-controlled to 60°C at each electrode.
- The parameters to the finite element model adjusted for best fit of the experimental data.

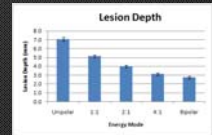


Finite element mesh, isometric view. Red: tissue, yellow: electrodes, gray: wire

## Results

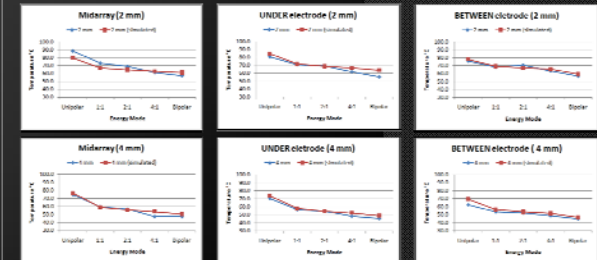
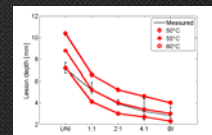
### Experimental

- Ablations were performed with set temperature of 60°C, ablation duration time of 60 seconds at all five energy modes (Unipolar, 1:1, 2:1, 4:1, Bipolar)
- The lesion depth decreased as the bipolar-to-unipolar RF energy delivery ratio increases.

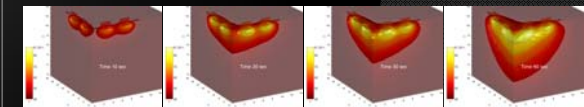


### Model and Numerical Simulation

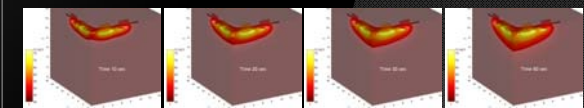
- Comparison of *in vitro* and simulation results for the mean lesion depth.
- The results illustrate reasonable accuracy of the simulation in predicting the lesion depth using isotherms established at the end of the active ablation event.



Comparison of *in vitro* and simulation results for maximum tissue temperature at the six thermocouple locations



Unipolar: Isosurfaces of temperature at various intervals



Bipolar: Isosurfaces of temperature at various intervals

## References

- Cao H, Vorperian V, Tsai J, Tungjitsulmun S, et al. (2000). Temperature Measurement within Myocardium During *In Vitro* RF Catheter Ablation. IEEE Trans. Biomed. Eng., 47(11), 1518-1524.
- Nakagawa Between Electrode Size and Lesion Size During Radiofrequency Ablation With Active Electrode Cooling. Circulation., 98, 458-465. a H, Wittkamp F.H, Yamamashi W.S, et al. (1998). Inverse Relationship
- Berjano E.J, Theoretical modeling for radiofrequency ablation: state of the art and challenges for the future, Biomedical engineering online, 5:24, 2006.

## Conclusion

- The experimental results indicate that lesion depth is modulated by energy mode. As the bipolar-to-unipolar RF energy delivery ratio increases, the lesion depth decreases.
- The preliminary FEA results indicate that the computed tissue temperature distribution and predicted lesion depth is well matched with the experimental data.
- FEA modeling can be utilized as a tool for predicting the performance of multi-electrode catheters and may broaden our understanding of RF tissue ablation.