Biomedical Application of Induction Heating
A Novel Therapy for Benign Prostatic Hyperplasia (BPH) Treatment

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What is Benign Prostatic Hyperplasia (BPH)?
- Age related growth of prostate tissue which commonly causes urethral obstruction.
- The prostate is a small, walnut-shaped organ measuring roughly 3-6cm in diameter, surrounding the urethra immediately below the bladder.

Motivation
- The prostate is the most commonly affected organ for either benign or malignant cell growth in men [1].
- BPH is so common that it has been said, "All men will have an enlarged prostate if they live long enough" [2].
- From a historical perspective, 99% of men in their eighth decade are found to have evidence of BPH [3].
- BPH can significantly decrease quality of life, causing:
  - decreased, incomplete, and slow urination
  - urinary tract infections
  - bladder and kidney damage
  - bladder stones

Current Treatment Options
- Transurethral Resection of the Prostate (TURP)
  - Surgical cutting of tissue to open urethra
  - Requires an operating room and anesthesia
  - 3-4 days of hospitalization, inconvenient and costly
- Transurethral Needle Ablation (TUNA)
  - Thermal ablation causing destruction of tissue
  - Sensitive heating system may cause charring
  - Nearly 90% require TURP within 3 years
- Transurethral Microwave Thermotherapy (TUMT)
  - Microwave energy heats tissue to thermal destruction
  - Failure to anatomically heat prostate
  - Depth of heat therapy questionable

What is Induction Heating?
Induction heating works by delivering an AC signal to a coil creating a local alternating magnetic field. This field induces eddy currents to flow in adjacent conductive materials which by the joule effect releases thermal energy.

Potential Application Benefits
- Targeted heating to treat specific regions of the prostate
- 37% Reduction in size of minimally invasive catheter diameter
- Low power, low cost, and high temperature generation
- Wide range of heating coil designs

Intermediate Analysis of Heating Method
- Promising results show the induction coil, designed to scale, has the ability to heat an external ferrous element to desired temperature of 50°C
- Heating rate at low power (14 Watts) shown to be impressive, 57°C/hrs
- 44-68% power absorbed by heater as determined by on/off cycles of power supply
- Better than predicted heating by finite element modeling (17°C/hrs)
- Concept of a "Wireless Heater" is feasible
  - Heated, ferrous element may be placed 4mm away from induction coil

Current Concept
- Anatomical dual balloon catheter system
- induction heating of balloon filled with injected materials:
  - Ferrous fluid
  - Superparamagnetic microspheres
- Treatment balloon allows for:
  - Smaller catheter size
  - Perfect fit to urethra wall
  - Passive targeting of luminal tissue

Future Directions
Current research into induction heating proves to be promising. Target temperatures of 50°C are easily reached with this heating method at low powers. This method may make depth of heat penetration a simple time dependent function, which would reduce complexity of the problem. Next step involves attempting to heat ferrous fluid, and maximizing the heating coil's effectiveness. If results remain promising prototype testing on biological model will come next. Plenty of work still needs to be done.

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References

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Little research has been done into the biomedical application of induction heating. Through the process of developing this novel treatment an extensive amount of research, design and analysis has been undertaken. The process of project development can be seen to the right. Pictures in each step show images ranging from early conceptual designs to actual constructed and tested heating coils.