

Non-Invasive Near Infrared Spectroscopy (NIRS) to Monitor Blood Flow and Tissue Coagulation During Prostate Thermal Therapies for BPH May Allow Optimization of Therapy

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Introduction and Objective: Most minimally invasive prostate thermal therapy devices for Benign Prostatic Hyperplasia (BPH) (including microwave, RF needles, or interstitial laser) don't account for individual variations in prostate blood flow that can limit efficacy by removing heat delivered to the prostate during a fixed treatment time.

Previous studies using Doppler ultrasound have shown that the initiation of thermal therapy causes an additional increase in regional blood flow by vasodilation, and that sufficient thermal accumulation results in a decrease or cessation of blood flow as blood and tissue coagulation progresses.

NIRS uses differential absorption of infrared wavelengths by hemoglobin (Hb), a primary blood protein, and oxyhemoglobin (HbO₂), the oxygenated form of the blood protein, to measure changes in blood volume/flow (Fig. 1).

The objective of this study was to evaluate a non-invasive device that uses the NIRS method of differential absorption of infrared wavelengths by hemoglobin and oxyhemoglobin to monitor blood volume/flow changes and tissue coagulation in the prostate during thermal therapy.



Figure 1 – NIRS Probe measures changes in light reflected from blood and other tissues.

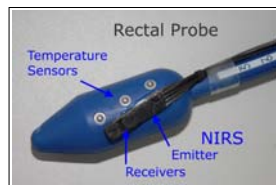


Figure 2 – Custom rectal probe with thermal and NIRS sensors.

Methods: Prostates 18 – 42g in 10 canines were monitored with Urodynamic NIRS Transducers placed transrectally during transurethral microwave treatment using a Prolieve Thermodilatation System at 15-50W. Laser diodes at three wavelengths sequentially emitted energy into the prostate through fiberoptics. Fiberoptic pickups placed at distances from the emitter allowed monitoring of various depths and volumes of tissue (Fig. 2). Custom computer algorithms evaluated laser reflections for changes in absorption. A real time graphical display was used to indicate changes in blood volume/flow and tissue coagulation at various depths in the prostate.

Initial *ex vivo* tissue studies were performed in liver and still whole blood to evaluate the effects of thermal coagulation on the NIRS signals in these tissue components separately.

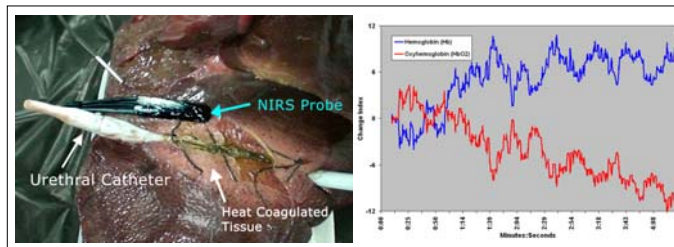


Figure 3 – Microwave thermal coagulation of *ex vivo* liver tissue results in increased Hb signal and decreased HbO₂ signal.

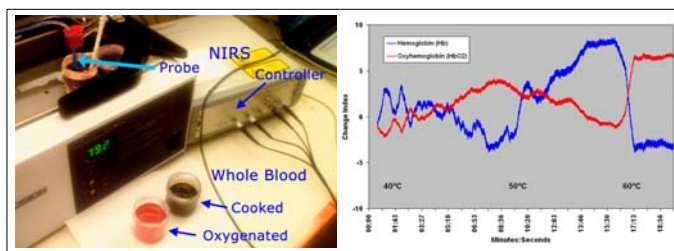


Figure 4 – Whole blood slowly heated in water bath shows increased Hb signal and decreased HbO₂ signal during coagulation near 50°C, and the opposite change on denaturing of hemoglobin and plasma near 60°C.

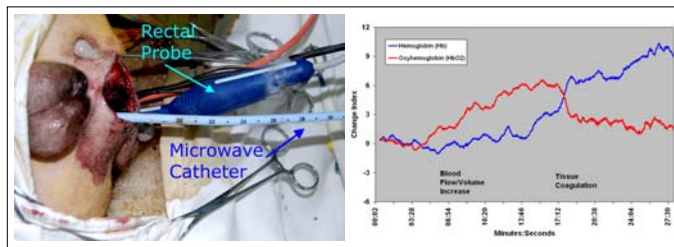


Figure 5 – Microwave thermal therapy of *in vivo* canine prostate shows increased Hb signal and decreased HbO₂ signal indicative of tissue coagulation and reduced blood volume/flow near 50°C.

Results: NIRS signals in both *ex vivo* liver and standing (anticoagulated) whole blood showed that the oxyhemoglobin signal decreased and the hemoglobin signal increased as the tissues began to be thermally coagulated by microwave or water bath heating to near 50°C (Figs. 3 and 4). In whole blood the signals dramatically reversed as the hemoglobin and blood plasma proteins fully denatured at about 60°C (Fig. 4).

During monitoring of *in vivo* prostate tissue, an initial rise in both Hb and HbO₂ likely reflective of vasodilation was seen as microwave power was ramped up. A precipitous drop in one or both signals were seen within 12-32 minutes as thermal coagulation progressed, reflecting a rapid reduction of blood volume/flow due to thermally induced vascular occlusion and/or thermal degradation of the hemoglobin and tissue proteins in the monitored volume (Fig. 5).

Histological evaluation showed thermal coagulative necrosis and thrombosis developing through the glandular and stromal tissues (Fig. 6) that were correlated with the locations of NIRS monitored tissue volumes.

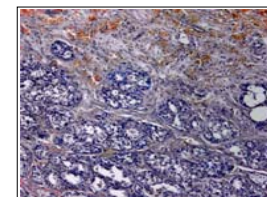


Figure 6 – Progressive thrombosis and coagulative necrosis (top of photo) following microwave thermal therapy of canine prostate.

Conclusions: This initial study indicates that NIRS monitoring of prostate for changes in blood volume/flow may provide the ability to non-invasively monitor the progress of tissue coagulation during thermal therapies. This may allow physicians to optimize treatment for each patient despite individual variations in prostate blood flow and target tissue volumes.