Fiber Optic Probe Based-on Near Infrared Spectroscopy for Improving the Accuracy of Breast Core Needle Biopsy

Bing Yu¹, Carmalyn Lubawy², Changfang Zhu², Elizabeth Burnside³, Gale Sisney³, and Nimmi Ramanujam³

¹Duke University, Dept of Biomedical Engineering, Durham, NC 27708-0281  
²University of Wisconsin-Madison, Dept of Biomedical Engineering, Madison, WI 53706  
³University of Wisconsin-Madison, Dept of Electrical and Computer Engineering, Madison, WI 53706  
⁴University of Wisconsin-Madison, Medical School, Madison, WI 53792

MOTIVATION

It is estimated that over one million needle biopsies are performed in the United States annually for the diagnosis of breast cancer. However, the false negative rate can be up to 8% and repeat biopsies are experienced by up to 7% of patients. The long-term goal of this project is to develop an optical sensor based on near infrared (NIR) diffuse optical spectroscopy that can potentially improve the sampling accuracy of current image-guided breast needle biopsy.

METHODS

Frequency domain photon migration (FDPM) is a technique in which intensity modulated light is launched into a tissue and then detecting the photon density wave (PDW) that propagated to another point within the tissue (Fig. 3 & 5). The attenuated amplitude and delayed phase of the detected PDW are used to determine the optical properties and concentrations of the physiological parameters of tissue using the Diffusion theory algorithm (Fig. 6). Tissue vascularity, hemoglobin saturation and water content, which have all been identified as diagnostic markers of breast cancer, can be quantified using this technique.

In order to implement the FDPM technique in breast cancer diagnosis, a fiber optic probe has been developed, by Dr. Nimmi Ramanujam’s group at the University of Wisconsin - Madison, which can be incorporated into the biopsy needles to take photon diffusion measurements during a clinical breast biopsy procedure. The probe tip consists of three side-firing fibers, with two as source fibers and one as a detector fiber.

The technique was first validated using synthetic phantoms and clinical study is still undergoing.

INSTRUMENTATION

![Diagram of multi-wavelength FDPM instrument](image)

Fig. 5 Diagram of our multi-wavelength FDPM instrument (50~150MHz).

![Signal processing scheme for optical properties and tissue structures](image)

Fig. 6 Signal processing scheme for optical properties and tissue structures.
Clinical Procedures:
- Instrument is set up in a biopsy procedure room, and allowed to warm up.
- Patient is positioned on table and targeting X-rays are taken.
- Biopsy needle is positioned in breast.
- Tissue collection chamber is removed from needle, optic probe is inserted, task lighting turned off.
- Spectroscopy measurement made.
- Task lighting turned on, probe removed from needle, tissue collection chamber attached.
- One tissue biopsy taken.
- Needle rotated to new position.
- Tissue collection chamber removed from needle, tissue sample removed from chamber, measurement procedure repeated.
- Biopsy procedure completed according to standard guidelines, and instrument calibrated.
- Pathology of tissue samples performed.

CONCLUSIONS

We have constructed a novel near infrared photon migration spectroscopy probe which will fit inside the bore of a Suros breast biopsy needle. This probe has been demonstrated to measure the optical properties of heterogeneous phantoms representative of human breast tissue. This probe has also been demonstrated to measure the physiological properties of hemoglobin concentration and hemoglobin oxygenation of human breast tissue at the end of a biopsy needle during a core needle biopsy of the breast.

RESULTS FROM PHANTOM AND CLINICAL STUDIES

For homogeneous agar phantoms with absorption coefficients ranging from 0.02 - 0.15 cm⁻¹ and a reduced scattering coefficient of 10 cm⁻¹, the retrieved absorption coefficients and scattering coefficient were within 17% and 30% of the actual values, respectively. For heterogeneous agar phantoms including a darker inclusion, the measured absorption coefficient was within 30% of the actual absorption coefficient for heterogeneities of 1 cm and larger.

So far, clinical data have been collected from 15 patients and the clinical study is currently undergoing at the UW-Madison Hospital. We plan to collect data from 25 patients at the end of the project. From each patient, 5–6 tissue samples at different directions are measured before a 15 mm long and 1.5 mm diameter tissue sample being removed. These samples are then send to a pathologist for composition analysis.

SPONSOR
The National Institute of Biomedical Imaging and Bioengineering (NIBIB), National Institutes of Health (NIH)