Validation of a novel Spectroscopic Diffuse Optical Tomography system for breast imaging with MRI

S. M. van de Ven[1], S. G. Elias[1], A. J. Wiethoff[2], M. van der Voort[3], A. Leproux[3], T. Nielsen[4], B. Brendel[4], L. Bakker[3], M. B. van der Mark[3], W. P. Mali[1], and P. Luijten[1]

[1]Radiology, University Medical Center Utrecht, Utrecht, Netherlands, [2]Philips Medical Systems, Best, Netherlands, [3]Philips Research Europe, Eindhoven, Netherlands, [4]Philips Research Europe, Hamburg, Germany

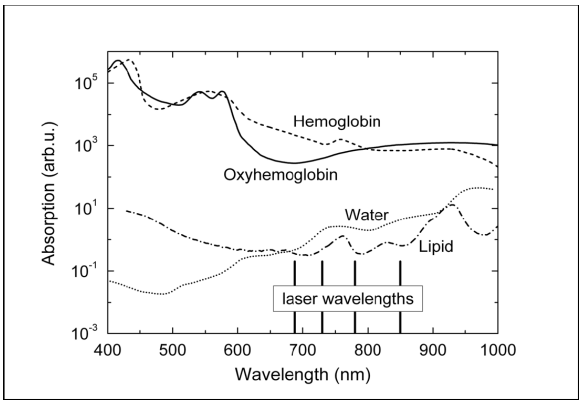
Introduction

Imaging techniques play a major role in breast cancer management. Limited sensitivity of X-ray mammography, [1] has fuelled interest in development of other imaging techniques such as breast Magnetic Resonance Imaging (MRI). [2] Despite substantial improvements in imaging technology, these techniques can only detect cancers of a certain size (usually > 4mm) since they rely on anatomic information. As the size of lesions upon discovery decreases with more efficient screening programs, the need for a non-invasive tool that provides more specific information about the lesions becomes obvious. Diffuse Optical Tomography (DOT) uses near-infrared (NIR) light to assess the three dimensional distribution of optical properties of tissue. [3] In the NIR range, light absorption as a function of the wavelength shows a minimum, allowing for sufficient penetration into breast tissue. By combining data acquired at multiple wavelengths (spectroscopy), tissue composition in terms of concentrations of oxy- and deoxyhemoglobin, water and lipid can be determined (Figure 1). Potentially, this non-invasive methodology can be used to discriminate benign from malignant lesions by spatially resolving the relative concentrations of these physiological components. Moreover, by the use of target-specific fluorescent probes, optical imaging techniques have molecular imaging potential. Other advantages of the technique are that DOT is relatively inexpensive, fast, comfortable, and makes no use of ionizing radiation. In this study, DOT measurements in cystic breast lesions were validated with MRI.

Materials and Methods

Ten patients (mean age 47, range 35-60) diagnosed with in total 24 cystic breast lesions by ultrasound were prospectively included between August 2006 and September 2007. In addition to the normal clinical diagnostic procedure of mammography and ultrasound, patients underwent optical imaging and MRI as a reference standard. Diffuse optical tomography (DOT) was performed on a new Diffuse Optical Tomography system (Philips Medical Systems, Best, The Netherlands). After data acquisition, a reconstruction algorithm computed three-dimensional optical images using four different wavelengths (690, 730, 780 and 850 nm, indicated on Figure 1). Tissue composition was analyzed using a spectroscopic tissue model in which the images at these four wavelengths were combined. Breast MRI was performed on a 3.0T clinical MR system (3.0T Achieva, Philips Medical Systems, Best, The Netherlands). The scan protocol included an axial high-resolution T1-weighted fast gradient echo (HR-T1FFE) fat suppressed series (TE/TR 1.7/4.5 msec; inversion delay SPAIR 130 msec; flip angle 10º; FOV 340×340 mm^2, acquired voxel size 0.66x0.66x1.6 mm^3, reconstructed voxel size 0.66x0.66x0.80 mm^3) and an axial T2-weighted fat suppressed series (TE/TR 120/9022 msec; inversion delay SPAIR 125 msec; flip angle 90º; FOV 340×340 mm^2, acquired voxel size 1.01x1.31x2.0 mm^3, reconstructed voxel size 0.66x0.66x2.00 mm^3).

Figure 1. The spectra of the main constituents of breast tissue [4]



Results

Seven of 24 cysts (29%) were visible with DOT irrespective of the wavelength. It was possible to visualize 17 of 24 cysts (71%) by combining the optical images at the four wavelengths and their high water and low total hemoglobin content was confirmed (Figure 2). The size and location of the cysts on the optical images showed good agreement with MRI (Pearson correlation coefficient 0.72). DOT overestimated the lesion size on average by 1.9 mm (95% CI, -1.3 to 5.0). The remaining cysts were not visible for reasons related to the detection limit and the current geometry of the optical measuring device, which precludes imaging of lesions close to the chest wall.

Conclusions and Discussion

The validation of a novel Diffuse Optical Tomography system for breast imaging was initiated in a cyst model with MRI as a reference standard. Cystic breast lesions can be visualized using DOT. Use of spectroscopic information by combining images made at several wavelengths had important added value for lesion detection. Spectroscopic analysis of the lesions elucidated their high water content and low total hemoglobin content. Future steps in the validation of this system will involve the use of breast cancer models, multi-modality imaging with MRI to merge functional optical data with anatomical MR data, and feasibility studies with target-specific fluorescent probes that may make molecular imaging of the breast possible in the future.

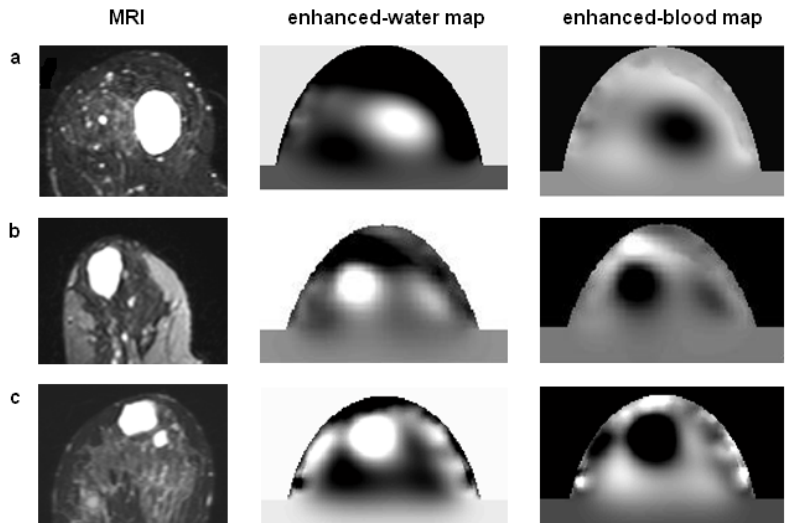


Figure 2. Examples of 3 patients (a,b,c): T2 weighted MRI with fat-suppression compared to the enhanced-water maps and the enhanced-blood maps of the optical data sets. The cysts show high signal intensity on the MRI and the enhanced-water maps (high water content), and low signal intensity on the enhanced-blood maps (low blood content).

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