Concurrent MR and optical mammography

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Introduction: Optical mammography utilizing near infrared spectroscopy (NIRS) has shown to be a promising tool for breast-tumor characterization [1]. This technique is non-invasive, does not involve ionizing radiation, is relatively inexpensive, and sensitive to functional parameters like tumor total hemoglobin concentration or blood-oxygen saturation. A substantial drawback, on the other hand, is its poor spatial resolution (1-2 cm) mainly due to the diffuse scattering of light in human tissue and the need to use oversimplified models for data analysis.

To address this issue we designed a new dual-modality instrument where time-resolved NIRS and MR mammography are performed simultaneously. A similar instrument has been described by Ntziachristos *et al.* [2]. Time-domain NIRS data allow to determine the (reduced) scattering coefficient μ_s' and the absorption coefficient μ_a, separately. From μ_a, measured at several wavelengths, physiological parameters can be inferred. The idea is to obtain the spatial distribution of the relevant tissue compartments (fat, glandular tissue, tumor, ...) from the segmented MR image. The subsequent analysis of the NIRS data is then tremendously simplified, since now only one set of optical coefficients per tissue component has to be determined instead of one parameter set per voxel. This reduces the number of free parameters by orders of magnitudes. The new instrument is still in a commissioning phase, here we report our very first *in-vivo* data on a healthy volunteer.

Materials and Methods: The MR compatible NIRS unit is shown in Fig. 1. The patient is lying in the prone position and the breast is slightly compressed by two adjustable plates. Short (100-500ps) laser pulses at five different wavelengths (650 - 880 nm) are multiplexed into a set of 35 optical fibers ending at different positions in one compression plate. The light diffusely transmitted through the compressed breast is collected by eight fiber bundles and guided to fast photomultiplier tubes (PMT) outside of the 3T Bruker Medspec 30/100 tomograph. To minimize pulse broadening sufficiently short collector fibers are needed leaving the PMTs within the stray field of our magnet. Properly oriented Hamamatsu R7400U-02/20 PMTs have been successfully tested under these conditions. The whole compression unit is enclosed by a transmit/receive surface coil in the horizontal plane. This way both optical projections (cranio-caudal or medio-lateral) can be measured by simply rotating the whole assembly by 90 degrees. The reduced sensitivity of this coil design was deliberately accepted.

Results and Discussion: Fig. 2 shows a MR image (3D gradient echo) acquired with the described setup. The shape of the breast is clearly determined by the gentle compression. The corresponding optical data for one selected source/detector combination are presented in Fig. 3. The figure shows the 'response' curve, i.e., the distribution of photon times of flight measured without any object between the compression plates, together with an *in-vivo* curve acquired simultaneously with the MR data of Fig. 2. Due to multiple photon scattering the *in-vivo* distribution is clearly delayed and broadened compared to the response curve. This demonstrates the temporal resolution of our setup is fully sufficient despite magnetic stray field and still relatively long fibers. The reconstruction algorithm to feed the MR information as prior knowledge into the NIRS analysis is still under development, however.

Conclusion: We report our first *in-vivo* measurements with concurrent NIRS and MR mammography. The principal feasibility of the experimental setup has been demonstrated on a healthy volunteer and we see the potential to improve the diagnostic accuracy of optical mammography substantially by this dual-modality approach. The specificity of MR mammography, on the other hand, should benefit from the NIRS information on tumor vascularization and oxygen saturation.

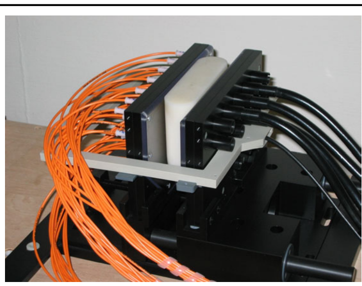

Fig. 1: Compression unit with breast phantom. Illumination fibers enter from the left, transmitted light is collected by fiber bundles on the right hand side. The surrounding surface coil produces a vertical B_1 , allowing the whole block to be rotated around that axis.

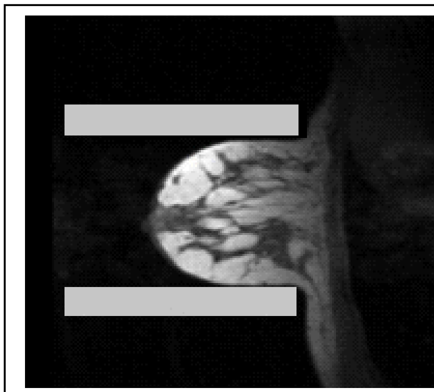

Fig. 2 MR image of human breast. Sagittal cut, resolution 1 mm x 1 mm x 1.5 mm; TR/TE = 8.5/2 ms. The compression plates (indicated by grey bars) are 71 mm apart.

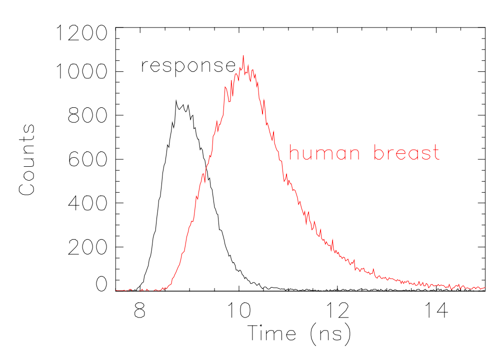

Fig. 3: Photon time-of-flight distributions measured in cranio-caudal projection at 660 nm. Black: system response. Red: *in-vivo* data. Time zero arbitrarily defined.

References:

[1] D. Grosenick et al., Appl. Optics **42,** 3170 (2003).

[2] V. Ntziachristos *et al.*, Rev. Sci. Instr. **69**, 4221 (1998).