Dual imaging technique improves breast cancer characterization

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Combining broadband near infrared spectroscopy and magnetic resonance imaging of breast tissue allows more accurate quantification of the constituents in suspected tumors.

Early detection of breast cancer improves the chance of successful treatment, and breast cancer screening programs often use mammograms (x-rays of the breast) to look for tumors that are too small to be felt. Yet mammograms are less effective for denser breast tissue, such as is found in younger women. Relying on mammograms can be a problem for some women at high risk of breast cancer, who are more likely to develop tumors when young. Particularly in such cases, magnetic resonance imaging (MRI) may be a useful complement to mammography.

MRI scans can flag anomalous breast tissue, but they cannot distinguish between cancerous and non-cancerous material. This results in many false positives, which leads to unneeded biopsies and other tests. However, cancerous and non-cancerous cysts differ in their levels of oxyhemoglobin (HbO₂), deoxyhemoglobin (Hb), and water. In addition to quantifying suspicious volumes of breast tissue, near infrared (NIR) spectroscopy can distinguish between different types of cysts because each molecule will absorb infrared radiation of specific wavelengths to different extents. As a result, combining MRI data and NIR spectroscopic data has the potential to improve accuracy in detecting cancerous cysts.

This approach has been considered theoretically and used experimentally in breast cancers to quantify optical indocyanine green (a diagnostic aid for blood volume determination). Broadband spectral approaches have been implemented in normal breast tissue imaging and also applied to full cancer tumor spectroscopy. Existing standard NIR spectroscopy is poor at quantifying the molecular data obtained, but we have shown that broadband measurements can overcome this problem.

In this work, we used a spectral reconstruction method to obtain physiological properties of tissue, such as chromophore concentrations and scattering properties. Multiple wavelengths of NIR data were processed simultaneously to calculate directly the concentrations of HbO₂, Hb, and water. It was also used to determine scattering amplitude and power. MRI structural information was incorporated into the NIR inversion calculation. The spatial information included the breast parenchyma pattern of adipose and fibroglandular tissue along with the position of possible tumor targets, as illustrated in Figure 1. In this way, the imaging problem is converted into a region-based spectroscopy problem.

To illustrate the improvement of including broadband frequency domain (FD) data, three strategies of spectral methods were chosen for simulation. 6 wavelengths (650–850nm) of frequency domain data, 31 wavelengths (650–950nm) of continuous wave (CW) data, and 31 wavelengths of FD data.

In Figure 1, a breast mesh (b) with layered structure and a complex boundary was generated from an MRI image of breast (a) to simulate realistic clinical situations. Compared to simple circular geometry, the breast mesh with irregular boundary leads to higher background noise in reconstructed images. As shown in Figure 2(a), including 31 wavelengths and using FD data effectively limits the background heterogeneity and makes

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layer structures well recovered, while in the 6-wavelength case (not shown), the images are dominated by artifacts.\cite{8} Broadband FD data gives better recovery results of chromophore concentration and scattering properties, especially in quantification of water concentration. In Figure 1(c), region information was obtained from MRI by segmenting adipose and fibroglandular layers. The spatial information was ‘hard’ coded into NIR image reconstruction.\cite{8} Featuring sufficient spectral data and accurate spatial prior information, the optimum NIR images are shown in Figure 2(b). Compared to Figure 2(a), the contrast of each chromophore is better quantified. Due to their similar spectral features in the NIR range, HbO\textsubscript{2} and water have significant crosstalk which can lead to confusion in the reconstructed images, but with FD data and many wavelengths, this crosstalk is reduced.

False positive cases are unavoidable in MRI due to its low specificity, and so a simulated false positive cyst with no contrast in hemoglobin was studied with spectral reconstruction (Figure 2). Although the cyst region would present as contrast in the MRI, the NIR image shows that the cyst region can be differentiated from cancerous tissue with separated hemoglobin and water images.

A broadband FD experimental system was developed to validate the predictions of simulation, using a mode-locked Ti:sapphire laser. The 80MHz pulsed signal was heterodyned with photomultiplier tube detection. Tissue-phantom experiments confirmed that more wavelengths provided better quantification of total hemoglobin.

In conclusion, there is a need to improve NIR spectroscopy through maximization of broadband wavelength information, even when using prior spatial information from other clinical modalities. NIR imaging without sufficient numbers of wavelengths can lead to erroneous spectral recovery. The accuracy of the chromophore estimates must be maximized if NIR spectroscopy is to be used in elimination of false positive regions identified by MRI. Further improvement will come in extending the spectral range to wavelengths beyond 850nm, which can be achieved with solid-state detector approaches.

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References

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