Optical –MRI Advantages and Challenges

Interest in optical imaging methods for in vivo tissue applications has grown considerably over the last decade with the advent of molecular imaging concepts, and the realization of optical imaging agents and probes that can provide diagnostic signatures or read-outs of molecular activity at the cellular level. Naturally occurring or intrinsic molecules of interest, for example, water and hemoglobin, among others, are also available as potential forms of endogenous optical imaging contrast in tissue. Unfortunately, light is not only highly scattered but also absorbed in tissue, and the depth at which optical imaging signals can be recorded is limited to a few millimeters in most cases. Near-infrared (NIR) wavelengths mitigate the absorption effects of light to some extent, but scattering remains problematic. Nonetheless, diffuse NIR light can travel many centimeters in less absorbing tissues, and holds out the possibility of imaging molecular signatures in tissues over distances up to 10 cm or more. In this setting, the imaging challenge becomes one of image formation or reconstruction; that is, inferring the localized optical parameters that produce the fully distributed light signals at distance which can be recorded non-invasively with light sensing instrumentation. Thus, even though the probing light propagation is sensitive to optical property change occurring on molecular spatial scales, the effects are small and non-linearly embedded within the diffuse light signal read-outs. One strategy to reduce this complexity (and the indeterminacy arising from the nonlinear estimation of optical absorber/scatterers at distance/depth from the light signal observations) is to incorporate priors on the spatial distribution of the optical property parameters of interest by integrating the optical technique with another modality that offers high resolution imaging of tissue structure. A natural partner is MRI, and the optical-MRI combination can be viewed analogously to PET-CT where the former provides functional information at lower spatial resolution while the later generates the structural information at higher spatial resolution needed for interpretation and/or localization of the functional image data. In the case of optical-MRI imaging the combination offers the additional benefit of spatially-encoded optical image reconstruction through the MRI image that significantly improves the estimation of the functional optical information.

In this presentation, the advantages and challenges associated with combining optical and MRI instrumentation and data/image acquisition and processing will be discussed. Several generations of instrumentation for both clinical and preclinical optical-MRI imaging will be highlighted. Clinical data from breast imaging will be presented which indicates the potential advantages of the optical-MRI combination. Specifically, results from preliminary study will suggest that the addition of optical image information improves the diagnostic performance of MRI alone (from an AUC of 0.86 to 0.94) in women with clinically evident but undiagnosed breast abnormalities. Preclinically, experience in brain tumor imaging with the optical-MRI dual modality approach will be presented. While positive results appear possible, challenges remain both in terms of MR-compatible hardware implementation, and MR-priored optical image reconstruction. In terms of the later, results from new attempt to determined image reconstruction procedures on patient and imaging-exam specific bases will be presented and discussed.