reach up to ~+110%. Note that these estimation errors in optical properties and resulting D_B may be affected by the selection of phantom properties for calibration.

4.4. In vivo tumor study data in comparison to phantom study results

In the tumor study, measured μ_a and μ_s' show large variations between subjects (see Figs. 7a and 7b). The range of variations, μ_a (830 nm) from 0.07 to 0.16 cm^{-1} and μ_s' (830 nm) from 5.35 to 13.1 cm^{-1}, is within the range studied using liquid phantoms. The influence of the μ_s' variations on flow indices was found to be greater than that of μ_a, supporting the phantom study results. This is exemplified by the trends shown in Fig. 7c. The overestimation of optical properties (using maximum μ_a and μ_s') leads to underestimation of DCS flow index ($\alpha D_{B\text{-}max}$) and underestimation (using minimum μ_a and μ_s') leads to overestimation of DCS flow index ($\alpha D_{B\text{-}min}$). These are in agreement with the trends of D_B estimation errors using inaccurate μ_s' in liquid phantoms (see Figs. 5c, 5f and 6). Percentage αD_B errors range greatly, from ~−70% up to ~ +280%, depending on optical properties assumed. Errors in flow indices (see Fig. 7d) produce an incorrect observation of trends in the αD_B magnitudes among patients (see Fig. 7c). It is evident that lack of consideration for optical property influences can lead to invalid results in similar studies.

4.5. Conclusions

The advent of DCS technology as a safe and quick alternative for measurement of blood flow in deep tissues has brought the need to further investigate potential errors, notably by the assumption of constant optical properties, μ_a and μ_s'. The flow index produced by DCS measurement is based on a solution to the correlation diffusion equation which includes parameters of μ_a and μ_s'. Utilizing a novel hybrid optical equipment setup, capable of measuring all three parameters of interest (i.e., flow index, μ_a, and μ_s'), with liquid phantom experimental protocols has made it possible to perform this investigation. The present study evaluates the influences of tissue optical properties on DCS flow indices through isolated variations of μ_a and μ_s' in liquid phantoms. It is found that the particle motions in liquid phantoms are not influenced by the variations in optical properties, and the usage of Einstein particle Brownian motion coefficient ($D_{B\text{-}Einstein}$) as true flow index is reasonable for comparison with DCS flow indices. During μ_a and μ_s' variations, μ_s' has a much greater influence on DCS flow indices than μ_a, regardless of the wavelengths used. Studies involving significant μ_a and μ_s' changes should concurrently measure flow index and optical properties for accurate extraction of blood flow information in tissue. The flow index errors resulted from the optical property assumptions in the tumor study elicit such need for concurrent monitoring of optical properties. Incorporation of laser sources at wavelengths beyond those tested in this study may be the subject of future investigation. The range of optical properties tested in the phantoms may also be extended to encompass a wider variety of tissues.

Acknowledgments

The authors would like to thank the University of Kentucky Research Foundation and NIH R01 CA149274 for funding support. We also thank Daniel Kameny, Jacqueline Sims, Karen Meekins, and Laura Reichel for their assistance in recruitment of patients.