In-vivo optical imaging and spectroscopy of cerebral hemodynamics

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Abstract:

Functional optical imaging techniques, such as diffuse optical imaging and spectroscopy and laser speckle imaging (LSI), were used in research and clinical settings to measure cerebral hemodynamics. In this thesis, theoretical and experimental developments of the techniques and their *in-vivo* applications ranging from small animals to adult humans are demonstrated.

Near infrared diffuse optical techniques non-invasively measure hemoglobin concentrations, blood oxygen saturation (diffuse reflectance spectroscopy, DRS) and blood flow (diffuse correlation spectroscopy, DCS) in deep tissues, e.g. brain. A noise model was derived for DCS measurements. Cerebral blood flow (CBF) measured with DCS was validated with arterial-spin-labeling MRI. Three-dimensional CBF tomography was obtained during cortical spreading depression from a rat using the optimized diffuse correlation tomographic method. Cerebral hemodynamics in newborn piglets after traumatic brain injury were continuously monitored optically for six hours to demonstrate the feasibility of using diffuse optical techniques as bedside patient monitors. Cerebral autoregulation in piglets and human stroke patients was demonstrated to be non-invasively assessable via the continuous DCS measurement. Significant differences of CBF responses to head-of-bead maneuvers were observed between the peri- and contra-infarct hemispheres in human stroke patients. A significant portion of patient population showed paradoxical CBF responses, indicating the importance of individualized stroke management.

The development of a speckle noise model revealed the source of noise for LSI. LSI was then applied to study the acute functional recovery of the rat brain following transient brain ischemia. The spatial and temporal cerebral blood flow responses to functional stimulation were statistically quantified. The area of activation, and the temporal response to stimulation were found significantly altered by the ischemic insult, while the magnitude of the CBF response was preserved in the early hours following the ischemia.

In total, this research has further developed the diffuse optical and laser speckle imaging techniques and translated their applications from laboratory to the clinic.