Supplemental Document

Biomedical Optics EXPRESS

Sensitivity of frequency-domain optical measurements to brain hemodynamics: simulations and human study of cerebral blood flow during hypercapnia: supplement

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Supplementary Materials

1. Ultrasound imaging of human skull thickness

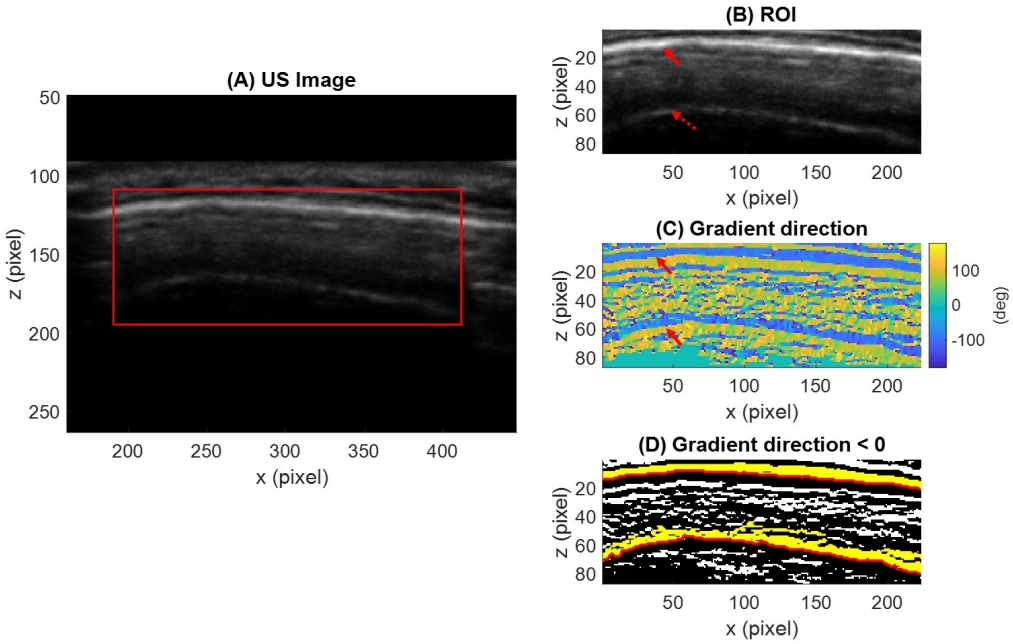

Fig. S1. An example of a single ultrasound (US) scan and processing steps to extract skull thickness. **(A)** The region of interest (ROI), in which skull thickness is determined, is selected from the US image. **(B)** ROI image showing the outer and inner tables of the cortical bone, indicated by red solid and dashed arrows, respectively. **(C)** A map of the gradient direction, obtained using the Prewitt operator technique [1] on the raw ROI image. The gradient direction map shows the orientations of the gradient vectors, in degrees (from $-180°$ to $+180°$) measured counterclockwise from the positive x-axis, as a function of image location. Reading downwards from the top of the image, the two red arrows indicate boundaries where regions with predominantly negative gradients (with orientations around $-90°$) rapidly transition to having predominantly positive gradients (with orientations around $+90°$). The two identified boundary lines thus trace the locations of the cortical bone tables. **(D)** We identify the two largest regions of predominantly negative gradients, highlighted here in yellow, and locate the boundary lines, indicated here in red. The skull thickness (in pixels) is calculated as the minimum Euclidean distance between the two boundary lines. We then compute the skull thickness in units of mm based on the provided scale from the instrument. Note that the instrument scale is based on the assumption that the traversed region contains only soft tissue, so we multiply the calculated skull thickness by a factor of 1.7 (corresponding to the ratio of the speed of sound in cortical skull to the speed of sound in skin).

2. Measurements of CVR

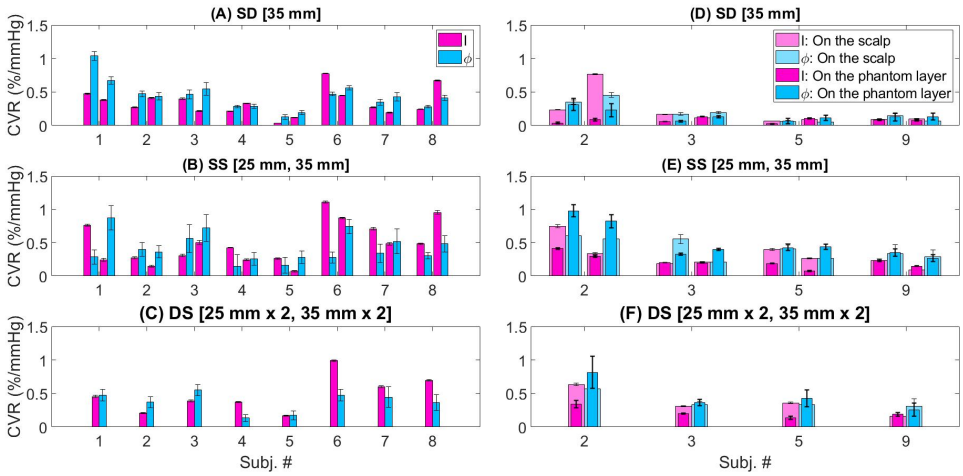

Fig. S2. Cerebrovascular reactivity (CVR) from eight subjects in experiment 1 (left column) and from four subjects in experiment 2 (right column) for single-distance [SD, **(A)** and **(D)**], single-slope [SS, **(B)** and **(E)**], and dual-slope [DS, **(C)** and **(F)**] methods. Intensity and phase measurements of CVR (CVR_I and CVR_ϕ) are shown in magenta and blue, respectively. For experiment 1, SD measurements are shown in the order of 1B and 2A; SS measurements are shown in the order of 1AB and 2BA. For experiment 2, measurements with optical probe on the scalp are shown in lighter colors with wider bars, and on the phantom layer are shown in darker colors with thinner bars. SD measurements are shown in the order of 1B and 2A for those obtained with optical probe on the scalp, and in the order of 3D and 4C for those obtained with optical probe on the phantom layer. Error bars represent standard deviations of CVR obtained from the fit.

References

1. J. M. S. Prewitt, "Object enhancement and extraction," in *Picture Processing and Psychopictorics,* B. Lipkin and A. Rosenfeld, eds. (Academic Press, New York, 1970), pp. 75 – 149.