Title: Generating a 3D ultrasound panorama to monitor neonatal post-hemorrhagic ventricle dilation

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Structured Abstract:

Introduction: Preterm infants suffer a number of health risks, one of which is post-hemorrhagic ventricle dilation (PHVD), which occurs when fluctuations in their blood pressure cause a rupture between blood vessels and the ventricles where cerebrospinal fluid (CSF) is generated. Blood seeping through the rupture clots, blocking CSF from circulating through the central nervous system. The buildup of fluid puts pressure on the brain, putting the child at risk of lifelong disability if not death. The condition is monitored to determine if/when a stent must be surgically implanted, but monitoring is largely qualitative (tactile pressure examination of the fontanel, 2D ultrasound (2DUS) to estimate ventricle volume) so a more quantitative measure is desirable. Our lab previously validated a method for generating a 3D ultrasound (3DUS) of the ventricular system and semi-automatically segmenting the ventricles for a volume measurement, but it required the entire system to be contained in one image. This was impossible in severe cases. We hypothesize that multiple 3DUS images could be aligned and fused into a single contiguous image such that the semi-automated segmentation algorithm could be used even in extreme cases.

Methods: From a previous study, 9 patients were identified where a) ventricles were too dilated to be imaged in a single 3DUS and b) MRI and 3DUS images were captured less than two days apart. The ITK library was used to create a registration and image stitching algorithm, using a Powell optimizer, normalized cross correlation metric, and rigid 3D versor transform. Importantly, the center of rotation for the registration was moved to correspond with the head of the 2DUS probe. To validate the effectiveness of the algorithm, FLE was calculated based on four anatomical markers in one image, selected in 7 trials with a 24-hour washout period. Following this, TRE was calculated based on four anatomical markers common to each image. To be clinically useful, the automated registration pipeline had to perform at least as well as a manual registration. To validate this, a manual registration was performed on each successful registration and both the TRE and time required (including selecting fiducials for registration) were recorded.

Results: The measured FLE for the trained user selecting anatomical markers was found to be 2.8 mm. With the automated registration pipeline, the mean TRE was found to be 4.25+/-1.95 mm, with a mean processing time of 38.6+/-10.8 seconds. The mean TRE for a manual registration was 8.39+/-4.78 mm with a mean processing time of 299.9+/-70.0 seconds. In two of the cases included in this study, registration failed to align the images correctly.

Discussion: The validation of the automated registration pipeline means the semi-automated segmentation algorithm can be implemented even in cases of severe PHVD, providing clinicians with a more objective measure when making decisions about if/when to perform surgery.