Quantitative Assessment of brain mass effect using mid-brain surface in stroke patients

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Introduction

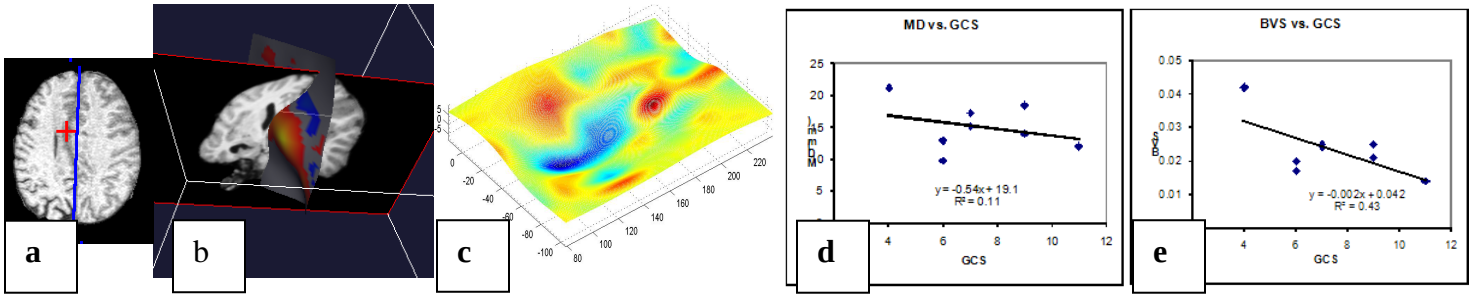
Accumulation of extra mass (blood or water) inside the brain could cause brain tissue compression and exhibit brain midline shift. Even though brain midline shift is a 3D phenomenon, currently, clinicians rely upon the measurement of 2D displacement between the altered brain midline and the putative normal midline shifts at specific anatomical landmarks including the pineal gland (PG), septum pellucidum (SP), and third ventricle (TV) so as to qualitatively evaluate the severity of mass effect [1,2,3]. Ropper reported that PG shift was the most consistent distortion of the brain causing impaired consciousness [2], while Ross et al and Inao et al found that both SP and PG shifts demonstrated significant reverse correlation with the level of consciousness during preoperative period[4,5]. In a later study with chronic subdural hematoma patients, Sucu et al found that SP shift correlated better than PG shift with the level of consciousness [6]. Although it remains unclear whether the discrepancy in these results was caused by the limitation of 2D brain midline shift measurement, a quantitative 3D approach is needed for a better understanding of the correlation between mass effect and patient clinical status. In this work, we propose to examine brain shift with the 3D geometry of brain mid-surface. In particular, we developed a volumetric measure for brain shift (BVS), which was computed as the volume enclosed by the deformed and an estimate of the un-deformed brain mid-surface normalized by brain volume.

Materials and Methods

This was an IRB approved study. T1 weighted anatomical images from six ischemic stroke and two intracranial hemorrhage patients (GCS, 7.38±2.20) were acquired. An initial detection of brain midline in patients was accomplished using an atlas based B-spline elastic registration approach. Subsequently, B-spline curves were fitted to all midlines points and a radiologist further manually edited the automatic detection if necessary. Following brain midline detection, a brain mid-surface was reconstructed by fitting a 2D B-spline surface model to all midlines. The brain deformation volume was computed as the space enclosed by this deformed brain mid-surface with an estimate of the undeformed mid-surface, which was the fitted plane to the end points of brain midline in axial slices. This volume was further normalized by the patient's brain volume (BVS). The maximal displacement (MD) from the deformed brain mid-surface towards the undeformed mid-plane was also computed to be compared with BVS. Both BVS and MD were correlated with patient's Glascow Coma Scale (GCS) scores to examine these two measures' correlation with patient's clinical status.

Results

The automatically detected brain midlines were compared with radiologist's manual revision, and the detection error was 1.34±0.59mm. The location of MD in one patient was indicated with the red-cross and the blue line represented the undeformed brain mid-plane's intersection with this axial slice in (a). A 3D rendering of the deformed brain mid-surface encoded with displacement from undeformed mid-plane and one coronal slice from the same patient was given in (b). The reconstructed deformed brain mid-surface for the same patient with mean curvature color encoding was given in (c) (red representing concave and blue representing convex) to demonstrate its complex geometry. The mean and standard deviation of BVS and MD were 2.34±0.86% and 15.18±3.59mm, respectively. The correlation between MD and GCS was not significant (d, P=0.40), and BVS had marginally significant correlation with GCS (e, P=0.09).



Discussion

In this study, we demonstrated a 3D approach to quantify mass effect through examining the geometry of deformed brain mid-surface. The automatic approach is in good agreement with that obtained using manual editing. Our results suggest that BVS is a better indicator for patient clinical status than MD, since it offers a means to assess whole brain distortion. Future work with a direct comparison of PG and SP shifts employed in the current clinical practice in a larger patient population is warranted.

References

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