In vivo assessment of brain motion and deformation patterns by Magnetic Resonance Imaging and its implication for cerebral contusion pathogenesis research

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Introduction/objectives
Among all types of injuries worldwide, brain injury is the most likely to result in death or permanent disability. This indicates a critical need for more effective ways of understanding the mechanisms of TBI (traumatic brain injury) in order to prevent brain injuries. Previous studies indicate the relative brain-skull motion as a determinant factor in the occurrence of TBI, particularly for closed brain injuries without skull fractures. Although relative brain motion has been studied for decades, the patterns of relative brain motion with respect to the skull are not yet thoroughly understood. This study further investigates brain motion patterns in humans under quasistatic loading conditions using experimental Magnetic Resonance Imaging (MRI).

Materials/Method
15 human volunteers with different age were scanned in four different head positions (left lateral, right lateral, prone and supine) with a resolution of 1.1 pixels/mm and using a 3 Tesla MRI scanner. Image analysis and segmentation were performed using MimicsTM®. Pair-wise comparison (prone vs. supine and left vs. right) of the obtained 3D models was performed for each volunteer by subjecting the skull models to a global registration process and alignment using 3-maticTM®. The whole brain motion, the regional brain motion patterns and the regions where brain deformation is dominant were analyzed using the Focus Inspection® 4.8 software.

Results
Head movement in the coronal plane determines a whole brain translation in the coronal plane with a slight rotation in the axial plane with maximum amplitudes between 2.01mm and 5.67mm. Head rotation in the sagittal plane leads to a whole brain rotation in the same plane with individual maximum amplitudes between 2.65mm and 12.02mm. These maximum amplitudes were seen at the inferolateral and medial cortex of the frontal and temporal lobes. For the lateral ventricles displacement, individual maximum values varied between 1.19mm and 3.44mm for lateral head movement and between 0.01mm and 6.38mm for prone-supine head movement. In general, higher displacement amplitudes were observed for the older volunteers. Beside head displacement, also brain deformation was observed, again being most pronounced for prone-supine head movement.

Conclusions
The relative brain-skull movement is most pronounced at the orbital gyri, the lateral aspect of the frontal lobes and at the inferolateral- and medial aspect of the temporal lobes. More important brain displacement and deformation occur in prone-supine head movement. The present study provides a possible etiology for the frontal and temporal lobes as being predilection sites for cerebral contusions. The results have also implications for the use of navigation in brain surgery, radiation therapy and for brain cine-MRI modalities.