Automatic brain vessel segmentation

Stereotactical procedures require exact trajectory planning to avoid blood vessels in the trajectory path. Innovation in imaging and image recognition techniques have facilitated the automatic detection of blood vessels during the planning process and may improve patient safety in the future. To assess the feasibility of a vessel detection and warning system using currently available imaging and vessel segmentation techniques.

METHODS: Image data were acquired from post-contrast, isovolumetric T1-weighted sequences (T1CE) and time.-of-flight MR angiography at 3T or 7T from a total of nine subjects. Vessel segmentation by a combination of a vessel-enhancement filter with subsequent level-set segmentation was evaluated using three different methods (Vesselness, FastMarching and LevelSet) in 45 stereotactic trajectories. Segmentation results were compared to a gold-standard of manual segmentation performed jointly by two human experts.

RESULTS: The LevelSet method performed best with a mean interclass correlation coefficient (ICC) of 0.76 [0.73, 0.81] compared to the FastMarching method with ICC 0.70 [0.67, 0.73] respectively. The Vesselness algorithm achieved clearly inferior overall performance with a mean ICC of 0.56 [0.53, 0.59]. The differences in mean ICC between all segmentation methods were statistically significant ($p < 0.001$ with post-hoc $p < 0.026$). The LevelSet method performed likewise good in MPRAGE and 3T-TOF images and excellent in 7T-TOF image data. The negative predictive value (NPV) was very high (>97%) for all methods and modalities. Positive predictive values (PPV) were found in the overall range of 65-90% likewise depending on algorithm and modality. This pattern reflects the disposition of all segmentation methods - in case of misclassification - to produce preferentially false-positive than false-negative results. In a clinical setting, two to three potential collision warnings would be given per trajectory on average with a PPV of around 50%.

CONCLUSIONS: It is feasible to integrate a clinically meaningful vessel detection and collision warning system into stereotactical planning software. Both, T1CE and MRA sequences are suitable as image data for such an application [1)].

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Neumann JO, Campos B, Younes B, Jakobs M, Unterberg A, Kiening K, Hubert A. Evaluation of three automatic brain vessel segmentation methods for stereotactical trajectory planning. Comput Methods Programs Biomed. 2019 Aug 16;182:105037. doi: 10.1016/j.cmpb.2019.105037. [Epub ahead of print] PubMed PMID: 31445207.