The inter-scan variations of flow quantifications on human basilar artery: A study controlled the scan conditions with automatic slice positioning and the automatic lumen-area segmentation.

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Introduction

The MR flow quantification of the vessels can be used to evaluate the response of the vessel-related surgery, for example, the percutaneous transluminal angioplasty (PTA)[1]. For the conventional approach, the slice position, tilt angle and the ROI of lumen area are manually selected. However, the manually operation may cause inconsistent conditions between flow measurement and therefore may deteriorate the robustness of the evaluation. In our study, in order to solve this problem, an automatic slice positioning (ASP) method combined with previously implemented automatic ROI selection method[2] were proposed to reduce the inter-scan variation.

Material and Methods

To achieve automatic slice positioning (ASP) for longitudinal flow measurements, the key idea is to acquire 3D T1 volumes in addition to the phase-contrast imaging sequence. By applying co-registration algorithm on the 3D volumes, the head movement (translation and rotation) between scans in different days can be estimated and thus slice position for the follow-up studies can be calculated. In our study, the ASP program was implemented on a workstation equipped with Core i7 920 (Intel CPU, USA, 4 cores) and GeForce GTX295 (NVIDIA GPU, USA, processor cores per GPU: 240 RAM per GPU: 896MB). The calculation program was implemented on the Matlab® system (Mathworks, Natick, MA, USA). The procedure of our program included two steps :(1) converting DICOM images into Analyze format ,(2) calculating the six rigid-body motion parameters between two 3D images by some SPM5 co-registration modules[3]. The mutual information (MI) [4] of two 3D volumes was evaluated as a similarity measure. Then, six rigid-body motion parameters (i.e. Translation: head-foot, anterior-posterior, left-right; rotation: yaw, pitch, roll) between two 3D volumes were estimated via Powell's optimization method [5]. Furthermore, to speed up the calculation of the image registration, we implemented a GPU (graphic process unit) approach to speed up the processing (will be presented in another abstract due to length restriction).

Seven healthy volunteers participated in this study. They were requested to undergo MR scans on three different days mimicking patients who undergo MR scans before and after PTA. Four different imaging sequences were performed: (1)conventional TOF MR angiogram (TOF),(2)3D T1-weighted imaging (TR/TE/FA: 1390ms/2.6ms/15°, FOV: 256×256×256 mm^3, Matrix: 128×128×128) (3DT1) ,(3) through-plane phase-contrast flow quantification of the basilar artery (TR/TE/FA: 34ms/3.9ms/30°, FOV: 108×98, Matrix:256×232, slice thickness:4mm)(FQ), (4)T2-weighted imaging by TSE (TR/TE/FA: 3440ms/102ms, FOV: 220×200 mm^2, Dimension:512×464, slice thickness: 6.5 mm, slice number: 20) (T2w).For the first day, the slice parameters of FQ and T2w were selected manually according to TOF. For the second and the third days, the slice parameters of FQ and T2w were determined by the ASP algorithm applied on the 3DT1 volumes. For comparison, additional sets of images (FQ and T2w) were acquired with manual slice positioning according to TOF. The flow analysis was done by the previously developed Matlab program [2] with automatic segmentation and pulsatility-based correlation.

Results

Figure 1 shows the T2-weighed images (one of twenty slices) acquired from one of the subjects in different days (1st day:(a), 2nd day:(b,d), 3rd day (c,e)). The slice positions of the upper row (a,b,c) and the lower row (d,e) were determined manually according to TOF and the ASP algorithm, respectively. The mutual information (MI, The higher MI, the more similarity of the two images.) between the follow-up images (b,c,d,e) and the first image (a) were noted on the left-top side. Notice that the MIs of the follow-up studies were obviously improved by the proposed ASP method. Figure 2 shows the measured flow rate of one cardiac cycle in different days. Notice that the three flow curves show close to each other. Although the profile of the day 3 is a slightly lower than others, we anticipated that the deviation is due to the normal variation of the physiology condition. Of the two subjects, the average inter-scan variations of flow measurements were 4.73±2.68%, 7.89±4.66% and 9.77 ±5.28% for the lumen area, the mean flow velocity, and the mean flow rate, respectively. For the volunteer datasets, the computation acceleration factor was 15.14±1.00.

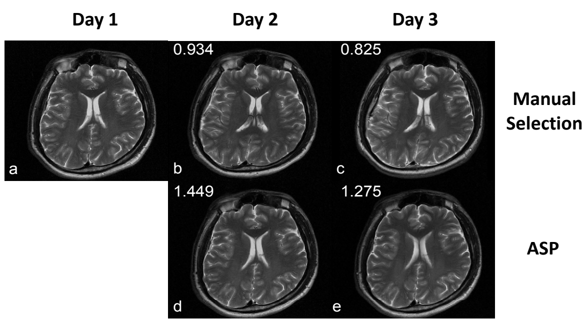

Fig.1 T2-weighted images acquired in different days. (a,b,c) manually selection according to TOF(d,e) slice selection by ASP. In (b,c,d,e), each mutual information with (a) is noted on the left-top. Notice that MI values of (d,e) are higher than (b,c)

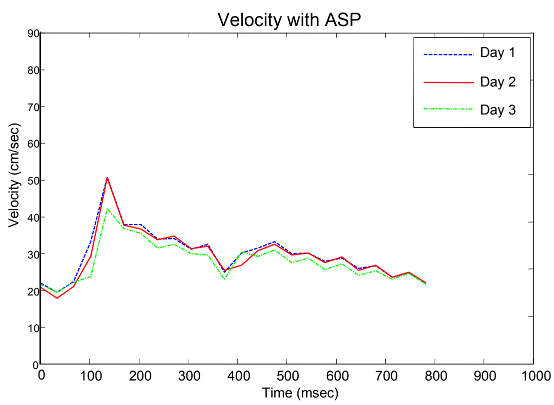

Fig.2 The velocity profiles of flow quantification from day 1 to day 3. Notice that the curves of three days show close to each other.

Discussion and Conclusions

In this study, the aim is to achieve robust evaluation of longitudinal studies of flow measurements by the automatic slice positioning method. Applying our program on 3D volumes acquired in different days, the head movement can be estimated and the slice position is automatically determined. The co-registration was done with the two 3D T1 volumes acquired in difference scan session. Hence, it is not as convenient as atlas-based coregistration proposed by van der Kouwe AJ et al. [6]. Nonetheless, our method may increase the accuracy of the slice positioning for blood flow quantification since the vessel structure varies a lot in difference subjects.

The proposed procedure needs no sequence modifications and the co-registration module (SPM) is an open-source program which is available worldwide. For other applications, the acquisition method for 3D volumes can be adjusted (e.g. the scan resolution or the pulse sequence). Thus, the detail procedure provided in this study can help the researchers working on the longitudinal MR studies. And our GPU-accelerated image registration makes the SPM-based method more practical in the clinical environment. From the results of the volunteer experiments, our program showed reliable because the MI values of the images acquired in different days was high. Combined with automatic segmentation of lumen area, the longitudinal quantifications of the blood flow at basilar artery showed very similar in the normal volunteers. Therefore, we anticipated this method can help to reduce the variation of blood flow measurement and improve the robustness of the evaluation of the treatment process.

Reference

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