Automatic Selection of Arterial Input Function Using K-mean Cluster Algorithm

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Introduction. In perfusion MRI, a reliable arterial input function (AIF) is essential to quantify cerebral blood flow (CBF) precisely. Since AIF depends on the tracer type used, a case-sensitive AIF is always needed for every tracer. In our previous study, D_2O perfusion was first realized on rat model[1]. However, a standard AIF of D_2O has not been directly determined from MR image to date. Traditionally, AIF is often calculated by manually selecting a possible region on MR images. Nevertheless, this process is difficult because of poor spatial resolution and human bias during ROI selection, which may reduce the reproducibility. Therefore, an objective method is important for choosing suitable AIF. In this study, k-means cluster analysis[2] was employed as an automatic algorithm for determining the AIF of D_2O on mice.

Materials and Methods. All experiments were conducted on 7T MRI. Six C57BL/6J mice weighting 22~23 g were anesthetized by 1.5% isoflurane with respiration rates in a range of 50~60 times/min. For each mouse, 2ml /100g dose of isotonic D_2O saline was bolus injected through tail vein. Six slices dynamic turbo-spin-echo (TSE) images were acquired with a surface coil with the following parameters: TE/TR =14/1000ms, turbo factor=8, thickness=1.5m, FOV=20mm, matrix size =128x64, temporal resolution= 9 s. ***Analysis Procedure:*** All analysis were performed on the slice containing middle cerebral arterial (MCA). First of all, motion correction and coil sensitivity correction were done on the raw data. The time-intensity curves were converted into relative concentration-time curve of D_2O by subtracting baseline level. Roughness was calculated to discard irregular concentration-time curves (25% discarded) by the equation: $\Lambda \mathbf{C} = \int_0^T (\mathbf{C}''(\mathbf{t}))\,\mathbf{dt}$.[2] .Since AIF is expected to be characterized by a high maximum concentration, an early time to peak and high slope, each parameter was calculated and divided into 6 clusters by k-means cluster algorithm. The intersections of these three clusters were selected to be candidate AIF. Then the candidate AIF curves were fitted by a bi-compartment model[3] and examined according to the following two criteria: (1) 2% of curves with the largest norm are discarded. (2) The maximum value of the fitted curve differs from the maximum value of original concentration curve by more than 10%. Three to six voxels with the minimal FWHM in these new AIF were picked out as final candidate AIFs and then averaged to generate the final AIF.

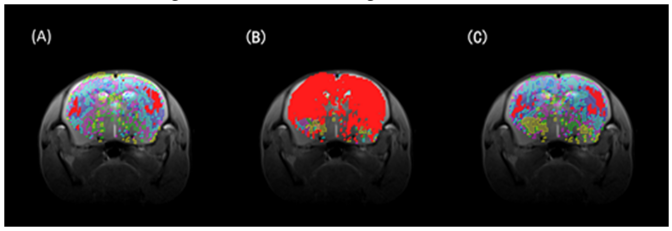

Fig. 1. Voxels were divided into 6 regions by k-mean clustering method based on C_{max} (A), TTP (B), and initial slope (C). Note that the red region is regarded as the highest possible location of AIF based on large C_{max}, early TTP and large slope criteria.

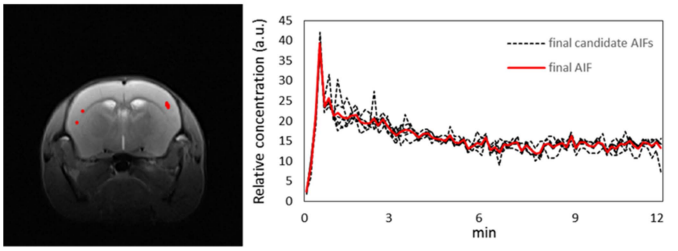

Fig. 2. (A) The locations of final candidate AIFs and (B) their relative concentration to time curves. Final candidate AIFs are plotted as black-dashed lines, and their average is red-bold.

Result. K-mean cluster analysis evaluated by maximum concentration (Cmax), time to peak (TTP), and initial slope on one of the mice is shown in Fig. 1. Six different colors stand for six clusters, and the red region is regarded as the highest possible location of AIF based on large Cmax, early TTP and large slope criteria. The locations of final candidate AIFs were shown in Fig. 2A. Note that the chosen pixels are close to middle cerebral artery. Fig. 2B depicts the final candidate AIF curves and their average, the final AIF. Quick wash-in phase of our AIF corresponds to common knowledge of AIF, where the long retention time in our results could be explained by the slow elimination of D_2O. Fig. 3 plots the average of relative signal-change to time curves, which can represent the shape of AIFs from six mice.

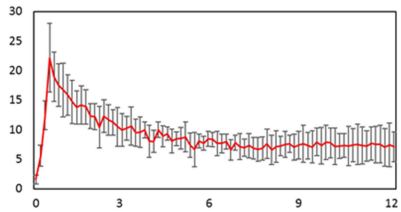

Fig. 3. The averaged AIF of six mice, represented by relative signal-change to time curve.

Discussion and Conclusion. D_2O AIF curves were successfully extracted from mouse brain images in this study through automatic algorithm. The TTP cluster shown in Fig.1-(B) presented a global distribution. This is due to the insufficient temporal resolution of TSE sequence, which is 9 seconds in this study. As a result, TTP may not be a valid estimation method in this experiment. The AIF curves in Fig. 2 present characteristics including curve shape similarity, high in peak, narrow width and regular shape, which implies that k-means provide a reliable AIF estimations. This is mainly due to two particular features of k-mean: the cluster analysis and iterative approach. Cluster analysis is able to collect voxels with similar hemodynamic kinetics, and unreliable voxels can be discarded by iterative approach. However, k-means algorithm has some drawbacks. For example, it is sensitive to extreme values. Since the AIF curves we found were similar in shape and arterial-like, this factor may have a minus impact on our results. Moreover, according to Dorr's work [4], the locations of final candidate AIF were near MCA or its branch. Thus the AIF found in our study should be plausible and reasonable. In summary, a k-mean automatic algorithm is applicable for AIF determination. Further investigations such as the identification of AIF through NMR method[5] can be carried out in the future.

Reference.

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