An automated method for determination of arterial input and venous output function using perfusion parametric joint histogram analysis

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[Introduction]
MR perfusion weighted imaging (PWI) using dynamic susceptibility contrast (DSC) technique has been used to evaluate tissue at risk in acute stroke patients. Quantitative or semi-quantitative evaluation of cerebral blood dynamics is potentially useful for stroke treatment decision-making. DSE-PWI quantitative analysis requires manually or semi-automatic operator input to determine arterial input function (AIF), venous output function (VOF) and other parameters. This complicated operation procedure may become a barrier to implement PWI into stroke examination protocol. This operator interaction also introduces the operator dependency into PWI analysis results and that may cause inconsistency in stroke diagnosis[1]. To overcome these issue, we developed a reliable automatic arterial and venous pixel detection to obtain AIF and VOF to achieve full automatic PWI quantitative analysis.

[Materials and Methods]
Time to peak (TTP) and highest tracer concentration (Cmax) maps were calculated from DSC images. The whole brain joint histogram between TTP and Cmax is generated. In this joint histogram, arterial pixel clusters located on high Cmax with short TTP and venous pixel cluster located on high Cmax but with longer TTP. The profile of arterial/venous pixel cluster on the joint histogram was shaped as a sharp peak. TTP values for AIF/VOF are determined by finding peak shape in the joint histogram. After these peaks were detected, the AIF/VOF candidate pixels were selected from the joint histogram. In the venous pixel cluster profile, pixels from tissue with delayed tracer arrival were contaminated. To eliminate these pixels, averaged tracer concentration after bolus passages was included to the joint histogram.
DSC image data of 24 stroke and brain tumor patients with various scan protocol were analyzed using the proposed algorithm to evaluate its accuracy and robustness. The location of detected AIF/VOF candidate pixels was visually assessed and accuracy was evaluated. Four candidate AIF/VOF pixels were detected and location was analyzed. When the 3/4 of the detected pixels was anatomically correct, we defined the AIF/VOF detection for that case was accurate.
Image processing algorithm was implemented in C++ using DICOM Toolkit ver.3.5.2. The platform used to implement and test the algorithms was DELL LATITUDE D430, Intel Core2 Duo processor 1.33 GHz, 1.99GB RAM running Windows XP operating system.

[Results and Discussion]
The proposed automatic AIF/VOF detection algorithms were applied to the four stroke cases. In the joint histogram between Cmax and TTP, two peaks can be clearly recognized in all four clinical cases that were used in the experiment. These peaks correspond to arterial and venous pixels as shown in figure 1. In this figure, the color in the histograms corresponds to the color in TTP maps. Red color means the pixel may be arterial pixels and blue color means the pixel may be venous pixel and green color means the pixel may be tissue pixel. This result suggests that the artery and vein pixels may be included in the peaks in Cmax/TTP joint histogram space. The detected AIF/VOF pixel locations in typical cases were presented in figure 2. The detected AIF pixels were located at the middle cerebral artery (MCA), but the AIF pixels were detected at the basilar artery in one case. The detected VOF pixels were located at sagittal sinus or sigmoid sinus. The detected AIF pixels were located in MCA or basilar artery. The detected VOF pixels were located at sagittal sinus or sigmoid sinus. By visual inspection, these detected pixel locations were anatomically reasonable. The detection accuracy of AIF pixel location was 0.87 per detected pixels and 0.88 per cases. For VOF, the detection accuracy was 0.57 per detected pixels and 0.4 per cases when TTP and Cmax joint histogram information was used. We obtained significant improvement in the VOF detection accuracy up to 0.88 per cases (Wilcoxson signed rank test, p=0.003), when the averaged tracer concentration after bolus passages was included to the joint histogram.

Using the proposed algorithm, it is possible to detect accurate AIF/VOF and this improves perfusion parameter quantification accuracy. And the fully automatic AIF/VOF detection improves workflow of MR perfusion exam in clinical setting and reduces inter-operator variance in MR perfusion analysis.

[Reference]
[1] http://asist.umin.jp

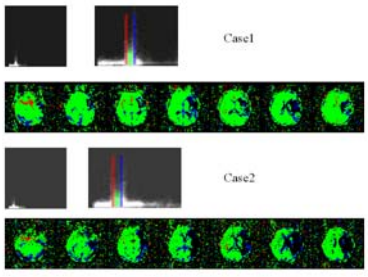

Figure 1: cluster and profile peak on TTP/Cmax joint histogram and corresponding pixel location in DSC
Red: histogram area and pixel location as artery candidate.
Blue: histogram area and pixel location as vein candidate

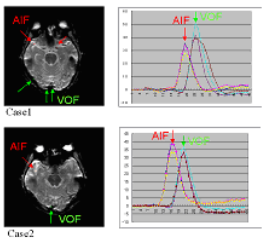

Figure 2: the detected AIF and VOF time course and location of the pixels.