Automatic Arterial Input Function Estimation for Prostate DCE-MRI

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Introduction

T1-Weighted dynamic contrast-enhanced (DCE)-MRI (using a contrast agent (CA), e.g. gadolinium) is an established imaging method for observing microvascular activities to diagnose cancerous regions in the prostate gland. Each voxel or any region of interest (ROI) on DCE images will display an intensity enhancement in time (a signal) that can be related to CA concentration. The intensity signal can be analyzed with different pharmacokinetic models to measure physiological parameters such as tissue perfusion, microvascular vessel wall permeability and extracellular volume fraction [1]. For most of the pharmacokinetic models, a reference intensity signal of healthy tissue is used to measure temporal concentrations of the agent in the feeding vessels, called arterial input function (AIF). There are two different methods to estimate AIF in DCE-MRI studies [2]. The first method uses an arterial catheter into the tissue and samples blood during imaging for further analysis Poor temporal resolution and invasive nature are the disadvantages of this method. The second method involves calculating the automated AIF extraction from the temporal DCE-MRI slices directly. The AIF (blood concentration) is extracted from either the descending aorta or iliac arteries voxels that show a maximum in blood concentration within 10 sec of the CA arrival time. However, at the beginning of this method, the operator must choose the slice that contains the suitable artery to calculate the time course of blood voxels in DCE-MRI. In this study, we presented an algorithm to detect the arterial regions automatically and calculate the average of AIF in prostate DCE-MRI.

Method

Prostate DCE-MRI images were acquired over a period of approximately 3 minutes for 17 subjects. To reduce the effect of noise, the 3D image (MR slices) were primarily smoothed with a Gaussian filter. The external iliac arteries (EIA) were used for extracting the AIF, so the next step was to detect the location of the EIA on the 3D image. To do so, the 3D image was divided into four square regions as shown in Figure1. One of the top square regions (containing the EIA) is selected to calculate the time course (contrast enhanced signal) for every voxel in that region. A voxel that shows the maximum intensity variation (the maximum difference between max and min in concentration) was picked as a seed for a "Connected Threshold" algorithm [3] to expand the EIA region (Figure 1). Finally, the AIF was calculated by averaging the time course of all voxels in the grown EIA region as represented in Figure 2.

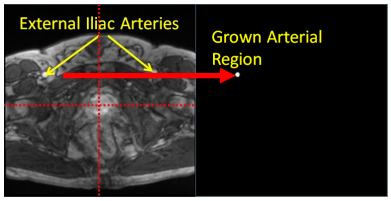

Figure 1. Left: Four square regions on 3D MRI, Right: Grown region.

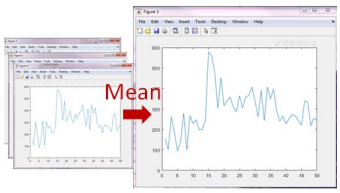

Figure 2. The estimated AIF by averaging all time courses in the grown region.

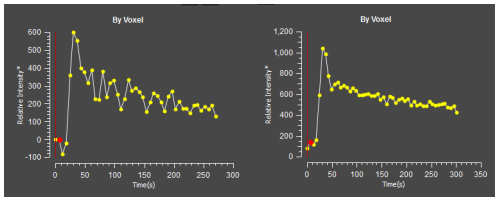

Figure 3. Left: manual AIF, Right: automatic AIF estimation

Results and Conclusion

We estimated the manual and automatic AIF for all 17 subjects (the manual AIF was calculated from selecting a point in the right iliac artery location). Figure 3 shows the results of manual and auto AIF calculations for one of the subjects. Since we used the average of the grown region in auto method, the AIF values after the main peak (5 sec in Figure 3) change smoothly (less fluctuation) in auto curve compare to the manual curve. As a result, the AIF curve in auto method is not dependent on the manual selection of the artery position on DCE images. We used the automatic estimated AIF method to calculate the pharmacokinetic parameters map (Kt). Comparing the results with manual method showed that the AIF automatic estimation is a reliable choice to detect lesions in prostate cancer.

References

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