Automatic correction of intensity inhomogeneity in multi-station MR angiography of the peripheral vessels

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Introduction

Patients with atherosclerotic peripheral arteries in the legs often have multiple stenoses. Gadolinium-based contrast-enhanced MR angiography can very well visualize these arteries and stenoses. Due to the length of the legs, it is not possible to capture all arteries within one image acquisition. Therefore multi-acquisition imaging techniques such as MobiTrak [1] were developed. With these techniques, different parts of the arteries are imaged in slightly overlapping different acquisitions, often called "stations". Imaging is performed before and after contrast injection and the arteries are visualized after subtraction of the pre- and post-contrast images. Often the technique of Maximum Intensity Projection (MIP) is used to visualize the arteries from various viewing points (front, side, …).

Figure 1a shows an example of a front-view MIP of all stations. Large intensity discontinuities can be observed at the position of the arrows, which are due to intensity inhomogeneity in the individual acquisitions. Figure 1b illustrates this frequently occurring acquisition artefact. It shows the average image intensity as function of the position along the z-axis (from head to feet). In clinical practice, the detection of stenosis is primarily performed visually using the MIPs. The presence of intensity inhomogeneity can seriously hamper this detection. Automatic vessel tracking [2] and stenosis quantification [3] methods are under investigation. Also these techniques perform suboptimally in the case of inhomogeneity. We have therefore developed a new multi-station merging technique that automatically corrects for the inhomogeneity in vessel intensity between stations.

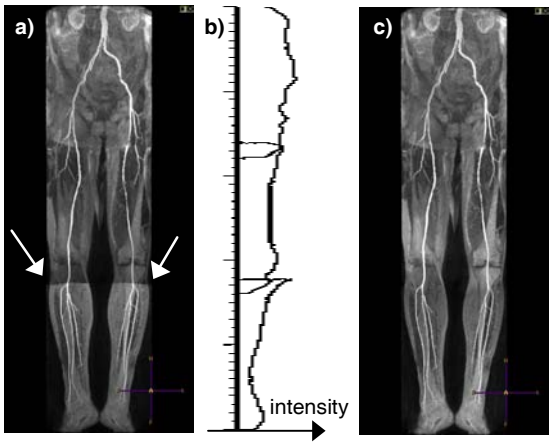

Fig. 1: a) MIP of original image data, b) average intensity along z-axis (per station), c) MIP of merged data after intensity inhomogeneity correction

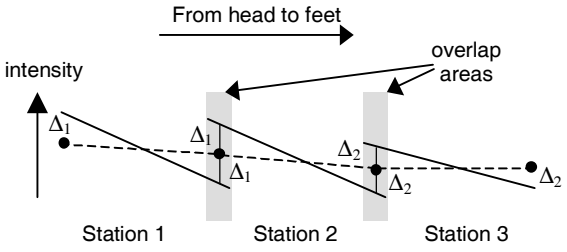

Fig. 2: Stylistic representation of the inhomogeneity correction method (——— = before, - - - - = after correction). The difference in average intensity between stations 1 and 2 is $2\Delta_1$ and between stations 2 and 3 is $2\Delta_2$.

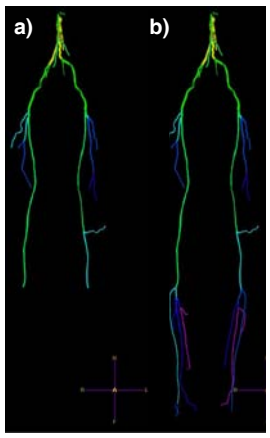

Fig. 3: Tracked vessel tree, a) without, b) with intensity inhomogeneity correction

Methods

The first step is the calculation of the average intensity in the middle slice (perpendicular to the z-axis from feet to head) through the overlapping areas. Figure 2 shows a stylistic representation of the intensity pattern along the z-axis (solid lines). The grey rectangle shows the overlap area, the black dots show the average intensities in the middle slice in this area. Based on these averages, the average intensity per slice (perpendicular to the z-axis) is scaled to a value shown by the dashed lines. The method has been applied to multi-station acquisitions from 10 patients, acquired at the Catharina Hospital Eindhoven, The Netherlands. MIPs without and with intensity inhomogeneity correction were visually compared.

Results

Figure 1c shows an example of the result of our merging method. The intensity inhomogeneity is now virtually invisible. Figure 3 shows the result of applying a vessel tracking method similar to the one published in [2] on the merged image, before (3a) and after (3b) applying our inhomogeneity correction (same vessel tracking parameter settings). The colour indicates the order of tracking of the vessel segments (red is first, blue is last). The complete arterial tree could be tracked only in the case that inhomogeneity correction was applied.

Conclusions

We have presented a new technique for the merging of multi-station contrast-enhanced MR angiography acquisitions of the peripheral arteries. The technique significantly reduces the visibility of intensity inhomogeneity that is present in the original image data. This leads to an increased visibility of the arteries. Furthermore, the inhomogeneity-corrected merged images are better suited for automatic vessel tracking and quantification techniques.

[1] T. Leiner et al. JMRI 11:368-377 (2000).
[2] Th. Bülow et al., Proc. MICCAI: 533-540 (2004).
[3] R.M. Hoogeveen et al. JMRI 8:1228-1235 (1998).