TIME-OF-FLIGHT AND BLACK BLOOD MAGNETIC RESONANCE 3D CAROTID ANGIOGRAPHY

F. P. Glor[1,2], B. Ariff[3], L. A. Crowe[4], P. R. Verdonck[1], A. D. Hughes[3], S. A. Thom[3], D. N. Firmin[4], X. Y. Xu[2]
[1]Cardiovascular Mechanics and Biofluid Dynamics Unit, Ghent University, Gent, Belgium, [2]Department of Chemical Engineering & Chemical Technology, Imperial College London, London, United Kingdom, [3]Clinical Pharmacology and Therapeutics, St Mary's Hospital, Imperial College London, London, United Kingdom, [4]Cardiovascular Magnetic Resonance Unit, Royal Brompton and Harefield NHS Trust, Imperial College London, London, United Kingdom

INTRODUCTION

Due to the social impact of cardiovascular diseases, angiography became a prime research field in constant evolution. The proposed relationships between arterial haemodynamics and plaque formation or aneurysm rupture has prompted researchers to visualise the blood flow in the arteries. For this purpose, the arteries are reconstructed in 3D from the angiogram. Flow data at the extremities of the considered artery and the 3D geometry allow complete flow prediction within the artery using computational fluid dynamics (CFD). Magnetic resonance angiography (MRA) is often considered as the 'gold standard' for image-based CFD. MRA techniques are divided into time-of-flight (TOF), phase-contrast (PC) and Black Blood (BB) methods. For carotid bifurcations, TOF and BB MRA are the most commonly used techniques (Glor, 2003; Thomas, 2003). In this study, the impact of using TOF or BB MRA on 3D carotid reconstructions was investigated.

METHODS

Eight young hypertensive subjects (ages 30-55, mean 42), free from carotid plaque, were scanned on three occasions, each 2 weeks apart. During each visit, BB MRA images of the carotid bifurcation were acquired using a standard protocol (Crowe, 2003). Simultaneously, TOF images were acquired at the same locations were the BB images were taken. Details of the segmentation, 3D reconstruction and flow calculation can be found in a previous study (Glor, 2003).

RESULTS

Figure 1a shows a Black Blood image taken in the right common carotid artery (CCA) of subject VH. Figure 1b shows the TOF image in the exact same plane. Similarly, Figure 1c and d show a BB and a TOF image of the internal (ICA) and external carotid arteries (ECA). Note the poor image quality for the ECA in Figure 1c. See Table 1 for a summary on the geometry agreement using cross-sectional area, vessel linearity (King, 2002) and bifurcation angle as markers. The ECA cross-sectional area is overestimated using BB MRA. In general, there was a good agreement in vessel centerlines, except in 16.7% of the cases where the ECA was confused with one of its branches. The calculated flow profiles reconstructed from BB MRA or TOF agreed well, allowing for the uncertainty related to BB and TOF MRA-based CFD (Glor, 2003; Thomas, 2003).

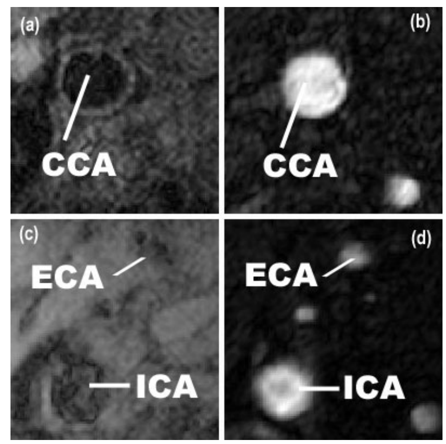

Figure 1: MR images of subject VH. (**a**) BB MRA in CCA; (**b**) TOF MRA in CCA at same location as (a); (**c**) BB MRA in branches; (**d**) TOF MRA in branches at same location as (c).

Table 1: Geometric parameter agreement. **Mean ± Std**: Mean Difference ± Standard Deviation, 'difference' is defined as the TOF value – BB value; **%**: mean difference as a percentage of the mean value; **RMSE**: root-mean-square error defined as the mean difference between the measured value and the technique-averaged value.

Parameter	Mean ± Std	%	RMSE
CCA Area [mm²]	1.03±3.04	2.10	1.26
ICA Area [mm²]	-0.06±4.22	-0.24	1.54
ECA Area [mm²]	-1.98±3.62	-11.10	1.39
CCA Linearity [%] **(King, 2002)**	2.27±0.85	2.49	1.13
Bifurcation Angle [°]	1.90±9.49	1.29	2.30

DISCUSSION AND CONCLUSION

Both TOF (Glor, 2003) as BB MRA (Thomas, 2003) proved to be reproducible in 3D carotid geometry and flow reconstruction. BB MRA has the advantage of allowing higher resolution images of carotid cross-sections when compared to the TOF images (in-plane resolution BB: 0.47mm; TOF: 0.63mm). Moreover, BB allows estimation of the intima-media thickness (IMT), an important marker of vascular disease (O'Leary, 2002). Slow flow introduces artifacts in both imaging modalities, but may be more difficult to identify when you do not have clear definition of the outer wall as in TOF. Although both techniques can be gated, the TOF protocol would induce a greater acquisition time than the BB protocol. On the other hand, BB is challenging to segment automatically and localising the carotid branches is often difficult.

The Black Blood protocol yielded poor image quality in the carotid daughter branches in general and the ECA in particular. This resulted in an overestimation of the ECA area and, in extreme cases, in a confusion between the ECA and its branches. Bifurcation angle was similar in both imaging techniques, but the vessel linearity was reduced by BB MRI, probably due to a greater uncertainty in vessel location in BB MRA.

Considering the agreement in TOF and BB-based results, the relative ease in reconstructing carotid bifurcations from TOF images and the importance of IMT measurements, we conclude that the 3D reconstruction of the carotid bifurcation should be done using TOF images. In case the IMT measurements are required, an extra Black Blood scan in a single plane in the CCA should be made.

REFERENCES

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