Optimisation of the Contrast Dose and Injection Rates in Whole Body Angiography at 3T

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Introduction and Aims: Atherosclerosis is a systemic disease that can affect the cerebrovascular system, kidneys and peripheral vessels. Comprehensive evaluation of the entire arterial system is therefore favourable and Whole Body MRI Angiography (WBA) has proven to be a useful clinical tool in assessing disease extent [1,2].

WBA acquires contrast-enhanced images of the entire arterial tree from the supraaortic vessels to the vessels of the lower legs, using surface coils to cover the whole body and moving patient table technology. The optimal contrast dose for WBA is unclear. Some publications have suggested using up to 45ml [3], while others suggest a dose based on patient weight may be more appropriate. Contrast delivery is also variable, with suggested injection rates of up to 2.0 ml/s [2]. WBA is carried out using a two-stage contrast injection, in order to maximise the concentration of contrast in the area of interest at the time of scanning. There is therefore the possibility that extra-vascular levels of contrast from the first injection may deteriorate the image quality of the second angiogram and this is believed to underpin the tendency to increase the contrast dose for subsequent injections [3]. Some publications suggest that increasing the contrast volume will result in an increase in image quality [3], however this is not practical in a clinical environment due to costs and potential toxicity.

With an increasing trend towards clinical imaging on 3.0 Tesla (T) scanners it is proposed that the increase in signal change after contrast administration in combination with increased signal to noise ratio (SNR) could potentially be used to reduce the contrast burden in patients, while still achieving the same image contrast and overall image quality. This could make the whole body scanning of the vascular system a realistic possibility for the detection of atherosclerotic disease.

The objective of this work was to examine a number of different contrast regimes in WBA scanning in order to optimise the contrast dose and delivery rate in a cohort of healthy normal volunteers.

Methods: Six groups of twenty asymptomatic adult volunteers (age range 40-75, mean 54 years), with a high clinical risk of cardiovascular disease, were recruited for this study. Each volunteer underwent a WBA assessment on a 3.0T MRI scanner (Magnetom Trio; Siemens, Erlangen). Subjects were imaged head-first and supine using surface coils to cover the entire body (head matrix coil, neck matrix coil, body matrices, peripheral angiography coil and spine matrix coils).

The WBA is acquired in four stations before and after the injection of contrast (Dotarem, Guerbet), and the images subtracted to produce the angiogram. Station 1 covers the vessels of the head and chest, station 2 covers the abdomen and pelvis, station 3 the upper legs, and station 4 the lower legs. After the first injection of contrast, stations 1 and 4 were imaged and stations 3 and 4 after the second injection. Contrast was injected via a power injector (Spectris Solaris, MedRad Inc.) and followed by 20ml of saline flush. Contrast doses and injection rates were systematically altered for each group as shown in Table 1.

Group	Contrast Dose (ml)		Rate (ml/sec)
	1st Injection	2nd Injection	
1	20	20	1.0
2	15	15	1.0
3	15	15	1.5
4	10	15	1.0
5	10	15	1.5
6	10	10	1.0

Table 1- Contrast dose and rate for each group

Images were acquired in the coronal plane using a 3D FLASH sequence with a parallel imaging acceleration factor of 3. Sequence parameters differed slightly for each station images, with TR= 2.6 - 3.58ms, TE= 1.06 - 1.1ms and flip angle= 16 - 37°. Fields of view were 500×360 mm for the head and lower legs stations and 500×344 mm for the abdominal and upper legs. The lower three stations were acquired using centric k-space ordering and linear reordering used for the head station. Slice thicknesses varied between 1.0 mm and 1.4 mm.

Analysis was carried out on a Leonardo Workstation using Maximum Intensity Projection (MIP) images. The vascular system was divided into 16 segments: left/right internal carotid arteries, left/right subclavian arteries, aortic arch, abdominal aorta, left/right renal arteries, left/right common iliac arteries, left/right superficial femoral arteries, left/right proximal posterior tibial arteries (knee level) and left/right posterior tibial arteries (ankle level). Regions of interest (ROI) of at least 5 pixels were drawn in each segment and background ROI's also drawn adjacent to the vessels to assess the contrast and noise level. Contrast to Noise (CNR) and SNR were calculated for each segment in each volunteer group using standard methods. T-tests were then calculated using SPSS 16.0 (Chicago, Illinois).

Results and Discussion: Qualitative analysis of the CNR for each station is displayed in Figure 1. Contrast groups 4, 5 and 6 produced the highest CNR, suggesting that a lower dose of contrast is likely to be optimal for WBA imaging at 3T. In the head station, Groups 4 and 5 produced the highest CNR in the carotid and subclavian arteries and the aortic arch, whilst group 3 and 5 maximised the contrast in the vessels of the abdominal station. In the upper legs, Group 5 resulted in high contrast in the femoral arteries and Group 4 and 6 proved the best for imaging the vessels of the lower legs. Overall, both groups 4 and 5 resulted in the highest CNR for all stations. There were no statistical differences between these two groups in any region (using a 95% confidence interval).

In atherosclerotic disease the lower extremities are generally the highest priority area of interest. In the upper and lower legs, Group 4 provides a statistically higher CNR in the femorals (p=0.03) than Group 1 (our previous protocol) relative to Group 5. The SNR is also higher for the upper leg station, although this does not reach significance (p=0.09) when compared to Group 5.
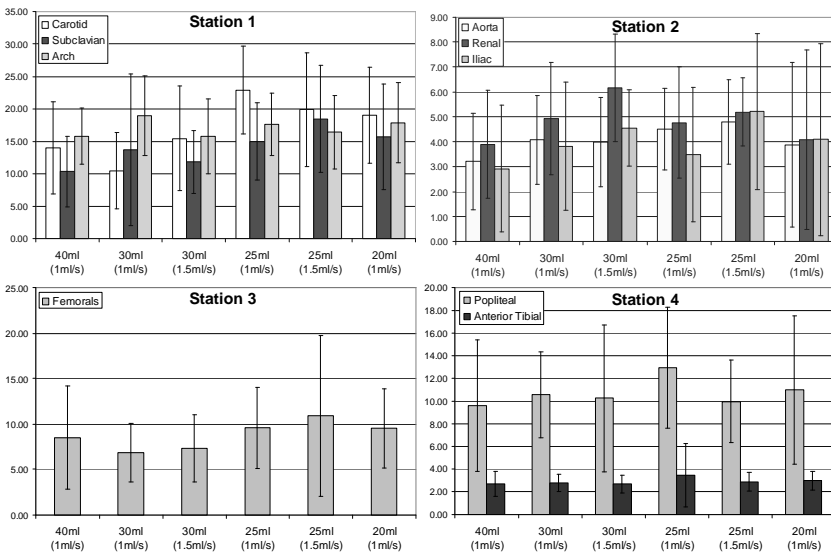
High doses of contrast produce a longer bolus, and therefore arterial peak, allowing scanning of a region while contrast is still present. This can result in venous contamination, reducing the diagnostic value of the final images [3] and for this reason, short injection times are used in angiography such that the short boluses coincide with the scanning of the centre of k-space. In WBA, short injection times are not practical as this does not allow time for table movement, therefore slower delivery times tend to be used. We have replicated a short bolus in this study by reducing the total contrast dose, which has produced good results, showing that high CNR can still be achieved. This study concludes that the optimal contrast delivery regime is that of Group 4 for WBA at 3T.

Conclusion: This study has demonstrated that reducing the contrast dose delivered in WBA at 3T can result in an increase in the CNR in the vessels of interest, without resulting in significant deterioration in SNR. Reducing the contrast dose may make this technique a cost-effective means for screening in the detection and diagnosis of atherosclerosis. This study examined only a limited number of different contrast regimes, and it is accepted there may be additional work required in order to further refine this technique.

Figure 1- Contrast to Noise ratio's for the four stations of the WBA and each contrast regime

References:
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