Assessing the reproducibility of aortic stiffness in patients with end-stage renal disease: a 3-Tesla cardiac magnetic resonance imaging study

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Background

Cardiovascular disease is the leading cause of death in patients with end-stage renal disease (ESRD) but is driven by a different set of risk-factors than classical coronary artery disease. One of these risk factors is increased aortic stiffness, which disrupts arterio-ventricular coupling and leads to left ventricular hypertrophy. Aortic stiffness is an independent predictor of cardiovascular mortality in ESRD and a potential imaging biomarker. It is measurable with cardiac magnetic resonance (CMR) imaging using:

- Aortic pulse wave velocity (aPWV) is an indirect measure of aortic stiffness
- Aortic distensibility (AD), a direct measure

For the first time in this population, the inter-study repeatability and the intra- and inter-observer variability of aPWV and AD was investigated with high resolution 3-Tesla CMR.

Methods

10 haemodialysis patients underwent two identical test-retest CMR scans within 2 weeks.

Analysis was offline and blinded. Aortic PWV was calculated from saggital-oblique cine images of the aortic arch to measure distance (Figure 1a) and phase contrast sequences of the ascending and descending aorta to derive transit time (Figure 1b-c). Ascending and descending AD (AAD and DAD) was calculated from axial cine images, at the level of the pulmonary artery bifurcation (Figure 1d).

aPWV was calculated as follows:

$$aPWV(ms) = \frac{Distance\ around\ arch}{Transit\ time\ for\ pulse\ wave}$$

AD was calculated as follows:

$$AD\ (mmHG^{-1} \times 10^{3}) = \frac{\Delta\ Aortic\ area}{Minimum\ aortic\ area \times Pulse\ pressure}$$

Inter-study repeatability was assessed by a single reader. Inter- and intra-observer variability were respectively assessed by two readers of 10 scans and one reader analysing 10 scans twice. Intra-class correlation coefficient (ICC), coefficient of variation (CoV) and Bland-Altman analyses were calculated to assess reproducibility.

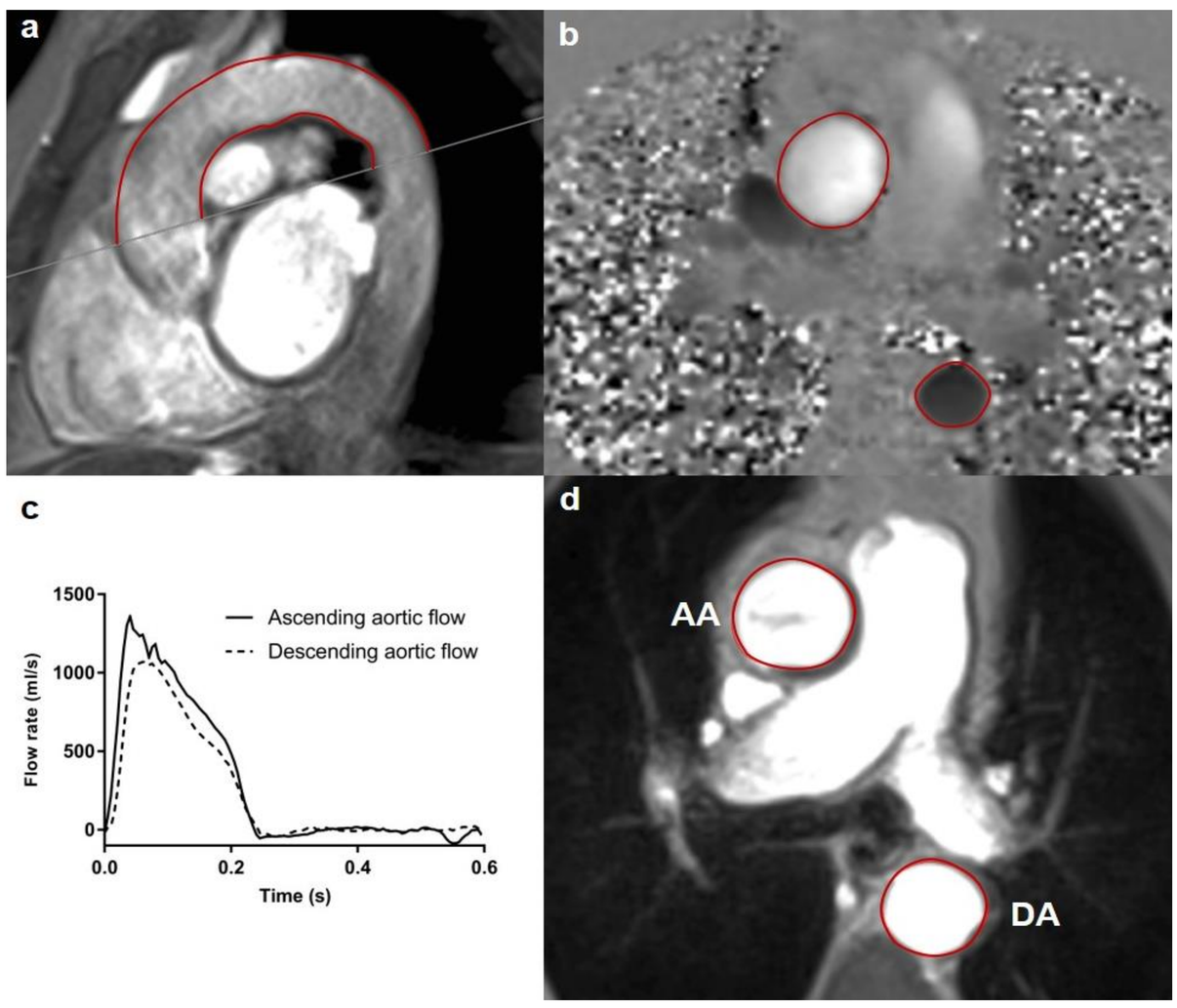


Figure 1: *CMR analysis of aPWV and AD.*

Results

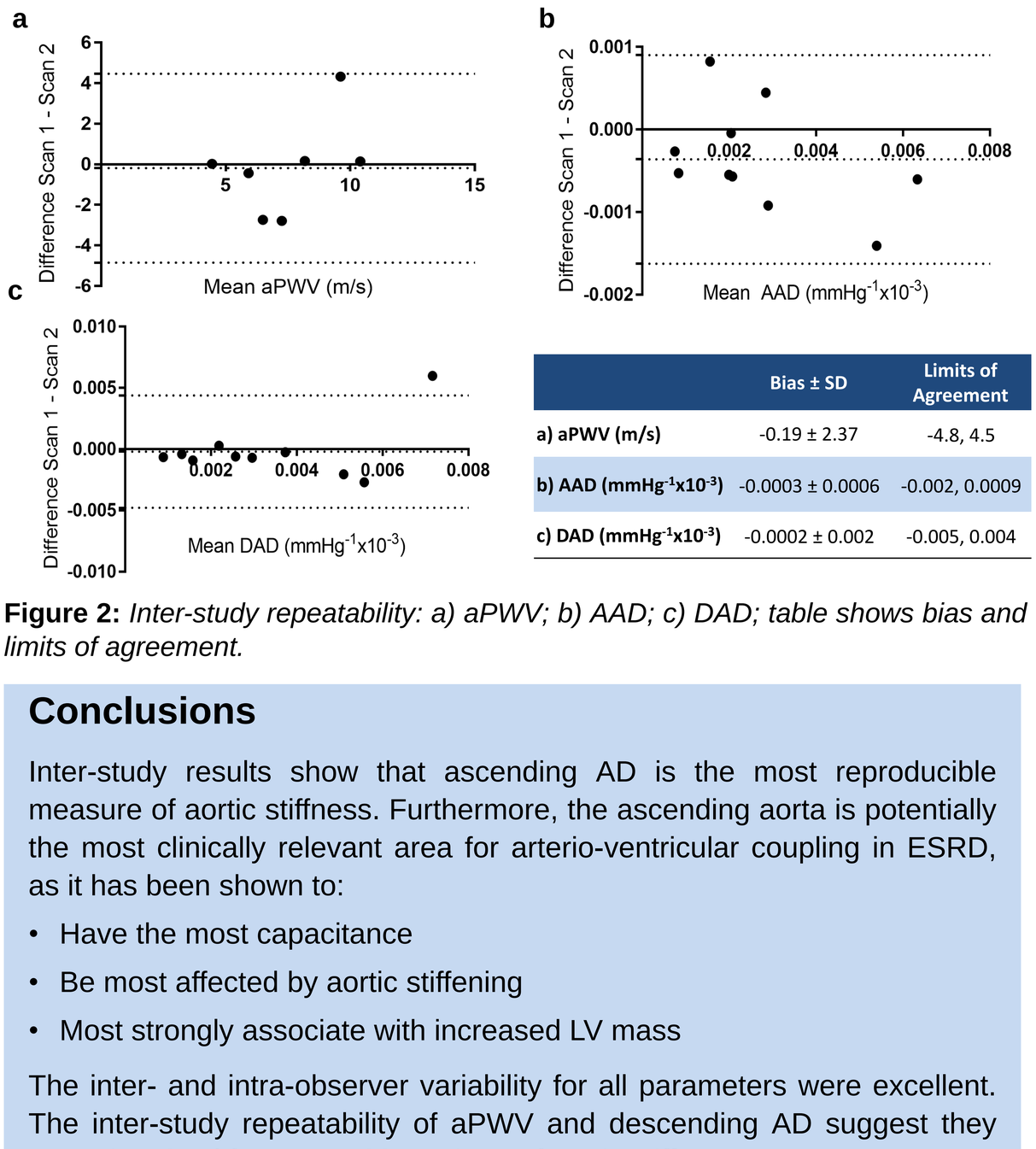
Population (n=10)	
Male; n (%)	8 (80)
Age; years (mean ± SD)	59 ± 15
HD vintage (months)	26.2 (±26.6)
Active on transplant list; n (%)	5 (50)
Ethnicity; n (%)	
Caucasian	3 (30)
BAME	7 (70)

Table 1: *Patient demographics. Normally distributed data presented as mean (±SD); non-normally distributed data as median (25^{th}, 75^{th} percentile); BAME, Black, Asian and Minority Ethnic*

All 10 patients completed the study. Demographics are presented in Table 1. Mean aPWV was 8.2m/s (±3.48), mean AAD was 2.5mmHg^{-1}x10^{-3} (±1.7), mean DAD was 3.2mmHg^{-1}x10^{-3} (±2.7). The repeatability and variability of parameters is shown (Table 2). Bland-Altman analyses revealed no systematic bias (Figure 2a-c).

Table 2: *Reproducibility of aPWV, ascending AD and descending AD.*
** Three inter-study aPWV scans were not analysable and excluded from analysis*

	aPWV (m/s) (n=7)	AAD (mmHg^{-1} x10^{-3}) (n=10)	DAD (mmHg^{-1}x10^{-3}) (n=10)
Inter-study repeatability	ICC: 0.51 (-0.31, -0.90)* CoV: 14.8%	ICC: 0.94 (0.78, 0.99) CoV: 13.3%	ICC: 0.51 (-0.13, 0.85) CoV: 33.7%
Inter-observer variability	ICC: 1.00 (1.00,1.00) CoV: 1.4%	ICC: 1.00 (0.99, 1.00) CoV: 2.7%	ICC: 1.00 (0.99, 1.00) CoV: 2.1%
Intra-observer variability	ICC: 1.00 (0.99,1.00) CoV: 1.8%	ICC: 0.97 (0.88, 0.992) CoV: 3.2%	ICC: 0.94 (0.77, 0.98) CoV: 4.1%



	Bias ± SD	Limits of Agreement
a) aPWV (m/s)	-0.19 ± 2.37	-4.8, 4.5
b) AAD (mmHg^{-1}x10^{-3})	-0.0003 ± 0.0006	-0.002, 0.0009
c) DAD (mmHg^{-1}x10^{-3})	-0.0002 ± 0.002	-0.005, 0.004

Figure 2: *Inter-study repeatability: a) aPWV; b) AAD; c) DAD; table shows bias and limits of agreement.*

Conclusions

Inter-study results show that ascending AD is the most reproducible measure of aortic stiffness. Furthermore, the ascending aorta is potentially the most clinically relevant area for arterio-ventricular coupling in ESRD, as it has been shown to:

- Have the most capacitance
- Be most affected by aortic stiffening
- Most strongly associate with increased LV mass

The inter- and intra-observer variability for all parameters were excellent. The inter-study repeatability of aPWV and descending AD suggest they are suboptimal for use as biomarkers of aortic stiffness.

@CycleHD15

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