Vascular CMR measurements

Table 3e.1: Comparative (validation) studies for CMR vascular endpoints with alternative techniques. Agreement is expressed as Pearson´s correlation coefficient (R), coefficient of variation (CoV, derived from SD of the difference between the measurements divided by mean value, expressed as %) or linear regression index (R^2). PWV – pulse wave velocity (expressed as m/s). CAD - coronary artery disease. Ao - aorta. T-p - through-plane velocity-encoding CMR. I-p - in-plane velocity-encoding CMR. BA-PWV - brachial-ankle pulse wave velocity. DST - distensibility. AA - ascending aorta. DA - descending aorta. C-F PWV - carotid-femoral pulse wave velocity. TOF – time of flight angiography

Study	**N**	**Population**	**Reference**	**Parameter**	**PWV(invasive) vs. CMR**		
					Agreement		
Grotenhuis [1]	18	Suspected CAD	Invasive PWV	PWV (total, proximal, distal)	Ao_{total}	6.5±1.1 vs 6.2±1.1	0.08
						R=0.53	
					Ao_{prox}	6.5±1.3 vs 6.2±1.1	0.16
						R=0.69	
					Ao_{distal}	6.9±1.1 vs 6.1±1.0	<0.01
						R=0.71	
Westenberg[2]	14	Suspected CAD	Invasive PWV	PWV Ao_{total}	T-p	R=0.58	0.03
						CoV 10%	
					I-p	R=0.75	0.003
						CoV 12%	
Westenberg [3]	17	Suspected CAD	Invasive PWV	PWV (proximal and distal)	I-p Ao_{prox}	R=0.69	0.002
						CoV 24%	
					I-p Ao_{distal}	PCC=0.91	<0.001
						CoV 19%	
Kim [4]	124	Healthy volunteers	BA-PWV	PWV (total, proximal, distal, abdominal) DST (AA, DAproximal, DAdistal, abdominal)	BA-PWV yields higher values (45% average)		
					PWV Ao_{total}	R^2=0.697	<0.001
					PWV Ao_{prox}	R^2=0.588	<0.001
					PWV Ao_{distal}	R^2=0.468	<0.001
					PWV Ao_{abd}	R^2=0.418	<0.001
					DST AA	R^2=0.673	<0.001

					DST DA_{prox}	R^2=0.626	<0.001
					DST DA_{distal}	R^2=0.596	<0.001
					DST $_{Abd}$	R^2=0.583	<0.001
Nelson [5]	20	Healthy volunteers	Aplanation tonometry (C-F PWV)	DST (AA, DAproximal, DAdistal)	DST AA	R^2=0.57	
					DST DA_{prox}	R^2=0.60	
					DST DA_{distal}	R^2=0.72	
Biasiolli [6]	18	Patients with significant carotid artery stenosis	TOF	Arterial Wall measurement		Cohen's κ = 0.68	
Chai [7]	26	Patients with significant carotid artery stenosis	Histology	T2 value (T2 mapping)	Plaque type (AHA classification)	R^2=0.808 (Cohen's κ = 0.73)	
					Lipid content (area)	R^2=0.85	<0.001

Table 3e.2. Reproducibility of vascular endpoints. Reproducibility is presented as coefficient of variation (CoV, derived from SD of the difference between the measurements divided by mean value, expressed as %), Pearson´s R§ or mean difference±SD*. PWV: pulse wave velocity. DST: distensibility. Ao: aorta. T-p: through-plane velocity- encoding CMR. I-p: In- plane velocity-encoding CMR.

Anatomical measures	**Chan**§[8]	**Roes**[9]		
	Patients (=16)	Healthy volunteers (n=10)		
Imaging technique	T2W-TSE	HASTE (T2-3D BB)		
Thoracic descending aorta	Interstudy	Intraobserver	Interobserver	Interstudy
Lumen area	0.99			
Mean vessel wall volume	0.85	2.3%	3.5%	0.945 5.8%

Functional measurements	**Westenberg**[2]						**Grotenhuis**[1]			**Noda***[10]	**Nelson**[5]
	PWV										**DST**
Measurement	Total Ao		Proximal Ao		Distal Ao		Total Ao	Proximal Ao	Distal Ao	Proximal Ao	
Method	T-p	I-p	T-p	I-p	T-p	I-p	T-p	T-p	T-p	T-p	T-p
Intraobserver	3%	3%	6%	4%	2%	3%				0.1±0.6	1%
Interobserver	3%	4%	11%	8%	5%	5%				0.1±1.4	2%
Interstudy	13%	7%	17%	10%	16%	12%	9%	13%	9%	-0.05±3.0	

Table 3: Normal values for aortic dimensions (Table A), PWV and aortic distensibility (Table B) with CMR according to age and sex. Dimensions expressed in mm (mean value followed by 95% CI in brackets, or mean value±SD); PWV m/s and distensibility as kPa $^{-1}$ x 10 $^{-3}$ or §mmHg-^{1}. PWV – pulse wave velocity. DST - distensibility. AA - ascending aorta. DA - descending aorta. AbdA – abdominal aortaBSA – body surface area.

Table A	**Sex**	**Age (years)**											
Turkbey [11]	**AA**	**45-54**		**55-64**		**65-74**		**75-84**					
	Male	31.6(27.2-37.3)		32.8(28.2-40.7)		34.2(28.1-40.7)		34.7(28.6-40.8)					
	BSA indexed (mm/m^2)	15.9 (13.3-19.5)		16.8 (13.6-21.1)		17.8 (14.2-21.8)		18.6 (15.2-22.6)					
	Female	28.8(24.6-34.4)		30.1 (25.7-36.4)		30.6 (26.1-36.3)		31.1 (26.8-37.1)					
	BSA indexed (mm/m^2)	16.7 (13.5-20.7)		17.6 (14.8-22.1)		8.1 (14.5-22.1)		9.7 (15.3-28.2)					
Burman [12]	**Aortic root cusp-commissure**	**20-29**		**30-39**		**40-49**		**50-59**		**60-69**		**70-79**	
		Systole	**Diastole**	**Systole**	**Diastole**	**Systole**	**Diastole**	**Systole**	**Diastole**	**Systole**	**Diastole**	**Systole**	**Diastole**
	Male	34.4(26–43)	32.8(25-40)	33.8 (26–41)	32.0(24-40)	36.0 (31–41)	34.1(30-40)	36.3(25-48)	35.2(24-47)	37.4(32-43)	36.2(31-41)	37.8(28-44)	37.9)30-44)
	BSA indexed (mm/m^2)	17.7 (14–22)	16.9(13–21)	17.2 (13–21)	16.2(12-20)	17.4 (15–20)	16.5 (14-19)	18.5 (14–23)	17.9 (13-23)	19.2 (15–24)	18.6 (15-23)	19.4 (17–22)	19.0 (16–22)
	Female	30.2 (21-40)	28.4(19-38)	30.0(24-36)	28.7(23-35)	33.9(29-39)	32.8(28-38)	31.4(26-36)	30.6(25-36)	32.8(28-37)	32.0(28-36)	32.9(30-36)	32.0(29-35)

	BSA indexed (mm/m^2)	17.6(13-22)	16.6(12-21)	18.4(16-21)	17.6(15-20)	19.0(14-24)	18.4(13-23)	18.9(16-22)	18.5(15-22)	19.0(14-24)	18.6(15-22)	19.8(18-22)	19.3(17-21)
Redheuil [13]	**AA**	**46±16**	**<30**	**>70**									
	Male	31±4	27.5±2.8	33.2±4.3									
	Female	30±4											
	DA												
	Male	24±3	20.3±1.6	24.3±2.7									
	Female	22±3											
	AbdA												
	Male	21±3	18.3±1.4	21.5±13.3									
	Female	20±2											

Table B	Numbers of participants (male)	Biomarker	Age					
			20-29	**30-39**	**40-49**	**50-59**	**60-69**	**≥70**
Redheuil [14]	122 (60)	Central PWV	3.5±0.5	3.9±1.1	5.6±1.4	7.2±2.3	9.7±2.9	11.1±4.6
		AA DST	74±23	61±23	31±18	18±7	12±7	10±6
		DA DST	72±18	70±24	38±17	29±13	18±8	17±6
			Sex					
			Men			**Women**		
Rose[15]	26 (13)	AA DST	6.1±2.5			8.6±2.7		
		DA DST	5.1±2.4			7.2±1.6		
Redheuil [13]	100 (45)	AA DST	3.8±2.7			3.8±3.1		
		DA DST	4.4±3.0			4.5±2.4		
		AbdA DST	8.8±3.8			7.3±4.7		
Voges [16]	71 (30)	Central PWV	3.7 ± 0.9			3.5 ± 0.6		
		AA DST	8.5 ± 4.2			9.2 ± 3.0		
		DA DST	7.7 ± 2.7			8.8 ± 3.1		

Table 4: Outcome studies with PWV with CMR confirming the predictive associations.
Dimensions expressed in mm; PWV m/s and distensibility as $kPa^{-1} \times 10^{-3}$ or §$mmHg^{-1}$. DST - distensibility. AA - ascending aorta. PWV – pulse wave velocity. * adjusted for age, sex, weight, height, ethnicity, mean BP, smoking, antihypertensive medication, total cholesterol, HDL cholesterol, and diabetes. § adjusted for age, sex, ethnicity, systolic blood pressure, use of blood pressure medication, resting heart rate, diabetes mellitus, current smoking, body mass index, and hypercholesterolemia.

	Study type	Population	Age, number of participants (male, %)	Follow up (years)	Endpoint	Outcome (event rate)	Statistics (HR (95%CI)
Redheuil [17]	Observational prospective	Asymptomatic participants	61±10 3675 (56)	8.5	AA DST	All-cause mortality (9.3%)	Univariate: 6.5 (2.4-12.3), p<0.001 (for upper quintile)
							Multivariate*: 2.3 (1.2-4.4), p=0.009
						CV mortality (6.7%)	Univariate: 5.7 (2.8-11.7), p<0.001 (for upper quintile)
							Multivariate*: 1.9 (0.9-3.8), p=0.09
Maroules [18]	Observational prospective	Asymptomatic participants	44±10 2122 (44)	7.8±1.5	AA DST	CV mortality (6.9%)	Univariate: 1.63 (1.50-1.77), p<0.001
							Multivariate§: 1.18(0.95-1.46), p=0.08
					PWV		Univariate: 1.25 (1.11-1.41), p<0.001
							Multivariate§:

							1.11(0.89-1.32), p=0.28

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