Impaired distensibility of dilated aortic autografts in Ross patients assessed with MRI

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Introduction

Pulmonary autograft replacement of a dysfunctioning aortic valve (Ross procedure) is widely used because of low numbers of reoperation, the lack of need for anticoagulation, and potential for growth of the autograft. However, recent reports indicate that dilatation of the autograft frequently occurs during follow-up. Therefore, with a new MRI approach we investigated the degree of dilatation and its effect on aortic root distensibility in 10 Ross patients, and compared the results to those in age and gender matched volunteers.

Echocardiography, currently used in clinical routine to study the aortic diameter for distensibility measurements, has important limitations when applied to the aortic root. Overlying structures such as ribs can complicate the measurement of the exact diameter of the aorta. Trans-esophageal echocardiography does not have this limitation, but is semi-invasive and patients often experience this as a discomforting examination. Another important limitation is the fixed acquisition plane, which is not adapted to cardiac motion. Due to cardiac contraction and relaxation, the aortic root will move through the acquisition plane (perpendicular to the aorta just above the sinus of Valsalva at end-systole). This through plane motion of the sinus will result in unreliable diameter measurements at other time-points during the cardiac cycle. MRI is a non-invasive, patient-friendly imaging tool. In the present paper MRI is used for exact positioning of a double-oblique acquisition plane in 3D at specific points in time during the cardiac cycle.

Purpose

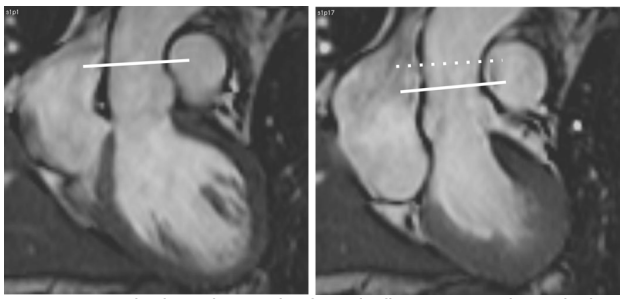
Evaluation of diameters and distensibility of the aortic root in Ross patients with MRI, compared with matched volunteers.

Methods

Ten Ross patients and 7 volunteers (matched for age and gender, mean (SD) age 18.1 (4.2) years; mean (SD) follow-up for Ross patients 7.8 (1) years) underwent a MR-imaging protocol at 1.5 Tesla (Philips Gyroscan Intera).

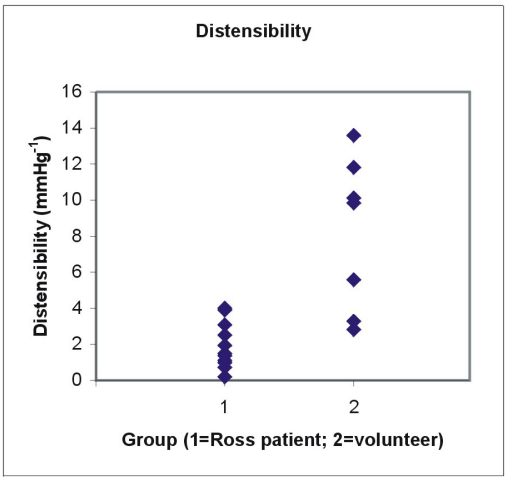
Diameters of the aortic root at the level of the annulus (ANN), sinus of Valvalva (SOV), sino-tubular junction (STJ) and the ascending aorta (AA) at the level of the pulmonary trunk were measured, while distensibility measurements were performed at the level of the STJ.

Distensibility is defined as: Dist ($mmHg^{-1}$) = $(A_{max} - A_{min}) / A_{min} \times (P_{max} - P_{min})$; (with A_{max} and A_{min} maximal and minimal cross-sectional lumen area (mm^2) respectively, and P_{max} and P_{min} systolic and diastolic blood pressure (mmHg) respectively.)



Imaging protocol

Two orthogonal scout cine image sets of the aortic root were obtained for planning of the acquisition planes. Minimal lumen area was expected early in the cardiac cycle during the iso-volumetric contraction phase, while the maximal area was expected when the peak of aortic flow passes through the AA. Therefore, first the flow was measured at the level of the AA with a phase-contrast sequence, to determine the optimal delay between the R-wave and timing of the acquisition of the cross-sectional minimal and maximal area measurements. The acquisition plane positions were manually set for both measurements, thus correcting for through-plane motion of the aortic root during contraction (Figure 1A and 1B). Fig 1A and 1B show slice positioning at minimal and maximal aortic flow, respectively. Distensibility was assessed using an SSFP-type sequence (B-TFE). Scan parameters included: FOV 220mm, scan matrix 176×176, voxel size 1.25mm×1.25mm×6mm, TR 3.2ms, TE 1.23ms. The phase-contrast study consisted of a FFE sequence, with scan parameters: FOV 300mm, scan matrix 128x128, voxel size 1.17mm×1.17mm×8.00mm, TR 4.8ms, TE 2.8ms. The high temporal resolution ranging between 4 and 7 ms of this flow measurement enabled optimal timing of the acquisition of the maximal and minimal cross-sectional areas. Total examination time did not exceed 25 minutes.



Results

The results are summarized in Table 1. A significantly decreased mean distensibility was observed in the Ross patient group compared to healthy volunteers (Mann-Whitney U-test $p < 0.01$) (Figure 2). Also, the diameters at all levels were significantly larger in Ross patients (Mann-Whitney U-test $p < 0.05$ for all 4 levels).

Table 1: Mean distensibility (SD) (in $mmHg^{-1}$) and mean (SD) diameters (in mm) for Ross patients and healthy volunteers.

	Ross patients mean (SD)	Volunteers mean (SD)	p-value Mann-Whitney U-test
Distensibility	1.94 (1.28)	6.60 (3.99)	$p < 0.01$
Diameter ANN	34.0 (7.8)	26.4 (2.6)	$p < 0.01$
Diameter SOV	43.5 (5.0)	30.0 (2.6)	$p < 0.01$
Diameter STJ	34.8 (7.3)	26.5 (7.3)	$p = 0.01$
Diameter AA	31.1 (6.6)	25.3 (2.9)	$p = 0.02$

Conclusion

With this new approach of measuring distensibility of the aortic root with MRI we demonstrated a significantly decreased mean distensibility of the aortic root as well as a significantly increased lumen diameter in patients after the Ross procedure, compared to healthy volunteers. MRI allows for fast and accurate assessment of these clinically relevant parameters, when accurate positioning of the acquisition plane adapted for through-plane motion of the aortic root during the cardiac cycle is done. Despite the overall good clinical results of the Ross procedure reported in literature, the presence of dilatation in combination with decreased distensibility of the aortic autograft might constitute a better indication for reoperation in the future than the currently used parameter of increasing dilatation. A cut-off value for abnormal distensibility applicable for risk-assessment of reoperation will be determined from a larger volunteer group.