

## Assessment of the clinical feasibility of phase contrast ultrashort TE

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**Introduction:** Aortic stenosis (AS) can give rise to high velocity jets of more than 400cm/s. Phase contrast (PC) has the potential to accurately diagnose lesion severity; however, flow in AS jets is complex and often very turbulent resulting in intravoxel dephasing that can introduce significant errors in peak velocity and flow estimates. Previously, we reported that reducing the TE is critical to obtain reliable stroke volume (SV) estimates in moderate to severe AS patients [1] and thus we proposed utilising the ultra-short TE centre-out radial readout trajectory (VC-UTE) [2] to reduce the TE. The VC-UTE sequence can achieve a TE of 1.3ms compared to 2.47ms using a Cartesian readout (VC-Cartesian) typically applied clinically.

**Purpose:** To evaluate the clinical feasibility of the proposed VC-UTE in a cohort of 20 moderate-severe AS patients.

**Materials and methods:** Two different retrospective 15 heart-beat segmented FLASH breath-hold acquisition schemes were used: i) a velocity compensated Cartesian readout (VC-Cartesian), currently used clinically, Venc 500cm/s, TR/TE 11.96ms/2.47ms, slice thickness 6mm, FOV 300-360mm, Matrix-size 192x132, flip angle 30° phase res. 92 lines and ii) a velocity compensated ultrashort TE centre-out radial readout trajectory (VC-UTE), Venc 500cm/s, TR/TE 5.216ms/1.30ms, slice thickness 6mm, FOV 250mm, Matrix-size 192x192, flip angle 13° 134 radial lines.

PC flow measurements were taken at two locations the main pulmonary artery (MPA) and at the tips of the aortic valve (AV) at end systole. The measurements were repeated three times to assess measurement to measurement variability. The order of the locations and the repetitions within each level was randomised to remove any influence from physiological variations. Background phase errors due to eddy currents were removed by imaging a static gel phantom directly after the patient with the same image parameters, position and orientation [3]. All measurements were performed on a 1.5T MRI scanner. (Avanto, Siemens Healthcare Sector, Erlangen, Germany).

Flow analysis was performed using customised Matlab scripts (The Mathworks Inc, MA, USA). PC SV and velocity time integral (PC VTI<sub>pk</sub>) was determined by numerical integration of the mean velocity over the cardiac cycle, and the peak velocity, without neighbourhood smoothing, over systole. The aortic valve area (AVA) was quantified as the mean PC SV over the mean PC VTI<sub>pk</sub> across repetitions. A gold-standard estimate of stroke volume (CMR SV) was provided by volumetric imaging of the left ventricle with magnetic resonance [4] and gold-standard VTI and AVA were measured with Doppler-echocardiography (echo VTI / echo AVA).

**Results:** Figure 1 shows the PC SV against the CMR SV before (a,b) and after (a',b') background phase correction for the MPA (a) and AV (b). At the MPA, free of turbulence induced intravoxel dephasing, the VC-Cartesian sequence correlated well with the CMR SV and experienced little change before (R<sup>2</sup>=82) and after (R<sup>2</sup>=84) correction. At the AV the agreement was reduced (R<sup>2</sup>=0.27/0.25) and the larger error bars (fig 1b) show disagreement between repeat measures.

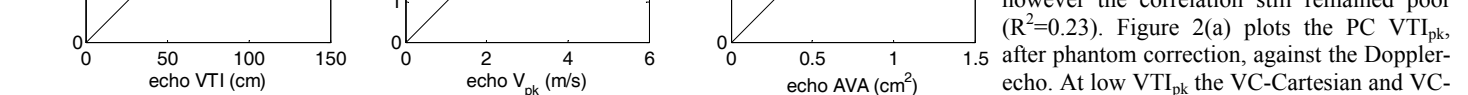
In comparison the VC-UTE sequence suffered from background phase errors at the AV. Similar to the VC-Cartesian sequence, a good correlation, though with a systematic underestimation of CMR-SV, is seen at the MPA after correction (R<sup>2</sup>=0.85 vs R<sup>2</sup>=0.52 before correction).

At the AV the smaller error bars show a better consistency between repeat measurements; however the correlation still remained poor (R<sup>2</sup>=0.23). Figure 2(a) plots the PC VTI<sub>pk</sub>, after phantom correction, against the Doppler-echo. At low VTI<sub>pk</sub> the VC-Cartesian and VC-UTE schemes generally agreed with Doppler-echo but began to underestimate at higher

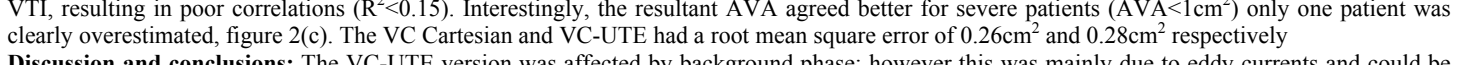
VTI, resulting in poor correlations (R<sup>2</sup><0.15). Interestingly, the resultant AVA agreed better for severe patients (AVA<1cm<sup>2</sup>) only one patient was clearly overestimated, figure 2(c). The VC Cartesian and VC-UTE had a root mean square error of 0.26cm<sup>2</sup> and 0.28cm<sup>2</sup> respectively

**Discussion and conclusions:** The VC-UTE version was affected by background phase; however this was mainly due to eddy currents and could be corrected. The SV variation across repeat measurements was smaller but there was a small systematic underestimation compared with the CMR SV and the VC Cartesian. Despite this the AVA estimated by the VC-Cartesian and VC-UTE sequences show similar trends and error but neither agree well with Doppler across the whole range. The smaller variability seen in the SV estimate of the VC-UTE sequence across repeat measurements tends to suggest that this sequence is more robust to the intravoxel dephasing errors than the VC-Cartesian sequence. Further optimisation of this sequence, explanation of the systematic underestimation and reduced sensitivity to background phase, may yield a more clinically reliable sequence for the evaluation of aortic stenosis patients with MR.

**References** [1] O'Brien K 28(2008):210 JMRI, [2] O'Brien K 62(2009):626 MRM [3] Chernobelsky 9(2007):681 JCMR [4] Young 216(2000):597 Radiology



**Figure 1** shows the mean SV across the repetitions against CMR SV before (a,b) and after (a',b') background phase correction for each acquisition scheme. The error bars indicate the maximum and minimum SV estimates.



**Figure 2** (a) shows the mean VTI and peak velocity (b) across repetitions after background phase correction and (c) provides the calculated AVA for each acquisition scheme.

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