was significantly increased in TOF patients (P=0.0004–0.006). Peak diastolic WSS was significantly higher than the temporally averaged WSS in TOF patients but not in controls (P=0.011 vs P=0.688). There was no differential spatial distribution of WSS across the MPA segments. Low intraobserver variability (2% mean percentage difference) was present between repeated WSS measurements.

4D flow CMR derived WSS values

	Patients (n=17)	Controls (n=6)	P value
Tangential mean WSS (N/m^2)	0.368±0.050	0.215±0.016	0.0004
Tangential peak diastolic WSS (N/m^2)	0.404±0.071	0.230±0.034	0.0005
Axial mean WSS (N/m^2)	0.229±0.037	0.134±0.021	0.0004
Axial peak diastolic WSS (N/m^2)	0.269±0.060	0.137±0.014	0.0004

Wall shear stress (WSS) values in patients and controls expressed as mean ± standard deviation. Mann-Whitney test was used for statistical comparison.

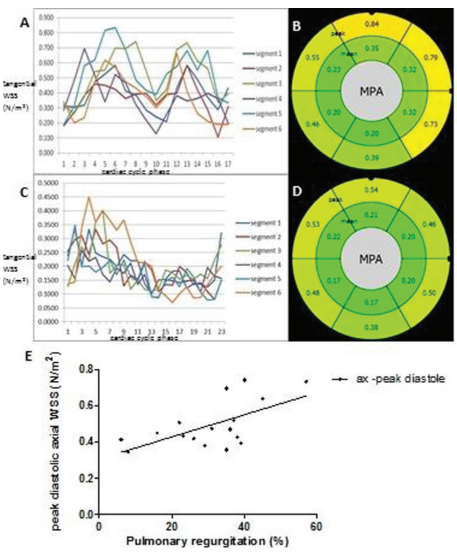

Figure. An example of temporal and spatial distribution of tangential wall shear stress (WSS) in the main pulmonary artery (MPA) in a patient (A,B) and a control (C,D); correlation of peak diastolic axial WSS with the severity of pulmonary regurgitation (E).

Conclusion: WSS in the MPA is elevated in TOF patients with a significantly higher diastolic peak, which correlates with the severity of pulmonary regurgitation. More 4D data analysis may give insight into the contribution of altered diastolic WSS to the pathogenesis of pulmonary artery remodelling in TOF patients.

P873
4D magnetic resonance flow imaging (4D flow MRI) in neonates - Normal values, changes over time and feasibility

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Background: New free-breathing 4D flow MRI techniques (ViosWorks, GE-Healthcare, USA) have made it possible to scan neonates without sedation. 4D flow MRI data analysis used to be technically demanding and time consuming, but with the advent of cloud supercomputing and machine learning (Arterys, USA), this analysis can now be performed quickly in a standard web browser. We present the first prospective CMR 4D flow study of changes in cardiac output and pulmonary blood flow in neonates.
Purpose: The aim of the study is to report normal values for cardiac index, pulmonary blood flow, pulmonary blood flow distribution, and changes during the neonatal period. Furthermore, it is the intention to investigate the feasibility of 4D CMRI in free breathing neonates without sedation and contrast.
Method: From the Baby Heart study (CBH), a cohort of 60 neonates was offered to participate in the CMR protocol, and parent to 32 children accepted.
The neonates were scanned on a 1.5 Tesla Optima MR450w (GE-Healthcare, USA) with ViosWorks, and data analysis was performed using Artery's cloud solution and software.
Results: It was possible to perform a good 4D flow acquisition without sedation in 26 of the 33 neonates (80%). After the study data was uploaded to the cloud, analyses of flow in the aortic arc and pulmonary circulation could be performed in less than 10 min (4D flow results table 1). Body surface area (BSA) was calculated using the Haycock formula. Cardiac index (CI) (mean 3,39±0,52) increased 60% during the first 33 days of life (P=0.002) (figure 1). This increase was due to a rise in stroke volume (SV) by 60% (P=0,02). The change in heart rate was small and not statistically significant.
Pulmonary blood flow (Qp) was on average 17% higher than cardiac output (Qs), probably reflecting the flow through the foramen ovale. There was trend of decreasing Qp/Qs with age, but the change was not statistically significant with n=26.

Table 1. 4D Flow MRI Results

	Age (days)	Weight (g)	lenght (cm)	BSA (m^2)	Qs (L/min)	Qp (L/min)	Qp/Qs	Qrpa (L/min)	Qlpa (L/min)	SV (ml)
Mean	20,7	4100	53,4	0,25	0,85	0,98	1,17	0,42	0,42	6,09
SD	6,7	530	1,7	0,02	0,15	0,17	0,15	0,11	0,08	0,92

Results of 26 neonates. Qs = systemic blood flow, Qp = pulmonary blood flow, Qrpa = right pulmonay artery blood flow, Qlpa = left pulmonary artery blood flow, SV = stroke volumen.

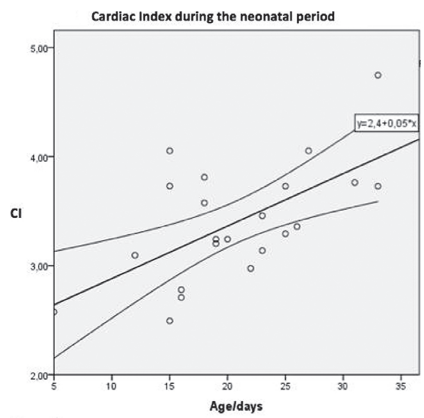

Figure 1:
Changes in cardiac index (CI) L/min/m2 during the first 33 days of life.
The plotted lines:linear regression and confidence intervals.

Conclusion: Normal values for CI and pulmonary blood flow is reported. CI was seen to rise 60% during the first 33 days of life, this is due to a gradual increase in stroke volume. Neonates has a 17% higher Qp compared to Qs, probably due to shunting through the foramen ovale.
4D flow using ViosWorks and Artery's software is feasible (80% success rate) and quick, the CMR scan takes 10 min and flow analysis less than 10 min.
Funding Acknowledgements: Danish Heart Association, Candies Foundation.

P874
Mitral and aortic flow adaptation to 58-days head-down bed-rest assessed by PC-MRI, and effectiveness of high-intensity jump training countermeasure

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Aims: Prolonged immobilization generates cardiac deconditioning, a cardiovascular disease risk factor, and efficient countermeasures (CM) are needed to prevent it. We aimed to assess by Phase-Contrast (PC) MRI the effects of long-term strict head-down (-6 degrees) bed-rest (BR) deconditioning and the effectiveness of high-intensity jump training CM on aortic and mitral flow.
Methods: 23 males (29±6 years, 181±6 cm, 77±7 kg) were enrolled. The experiment was conducted at Envihab research facility as part of the European Space Agency BR studies. Participants were randomly allocated to the jump training group (JUMP, n=12) or to the control group (CTRL, n=11). A typical training session consisted of 4x10 countermovement jumps and 2x10 hops in a horizontal sledge jump system, with 5–6 sessions/week. PC-MRI images (3T Biograph mMR) with interleaved 3-directional velocity encoding (VENC: x and y: 80 cm/s; z: 150 cm/s) were obtained (spatial resolution 1.4x1.4 mm^2) at the level of the aortic root, and of the mitral plane, before (PRE) and after 58-days (HDT58) of BR. The resulting planar magnitude data and 3-directional velocity images were semi-automatically analysed with previously validated custom software to compute the following parameters: cardiac output (CO), stroke volume (SV), flow rate (Qpeak), systolic duration (Sys) and heart beat duration (RR), rapid filling (Efill) and inflow rate (Epeak).
Results: In CTRL, compared to baseline values, at HDT58 a significant ($p<.05$, paired t-test) RR (14%) and systolic (10%) shortening, with a decrease in CO (8%), SV (22%), Qpeak (12%), Efilling (26%), Epeak (26%) were observed. In CM, only RR was shortened (8%), together with a decrease in SV (12%), Qpeak (7.5%), Efilling (11%), Epeak (15%).
Conclusions: This is the first study addressing aortic and mitral flow using PC-MRI during BR. Cardiac adaptation to deconditioning due to prolonged immobilization resulted in a reduction of aortic outflow and mitral inflow. The applied CM appeared only partially effective in opposing this phenomenon. This information could be useful to better understand physiologic changes in patients undergoing long periods of immobilization, and to improve countermeasures to reduce cardiac deconditioning.

Table 1

		RR (ms)	Sys (ms)	CO (l/min)	SV (ml)	Qpeak (l/min)	Efill (cc)	Epeak (l/min)
CTRL	PRE	988±114	390±31	7.01±1.2	115±18	33.4±4.4	82±13	31.4±4.7
	HDT58	846±113*	352±47*	6.45±0.8*	90±9*	29.4±2.5*	61±10*	23.1±3.3*
JUMP	PRE	987±137	367±26	6.46±0.8	105±7	31.2±1.9	78±13	31.4±4.2
	HDT58	905±105*	352±36	6.13±1	92±16*	28.8±4*	69±17*	26.7±5.1*

*$p<0.05$ paired t-test PRE vs HDT58.

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P875

Atrial stasis measured by cardiac magnetic resonance 4D flow particle tracing is present during sinus rhythm in patients with paroxysmal atrial fibrillation and is associated with higher stroke risk

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Background: Acquisition of 4D flow cardiac magnetic resonance (CMR) imaging allows visualisation of blood flow in the cardiac chambers and great vessels. Post-processing of the underlying flow data allows determination of the residence time distribution (RTD), a novel means of assessing atrial function. RTD was originally devised to assess efficiency of chemical reactors and reflects the cumulative distribution of the time it takes for a blood volume to transit a cardiac chamber.

Purpose: Assessment of atrial function is often challenging. We have developed a tool using 4d flow CMR to assess atrial transit time as a surrogate for atrial stasis, with the hypothesis that increased atrial stasis in patients with paroxysmal atrial fibrillation (pAF) is a risk factor for thrombus.

Methods: One hundred and nine participants underwent CMR studies including 4D flow, comprising 18 volunteers and 91 patients with pAF. The RTDs were created by seeding "particles" at right upper pulmonary vein plane in the post-processing software (coded in MATLAB), following these particles with the measured blood velocity and counting them (and recording their exit time) as they passed the mitral valve. The RTDs were normalised to 5 heart beats, and the efficiency of atrial flow was then determined from the RTDs based on the time constant (tau=-1/B) of the exponential decay (Figure 1).

Results: Atrial stasis, indicated by a higher RTD time constant (RTDTC), was observed in patients with PAF compared with gender-matched controls (1.68±0.46 vs 1.51±0.20; p=0.005). In patients with PAF, there was a greater atrial stasis in those with CHA_2DS_2-VASc scores ≥2 (RTDTC of 1.85±0.76 vs 1.59±0.40; p=0.045); female gender and left ventricular ejection fraction (LVEF) contributed significantly to the atrial RTDTC (p=0.002 and p=0.046 respectively).

Conclusions: Atrial stasis quantified by CMR 4D particle tracing occurs during sinus rhythm in patients with PAF and is associated with higher CHA_2DS_2-VASc scores. Female gender and reduced LVEF were significant predictors of atrial stasis. Evidence of atrial stasis in PAF even when in sinus rhythm suggests an additional mechanism for cardio-embolism in this patient group.

P876

Relationship between breathing pattern and aortic flow measurement: head-to-head comparison between high temporal resolution free-breathing phase contrast CMR and standard breath-hold sequence

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Background: Percutaneous aortic and mitral valve interventions are increasingly performed in routine cardiology. Accordingly, there is a need for precise quantification of valve function. Total systolic aortic flow measured by phase contrast (PC) MRI and left ventricular stroke volume (LVSV) allow quantification of mitral insufficiency. To this goal, various aortic flow measurements were evaluated.

Purpose: To evaluate the influence of breath-holding during flow measurements by comparing a high temporal resolution free-breathing (Flow-FBhighres) PC sequence with a standard (Flow-BHstandard) and high-resolution (Flow-BHhighres) breath-hold sequence.

Materials and methods: In 30 patients without relevant valvular disease (4 women, 26 men, 56±12y), a conventional PC sequence was applied in the proximal ascending aorta during breath-holding (Flow-BHstandard; spatial/temp resolution 1.9x1.9mm²/40.9ms; slice thickness 10mm, segments 4; cardiac phases 20; acquisition duration 17 beats); in addition, a high temporal resolution PC sequence was applied at the same aortic position during free breathing (Flow-FBhighres; spatial/temporal resolution 2.1x2.1mm²/9.9ms; segments 1; cardiac phases 60; acquisition duration 262 beats) and also during breath-holding (Flow-BHhighres; spatial/temporal resolution 3.75x3.75mm²/9.4ms; segments 1; cardiac phases 60; acquisition duration 26 beats). In order to verify whether patients performed accidentally a Valsalva-like maneuver during breath-holding, a cine real-time acquisition of a modified LV short-axis view (=single-oblique coronal orientation) was also acquired during breath-holding in these patients and the difference between the LV end-diastolic cavity at the beginning and the end of the breath-hold was measured.

Results: Aortic flow measured by Flow-FBhighres was higher than by Flow-BHstandard (84±15ml vs 73±20ml, p=0.0002, see Figure) and by Flow-BHhighres (72±21ml, p=0.0003). In comparison with the LVSV of 84±23ml, Flow-FBhighres was not different (p=0.764), while Flow-BHstandard and Flow-BHhighres tended to underestimate flow (p=0.001 and p=0.0011, respectively). The acquisition duration for Flow-FBhighres, Flow-BHstandard, and Flow-BHhighres were 234±42s, 15±3s, and 23±4s, respectively. The underestimation of aortic flow by Flow-BHstandard vs Flow-FBhighres (expressed as percentage of Flow-FBhighres) correlated positively with a reduction in LV cavity size during breath-holding (change expressed as percentage of cavity size at the beginning of breath-holding) with $p<0.006$ and r=0.49; and by Flow-BHhighres vs Flow-FBhighres with $p<0.006$ and r=0.59.

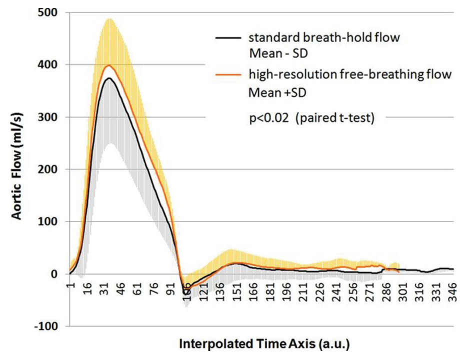

Figure 1.Flow-BHstandard vs Flow-FBhighres.

Conclusions: Aortic flow may be underestimated when measured with a standard breath-hold PC pulse sequence and this underestimation may partly be explained by a Valsalva-like maneuver provoked by breath-holding. A high temporal resolution free-breathing PC acquisition may avoid this source of error. Further studies are needed to confirm these findings.

P877

Left atrial phasic function by cardiac magnetic resonance feature-tracking is a strong predictor of incident cardiovascular events

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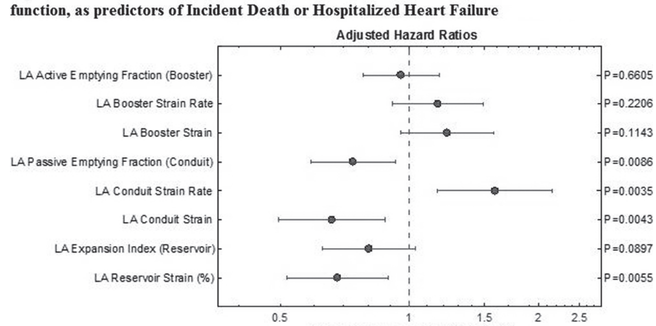
Background: The prognostic importance of left atrial (LA) dysfunction is increasingly recognized. Magnetic Resonance Imaging (MRI) can provide excellent visualization of the left atrial wall.

Purpose: We aimed to study the association of LA dysfunction measured using feature-tracking MRI with incident adverse cardiovascular events among subjects with or without HF at baseline.

Methods: We prospectively studied 640 adults without HF (n=419), HF with preserved ejection fraction (HFpEF, n=101), or HF with reduced ejection fraction (HFrEF, n=120). We measured phasic LA function by volumetric and feature-tracking methods to derive longitudinal strain. Incident heart failure hospitalization and death were adjudicated over a median follow-up of 37.1 months.

Figure: Standardized Hazard Ratios for various measures of left atrial function, as predictors of Incident Death or Hospitalized Heart Failure



*Adjusted for left ventricular ejection fraction, left ventricular mass, left atrial volume index, heart failure status, age, sex, African-American ethnicity, body mass index, systolic and diastolic blood pressure, hypertension, diabetes and coronary artery disease.

Figure 1