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Prediction of pressure gradient in aortic coarctation by computational fluid-dynamic simulations.

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INTRODUCTION: Current clinical assessment of borderline aortic coarctation may involve invasive catheterization pressure measurements to evaluate the pressure gradient at rest and during isoprenaline pharmacological stress. The purpose of this study is to predict the aortic pressure distribution in patients with aortic coarctation at rest and pharmacological stress using a transient rigid-walled computation fluid dynamics model (RW-CFD).

Study number	Heart rate [bpm]	ΔP Clinical [mmHg]	ΔP CFD [mmHg]	Difference in ΔP (CFD – Invasive) [mmHg]
REST CONDITION				
AoCo-1	48	23±3	22	**-1±3**
AoCo-2	86	18±3	5	**-13±3**
AoCo-3	69	12±4	9	**-2±4**
AoCo-4	81	10±2	8	**-2±2**
AoCo-5	60	20±2	31	**11±2**
AoCo-6	47	9±2	6	**-3±2**
AoCo-7	51	7±3	8	**1±3**
STRESS CONDITION				
AoCo-1	150	39±6	54	**18±6**
AoCo-2	136	40±10	23	**-17±10**
AoCo-3	130	64±6	42	**-22±6**
AoCo-4	140	66±4	44	**-22±4**
AoCo-5	102	52±7	78	**26±7**
AoCo-6	141	37±7	58	**21±7**
AoCo-7	119	69±7	179	**110**

METHODS: The study cohort comprises 7 patients(age 19±3 years, mean±standard deviation) with native or recurrent aortic coarctation and 3 control patients(age 3±2 years) with healthy aortic arches, who underwent both CMR and catheterization at rest and pharmacological stress. The model workflow (Figure 1) requires, as input parameters, the aortic geometry, extracted from a CMR 3D gadolinium contrast-enhanced sequence, and definition of the three boundary conditions (1)Ascending aortic root: The inlet flow is extracted from the phase-contrast CMR flow.(2) Supra-aortic vessels: The flow rate is calculated as a proportion of the inlet flow based on the assumption of a constant wall shear stress (3)Diaphragmatic aorta: The pressure waveform is extracted from the invasive catheter data. The clinical invasive aortic pressure gradients were compared with the predicted pressure distribution along the centreline in the RW-CFD model at the time of peak flow (Table 1).

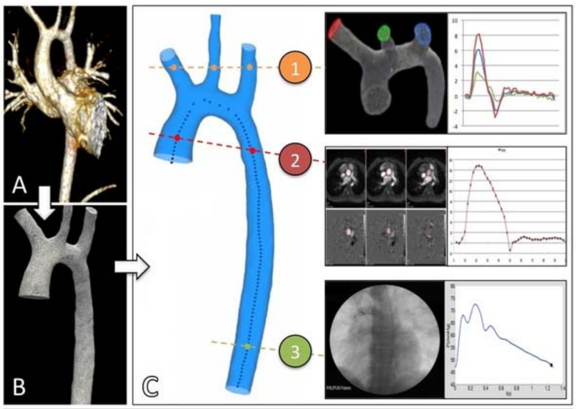

Figure 1. **Workflow to run the CFD simulation. A.** Contrast enhanced cardiovascular magnetic resonance (CMR) acquired to image the aortic arch. **B.** Extracted aortic geometry from the CMR dataset. **C.** Boundary condition setup in the three openings of the aortic geometry: 1) The applied flow rate is constructed as a proportion of the inlet flow in order to have a constant wall shear stress [l/min] 2) Phase-contrast CMR flow obtained in the ascending aorta [l/min]. 3) Catheter pressure measurements at the level of the diaphragmatic aorta [mmHg].

RESULTS: For patients with aortic coarctation, during pharmacological stress, there was an increase in both heart rate (68±22bpm) and invasive pressure gradient drop across the coarctation (38±18mmHg, Table). The RW-CFD model predicted accurately the pressure drop at rest (-1±7 mmHg), and gave a moderate agreement at stress 16±46 mmHg (Table).

CONCLUSION: For patients with aortic coarctation, the RW-CFD simulations accurately predict the pressure gradient at rest and give indication of the gradient severity during stress, with no predicted gradient in control patients. These preliminary results are promising and represent the first step towards an image-based fluid-solid-interaction CFD analysis. In the future, it is envisaged that CFD models could be based on a patient-specific, non-invasive and non-ionising radiation assessment such as CMR in order to predict the hemodynamic conditions in the aorta and avoid invasive cardiac catheterization.