

## Can a single phase contrast aortic flow acquisition be used to define a surrogate marker of cardiac index?

F. Frouin<sup>1,2</sup>, M. Lefort<sup>1,2</sup>, M. Bensalah<sup>1,3</sup>, A. De Cesare<sup>1,2</sup>, C. Pellot-Barakat<sup>1,2</sup>, E. Mousseaux<sup>1,3</sup>, and A. Herment<sup>1,2</sup>  
<sup>1</sup>UMR\_S 678, Inserm, Paris, France, <sup>2</sup>UMR\_S 678, UPMC, Paris, France, <sup>3</sup>HEGP, AP-HP, Paris, France

### Introduction

Cardiac index is a well established marker for the assessment of the global cardiovascular health. It has recently been shown a link between cardiac index and brain aging [1]. Thus for studies associating both cardiovascular and cerebral aging, MR acquisitions are of course well adapted and should be optimized in order to reduce total scan duration and time required for data analysis. In this context, our objective was to study whether cardiac index could be estimated from one single phase contrast (PC) aortic flow acquisition.

### Patients and Methods

Seventy-two subjects (47 men / 25 women) without cardiovascular diseases, mean age 41 years (range 20-81), were considered for this study. For all subjects, SSFP cine cardiac and PC aortic data were acquired using conventional clinical settings. Acquisitions were performed with a thoracic phased-array surface coil on a 1.5 T system using ECG gating and breath-holding. Short-axis cine cardiac images from left ventricular apex to base were acquired using a SSFP sequence with a TR=4 ms, TE=1.6 ms, flip angle=50°, slice thickness=8 mm. A plane, perpendicular to the ascending aorta proximal to the bifurcation of the pulmonary artery was selected for phase contrast acquisitions, using TR=7.5 ms, TE= 1.4 ms, flip angle=20°, slice thickness: 8 mm, maximal velocity encoding=200 cm/s. The stroke volume (SV) was estimated from cardiac SSFP (SVc) and from the aortic velocity (SVa) acquisitions. SVc was estimated from the manual segmentation of myocardial borders using all short-axis levels at end-diastole and end-systole by an expert. SVa was estimated from the blood flow curve defined as the sum of through-plane velocity components inside the ascending aorta. To achieve this, an automated temporal segmentation of the aorta was used [2]. Figure 1 shows the main steps of the process.

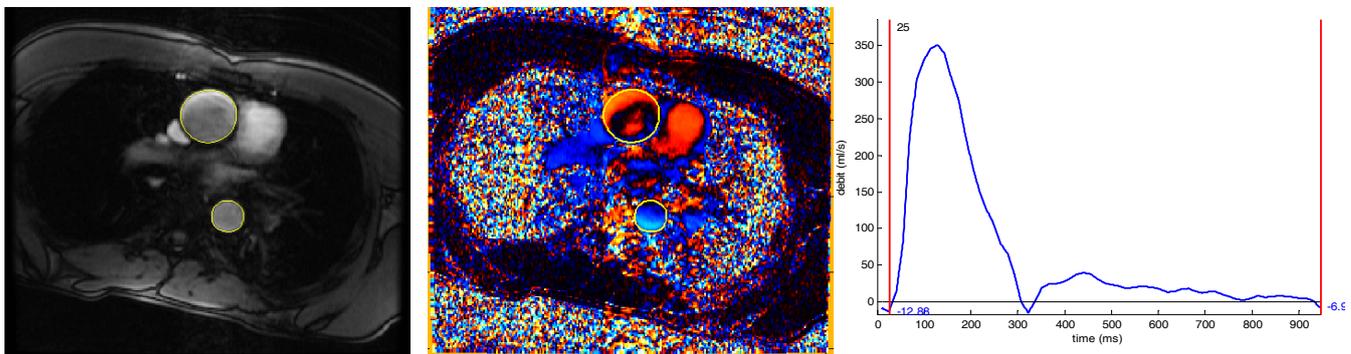


Figure 1: From left to right: Modulus and phase images with the automated segmentation of the aortic lumen during the cardiac cycle, and the resulting blood flow curve using the ART-FUN software. SVa corresponds to the area under the curve.

### Results

SV were successfully estimated using cardiac and aortic studies. In the latter case, no failure of the automated procedure was reported in the studied population. Using these values and heart rate (mean value 68 bpm, range 34-102) cardiac output (CO) was computed. Finally cardiac index (Figure 2) was derived by introducing the body surface area (mean value: 1.83 m<sup>2</sup>, range 1.37– 2.23). Linear regression between the cardiac and aortic series of values showed a high correlation:  $r=0.80$  for VE,  $r=0.78$  for CO and  $r=0.76$  for CI. However, the VEa, COa, and CIa values derived from PC aortic sequences were clearly underestimated when compared to the same values derived from cardiac images. For the three indices, the underestimation ratio was estimated to be 15%.

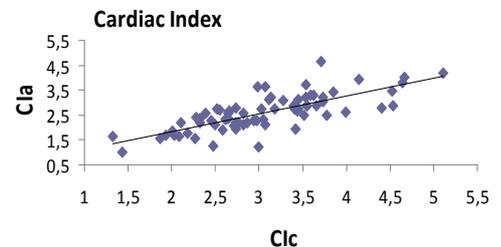


Figure 2: Cardiac Index estimated by both methods

### Discussion

In fact, the observed underestimation of SV when using PC aortic studies can be easily understood. First of all, coronary blood flow (about 5% of the general blood flow) is excluded when measuring flow in the ascending aorta. Moreover, a slight error in the alignment of the perpendicular to the ascending aortic slice with the blood flow direction (angle  $\theta$ ) can also provide a systematic underestimation of the velocity module ( $\cos\theta$ ) and thus an underestimation of the blood flow. In addition, some dispersion of the velocity values at the contours of the lumen or in flow inversion areas could contribute to the underestimation. A last bias in the VEa values may be due to an inaccurate phase offset correction as underlined in [3] and it was estimated that it could be responsible for a 5% error in the CO estimation. Overestimation of SVc by SSFP can be also due to the inclusion of papillary muscles in the cavity at end-diastole which cannot be excluded from the cavity at end-systole.

### Conclusion

Providing that the underestimation of the cardiac index would be appropriately compensated, the single PC aortic acquisition could be an interesting alternative to a whole cardiac acquisition to estimate the cardiac index. Moreover the automated processing of aortic acquisition enables to drastically reduce the operator's intervention. Furthermore, it would enable a reduction of the acquisition duration, which is highly desirable in combined vascular and brain protocols applied to an aging population. Finally, ascending aortic strain and pulse wave velocity in the aortic arch (requiring a supplementary sagittal acquisition), which are considered as promising biomarkers of vascular aging [4], could be equally estimated easily.

### References

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