Towards a subject-specific calibration of a systole model for CMR undergoing heart rate variations

Pierre-André Vuissoz[1,2], Christophe Meyer[1,2], Jacques Felblinger[3,4], and Laurent Bonnemains[1,2]
[1]*Imagerie Adaptative Diagnostique et Interventionnelle, Université de Lorraine, Nancy, France,* [2]*U947, INSERM, Nancy, France,* [3]*CIC-IT 1433, INSERM, Nancy, France,* [4]*University Hospital Nancy, Nancy, France*

TARGET AUDIENCE: Researchers and physicians interested in the temporal component of cardiac motion.

PURPOSE: Cardiac Magnetic Resonance requires the determination of a cardiac minimal motion period in which to acquire data without motion for triggered acquisition [1] or of a cardiac phase model to label acquired k-space lines with cardiac phases in retrospective cine acquisitions [2]. We calibrate such a cardiac model that is subject specific and compare the predicted systole durations between the subject-specific model and a global model.

METHODS: Twenty-three healthy volunteers underwent cardiac MRI examination on a Signa HDxt 3T (General Electric, Waukesha). A phase contrast sequence modified to acquire only the central k-space line was used in a short axis scan plane crossing the aorta. The frequency encoding direction was angulated to be anteroposterior (AP) in order to project the ascending and descending aorta components into separate regions. Relevant parameters were: through-plane velocity encoding, 256-point frequency k-space size, 35 cm FOV, 1 view per segment, 150 cm/s velocity encoding and 6.6 ms TR. Data were acquired during 128 heartbeats and then Fourier transformed into 1D+t image space, subjected to SVD decomposition for automatic spatial segmentation and finally automatic temporal domain detection of ejection (Fig 1.). This process led to the measurement of the systolic ejection duration for each heartbeat. Duration of electromechanical systole was modeled as a function of heart rate with several linear fits: 1) one fit per subject to build a subject-specific model (Adaptive) and 2) one fit for the whole cohort to build a global model (Global). Measured and predicted (30%) end-systole times were compared.

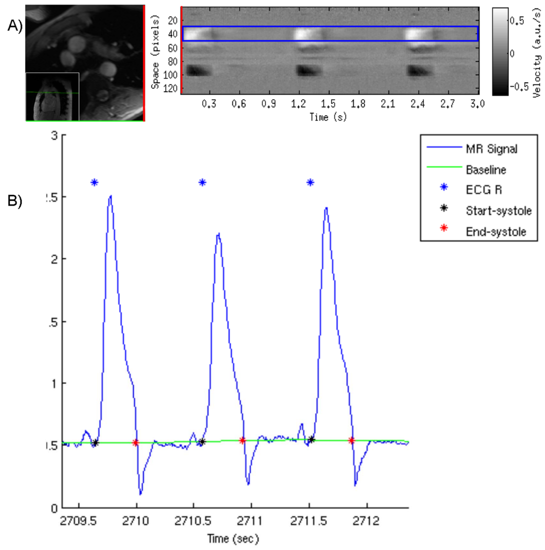

Fig. 1 : (A) Scan plane positioning and time velocity map (B) Automatic detection of systolic ejection durations for each cardiac cycle. Magnitude MR signal is traced along with the computed baseline. ECG's R-wave detection, start and end of systole are marked

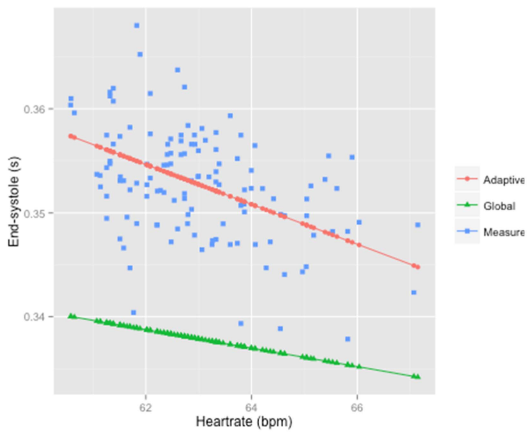

Fig. 1 : Measured systole durations as a function of instantaneous heartrate is plotted and global and adaptive models are traced, for one example subject (128 heartbeats)

RESULTS: The adaptive cardiac model predicted end-systolic time significantly ($p<10^{-7}$) better than the global model: 9.0 ms vs 16.8 ms average absolute error. The standard deviation of the absolute error was also significantly ($p<10^{-16}$) reduced from 20.0 ms (global model) to 11.5 ms (adaptive model). Also, the maximum absolute error was reduced from 193 ms (global) to 116 ms (adaptive).

DISCUSSION: Calibration is limited by the temporal resolution of acquisition (6.6 ms). Nevertheless, personalization of subject-specific cardiac model is feasible automatically in MRI and reduces the systole prediction error.

CONCLUSION: A better prediction of systole was shown and should benefit to high temporal resolution cine reconstructions and to techniques based on trigger delay, especially those targeting the systolic cardiac phase.

REFERENCES: [1] Fernandez, B. *et al.* MRM 64 :1760 (2010). [2] Vuissoz, P.-A. *et al.* JMRI 35 :340 (2012).