Adaptive Prediction of RR interval for online MR parameters changes

J. Oster[1], F. Odille[1], G. Bosser[2], O. Pietquin[1,3], C. Pasquier[1], P-A. Vuissoz[1], and J. Felblinger[1]

[1]IADI, Nancy University; INSERM ERI 13, Nancy, France, [2]Cardiac Rehabilitation Unit, CHU de Nancy, Nancy, France, [3]Supélec, Metz, France

INTRODUCTION:

Cardiac MRI sequences are generally synchronized on the R wave of the ECG and the read out is done in the ventricular diastole. Depending to the heart rate (HR) and so on the RR interval, an optimal trigger delay (TD), an acquisition time (AT) (which is a function of MR parameters) and a trigger window (TW) are defined before scanning. For Black Blood acquisition, IR pulses are currently played directly on the R wave to have an inversion time (TI) of the blood on read out. Unfortunately, physiological changes of the RR timing especially during breath hold make all these fixed timings non optimum. Additionally, optimal TI for complete nulling of wash in blood is not always compatible with HR > 85 bpm. Moreover, if acquisition of systolic phase [1] is desired, these IR pulses have to be place before the current R wave in the preceding heart cycle. We propose a prediction of the next RR duration based on previous RR cycles (Fig. 1). The prediction of RR interval will be used to adapt MR timing parameters (TD, TW, TI, AT) during scanning and enable black blood images in the systolic phase.

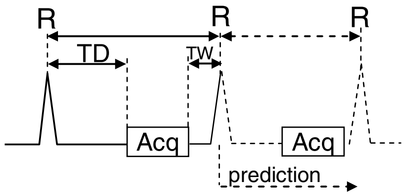

Fig. 1: The prediction algorithm estimate the duration of the coming RR duration

METHODS:

Five healthy subjects performed two breath hold in inspiration and two other in expiration in supine on an 1.5 T GE SIGNA Excite HD MR system (General Electric, Milwaukee, WI). The breath hold duration was about 30 seconds. Signal from a respiratory belt and ECG was carried by the Maglife (Schiller Médical, France) patient monitoring system and recorded along with MRI gradients and acquisition window signal on the Signal Analyzer and Event Controller (SAEC) custom computer and electronics [2]. During breath hold, ECG, R wave detection and scan timing was collected for off line analysis. The absolute HR variation was first evaluated. Several fitting strategies of the HR variation were then tested intra and inter subjects. Prediction of RR was performed using a standard linear prediction model defined by following equation $\hat{RR}_n = \sum_{i=1}^{p} a_i RR_{n-i}$ (1)

For the first algorithm, estimation of the AR (Auto Regressive) parameters was done by solving the Yule Walker equation using RR variation form a first breath hold. RR duration prediction was then applied and AR coefficients were continuously updated using an LMS (Least mean square) algorithm. $\underline{\hat{a}}_n = \underline{\hat{a}}_{n-1} + \mu e_n \underline{y}_n$ where $e_n = RR_n - \hat{RR}_n$ and $\underline{y}_n = [\hat{RR}_{n-1} \ldots \hat{RR}_{n-p}]^T$ (2)

The order of the AR model was fixed to 3 and μ=0.1 for this evaluation. For the second algorithm the order of the AR model was fixed to 1 and the coefficient too, so $\hat{RR}_{n+1} = RR_n$.

RESULTS:

The maximum of variation of the RR ranged from 261 to 590 ms in inspiration and from 143 to 715 ms in expiration during the 30s breath hold. As shown in figure 2, the RR over time was very different from one subject to another. The shape seems similar for a same subject and breath hold mode. However, modelling by linear or exponential functions was not possible for all cases/subjects. A typical example (Fig. 3) of both prediction strategies shows that the convergence was good. Averaged on all subjects, the best mean square error with constant RR was 65ms (using the mean HR over the apnea), 26ms with the first algorithm and 24ms with the second.

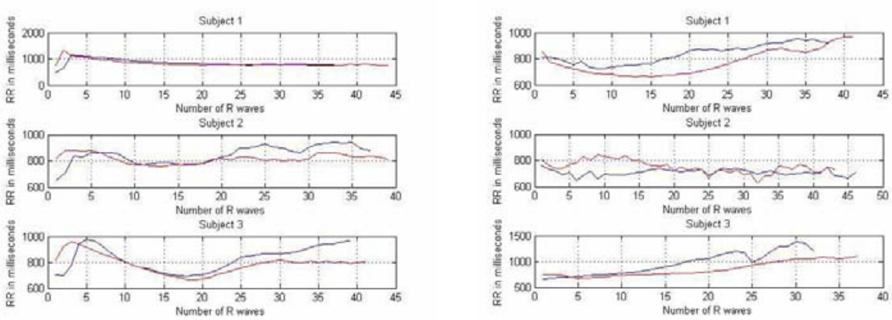

Fig. 2 : HR variations during breath hold in inspiration (left) and in expiration (right)

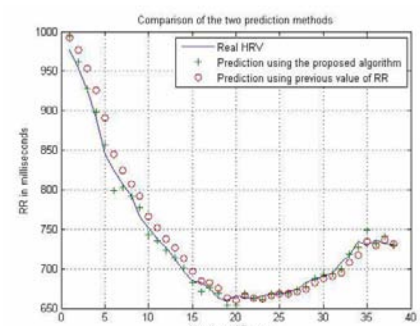

Fig. 3 : Comparison between the two methods

DISCUSSION:

The results show that the HR variation can be very important during a breath hold. The variation is subject dependant and modelling the variation is difficult. The proposed algorithms gave good results for the prediction of the coming RR interval. This prediction model can easily be applied in real time for adaptive changes of MR parameters. TD could be adapted using [3], optimum TI applied before the R wave, and the read out adapted according to the foreseen time slot. A optimized prediction is a critical point in order to achieve systolic MRI. These methods need clean ECG trace (without gradient artefact) [2] and optimised R wave detection.

REFERENCES:

[1] Slavin G.S et al, ISMRM 83(2005), [2] Odille F. et al, IEEE T BIO-MED ENG in press, [3] Liu G. and G.A. Wright, ISMRM 2157 (2006).