Onset of the diastolic cardiac rest period: Intra-volunteer variability

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Introduction

In order to minimize motion artefacts, image data acquisition in coronary MRA is performed preferably in the diastolic cardiac rest period. For this purpose, a trigger delay of the acquisition window with respect to the preceding R-wave of the ECG is chosen prior to the scan. The delay time, which is determined either directly from cardiac cine scans or from empirical formulas [1,2] according to the actual heart rate of the patient, is kept at a constant value during the MR scan. However, the duration of the RR-intervals may vary during long scans due to respiratory sine arrhythmia (RSA) and emotional stress or relaxation of the patient. Hence, it is questionable whether the position of the cardiac rest period may be described accurately by a constant trigger delay. Therefore, we have determined onset and duration of the cardiac rest period for 10 volunteers both at rest and directly following physical stress, leading to increased heart rates.

Methods

A 2D ECG-triggered cardiac cine protocol taking images of 50 successive heart phases was used to record cardiac motion (balanced FFE, SENSE factor 2, FOV: 260² mm², 144² scan matrix, 10 mm slice thickness, TE=1.5ms, α=60°) on a whole body 1.5T MR system (Gyroscan ACS-NT 15, Philips Medical Systems) with a 5-element cardiac coil. A transverse slice containing the intersection with the RCA was chosen. Image acquisition was performed in breath hold at normal expiration over 4-8 RR-intervals, depending on the momentary heart rate of the volunteer. In between the scans, volunteers were stressed by physical exercises with an MR-compatible elastic band. In this way, measurements could be performed at various heart rates of the same volunteer. The study population included 10 healthy adult male subjects.

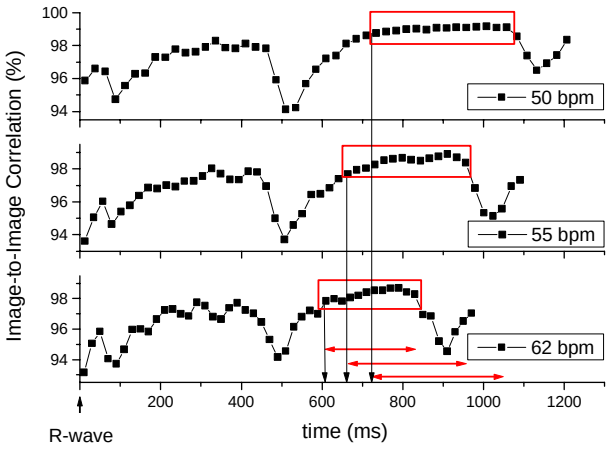

Fig. 1: Correlation plots for a single volunteer at three different heart rates. The red boxes indicate the position of the automatically determined diastolic rest period. Onset (vertical black lines) and duration (horizontal red arrows) of the rest period vary.

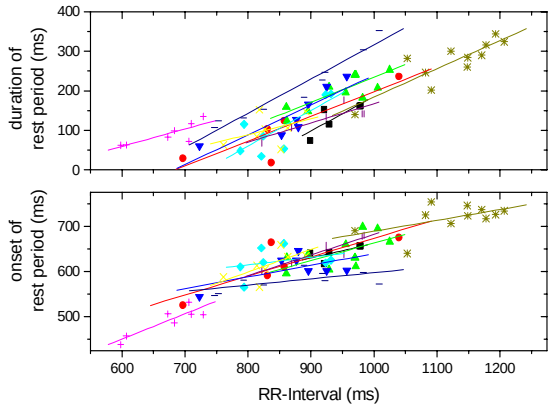

Fig. 2: Scatterplots and linear fits of the onset and the duration of the diastolic rest period vs. the respective RR-interval length.

The cross-correlation of each pair of successive images in the cine scan was calculated in the cardiac region using the shim value as an image mask. This method has proven to be a robust measure for cardiac motion [3]. A phase of high correlation corresponds to low cardiac motion. In order to determine the rest period automatically, the top-10%-interval of the correlation coefficients appearing in the respective data set was determined. The lower bound of this interval was taken as a lower acceptance limit for data points of the diastolic rest period. The results of this approach were consistent with a determination of the cardiac rest period by direct inspection of the cine scan images for selected volunteers.

Results

As an example, figure 1 shows correlation plots and the automatically determined cardiac rest period of one volunteer at three different heart rates (50, 55, 62 beats/minute). It is clearly visible that the truncation of the diastole is the dominant effect in shortened RR-intervals. However, one also finds a contraction of the systolic period, leading to a shift of the onset of the rest period to the preceding QRS-complex. Figure 2 shows onset and duration of the diastolic rest period versus the length of the RR-interval for all volunteers at various heart rates. The data sets of each volunteer are given as a scatterplot in a unique color along with a least-squares regression line.
For the onset, the mean value of the occurring slopes is 0.33 (lowest: 0.14, highest: 0.56). Our results agree qualitatively with the data of W. Yong Kim et al. [1] who have investigated the relationship between the start of the rest period and the length of the RR-interval for different subjects (slope of the regression line in [1]: 0.19). The present study demonstrates that a similar relationship holds also within the same subject. Accordingly, we investigated the relationship between the duration of the rest period and the length of the RR-interval. Again, linear regression leads to a straight line for each volunteer. The mean value of the occurring slopes is 0.67 (lowest: 0.49, highest: 0.90).

Discussion

The initial results obtained in this study demonstrate that within the same subject, a shortening of the RR-interval leads both to a truncation (67%) and to a shift (33%) of the diastolic rest period. Notable deviations of the individual parameters for the different volunteers have been observed.
This result supports the idea of a dynamic adaptation of the trigger delay in long MRI-scans. For such an approach, a simple model for the prediction of RR-intervals is needed which can account for both short-term and long-term variations of the instantaneous heart rate of the patient. The benefit of this method would be that image data acquisition is placed better within the cardiac rest period. In this way, a mixing of different cardiac phases in the MR data may be avoided.

References

1. Kim WY. et al., JMRI 14:383-390 (2001)
2. Stuber M. et al., Radiology 212:579 (1999)
3. Nehrke K. et al., ISMRM 2003; 1623