Improved Reproducibility of Black-Blood T2-Weighted CMR Assessment of Area at Risk with Myocardial Segmentation from b-SSFP Short-Axis Images

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Purpose

The myocardial area-at-risk (AAR) in acute myocardial infarction (AMI) is characterized by formation of edema induced in the hypo-perfused myocardial tissue [1]. Black-blood T2-weighted Short Tau Inversion Recovery (T2-STIR) Cardiovascular Magnetic Resonance (CMR) imaging can visualize edematous risk areas producing hyper-intense signal intensity relative to normal tissue through a triplet of inversion recovery pulses [2]. Slow flowing blood, e.g. present at the hypokinetic and trabeculated myocardial walls, may be insufficiently suppressed yielding a bright signal at the endocardial borders indistinguishable from edematous myocardial tissue and thereby producing bias when delineating the myocardium. Compared to the black-blood T2-STIR sequence, balanced Steady-State Free Precession (b-SSFP) is less sensitive to flow making it ideal for accurate segmentations of the myocardium. We investigated whether the use of b-SSFP scans would improve the accuracy of manual segmentation of T2-STIR AAR measurements, hypothesizing that the flow insensitivity of b-SSFP would improve discrimination between slow moving blood and edematous myocardial tissue and thereby reduce intra- and inter-observer viability.

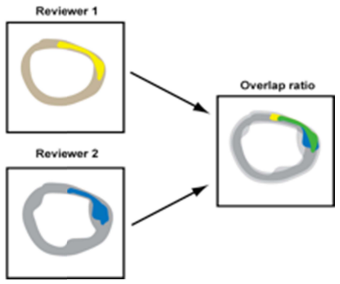

Fig 1. Segmentation approach and K-means clustering. Reviewer 1 and 2 report the size of the left ventricular myocardium based on endocardial end epicardial borders (in brown and gray). K-means algorithm report AAR on the data provided by the reviewers (in yellow and blue) Overlap ratio is the green area.

Methods

The population included forty-two patients undergoing primary coronary angioplasty for ST-elevated myocardial infarction (age 63±11 years, 31 males). Patients underwent CMR imaging 10±2 days post-infarction. Images were acquired using vector electrocardiogram gating and a respiratory navigator was employed. Data was anonymized and randomized. Myocardial segmentation for each left ventricular (LV) short-axis was performed manually two times using the Segment v1.8 (http://segment.heiberg.se), employing a semi-automatic method for delineating borders. First, segmentations were performed solely on T2-STIR LV short-axis images. Second, segmentations were performed on b-SSFP short-axis LV images, which afterwards were transferred to the T2-STIR images. Segmentations were assessed by two independent reviewers and performed twice by reviewer 1 and once by reviewer 2 for intra- and inter-observer viability. Results were imported into Matlab 2010a, and converted into a masked stack of files with data from the T2-STIR segmentation. The reference region was calculated in a fully automated manner using K-means clustering to divide the segmented LV into groups based on the signal intensity, slice position, and the x- and y-coordinate of each pixel. Each variable was normalized to range from 0 to 1, with signal intensity receiving an additional weighting by an empirically chosen value of 5.8. Using the mean and S.D. of the reference region, the AAR was calculated as tissue exceeding an intensity of mean + 3.5 S.D. Even if two reviewers report equal AAR, the two delineated areas do not need to overlap, since there is no spatial constriction on the AAR segmentation (fig. 1). Therefore, a separate metric of agreement, designated the overlap ratio, was examined. This measure reflects the volume of agreement (overlap) relative to the mean of the two reported volumes within a subject. If there is no overlap the ratio will be zero, while for identical volumes the ratio will be one.

Results

Least variability was seen in both intra- and intra-observer studies when the b-SSFP images were used as template. Intra-observer: STIR bias was 4.5 ml (limits of agreement: -17.43 ml to 26.47 ml), b-SSFP was bias 0.12 ml (limits of agreement from -12.73 ml to 12.97 ml). Inter-observer: STIR bias was 46.93 ml (limits of agreement: 3.00 ml to 90.86 ml), b-SSFP bias 2.89 ml (limits of agreement: -49.15 ml to 54.92 ml). The median overlap ratio graph is shown in fig. 2. Most of the markers are located above the dotted line favoring K-means clustering based AAR based on myocardial segmentation using b-SSFP.

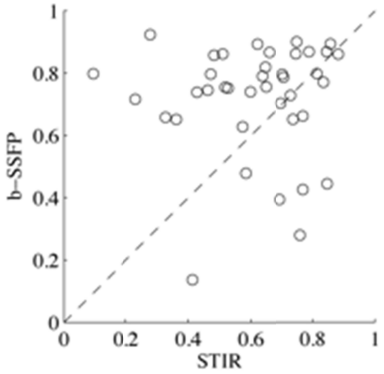

Fig. 2. The median overlap ratio. The graph shows implications on inter-observer agreement. If the overlap ratio is one this represents identical observer delineation. Most of the markers are located above the line, which favor delineation based on b-SSFP and then transposed to T2-STIR.

Conclusion

Delineation of endocardial and epicardial borders based on b-SSFP data in addition to T2-STIR data displayed higher reproducibility for both intra- and inter-observer viability compared to segmentation based solely on T2-STIR data. The median overlap ratio graph also favored segmentation based on b-SSFP. Based on this study, we recommend acquiring b-SSFP images in addition to black-blood T2-STIR when evaluating the extent of edematous myocardial tissue and the degree of salvageable myocardium.

References

1. Friedrich, M.G., et al., *The salvaged area at risk in reperfused acute myocardial infarction as visualized by cardiovascular magnetic resonance.* Journal of the American College of Cardiology, 2008. **51**(16): p. 1581-7.
2. Green, J.D., et al., *Single-shot steady-state free precession can detect myocardial edema in patients: a feasibility study.* Journal of magnetic resonance imaging : JMRI, 2009. **30**(3): p. 690-5.