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Blind Source Separation Improves the Precision and Robustness of Self-Gated Motion Extraction in Free-Running 4D Whole-Heart MRI

Isabel Montón Quesada[1], Augustin C. Ogier[1], Jérôme Yerly[1,2], Jonas Richiardi[1], Christopher W. Roy[1], Juerg Schwitter[3], Matthias Stuber[1,2], Ruud B. van Heeswijk[1]

[1] Department of Radiology, Lausanne University Hospital (CHUV) and University of Lausanne (UNIL), Lausanne, Switzerland; [2] CIBM Center for BioMedical Imaging, Lausanne, Switzerland; [3] Cardiology Service, Cardiovascular Department, Lausanne University Hospital (CHUV) and University of Lausanne (UNIL), Lausanne, Switzerland

BACKGROUND

- A free-running framework with self-gating[1] was recently proposed to simplify cardiac MR exams by acquiring cardiac and respiratory motion-resolved whole-heart images without the need for ECG triggering or respiratory navigators.
- Automated self-gated (SG) motion extraction with principal component analysis (PCA) alone remains challenging and sometimes fails to correctly identify the components related to cardiac motion.

AIMS

Ascertain the most precise and robust technique from PCA and 3 blind source separation techniques (fastICA, ICASSO, SOBI) for cardiac motion extraction in free-running self-gated whole-heart 4D MRI.

METHODS

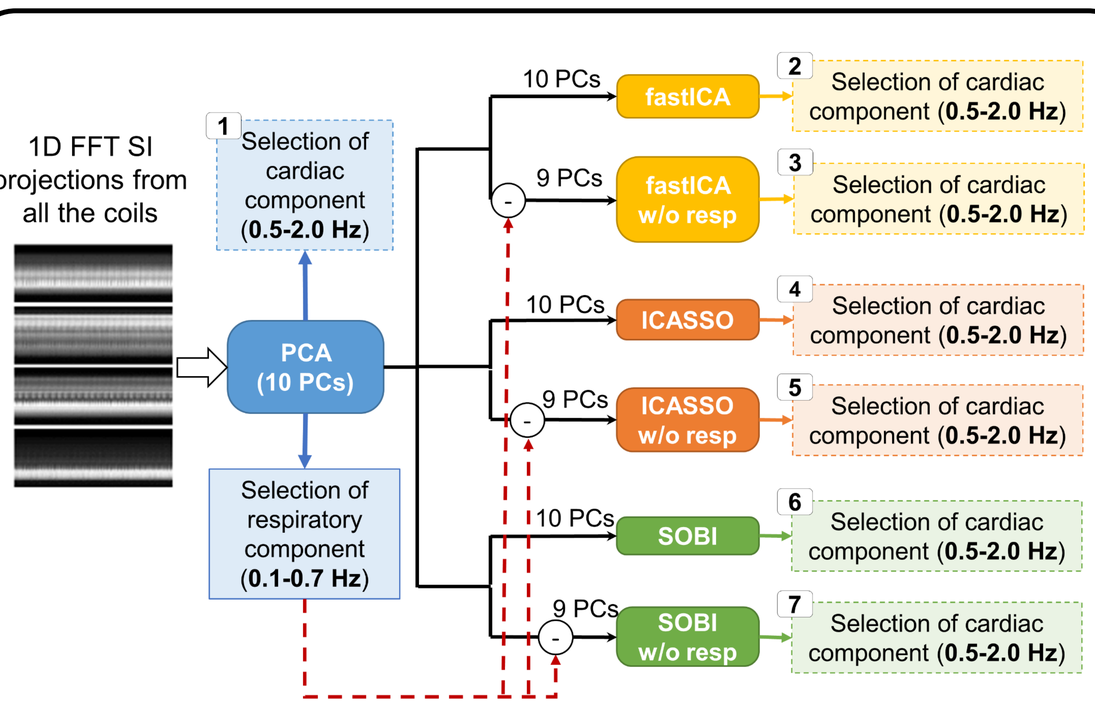

Figure 1. *The cardiac and respiratory signal extraction pipeline.*

- 10 healthy volunteers were scanned on a 1.5T Siemens scanner.
- The respiratory component was always selected with PCA. Three blind source separation (fastICA[2], ICASSO[4], and SOBI[5]) algorithms were implemented to extract cardiac motion.
- The three algorithms were also tested after first discarding the respiratory principal component.
- The precision of the cardiac trigger extraction was assessed by calculating the standard deviation σ of the difference between the estimated SG cardiac intervals and their corresponding ground-truth ECG intervals.
- The respiratory motion was corrected using fNAV[6] and 4D images were reconstructed using compressed sensing[7].
- The sharpness of the reconstructed images was quantified at the blood pool-myocardium interface.

RESULTS

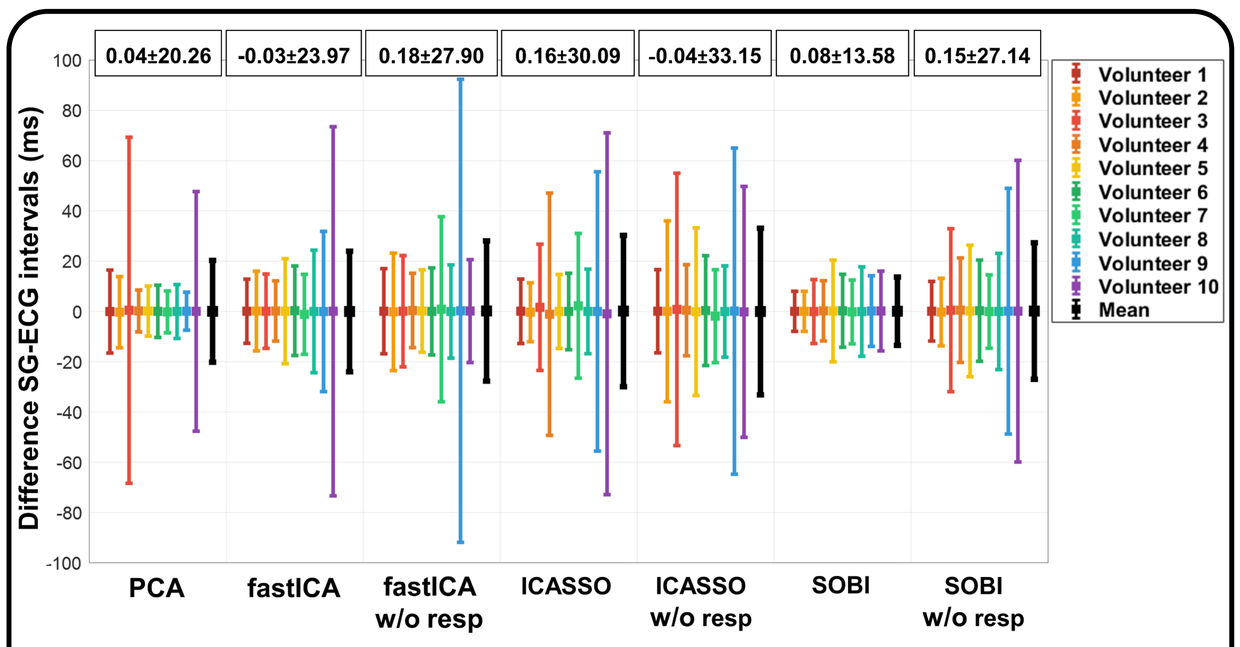

Figure 2. *Comparison of the performance of the methods.*

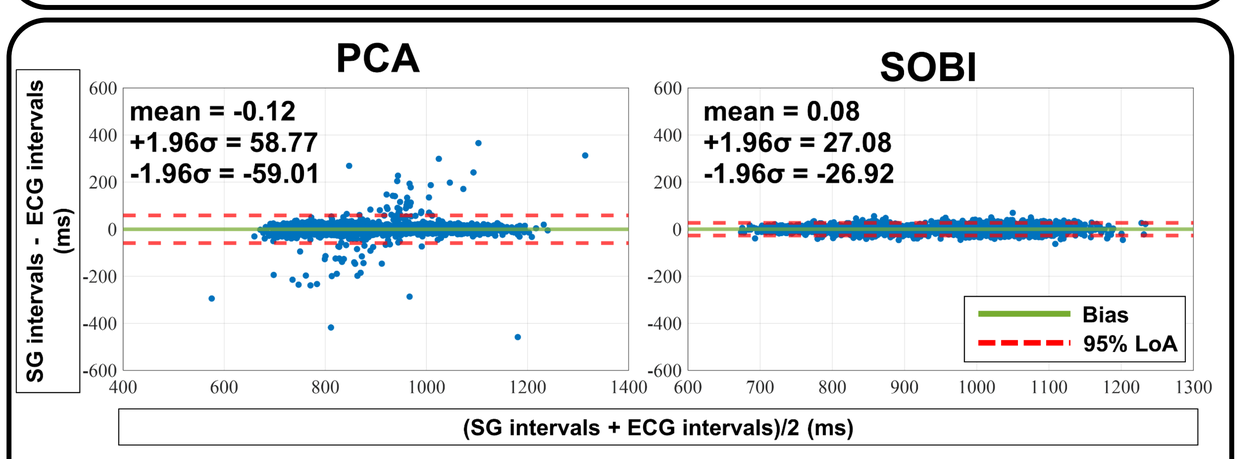

Figure 3. *Bland-Altman analysis between ECG and SG intervals in PCA and SOBI.*

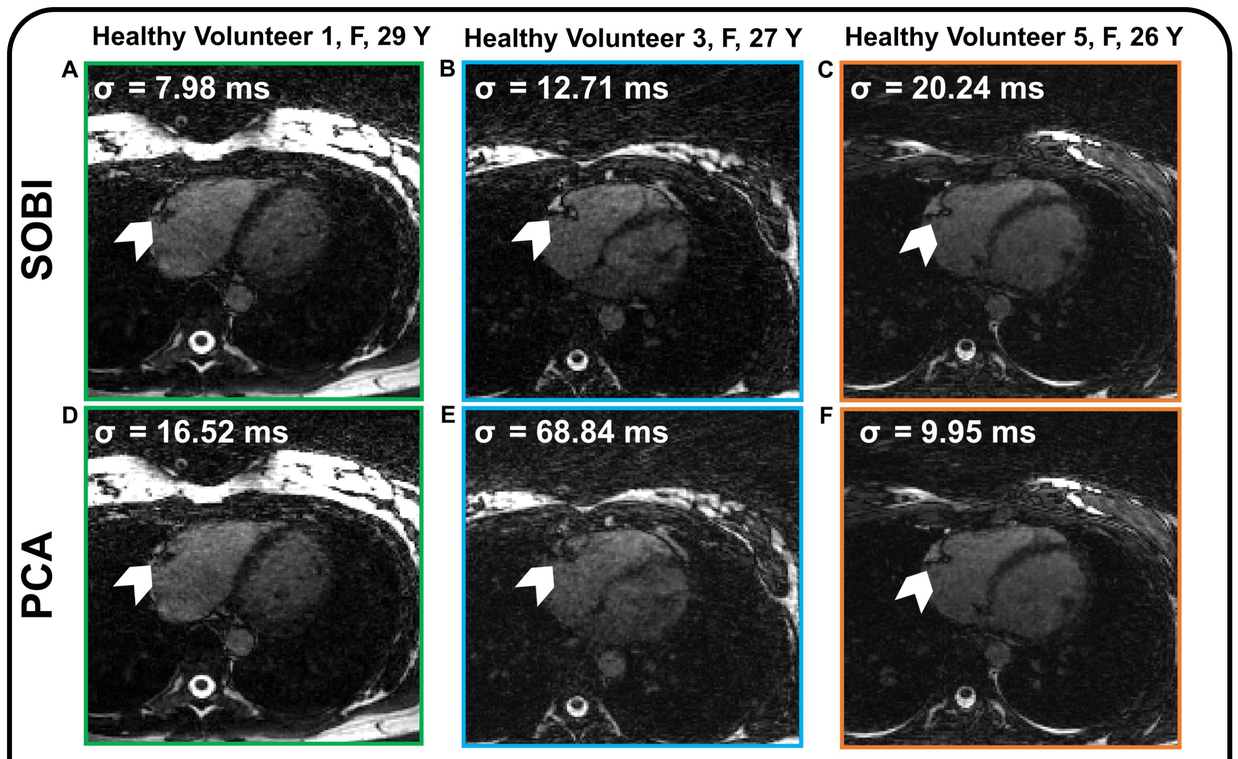

Figure 4. *Cardiac image reconstructions in healthy volunteers with SOBI and PCA.*

The precision (1/σ) in the estimation of the SG intervals improved most when applying SOBI after PCA instead of PCA only (σ_{SOBI}=13.6±3.9ms and σ_{PCA}=20.3±20.8ms, p=0.03).

CONCLUSION

The use of SOBI with principal components improves the precision and robustness of cardiac motion extraction in whole-heart 4D free-running acquisitions and results in sharper images.

References: [1] Di Sopra L, MRM 2019, 82(6):2118-32 [2] Hyvärinen A, NN 2000, 13(4-5):411-30 [3] Piccini D, MRM 2011, 66(4):1049-56 [4] Himberg J, IEEE NNSP 2003, doi: 10.1109/NNSP.2003.1318025 [5] Belouchrani A, IEEE TSP 1997, 45(2):434-44 [6] Roy CW, JCMR 2021, 23(1):1-7 [7] Lustig M, MRM 2007, 58(6):1182-95

FREE-RUNNING