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3D-CINE whole heart reconstruction from Free-Running acquisition with Deformation-Field informed regularization

Bastien Milani[1], Christopher Roy[1], Jean-Baptiste Ledoux[1], David C. Rotzinger[1], Salim Si-mohamed[2,3], Ambra Masi[1], Jerome Yerly[4], Tobias Rutz[1], Milan Prsa[1], Juerg Schwitter[1], Matthias Stuber[1,4]

[1]Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland. [2]University Lyon, INSA-Lyon, University Claude Bernard Lyon 1, CNRS, Inserm, CREATIS, France; [3]Louis Pradel Hospital, Hospices Civils de Lyon, France; [4]Center for Biomedical Imaging (CIBM), Lausanne, Switzerland.

BACKGROUND

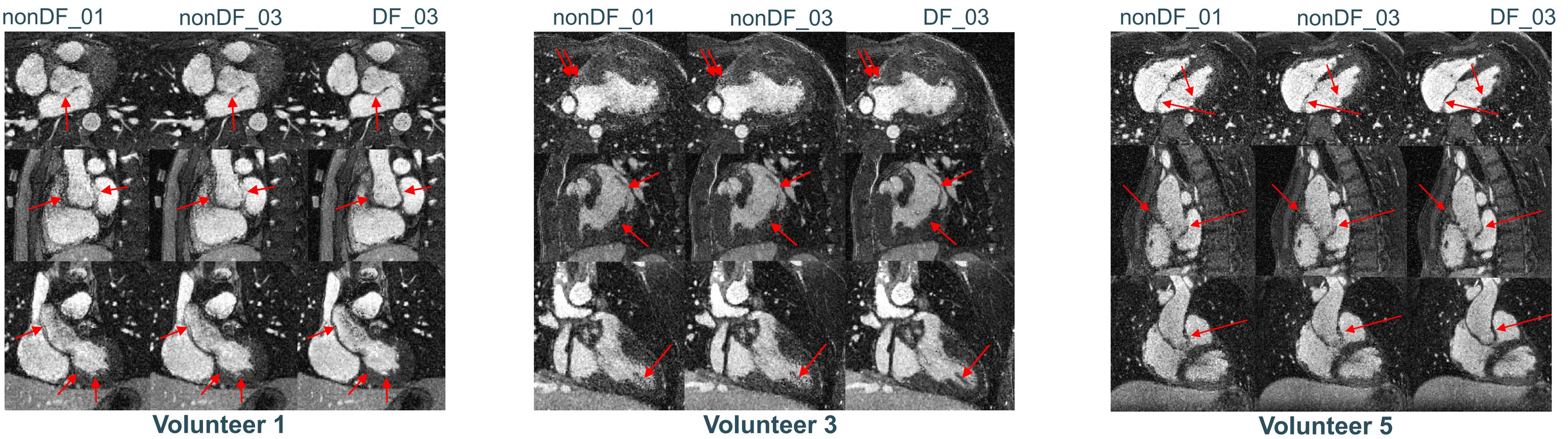
This work presents a whole-heart 3D-CINE reconstruction for fully self-gated 3D-radial free-running data. The reconstruction is based on compressed sensing and makes use of a regularization term that promotes sparse motion-corrected residuals between adjacent frames by the use of deformation fields (DF). We test 3 reconstruction-parameter-sets :

- No DF and regularization parameter 0.1 (recon-nonDF_01)
- No DF and regularization parameter 0.3 (recon-nonDF_03)
- With DF and regularization parameter 0.3 (recon-DF_03)

AIMS

- To implement and test a whole heart 3D-CINE compressed sensing reconstruction from free-running fully self gated acquisition with temporal-total-variation regularization based of motion corrected residuals.
- To measure the improvement qualitatively and quantitatively as compared to the same reconstruction with temporal-total-variation regularization but without information from deformation fields.
- To evaluate the ejection fraction with this reconstruction and compare it to conventional 2D-CINE measurement.

RESULTS



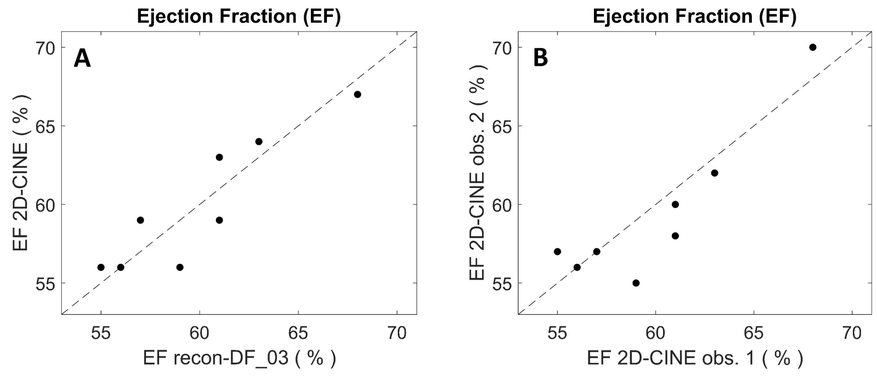
Volunteer 1 **Volunteer 3** **Volunteer 5**

Top row shows an axial plane. Middle raw shows a sagittal plane. Bottom row shows a coronal plane. For each of the three displayed volunteers, the left column results from recon-nonDF_01, the middle column from recon-nonDF_03 and the right column from recon-DF_03. That last reconstruction exhibit a better quality than the two other, especially for moving structures as depicted by red arrows.

Comparison criteria	Number of patient for which recon-DF_03 was visually considered of superior quality	p-value of two-sided binomial-test
Perceived Noise	**12/12***	**4.9e-4**
Sharpness of aortic branch vessels interface	8/12	0.39
Sharpness of aortic valve leaflets	9/12	0.15
Sharpness of LCA	**11/11***	**9.8e-4**
Sharpness of LAD	**12/12***	**4.9e-4**
Sharpness of LCx	**11/12***	**6.3e-3**
Sharpness of RCA	9/11	0.065
Overall diagnostic confidence	**12/12***	**4.9e-4**

Left: results of the qualitative analysis performed by the radiologist.

Right: (A) EF measured on recon-DF_03 versus EF measured on conventional 2D-CINE. (B) EF measured on conventional 2D-CINE by an observer versus another observer.



METHODS

FREE-RUNNING

Fully self-gated data were acquired with a 3D-radial free-running gradient echo sequence after slow injection of a 2mg/kg dose of ferumoxitol contrast medium in 12 congenital heart disease patients (age = 22 ± 9 years). Data were binned into motion-consistent sets of lines in k-space to resolve both respiratory and cardiac motion. The reconstruction consisted is solving

$$\underset{x}{\operatorname{argmin}} \ \frac{1}{2}\sum_{i=1}^{nFr}\left\|F^{(i)}C\,x^{(i)}-y^{(i)}\right\|^2_{Y^{(i)},2}+\frac{\lambda}{2}\left\|T^{(i)}x^{(i)}-\,x^{(i-1)}\right\|_{X^{(i)},1}$$

Motion between adjacent frames was then estimated using non-rigid registration. A second reconstruction (recon-DF_03, $\lambda = 0.3$) including the use of deformation fields was then performed by setting $T^{(i)}$ equal to the linear map that deforms frame $x^{(i)}$ into $x^{(i-1)}$ by utilizing of the previously estimated deformation fields.

CONCLUSION

By incorporating frame-to-frame deformation motion fields into the compressed sensing reconstruction, anatomical structures become more conspicuous, which is supported by both quantitative and qualitative findings. We also show that the ejection fraction can be accurately measured on fully self-gated 3D-radial free-running images.

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