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# Direction-dependent decomposition of 3D right ventricular motion: beware of approximations.

Nicolas Duchateau<sup>a</sup>, PhD, Pamela Mocerì<sup>b,c</sup>, MD, PhD, Maxime Sermesant<sup>d</sup>, PhD.

<sup>a</sup>CREATIS, CNRS UMR 5220, INSERM U1206, Université Lyon 1, France;

<sup>b</sup>Centre Hospitalier Universitaire de Nice, Service de Cardiologie, Nice, France;

<sup>c</sup>UR2CA, Université Côte d'Azur, Faculté de médecine, Nice, France;

<sup>d</sup>Inria, Université Côte d'Azur, Sophia Antipolis, France.

## Corresponding author:

Nicolas Duchateau

CREATIS, Université Lyon 1,

INSA Bâtiment Blaise Pascal

7 avenue Jean Capelle, 69621 Villeurbanne Cedex

Tel: +33.472437147

Email: [nicolas.duchateau@creatis.insa-lyon.fr](mailto:nicolas.duchateau@creatis.insa-lyon.fr)

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Assessing myocardial motion in 3D requires careful standards. Defining anatomically-relevant directions<sup>1</sup> is crucial for inter-subject comparisons and disease understanding, but is challenging due to the peculiar right ventricular (RV) geometry. Thus, the advantages and drawbacks of existing computational methods should be considered when interpreting results. We illustrate this on the RV endocardial surface of a representative healthy volunteer (47 years, female) from a previously published study<sup>2</sup>, tracked across a 3D echocardiographic sequence using commercial tools (4D RV Function 2.0, TomTec Imaging Systems GmbH, Unterschleißheim, Germany) and post-processed using custom software (written in C++/VTK, v7.10, Kitware, New York, USA).

Figure 1a depicts the local radial-circumferential-longitudinal directions required at each point of the RV to decompose motion or deformation<sup>1</sup>. The radial direction is orthogonal to the RV. The longitudinal direction points towards the apex along the RV. The circumferential direction is orthogonal to the longitudinal direction and tangential to the RV surface. In practice, the radial direction is easily obtained as the local normal to the RV surface. The long-axis joins the basal edge point equidistant from the valves, and the apex. Then, the local circumferential direction can be estimated as the cross-product between the radial direction and the long-axis, and finally the longitudinal direction as the cross-product between the radial and circumferential directions<sup>2</sup>. This methodology provides an approximation of the longitudinal direction. For more relevant longitudinal direction at every point of the RV surface, one should actually estimate the shortest path between each point and the apex (called geodesics), and compute the tangent at their starting point. Geodesics can be estimated through widely proven methods<sup>3</sup> and publicly available code<sup>4</sup>, as used in Figure 1a.

These computations are fully 3D and compatible with any convex/concave surface, but require engineering expertise and custom software. To facilitate understanding, some authors recently proposed a *directional* version of ejection fraction<sup>5</sup>, with publicly available software. Their algorithm consists in warping the end-diastolic RV surface according to a single motion component after setting the two others to zero (Figure 1b). Ejection fraction is estimated using the warped RV surface at end-systole. Although referred to as radial-circumferential-longitudinal or radial-anteroposterior-longitudinal decomposition of motion, computations actually decompose motion along fixed directions (the x-y-z axes). Therefore, they require pre-alignment of the RV with these axes, which is not

straightforward and whose uncertainty directly impacts the directional ejection fraction values. Figure 1c reveals how the directional ejection fraction varies when the alignment with the x-y-z axes is imperfect (here, achieved by rotating the RV surface around the x-y-z axes). Absolute variations up to 20% are observed with moderate rotations between  $-30^{\circ}$  and  $30^{\circ}$ .

Decomposing RV motion along specific directions helps to understand the components of 3D motion linked with a specific cardiac condition. The radial-circumferential-longitudinal directions may be challenging to estimate for the RV but are robust to inter-subject misalignment. Given the rising interest for 3D RV imaging, we strongly recommend to consider the pros and cons of the proposed computational solutions, and call for better standardization of such computational tools.

**Conflict of interest**      None declared.

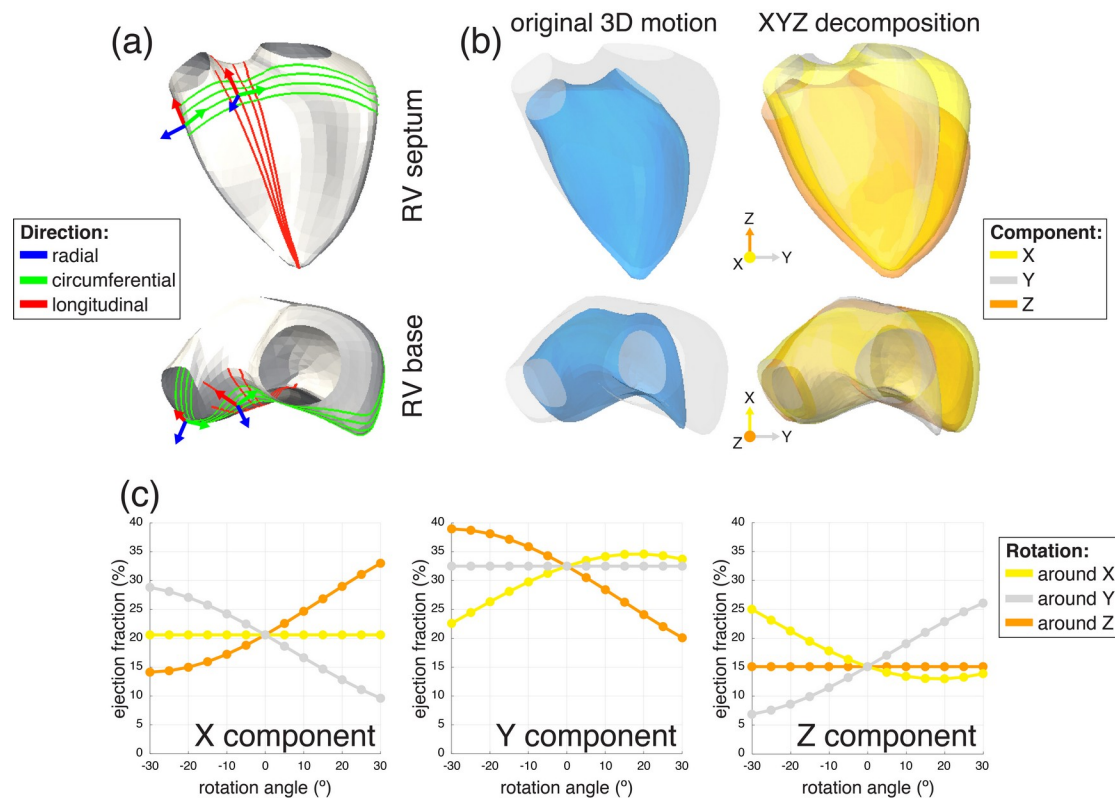
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## Figure legends

**Figure 1:** (a) Radial, circumferential, and longitudinal directions on the RV surface. The green lines correspond to sample isocontours of the geodesic distance to the apex, while the red lines correspond to sample geodesics joining basal points and the apex\*. (b) Direction-dependent decomposition of 3D RV motion from end-diastole to end-systole, along the x-y-z directions. (c) Variations in the RV alignment (rotations around the x-y-z axes) substantially impact the ejection fraction estimated for each decomposition.



\*The geodesics computations were based on the code provided at<sup>4</sup>:  
<http://hdl.handle.net/10380/3415>