

## Supplementary Material

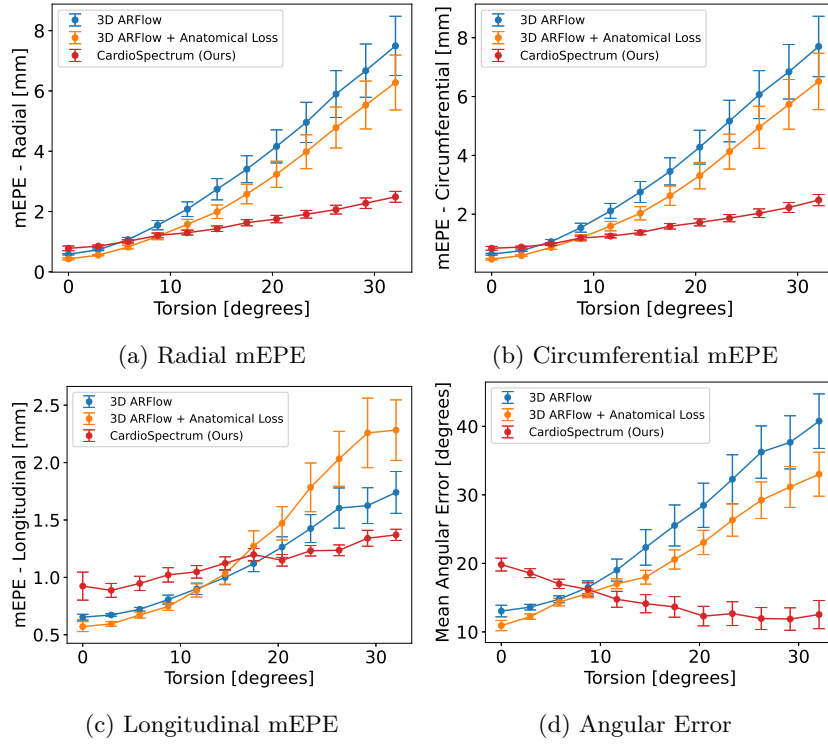


Fig. 1: Additional comparison of the proposed model and two baselines in capturing cardiac deformation across torsion angles, breaking down mEPE into radial (1a), circumferential (1b), and longitudinal (1c) components. Radial and circumferential mEPE consistently showcase our model’s superior performance. Although performance relatively decreased at lower torsion angles in the longitudinal component, all models had lower errors than in other components. Subfigure 1d shows dissimilarity between predicted and true flow directions based on angular error, with our method outperforming baselines particularly at higher torsion angles. Error bars represent standard errors (SE). These figures supplement Figure 3 and Section 5.1 of the main paper.

Table 1: Comparison of mEPE within the myocardium segmentation mask, along SE, at various torsion angles using CardioSpectrum and two baseline methods. Bold values denote significant improvement, and underlined values indicate comparable performance.

Torsion [deg]	mEPE $\pm$ SE [mm]		
	3D ARFlow	3D ARFlow + Anatomical Loss	CardioSpectrum (Ours)
0	1.25 $\pm$ 0.043	<b>0.99 <math>\pm</math> 0.06</b>	1.67 $\pm$ 0.13
2.9	1.44 $\pm$ 0.039	<b>1.16 <math>\pm</math> 0.04</b>	1.73 $\pm$ 0.06
5.8	1.92 $\pm$ 0.11	<b>1.60 <math>\pm</math> 0.10</b>	1.94 $\pm$ 0.08
8.7	2.67 $\pm$ 0.24	<u>2.14 <math>\pm</math> 0.17</u>	<u>2.26 <math>\pm</math> 0.11</u>
11.7	3.53 $\pm$ 0.39	2.80 $\pm$ 0.27	<b>2.38 <math>\pm</math> 0.10</b>
14.6	4.56 $\pm$ 0.56	3.51 $\pm$ 0.38	<b>2.59 <math>\pm</math> 0.13</b>
17.5	5.65 $\pm$ 0.71	4.52 $\pm$ 0.55	<b>2.93 <math>\pm</math> 0.15</b>
20.4	6.90 $\pm$ 0.88	5.61 $\pm$ 0.72	<b>3.08 <math>\pm</math> 0.18</b>
23.3	8.25 $\pm$ 1.08	6.93 $\pm$ 0.96	<b>3.35 <math>\pm</math> 0.19</b>
26.2	9.72 $\pm$ 1.26	8.24 $\pm$ 1.14	<b>3.59 <math>\pm</math> 0.22</b>
29.1	10.93 $\pm$ 1.43	9.51 $\pm$ 1.34	<b>3.94 <math>\pm</math> 0.27</b>
32.1	12.26 $\pm$ 1.59	10.68 $\pm$ 1.50	<b>4.29 <math>\pm</math> 0.29</b>

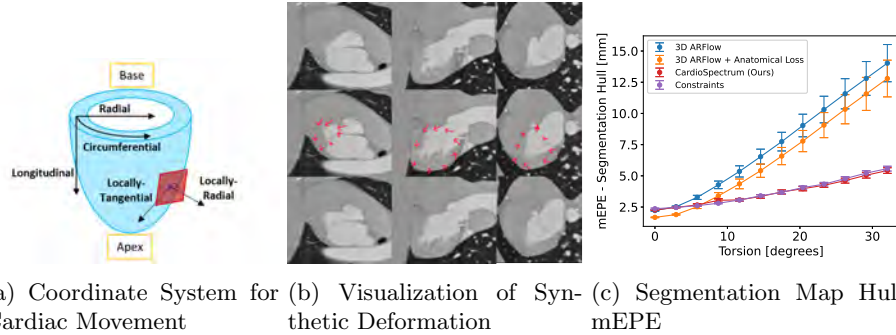


Fig. 2: (2a) The cardiac cycle involves *radial* (LV cavity center to myocardial wall), *circumferential* (tangential along the epicardial wall), and *longitudinal* (along the LV’s long axis) LV movements. *Locally-tangential* and *locally-radial* movements refer to projections onto and perpendicular to the myocardial surface’s tangent plane.

(2b) A sample before (top) and after (bottom) deformation. Arrows represent selected ground truth annotations. Sample from the 3D Slicer library (<http://www.slicer.org>).

(2c) Comparing mEPE of CardioSpectrum, baselines, and ZoomOut-derived constraints across torsion angles, evaluated over the segmentation map hull. ”Constraints” is composed of errors from ZoomOut and voxel-mesh conversions, impacting CardioSpectrum’s performance, especially at lower angles.