

Deep Learning Left Ventricular Mechanical Analysis – Sensing Bi-Ventricular Dysfunction in Tetralogy of Fallot

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INTRODUCTION

- Patients with repaired tetralogy of Fallot (rTOF) frequently develop right ventricular (RV) dysfunction secondary to pulmonary valvular regurgitation and are consequently followed with MRI. However, some patients may also develop left ventricular (LV) dysfunction.

OBJECTIVE

- To assess whether regional measures of LV strain might sensitively detect signs of LV dysfunction amongst this patient population.

METHODS

- We retrospectively collected cine SSFP MRI images from an international cohort of 198 patients with rTOF.
- Using deep learning synthetic strain (DLSS), a new fully-automated algorithm for regional strain quantification from short-axis cine SSFP images, we calculated LV strain across 16 AHA segments.
- We then performed a clustering analysis to identify groups of patients with similar patterns of LV contraction, including segmental peak strain and measures of dyssynchrony.
- We further characterized these patient groups by comparing traditional global metrics of ventricular volume and function and assessed subsequent progression to pulmonary valve replacement (PVR).

RESULTS

- Clustering of rTOF patients based on fully-automated measurements identified three unique patterns of LV contraction.
- Clusters 1 (n=39) and 2 (n=130) were characterized by reduced strain in the septal segments, though cluster 1 also showed increased dyssynchrony. Cluster 1 showed elevated RV end-diastolic volume relative to clusters 2 and 3 (155 ± 34 vs. 125 ± 31 and 131 ± 37 mL/m², ANOVA p<0.001).
- In contrast, cluster 3 (n=29) was characterized by globally reduced LV strain. Cluster 3 showed reduced LVEF relative to cluster 2 (53 ± 10 vs. 60 ± 6%, t-test p<0.001), but no statistical difference from cluster 1 (53 ± 10 vs. 56 ± 5%, t-test p=0.30).
- Patients in cluster 1 had decreased time to PVR relative to clusters 2 and 3 (23 ± 21 vs. 33 ± 28 and 38 ± 33 months, log-rank p<0.001).

Patients with repaired tetralogy of Fallot separate into distinct groups based on regional patterns of LV mechanics, which are predictive of right ventricular dysfunction and pulmonary valve replacement.



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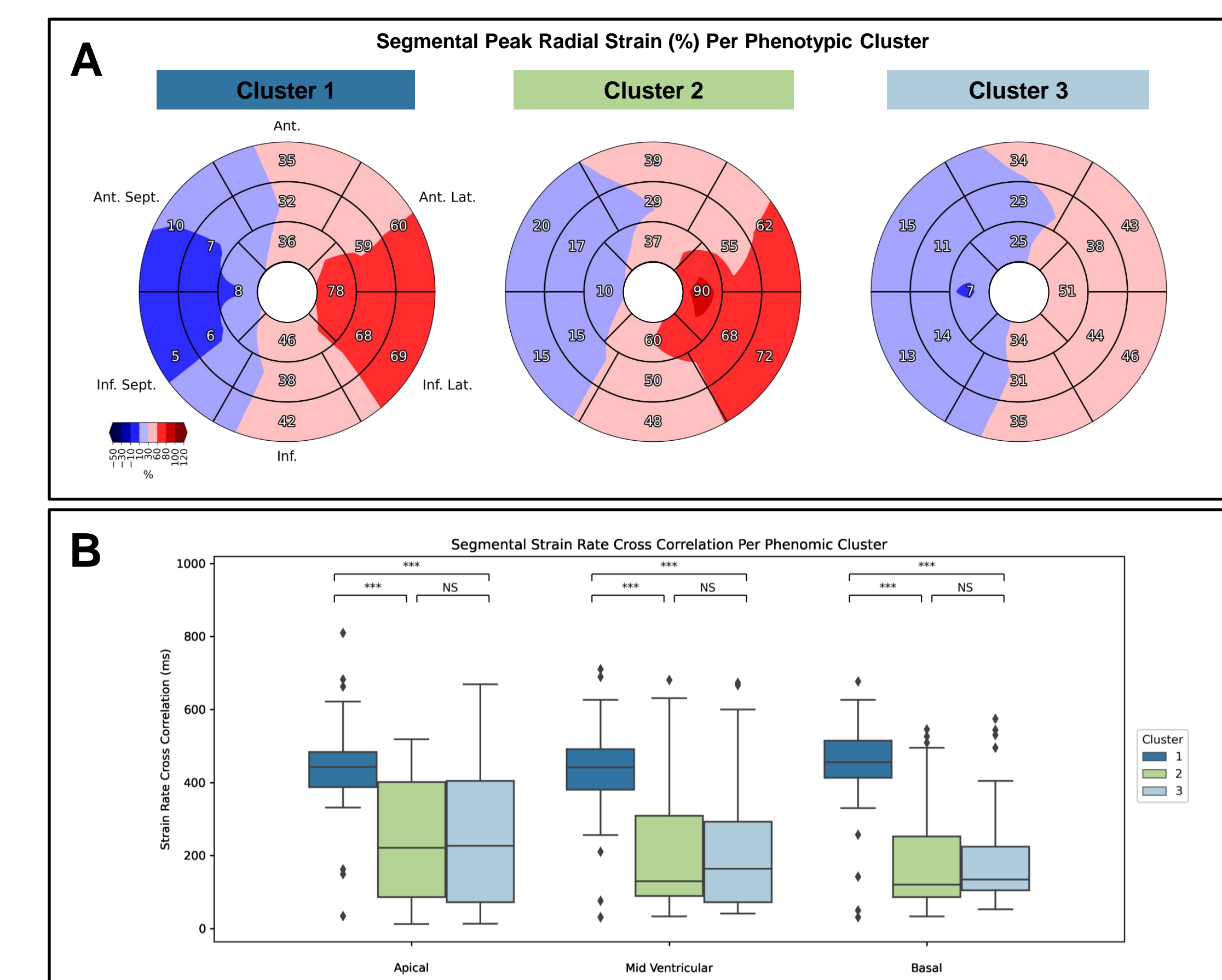


Figure 1: Characteristics of LV mechanical clusters. **1A)** 16 AHA segment bull's eye plots of radial strain for clusters 1, 2, and 3. **1B)** Strain rate cross correlation (SRCC) per cluster, showing that cluster 1 is characterized by increased dyssynchrony relative to clusters 2 and 3. ***=p<0.001; NS = not significant.

	Cluster 1 (n=39)	Cluster 2 (n=130)	Cluster 3 (n=29)	p-value
Demographics				
Age (years)	22.0 ± 10.9	20.9 ± 11.7	30.5 ± 13.4	<0.01
Age at Repair (years)	3.4 ± 4.1	2.2 ± 3.6	4.4 ± 5.0	0.02
Prior PVR (n)	2 (5.1%)	26 (20.0%)	9 (31.0%)	0.02
Time Since PVR	4.5 ± 4.5	6.6 ± 5.5	5.1 ± 5.6	0.74
Volume and Function				
RVEDVi (mL/m ²)	153.0 ± 33.9	124.5 ± 31.1	130.5 ± 37.4	<0.001
RVESVi (mL/m ²)	73.2 ± 19.1	62.9 ± 20.0	71.8 ± 26.5	0.02
RVSVi (mL/m ²)	73.3 ± 15.9	62.3 ± 18.7	58.8 ± 15.9	<0.01
LVEDVi (mL/m ²)	69.0 ± 27.3	58.4 ± 28.7	70.8 ± 26.8	0.03
LVESVi (mL/m ²)	38.6 ± 8.7	37.0 ± 8.9	45.1 ± 15.1	<0.01
LVSVi (mL/m ²)	42.7 ± 12.1	45.4 ± 11.8	37.5 ± 11.9	0.02
RVEF (%)	49.3 ± 6.2	51.1 ± 8.7	45.7 ± 7.2	0.01
LVEF (%)	56.0 ± 5.6	59.8 ± 5.9	52.6 ± 10.2	<0.001
Flow and Regurgitation				
Pulmonary Net Flow (L/min)	4.9 ± 1.6	5.1 ± 1.3	5.2 ± 1.5	0.70
Pulmonary RF (%)	38.8 ± 14.4	31.2 ± 19.1	24.6 ± 17.2	0.03

Note – Data is reported as the mean and standard deviation. P-values are calculated using a one-way ANOVA for continuous variables and a Pearson's chi-squared test for categorical variables. Significant values (p<0.01) are bolded.

Table 1: Patient demographics, traditional global metrics of ventricular volume and function, and regurgitation metrics for clusters 1, 2, and 3.

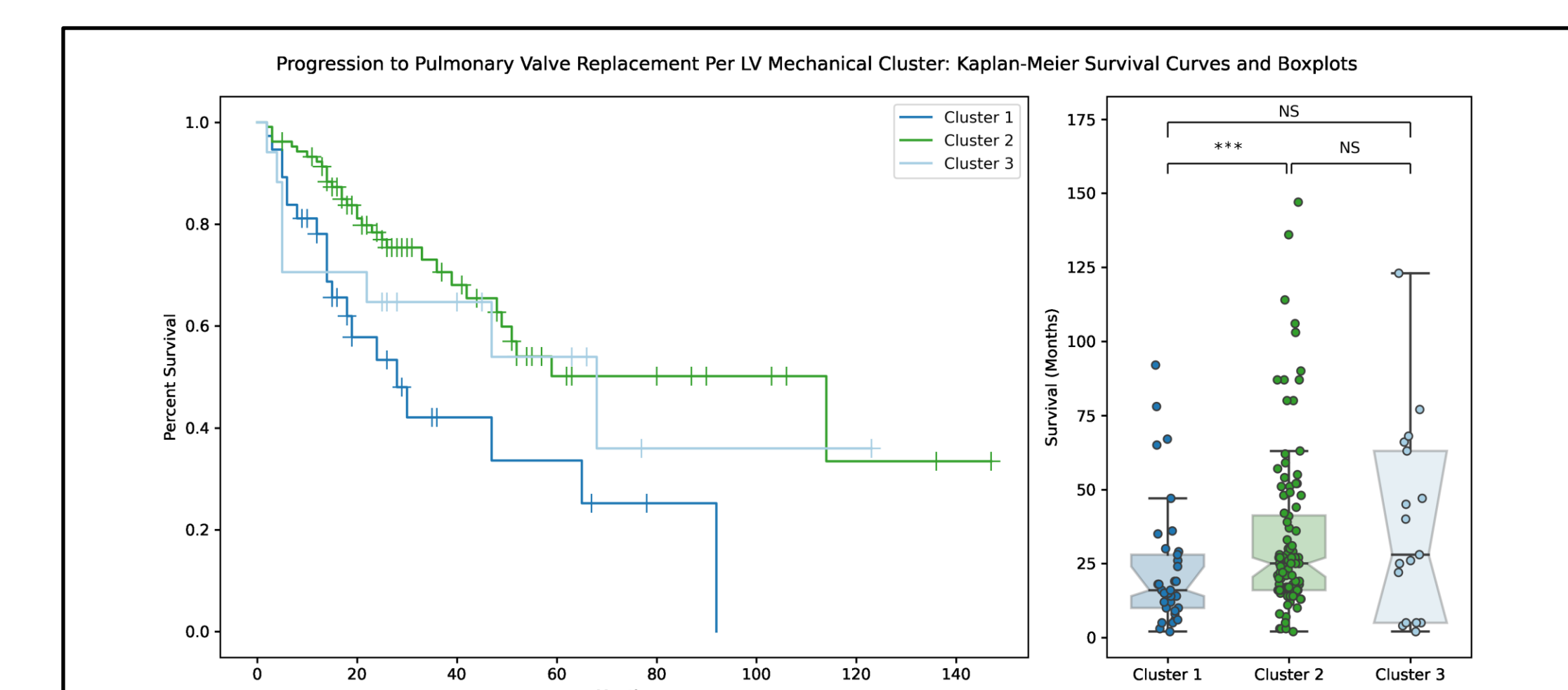


Figure 2: LV mechanical clusters are predictive of progression to PVR, with cluster 1 having a significantly decreased progression free survival relative to clusters 2 and 3. ***=p<0.001; NS = not significant.

ACKNOWLEDGMENTS

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