



# Right Ventricular Mechanical Dyssynchrony in Children with Hypoplastic Left Heart Syndrome



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## Abstract

### Background

Mechanical dyssynchrony predicts response to cardiac resynchronization therapy in adults with heart failure. Children with HLHS are susceptible to RV failure; however, mechanical dyssynchrony has not been recently studied in this population. We investigated right ventricular (RV) mechanical dyssynchrony in children with Hypoplastic Left Heart Syndrome (HLHS) using vector velocity imaging (VVI).

### Methods

We used VVI to quantify the standard deviation of time to peak velocity, strain and strain rate between 6 RV segments to define intra-ventricular RV dyssynchrony in 16 children with HLHS and RV and left ventricular (LV) dyssynchrony in 16 healthy age-matched controls. We further investigated relations between electrical and mechanical dyssynchrony and between mechanical dyssynchrony and systolic function.

### Results

Children with HLHS had significant RV mechanical dyssynchrony versus LV and RV controls (Strain:  $37\pm35$  vs.  $8\pm8$  msec,  $p=0.003$  (LV),  $9\pm11$  msec,  $p=0.005$  (RV); strain rate  $31\pm37$  vs.  $10\pm13$  msec,  $p=0.04$  (LV),  $14\pm15$  msec,  $p=0.09$  (RV)). There was no significant relationship between electrical and mechanical dyssynchrony.

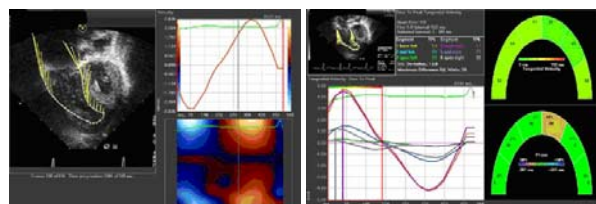
### Conclusions

Children with HLHS have RV mechanical dyssynchrony unrelated to electrical dyssynchrony as measured from surface ECG duration. This may contribute to RV dysfunction and may indicate the usefulness of CRT in this population.

## Introduction

The right ventricle (RV) is susceptible to failure in children with hypoplastic left heart syndrome (HLHS). A portion of these patients develop clinically significant RV dysfunction, a particularly worrisome situation in the setting of a partial or total cavo-pulmonary connection, which increases morbidity and mortality and may require further intervention or heart transplantation. Cardiac mechanical dyssynchrony is prevalent in adults with cardiomyopathy and its presence predicts response to cardiac resynchronization therapy (CRT). Short-term multisite pacing has been investigated in the post-operative setting in children with single-ventricle physiology; however, RV mechanical dyssynchrony has not been investigated in children with HLHS. The presence of mechanical dyssynchrony in these patients would provide a mechanistic basis for investigation of the utility of long-term CRT in this group, and might provide insight into the cause of RV dysfunction in this setting. The objective of this study was to investigate RV mechanical dyssynchrony in children with HLHS using vector velocity imaging (VVI).

Figure 1: VVI Imaging Technique



Example of vector velocity imaging (VVI) imaging from a patient with hypoplastic left heart syndrome. Myocardial velocity is indicated by the arrows along the endocardial border in the left panel. On the right panel, the velocity profiles for 6 myocardial regions are plotted. The standard deviation of the time to peak velocity, strain or strain rate between the 6 cardiac segments is used as a dyssynchrony index.

## Methods & Materials

### Patients

Patients between 0-18 years with HLHS were identified from the pediatric echocardiography database at the Lucile Packard Children's Hospital from echocardiograms performed between 4/2005 and 1/2006. Patients with HLHS were included at any stage of palliation. We excluded patients who were paced. Control subjects were matched for age and had normal echocardiograms obtained for investigation of a murmur. The institutional review board approved the study.

### Echocardiography

**Systolic function:** The fractional area of change was calculated for the RV in patients with HLHS by obtaining the RV area from a 4-chamber view equivalent. The fractional shortening was used to assess systolic function in normal controls.

**Velocity Vector Imaging:** Velocity vector imaging (VVI) (Siemens, Mountain View, CA), is an angle-independent method that calculates tissue velocity, strain and strain rate using 2-dimensional images. VVI combines speckle tracking with other reference points to calculate myocardial velocities from which strain and strain rate are derived. In patients with HLHS, the RV endocardial border was traced manually in diastole, in a 4-chamber view equivalent from digitally stored images. In controls, the RV and LV endocardial borders were traced from the 4-chamber view. The traced contour was then automatically tracked by the software algorithm over 1 cardiac cycle, yielding local velocity, which is then converted to strain and strain rate. For each parameter (velocity, strain, strain rate), the mechanical dyssynchrony was defined as the standard deviation of time to peak event between 6 cardiac segments in a 4-chamber view (Figure 1).

### Data analysis

Continuous variables were compared using the unpaired student's t-test or, for multiple categories, ANOVA. We divided children with HLHS into those who had a longer QRS duration (defined as QRS duration greater than study population median of 93 msec) to those with a shorter QRS (less than median). Results are expressed as mean  $\pm$  1 SD. All p-values are 2-sided. A p-value of  $< 0.05$  was accepted as significant.

## Results

Table 1: Patient Characteristics

	Controls (n=16)	HLHS (n=16)
Age, yrs	4.9 $\pm$ 4.6	4.8 $\pm$ 4.4
Male (%)	9 (53)	11 (65)
Systolic Function	FS %: 38 $\pm$ 6	FAC % 44 $\pm$ 11
Stage 1 palliation		2
Stage 2 palliation		9
Stage 3 palliation		6
Norwood type		
RV-PA conduit		7
BT shunt		7

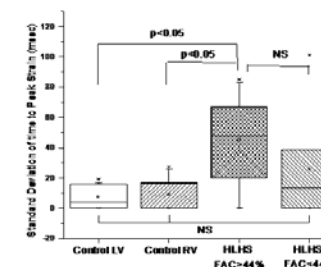
Table 2: Mechanical Dyssynchrony

	HLHS	Controls LV	p	Controls RV	p
SD of Time to Peak Velocity (msec)	43 $\pm$ 67	11 $\pm$ 6	0.07	12 $\pm$ 7	0.08
SD of Time to Peak Strain	37 $\pm$ 35	8 $\pm$ 8	<0.01	9 $\pm$ 11	<0.01

Table 3: Influence of QRS Duration on Mechanical Dyssynchrony

	QRS < median	QRS > median	p
Age, years	3.8 $\pm$ 3.7	5.9 $\pm$ 5.02	NS
SD of Time to Peak Velocity (msec)	35 $\pm$ 33	54 $\pm$ 99	NS
SD of Time to Peak Strain (msec)	26 $\pm$ 34	50 $\pm$ 34	NS

Figure 2: Influence of Ventricular Function on Mechanical Dyssynchrony



## Conclusions

### Electrical Dyssynchrony

Electrical dyssynchrony was not prevalent in children with HLHS (QRS median duration 93 msec, range 71-140). Only 2 patients had a QRS  $\geq$  120 msec. These patients had QRS durations of 120 and 140 msec with RBBB. No patient displayed LBBB.

### Mechanical Dyssynchrony

Children with HLHS had significant RV mechanical dyssynchrony as compared to both the right and left ventricles of normal controls, as evidenced by strain and strain rate VVI (strain rate data not shown but similar to strain). Myocardial velocity data were similar to results for strain and strain rate, but did not reach statistical significance, likely due to the relatively small sample and the large variance.

There was no difference in the SD of time to peak strain between those HLHS patients who had undergone a Blalock-Tausig shunt versus those who had undergone an RV-PA conduit (37 $\pm$ 38 vs. 26 $\pm$ 36 msec, NS). There was no relation between the SD of time to peak strain and the fractional area of change in patients with HLHS ( $r=0.44$ ,  $p=0.09$ ).

### Relationship between electrical and mechanical dyssynchrony

Children with HLHS who had a longer QRS duration ( $>$  median, 93 msec) had a similar degree of RV mechanical dyssynchrony as those with a narrow QRS ( $<$  median) using SD of time to peak velocity, strain or strain rate.