Strain imaging in children: from Tissue Doppler to 3-D

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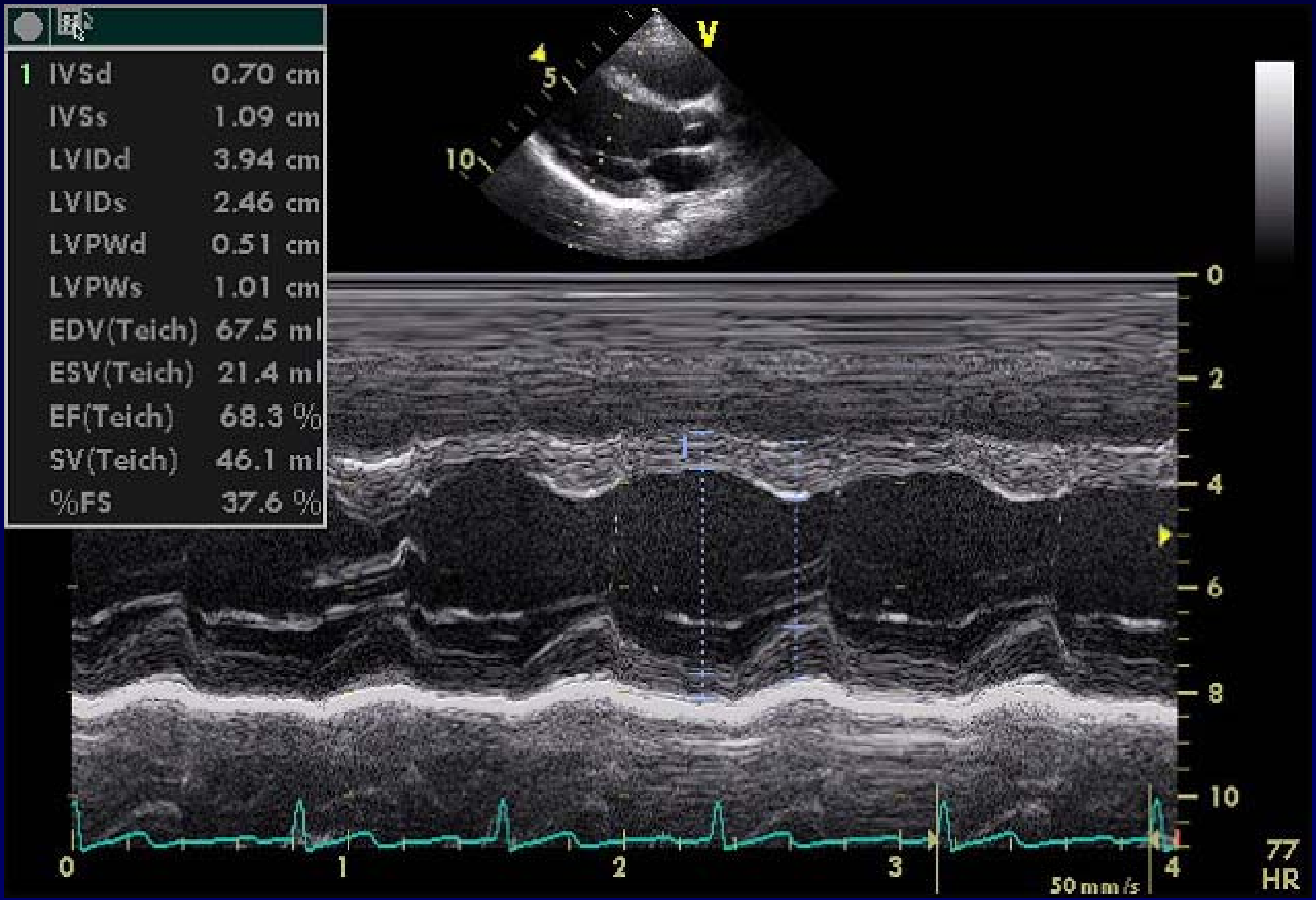
Outline

- Deformation in the fetus and neonate
- Deformation in pediatric cardiomyopathy (briefly!)
- Deformation in Congenital heart disease:
  - Tetralogy of Fallot
  - Hypoplastic left heart syndrome
  - ccTGA
- 3-D strain

Strain imaging in children: From M-mode to 3D?



Normal strain values in pediatrics

Table 2 Systolic and diastolic strain (unit %) for regional left ventricular longitudinal function

	Strain		
	Systolic	**Early diastolic**	**Late diastolic**
Septum (4CH):			
Base	–24 ± 06	17 ± 05	07 ± 06
Mid	–24 ± 08	14 ± 05	07 ± 06
Apic	–24 ± 05	19 ± 07	03 ± 06*
Lateral (4CH):			
Base	–26 ± 11	14 ± 08	11 ± 07
Mid	–26 ± 08	19 ± 11	06 ± 06
Apic	–25 ± 07	19 ± 11	03 ± 06*
LV Inferior (2CH):			
Base	–24 ± 06	17 ± 05	07 ± 09
Mid	–24 ± 09	16 ± 07	06 ± 06
Apic	–26 ± 09	20 ± 09	05 ± 05

Weideman, JASE 2002;15:20

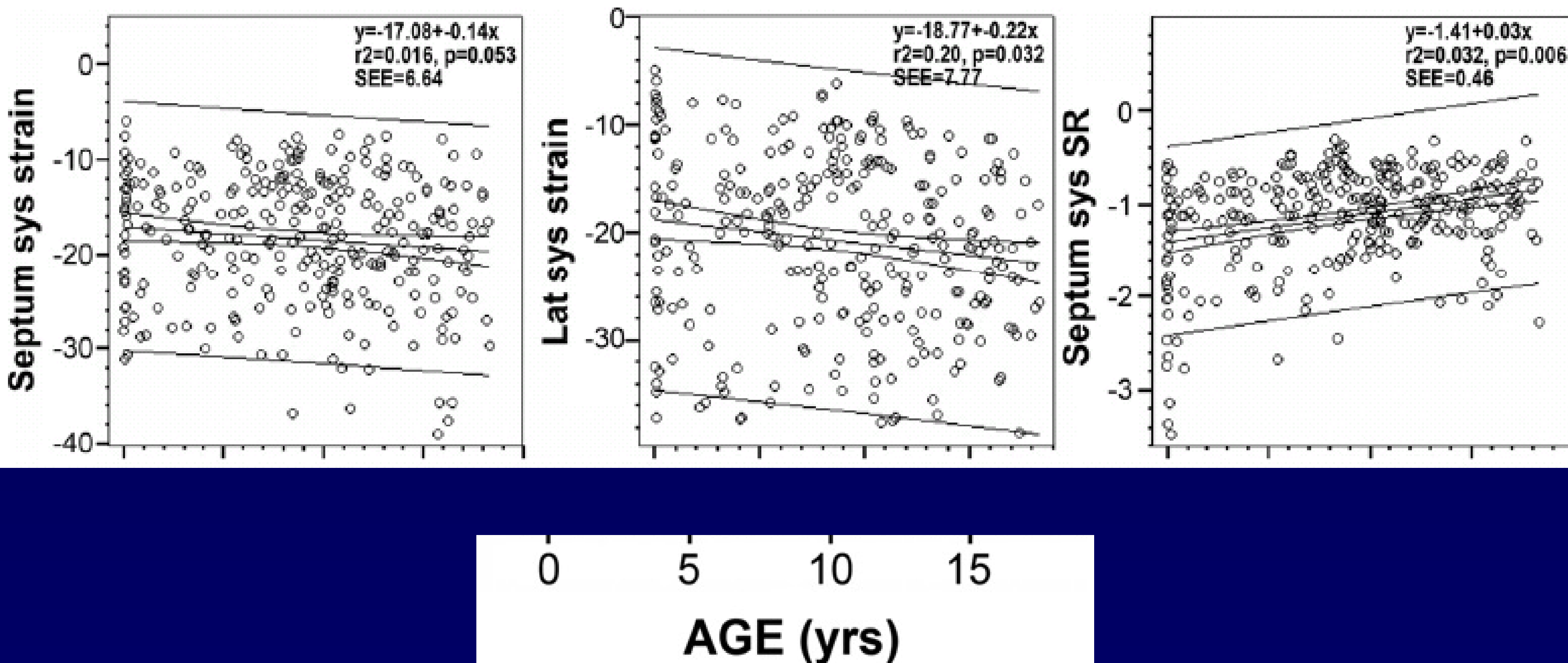
Normal strain values in pediatrics

Table 2 Myocardial velocity, strain, and strain rate measurements at the septal and lateral attachments of the mitral valve by age group

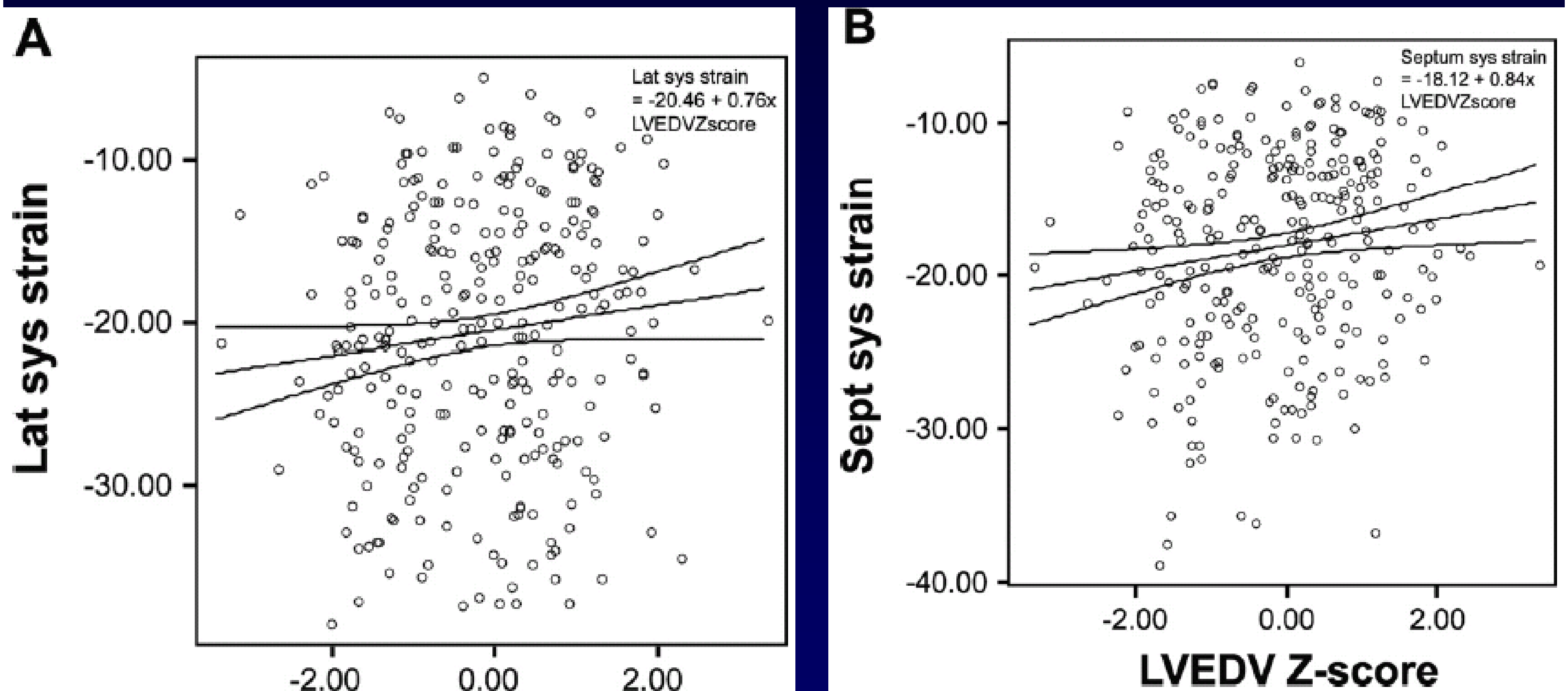
	0-1 y		1-5 y		6-9 y		10-13 y		14-18 y		Total	
	N	Mean ± SD	N	Mean ± SD	N	Mean ± SD	N	Mean ± SD	N	Mean ± SD	N	Mean ± SD
Sept ε (%)	37	−17.97 ± 7.02	53	−17.99 ± 5.92	66	−16.65 ± 6.29	71	−18.80 ± 6.60	57	−20.11 ± 7.31	284	−18.30 ± 6.67
Lat ε (%)	37	−18.51 ± 9.39	53	−21.13 ± 8.44	66	−18.31 ± 7.43	71	−22.07 ± 8.19	57	−22.70 ± 6.49	284	−20.68 ± 8.08
Sept SR S (s^{-1})	37	−1.66 ± 0.79	53	−1.23 ± 0.48†	66	−0.98 ± 0.46	71	−1.00 ± 0.33	57	−1.04 ± 0.44	284	−1.13 ± 0.53
Sept SR E (s^{-1})	11	1.58 ± 0.63	37	1.46 ± 0.74	64	1.15 ± 0.51*	71	1.24 ± 0.53	57	1.23 ± 0.57	240	1.32 ± 0.52
Sept SR A (s^{-1})	11	0.72 ± 0.45	37	0.52 ± 0.36	64	0.45 ± 0.28	71	0.46 ± 0.28	57	0.42 ± 0.24	240	0.47 ± 0.29
Lat SR S (s^{-1})	37	−1.72 ± 0.91	53	−1.59 ± 0.79	66	−1.19 ± 0.53†	71	−1.20 ± 0.56	57	−1.22 ± 0.52	284	−1.34 ± 0.68
Lat SR E (s^{-1})	12	1.82 ± 0.90	37	1.70 ± 0.96	64	1.47 ± 0.84	71	1.70 ± 0.85	57	1.63 ± 0.81	241	1.68 ± 0.89
Lat SR A (s^{-1})	12	0.52 ± 0.25	37	0.44 ± 0.29	64	0.40 ± 0.30	71	0.40 ± 0.20	57	0.37 ± 0.24	241	0.40 ± 0.26
Sept S' (cm/s)	37	3.14 ± 1.32	53	4.91 ± 1.28†	66	4.82 ± 1.05	71	5.21 ± 0.96	57	5.62 ± 1.10	284	4.88 ± 1.33
Sept E' (cm/s)	11	−3.25 ± 1.52	36	−6.67 ± 1.45†	63	−6.41 ± 1.61	71	−6.93 ± 1.50	57	−6.91 ± 2.07	238	−6.30 ± 2.02
Sept A' (cm/s)	11	−2.35 ± 0.94	36	−2.25 ± 0.98	63	−2.10 ± 0.85	71	−2.20 ± 0.71	57	−2.23 ± 0.74	238	−2.19 ± 0.80
Lat S' (cm/s)	37	3.49 ± 1.62	53	4.87 ± 1.34†	66	4.88 ± 1.29	71	5.16 ± 1.18	57	5.68 ± 1.37	284	4.93 ± 1.47
Lat E' (cm/s)	12	−3.68 ± 2.32	36	−6.32 ± 1.83†	63	−6.16 ± 2.29	71	−6.80 ± 1.91	57	−7.37 ± 2.49	239	−6.25 ± 2.41
Lat A' (cm/s)	12	−1.78 ± 0.66	36	−1.77 ± 0.88	63	−1.75 ± 0.74	71	−1.92 ± 0.73	57	−1.92 ± 0.82	239	−1.84 ± 0.77
Sept E'/A'	11	1.47 ± 1.13	36	3.38 ± 1.41	63	3.43 ± 1.35	71	3.53 ± 1.77	57	3.41 ± 1.43	238	3.40 ± 1.54
Lat E'/A'	12	1.91 ± 1.28	36	4.27 ± 2.71*	63	4.10 ± 2.47	71	4.03 ± 1.86	57	4.34 ± 1.65	239	4.06 ± 2.16
Sept SR E/A	11	2.25 ± 1.51	37	3.67 ± 1.82	64	3.28 ± 1.66	71	3.38 ± 1.86	57	3.41 ± 1.62	240	3.35 ± 1.76
Lat SR E/A	12	3.16 ± 2.11	37	5.56 ± 4.24	64	4.54 ± 3.07	71	5.11 ± 3.27	57	5.29 ± 3.22	241	5.02 ± 3.34

A', Late diastolic myocardial velocity; *E'*, early diastolic myocardial velocity; *E*, early diastolic; *Lat*, lateral; *Sept*, septum; *S'*, systolic myocardial velocity; ε, systolic strain; *S*, systolic; *SR*, strain rate.
$^*P < .05$.
†$P < .01$ when compared with previous group.

Lorch , JASE 2008 ; 21:1207

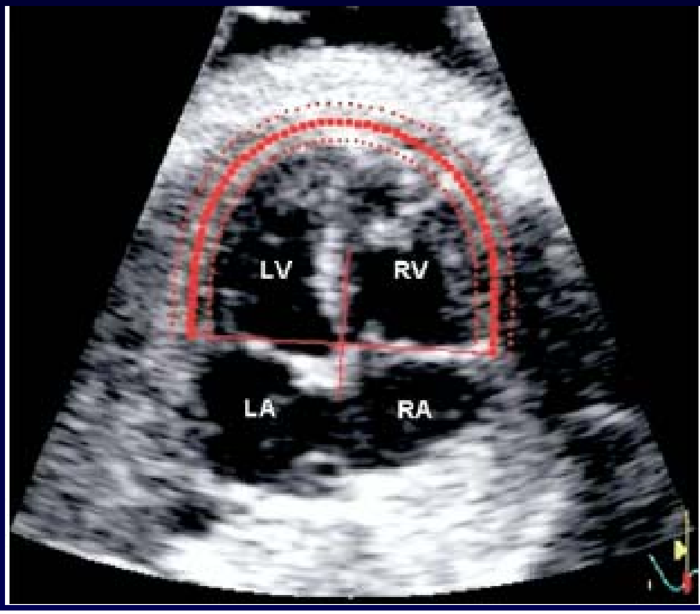


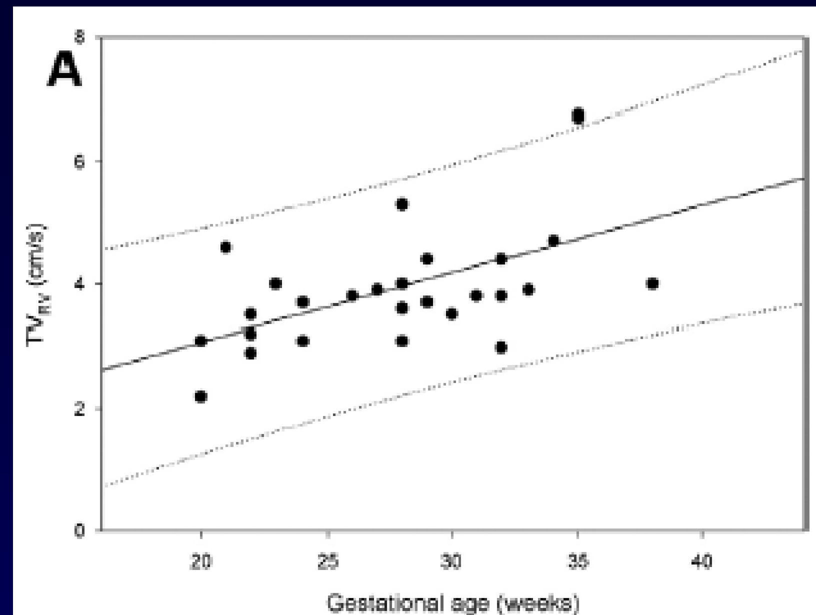
Lorch , JASE 2008 ; 21:1207

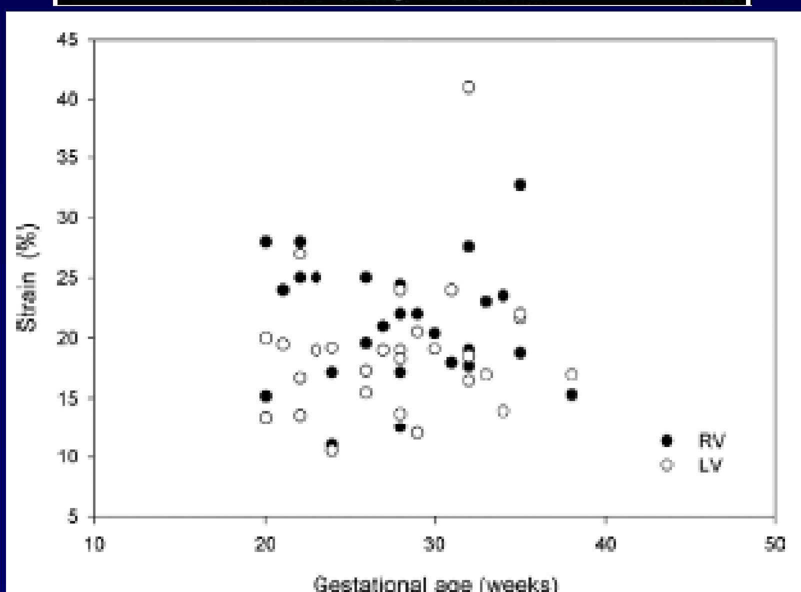


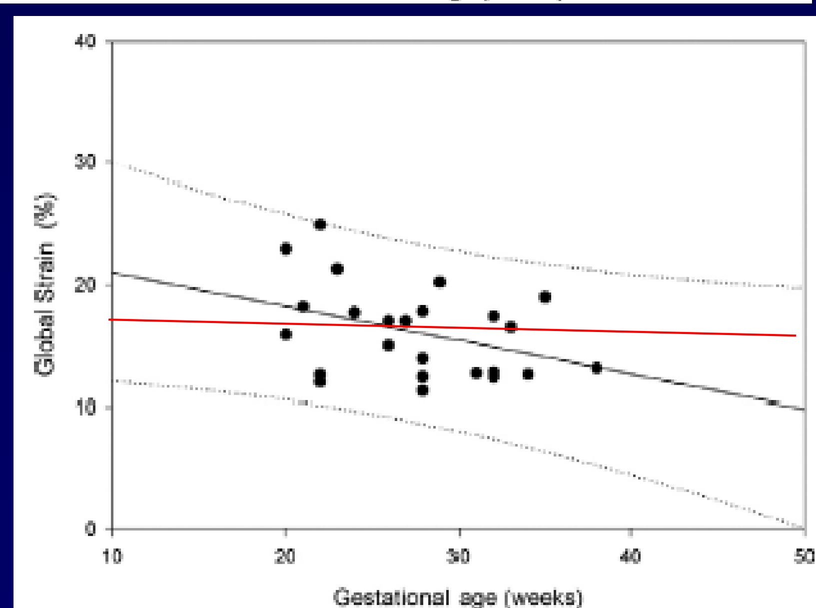
Lorch , JASE 2008 ; 21:1207

2D speckle tracking in the fetus



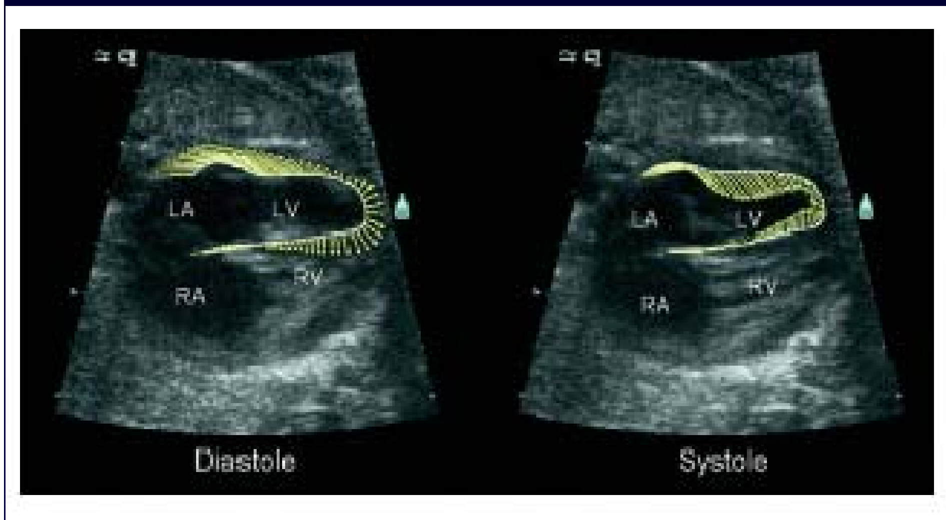


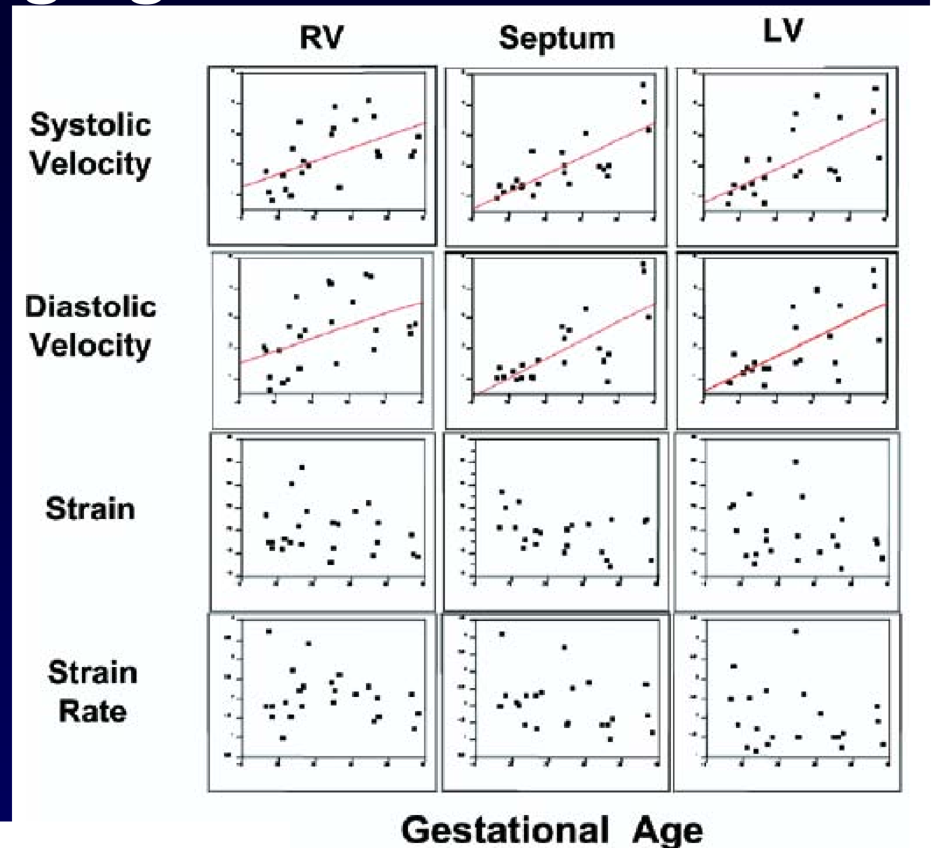


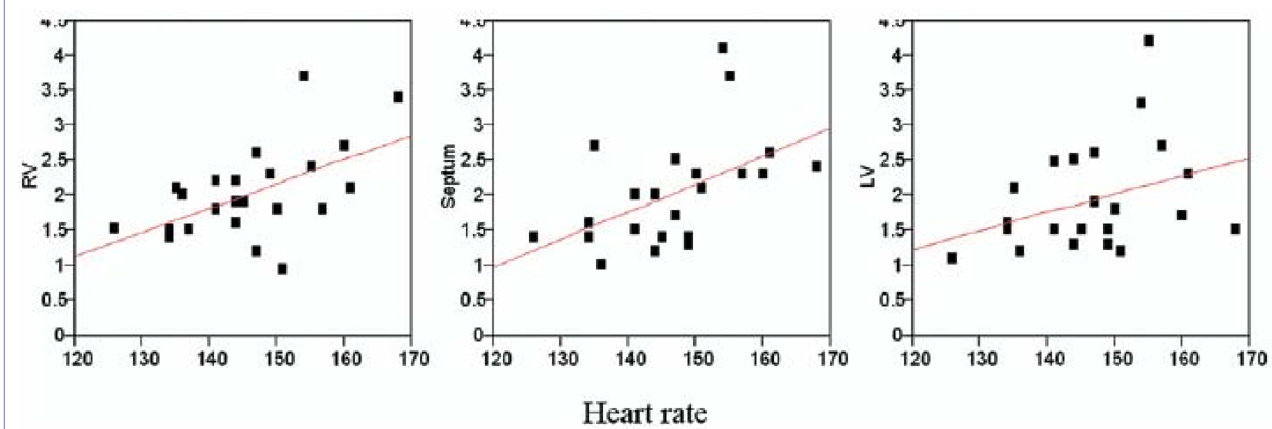


Ta-Shma A. J Am Soc Echocardiogr. 2008 21:146-50.

Velocity Vector Imaging in the Fetus







Younoszai , JASE 2008 21:470.

Evolution in neonatal life

Table 3 Comparison between SR and ϵ measurements of the septum obtained from the longitudinal apical view: regional LV longitudinal function

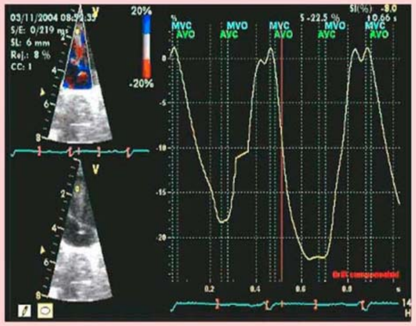
Component	Segment	SR (s^{-1}) Exam 1	SR (s^{-1}) Exam 2	SR P	ϵ (%) Exam 1	ϵ (%) Exam 2	ϵ (%) P
Systolic	Basal	−2.02 ± 0.77	−1.84 ± 0.33	.113	−26.42 ± 5.56	−23.63 ± 3.65	.000*
	Middle	−1.90 ± 0.58	−1.85 ± 0.29	.498	−25.58 ± 3.39	−23.10 ± 2.55	.000*
	Apical	−1.62 ± 0.26	−1.65 ± 0.24	.471	−24.94 ± 3.38	−22.97 ± 2.03	.001*

Table 4 Comparison between SR and ϵ measurements: regional RV longitudinal function

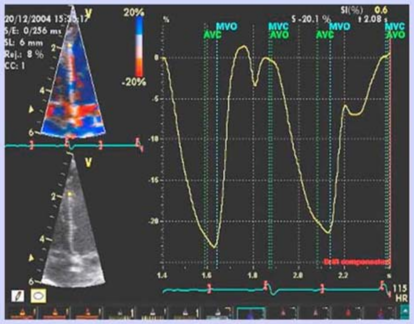
Component	Segment	SR (s^{-1}) Exam 1	SR (s^{-1}) Exam 2	SR P	ϵ (%) Exam 1	ϵ (%) Exam 2	ϵ (%) P
Apical 4-chamber free lateral wall							
Systolic	Basal	−2.00 ± 0.64	−2.25 ± 0.42	.013*	−28.45 ± 5.23	−37.03 ± 5.42	.000*
	Middle	−1.95 ± 0.59	−2.25 ± 0.59	.002*	−33.21 ± 6.68	−42.56 ± 4.76	.000*
	Apical	−2.23 ± 0.61	−2.25 ± 0.60	.878	−33.33 ± 4.83	−41.08 ± 5.51	.000*

LONGITUDINAL

EX I



EX II



Pena, JASE 2010;23:294

Children with cardiomyopathy

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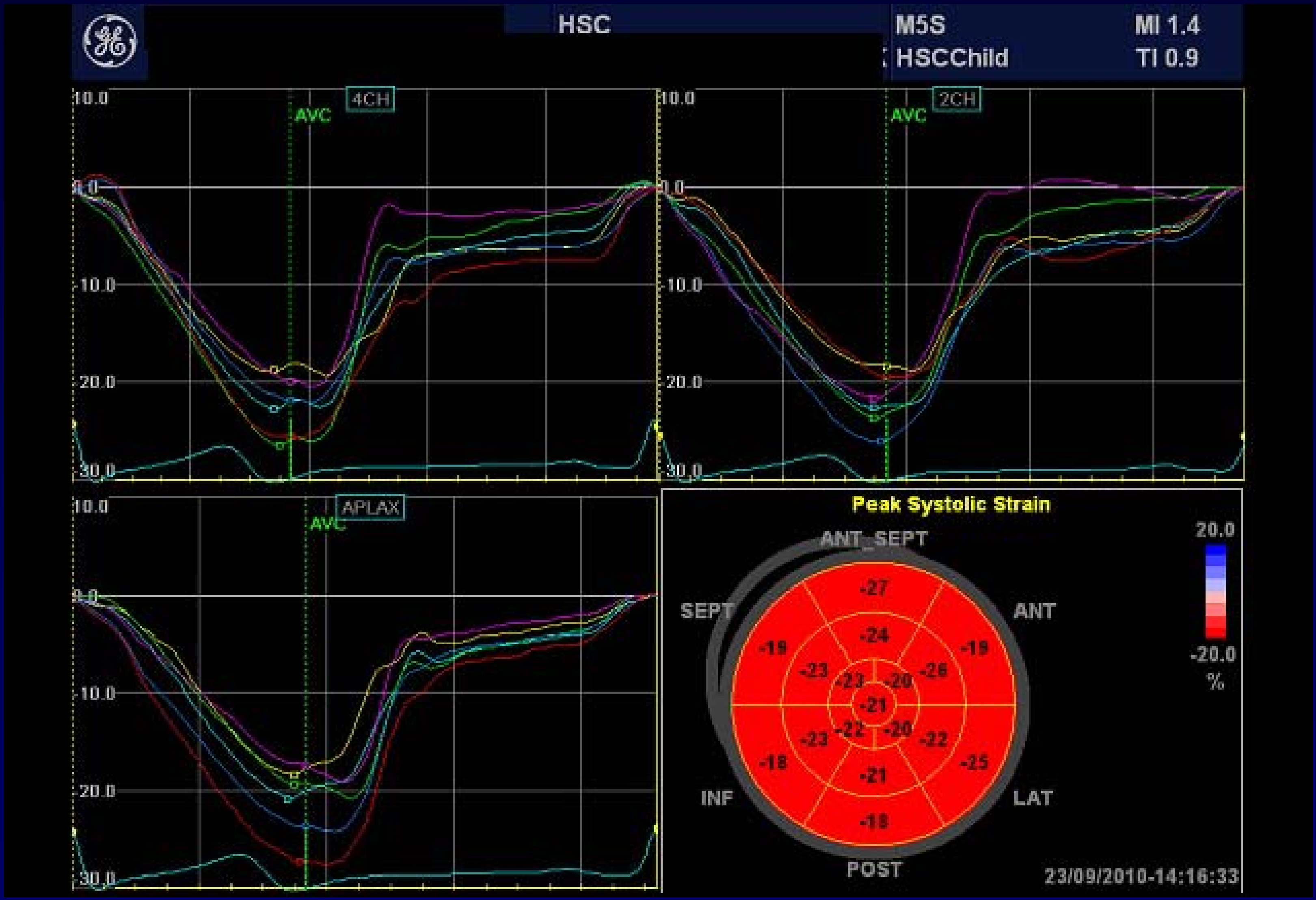
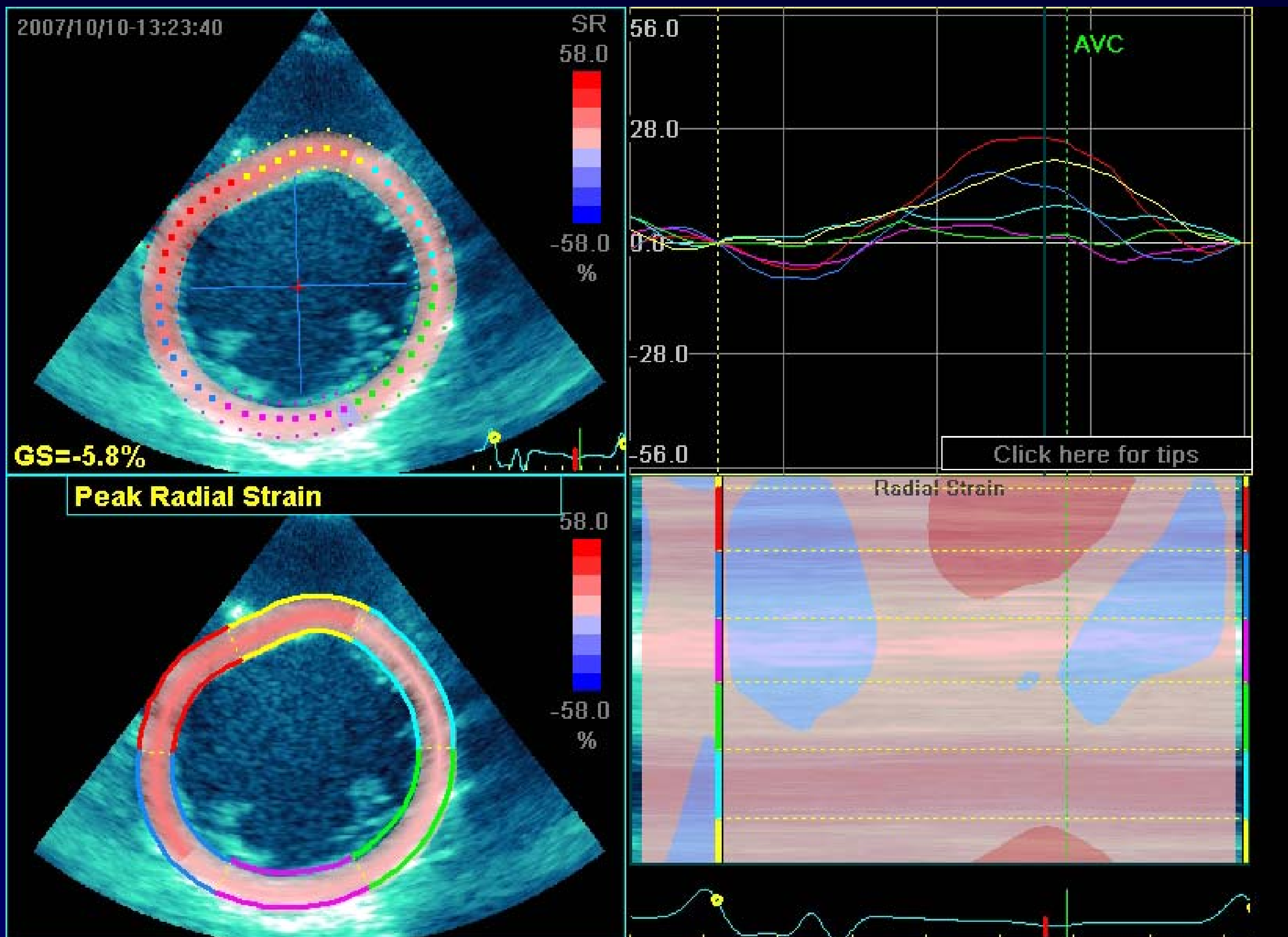
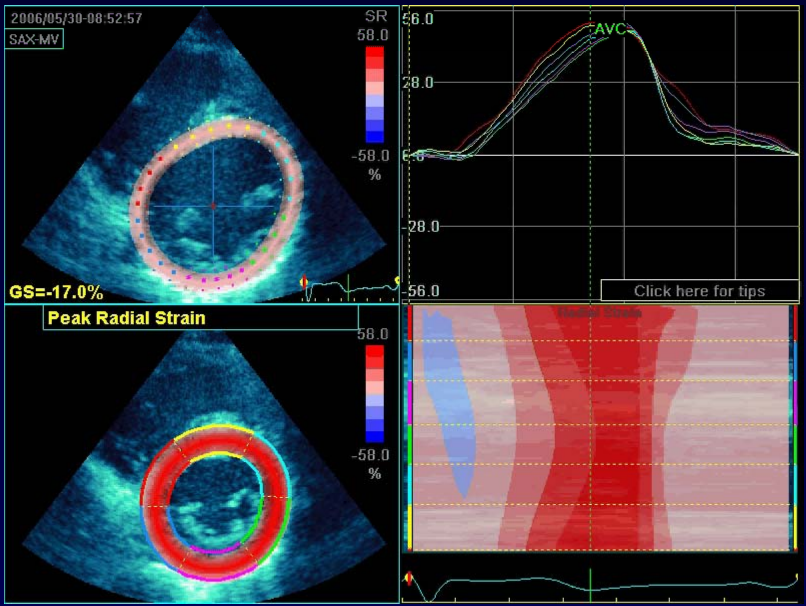


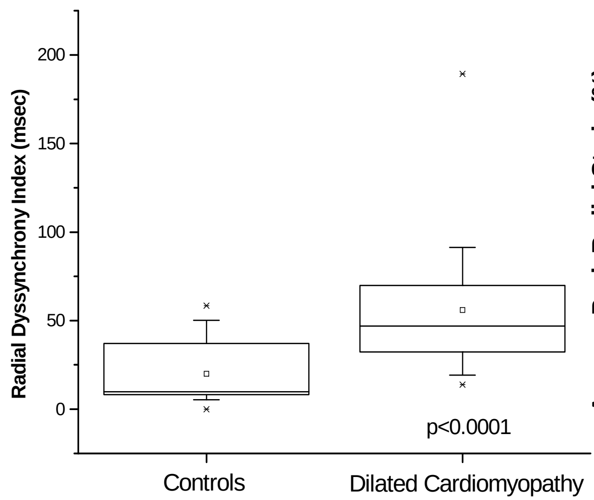
Children with cardiomyopathy

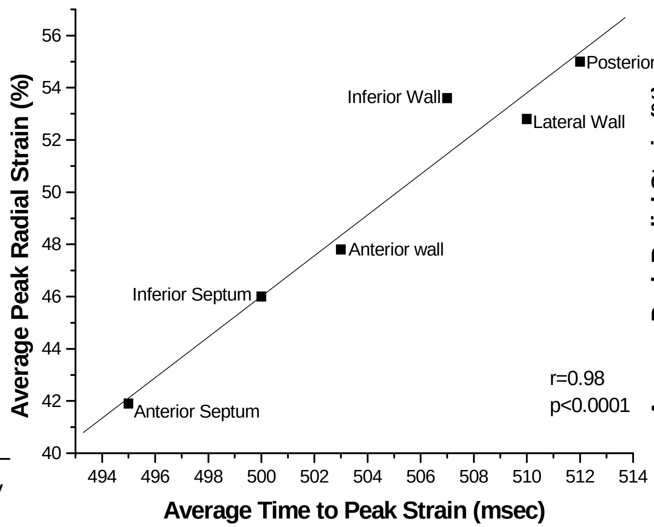


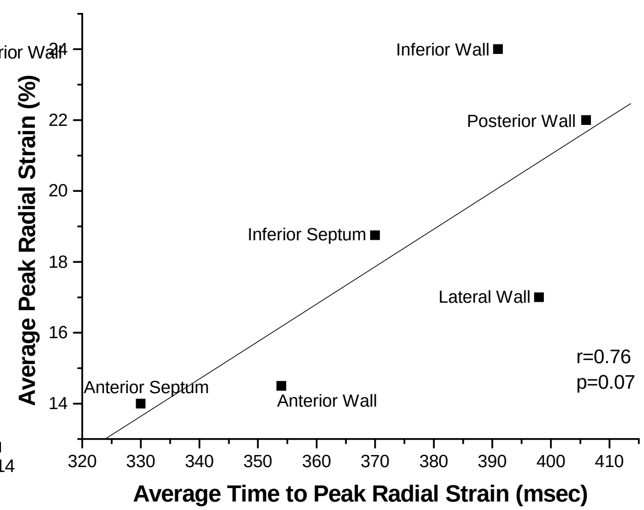
Radial strain to investigate dyssynchrony and function in DCM

	Controls	Dilated Cardiomyopath y	p
Anterior Septum	41.9 ± 16.4	14 ± 13	<0.0001
Anterior Wall	47.8 ± 15.6	14.5 ± 12	<0.0001
Lateral Wall	52.8 ± 15.8	17 ± 10	<0.0001
Posterior Wall	55 ± 13.2	22 ± 10	<0.0001
Inferior Wall	53.6 ± 13.8	24 ± 13.6	<0.0001
Inferior Septum	46 ± 15.4	18.7 ± 12.8	<0.0001









Friedberg AJC, 2008

Regional deformation by TDI strain in HCM

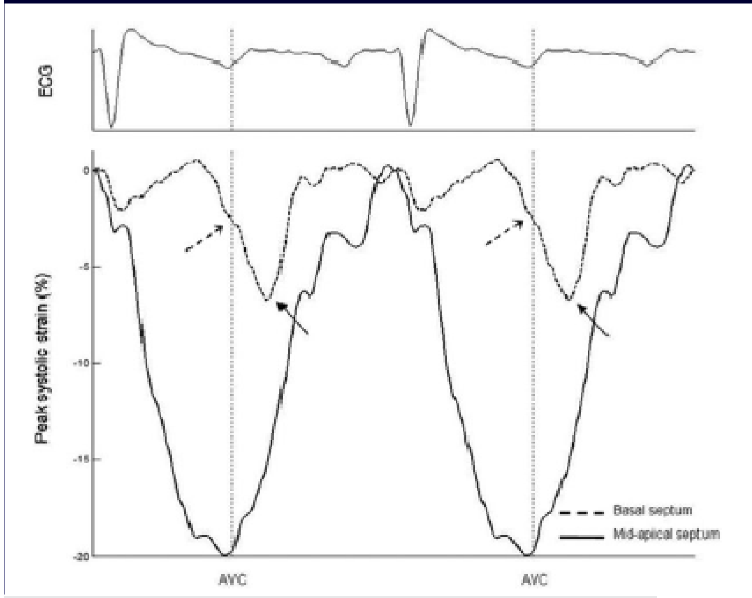
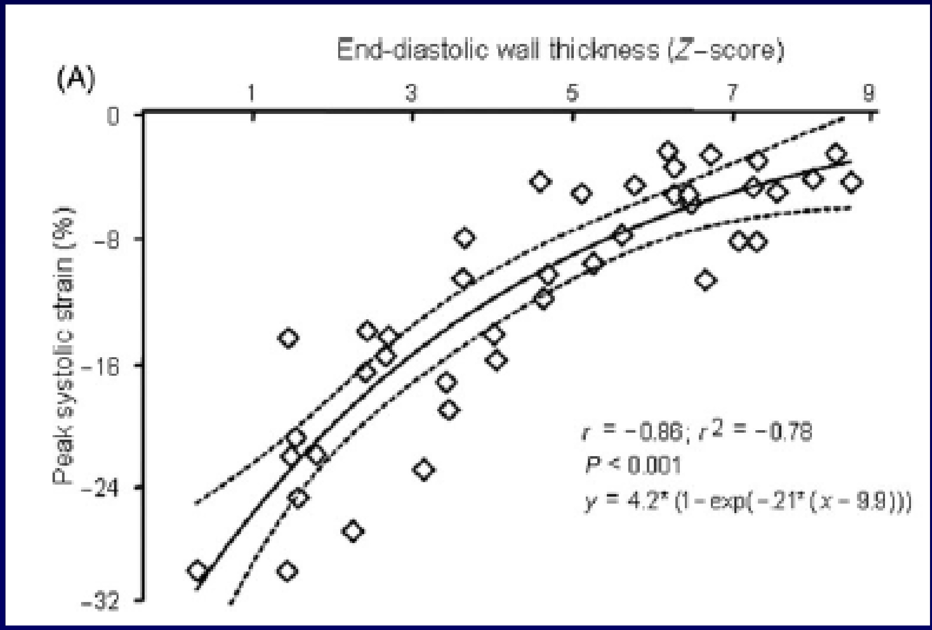


Table 5 Clinical characteristics and echocardiographic indices of LV function at the basal septum in children with HCM, with and without ventricular tachycardia

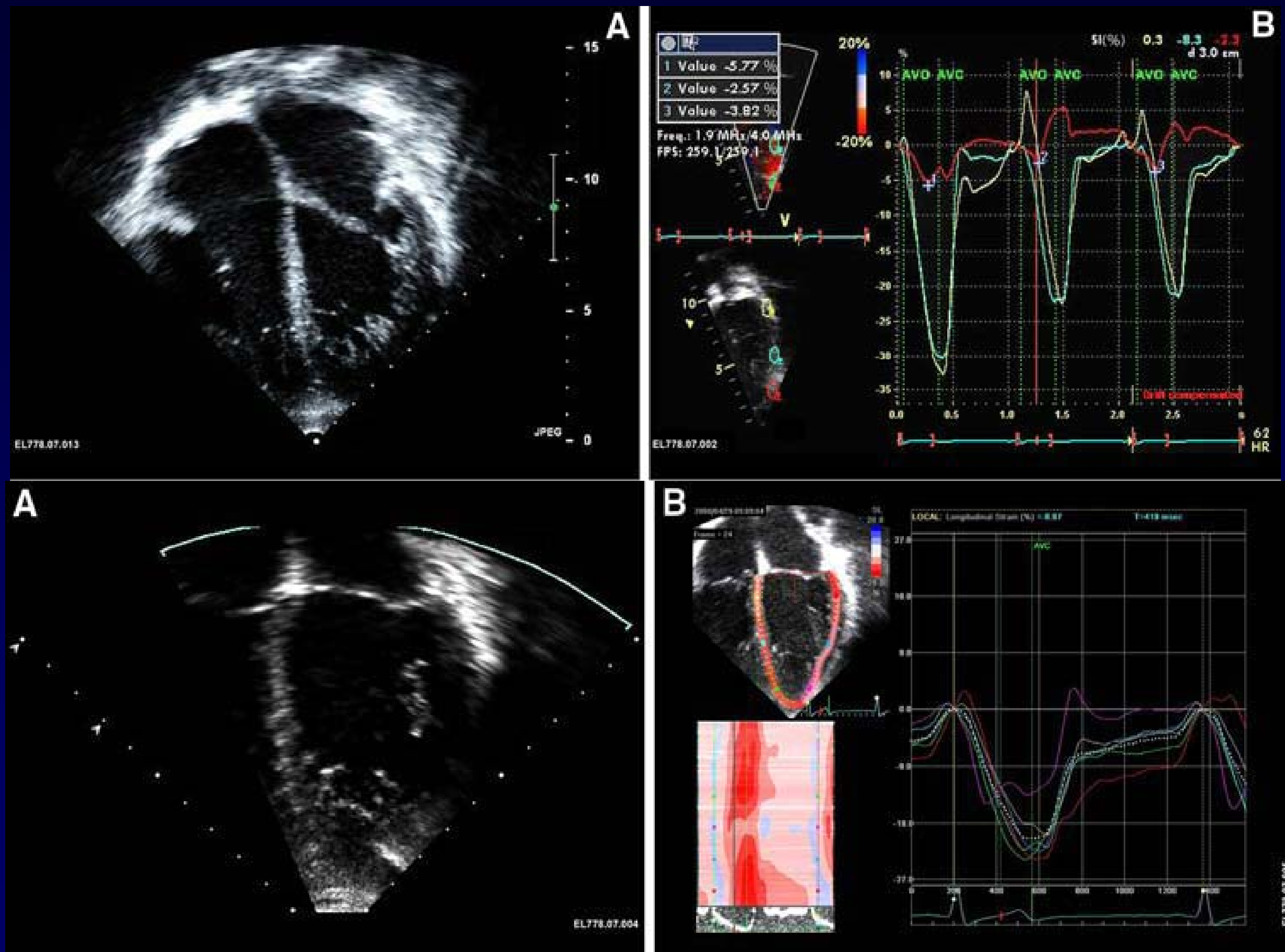
	HCM with VT ($n = 7$)	HCM without VT ($n = 34$)	*P*-value
VO_2 max (%)	38 ± 15	71 ± 27	0.01
Strain pattern on ECG	6/7	20/34	0.23
IVSTd (*Z*-score)	6.3 ± 2.3	4.2 ± 2.3	0.04
EF (%)	58.7 ± 14.4	63.6 ± 14.4	0.26
E/*A* ratio	1.8 ± 0.7	1.9 ± 0.5	0.69
E/*E*′ ratio (septal)	17.7 ± 7.9	12.8 ± 4.0	0.02
Vel sys (cm/s)	3.2 ± 1.6	3.5 ± 1.0	0.56
E′ (cm/s)	−2.7 ± 1.4	−5.2 ± 2.8	0.02
A′ (cm/s)	−2.6 ± 1.6	−3.1 ± 1.2	0.29
SR sys (s^{-1})	−0.5 ± 0.4	−1.0 ± 0.6	0.01
ϵ sys (%)	−3.8 ± 4.1	−12.1 ± 9.0	0.01
PSS (%)	133.0 ± 164.6	43.6 ± 89.7	0.04
Time to max ϵ (ms)	524 ± 85	447 ± 97	0.04

VT, ventricular tachycardia; VO_2 max, percentage of predicted maximal oxygen uptake; other abbreviations as in *Tables 3* and *4*.



Ganame, EHJ, 2007 28, 2886

Speckle tracking for diagnosis of LVNC?



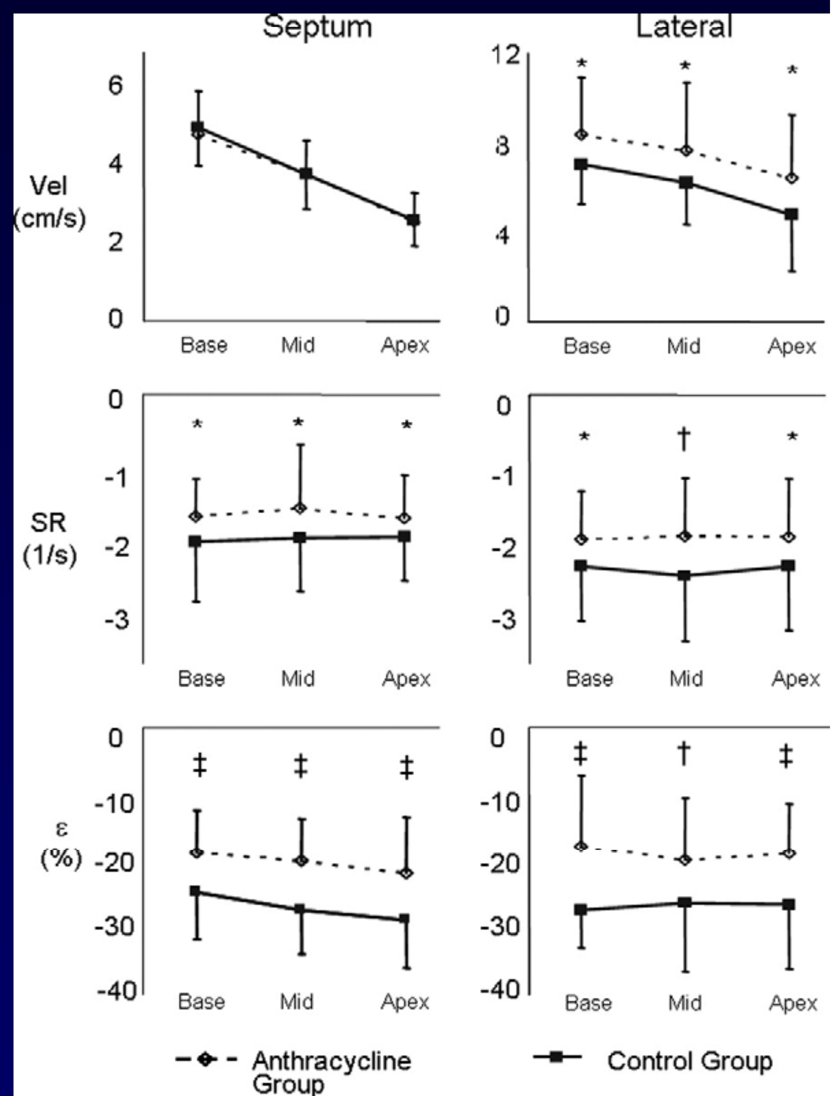
Eidem, Pediatr Cardiol. 2009 ;30:682-9.

Effect of anthracyclines on deformation

Table 2 Clinical and standard echocardiographic parameters of systolic function

	Anthracycline (n = 56)	Control (n = 32)	*P*
Age, y	12.7 ± 4.9	13.1 ± 6.8	.75
Heart rate, beats/min	75.4 ± 15.3	74.2 ± 14	.72
Systolic blood pressure, mm Hg	103.2 ± 12.9	101.8 ± 14.6	.61
LV ED diameter, mm	45.3 ± 6.5	43.7 ± 6.0	.25
LV ES diameter, mm	29.0 ± 5.0	28.2 ± 4.8	.44
ED inferolateral WT, mm	7.6 ± 1.3	7.7 ± 1.4	.70
ED IVS WT, mm	7.8 ± 1.2	8.0 ± 1.5	.47
LV fractional shortening, %	34.1 ± 4.6	35.7 ± 3.9	.32
LV ejection fraction, %	64.3 ± 6.3	65.7 ± 5.1	.30
Inferolateral wall thickening, %	52.3 ± 24.1	63.8 ± 14.5	.02
LV mass, g	116.1 ± 38.3	115.5 ± 31.6	.94
End systolic wall stress, g/cm²	123.3 ± 20.1	112.2 ± 22.0	.02
Ring displacement LV lateral (mm)	11.4 ± 2.0	16.0 ± 2.2	<.001
Ring displacement IVS, mm	11.6 ± 1.9	14.6 ± 2.0	<.01
Ring displacement RV, mm	20.9 ± 2.9	20.7 ± 3.5	.69
MPI	0.34 ± 0.11	0.27 ± 0.11	<.01

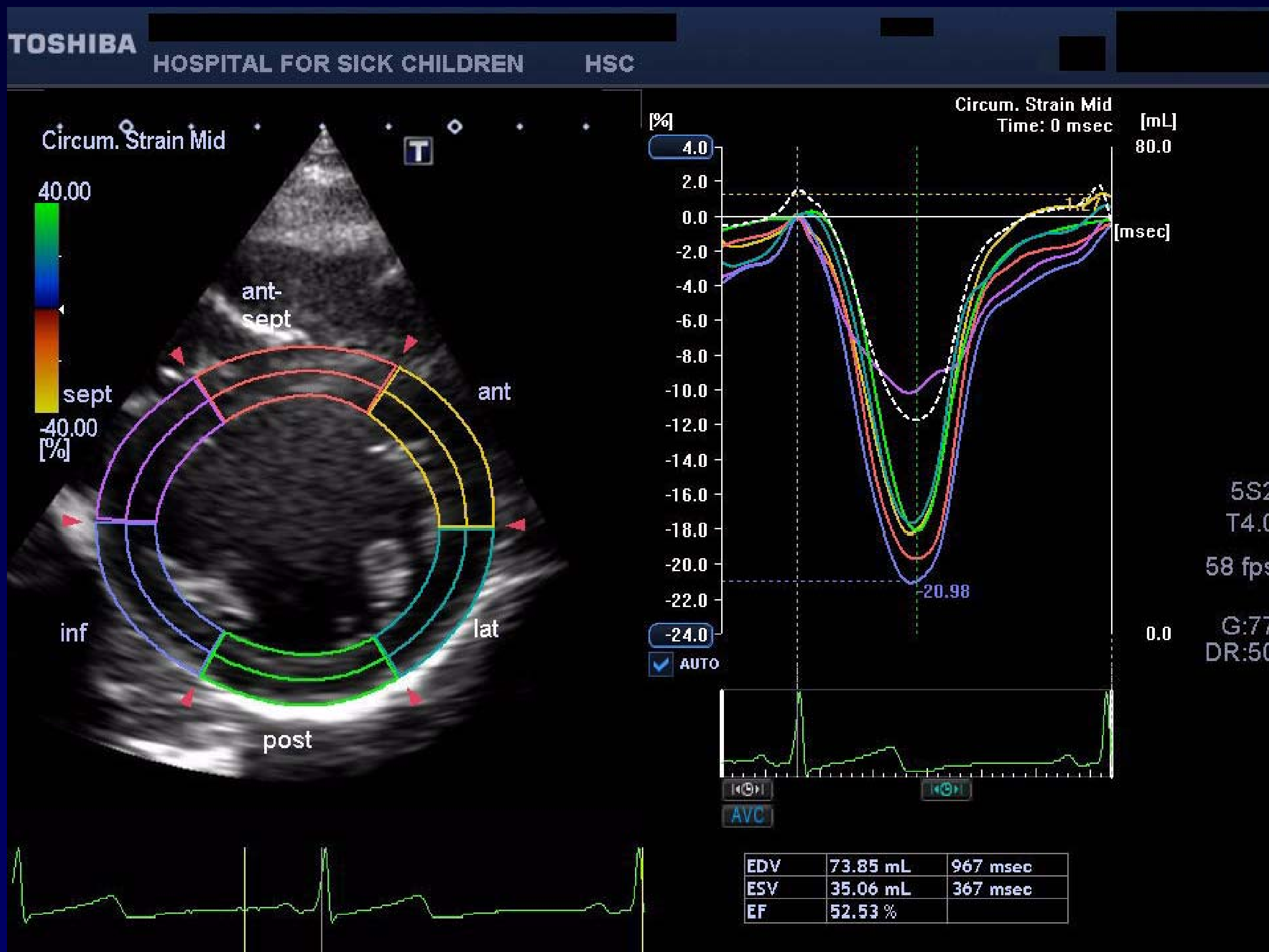
ED, End-diastolic; *ES*, end-systolic; *WT*, wall thickness; *IVS*, interventricular septum; *RV*, right ventricle; *LV*, left ventricle; *MPI*, myocardial performance index.



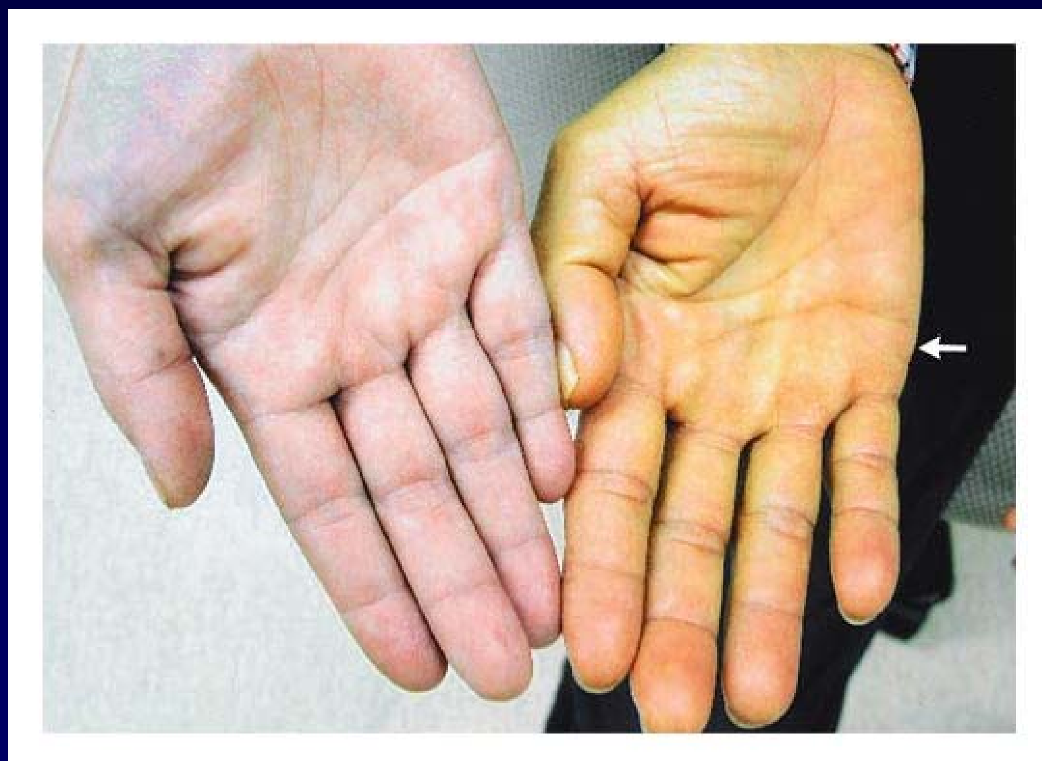
* p <0.05 vs. controls; † p <0.01 vs. controls; ‡ p <0.001 vs. controls

Ganame, JASE 2007;20:1351

9y F, after chemotherapy



Congenital heart disease

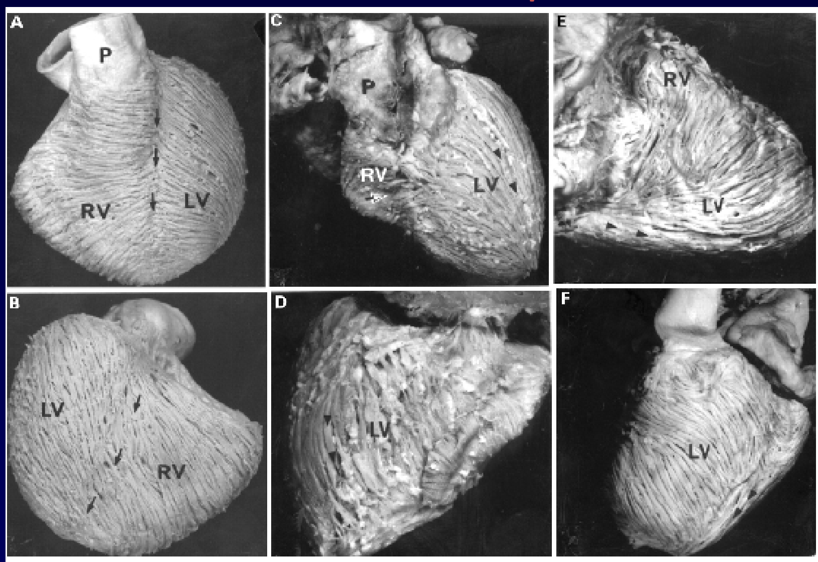


Congenital heart disease and fiber orientation

Superficial layers

normal

tricuspid atresia



Sanchez-Quintana, D et al. Heart 1999 ;81:182

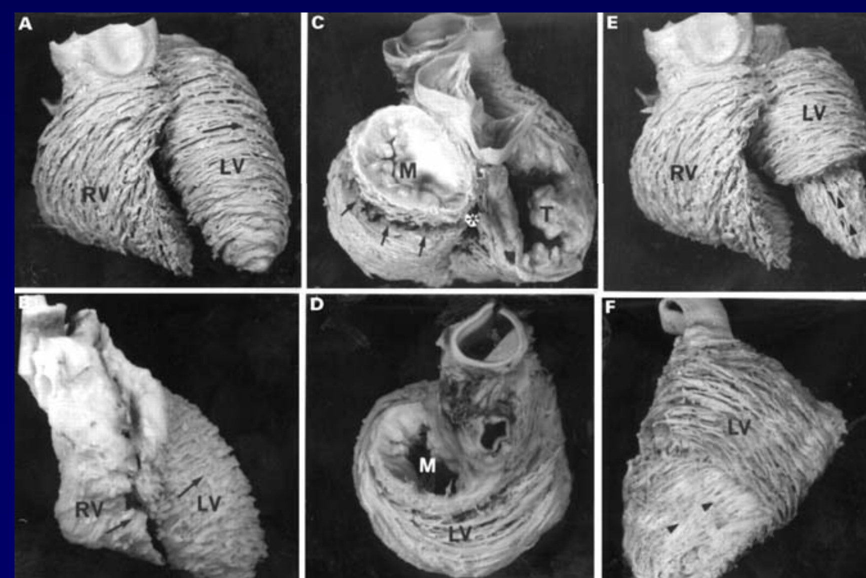
Different fiber orientation

↓

Different 3-D deformation

Middle layers

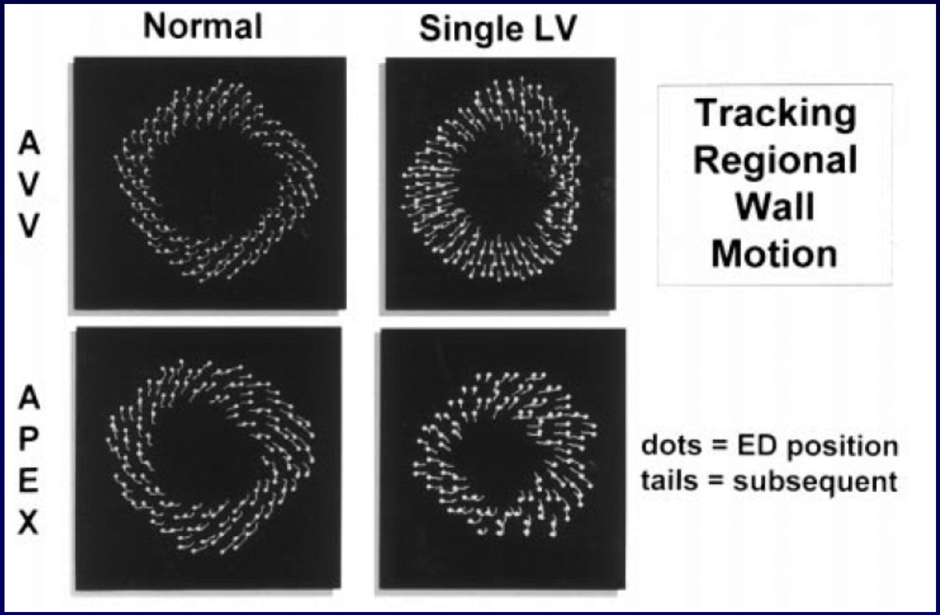
normal

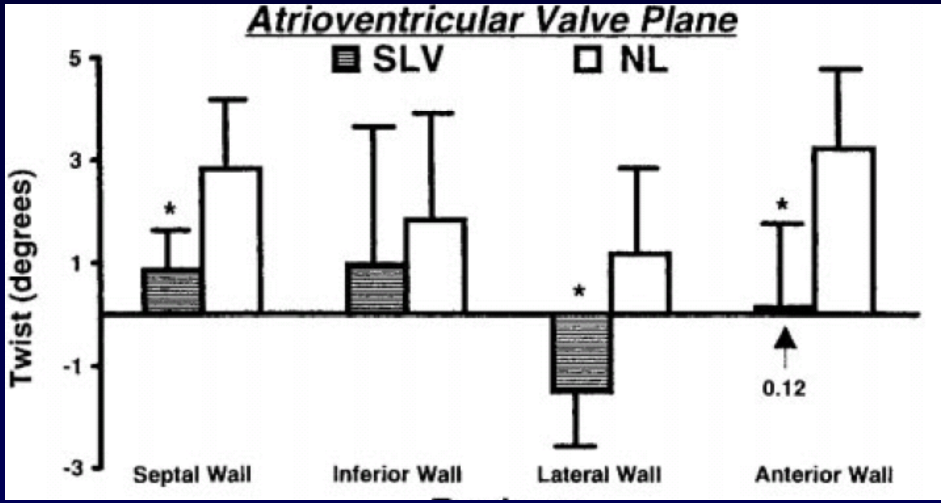


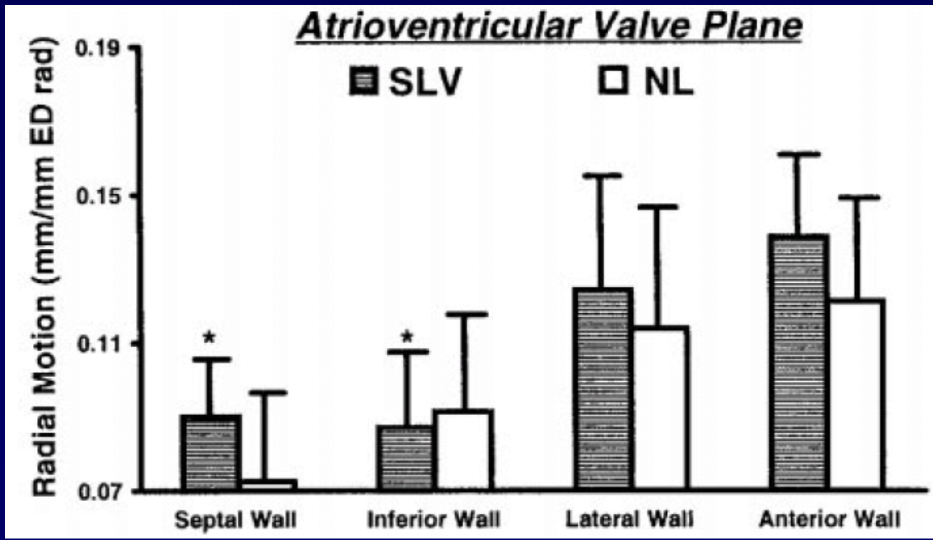
tricuspid atresia

Slide courtesy of Luc Mertens

Small/ absent contra-lateral ventricle affects ventricular strain and torsion







Fogel , *Circulation 1998;98;330*

RV strain

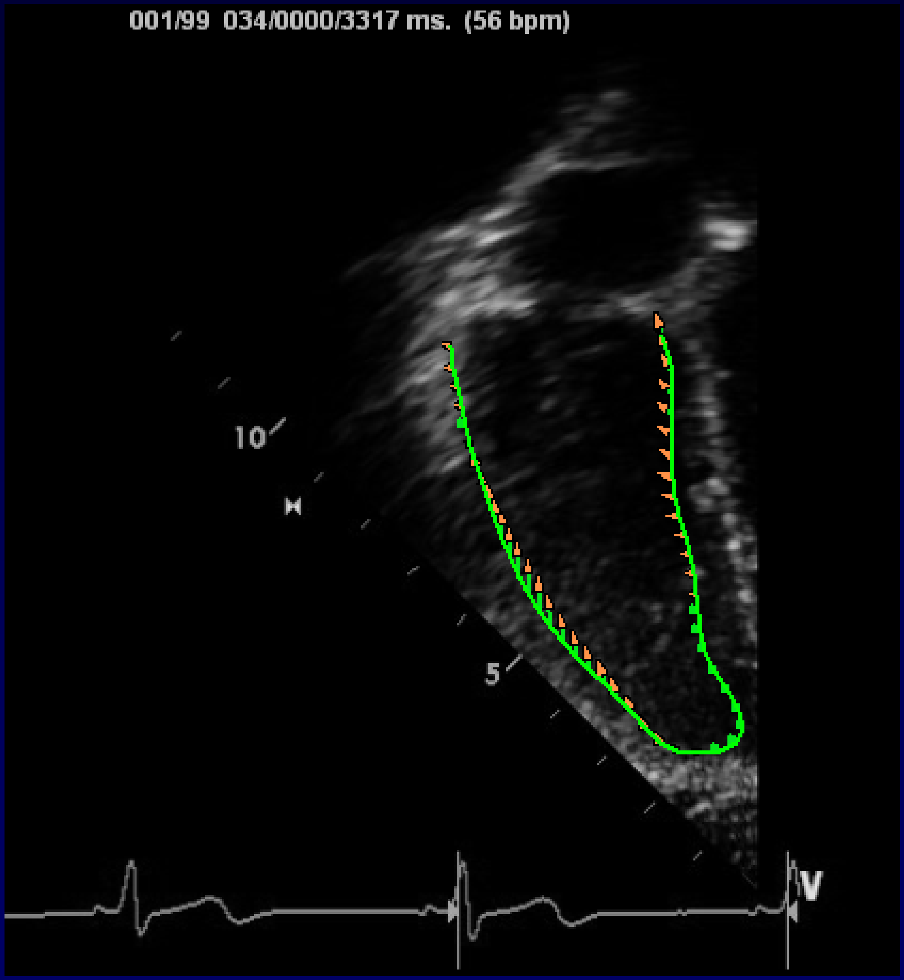
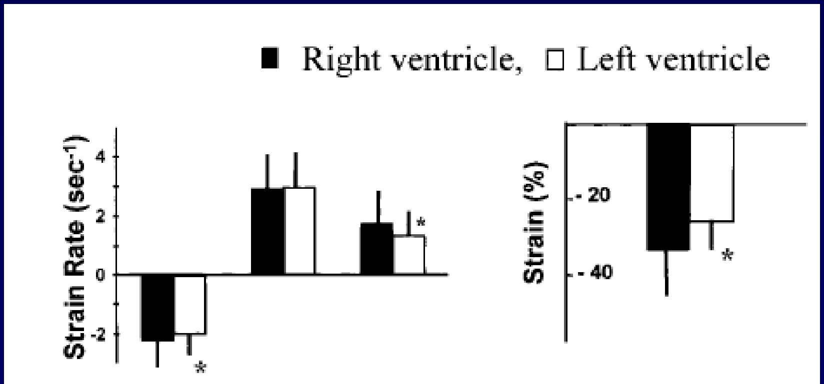


Table 5 Systolic and diastolic Strain (unit %) for regional right ventricular longitudinal function

	Strain		
	Systolic	Early diastolic	Late diastolic
RV free (4CH):			
Base	−36 ± 11	24 ± 09	13 ± 06
Mid	−45 ± 13†	29 ± 11	15 ± 07
Apic	−34 ± 11	25 ± 12	11 ± 07
RV inferior (2CH):			
Base	−25 ± 05*	20 ± 06	08 ± 06*
Mid	−26 ± 06*	19 ± 07*	07 ± 04*
Apic	−27 ± 05	17 ± 09	06 ± 05



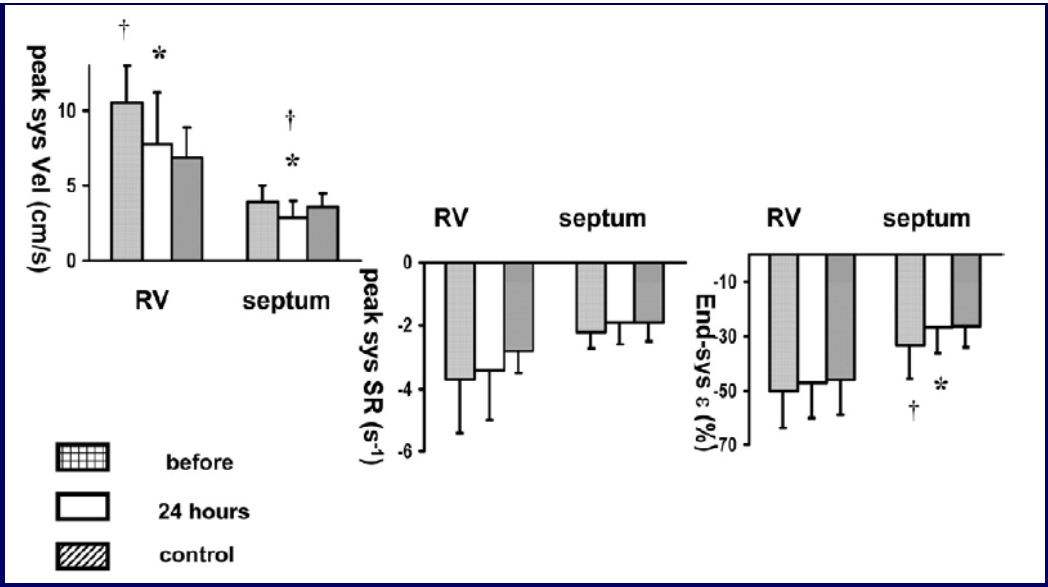
Weideman, JASE 2002;15:20-8

RV deformation after ASD closure

Table 3 Peak systolic velocities, peak systolic strain rate and end-systolic strain in the right ventricle and the interventricular septum before and 24 hours after atrial septal defect closure

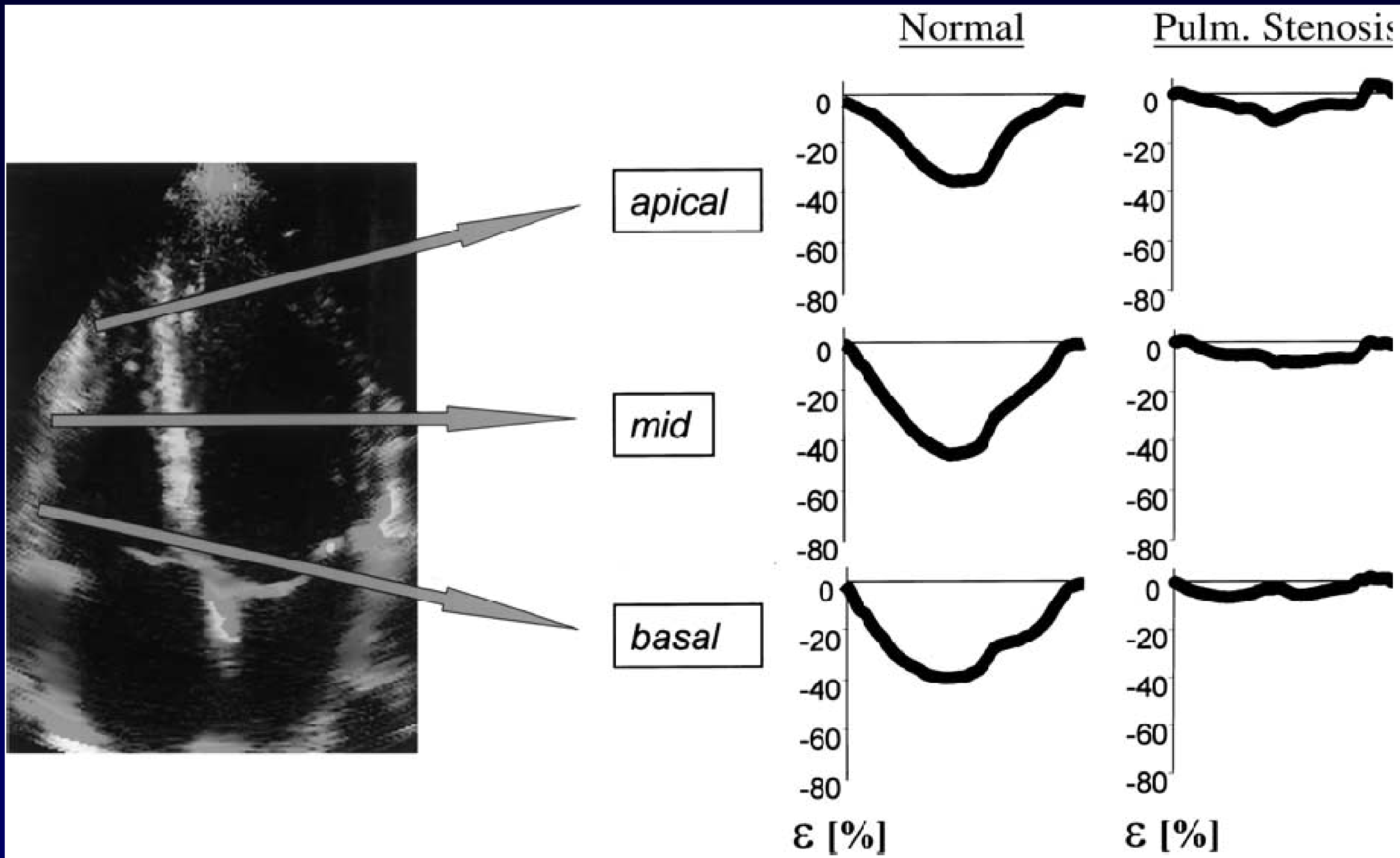
	Before	24 hours	Control	*P* value*
RV mid				
Peak sys vel (cm/s)	10.5 ± 2.5†	7.8 ± 3.4	6.9 ± 2.0	< 0.001
Peak sys SR (s^{-1})	−3.5 ± 1.6	−3.4 ± 1.6	−2.8 ± 0.7	NS
End-sys ε (%)	−50.1 ± 13.6	−47.2 ± 12.8	−45.9 ± 12.9	NS
Septum mid				
Peak sys vel (cm/s)	3.9 ± 1.1	2.9 ± 1.1†	3.6 ± 0.9	0.003
Peak sys SR (s^{-1})	−2.2 ± 0.5	−1.9 ± 0.7	−1.9 ± 0.6	NS
End-sys ε (%)	−33.4 ± 12.1†	−26.8 ± 9.4	−26.3 ± 7.8	0.016

RV = right ventricular; mid = midsegment; *ASD* = atrial septal defect; *before* = before ASD closure; *24 hours* = 24 hours after ASD closure; *sys vel* = systolic velocity; *sys SR* = systolic strain rate; *sys* ε = systolic strain.
*$P < 0.05$ 24 hours after versus before ASD closure; †$P < 0.05$ versus controls.

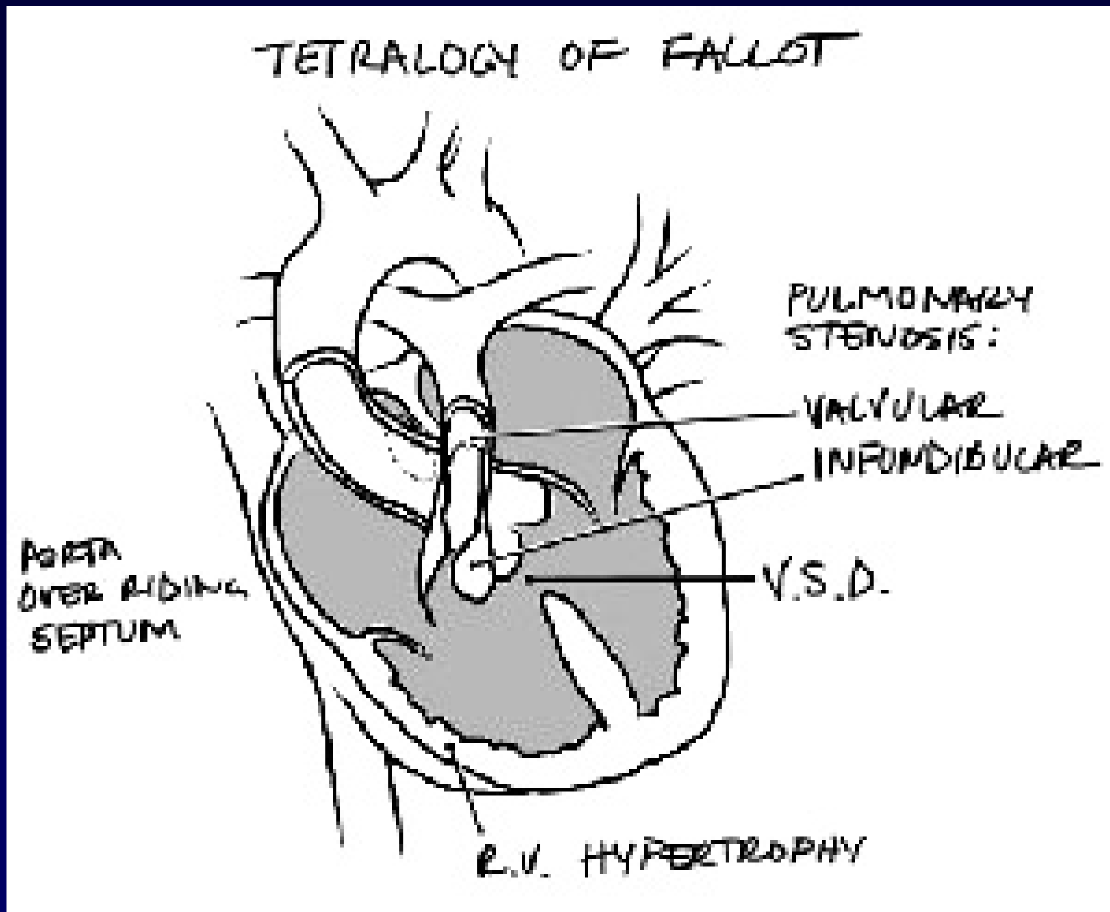


Eyskens, JASE 2006;19:994

RV strain in Pulmonary valve Stenosis



Weidemann, Ped Cardiol, 2002;23:292


TETRALOGY OF FALLOT
PULMONARY STENOSIS:
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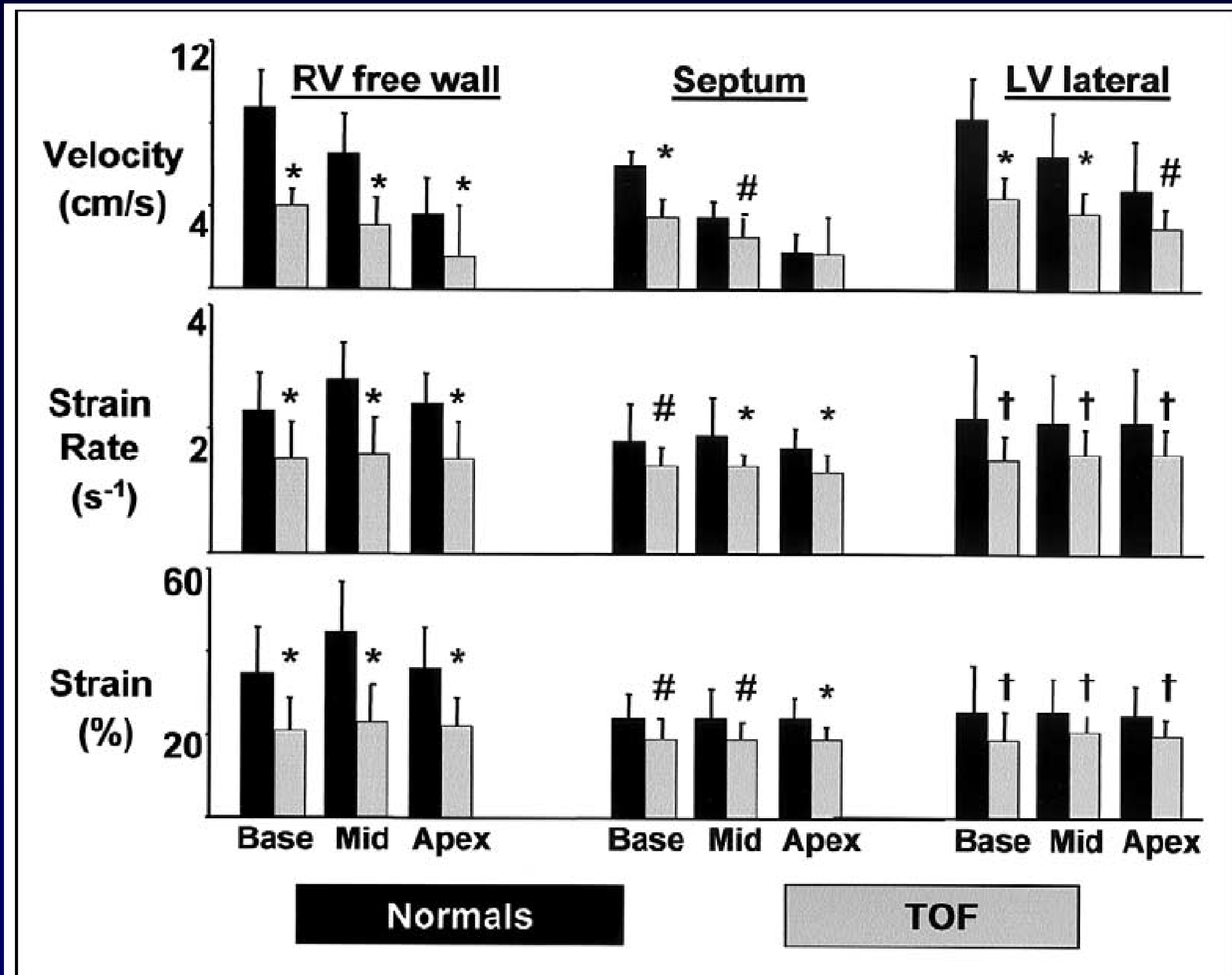
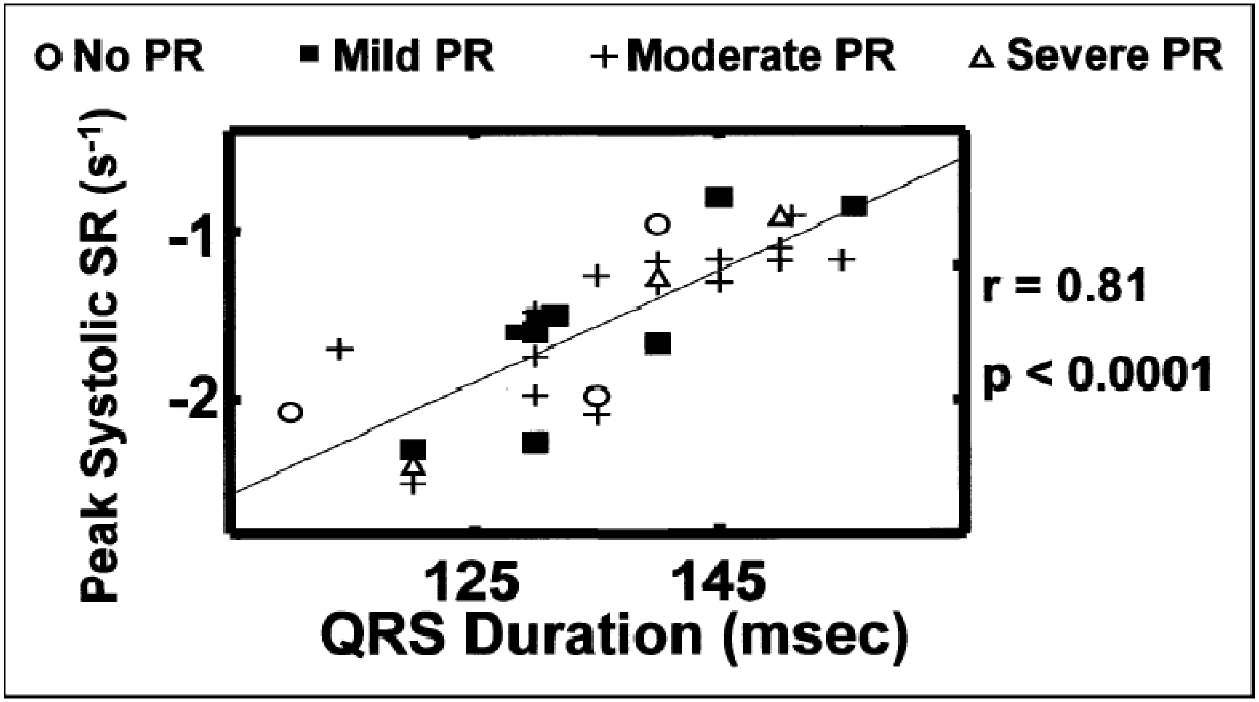
AORTA OVER RIDING SEPTUM
R.V. HYPERTROPHY

Strain and strain rate after TOF repair



Weidemann, Am J Cardiol 2002;90:133–138

Strain and strain rate after TOF repair



Weidemann, Am J Cardiol 2002;90:133–138

Comparison of longitudinal strain between patients with tetralogy of Fallot classified according to QRS duration

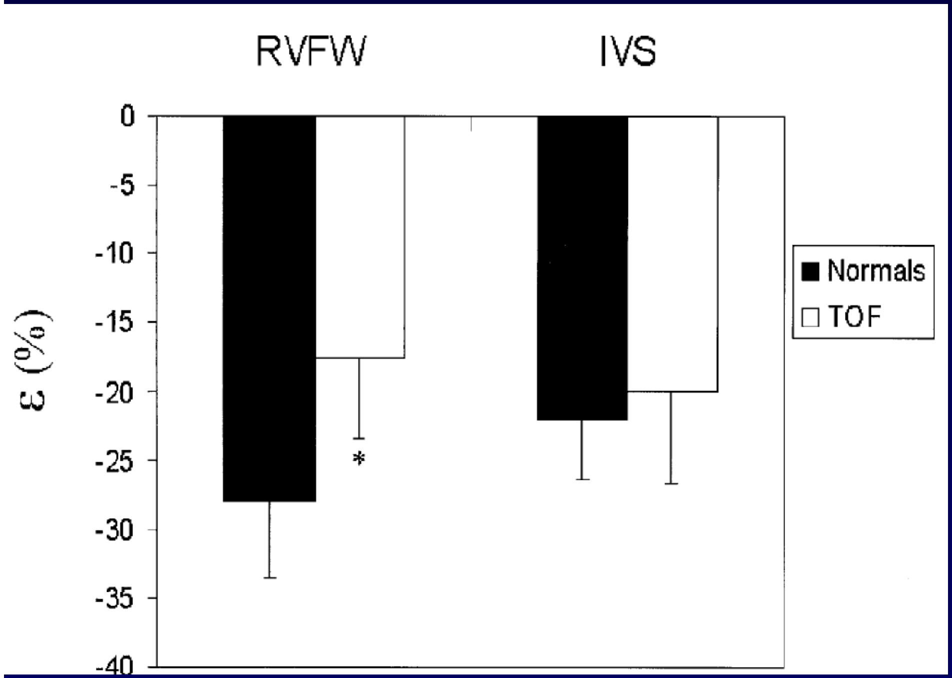
Parameter	QRS Duration (ms)				
	<140 (n = 19)	140–159 (n = 17)	160–179 (n = 16)	≥180 (n = 23)	p Value
Lateral basal ε (%)	−23 ± 1%	−22 ± 1%	−19 ± 4%	−18 ± 2%	0.001
Lateral mid ε (%)	−21 ± 2%	−21 ± 2%	−20 ± 2%	−19 ± 3%	0.001
Lateral apex ε (%)	−20 ± 1%	−18 ± 1%	−17 ± 2%	−15 ± 2%	0.001
Septal basal ε (%)	−20 ± 2%	−18 ± 1%	−12 ± 2%	−10 ± 3%	0.001
Septal mid ε (%)	−19 ± 1%	−18 ± 1%	−11 ± 3%	−11 ± 3%	0.001
Septal apex ε (%)	−18 ± 1%	−17 ± 1%	−11 ± 2%	−8 ± 5%	0.001
Peak to peak (ms)	12 ± 4	44 ± 30	72 ± 32	157 ± 51	0.001
Postsystolic shortening	0	2	10	23	0.01

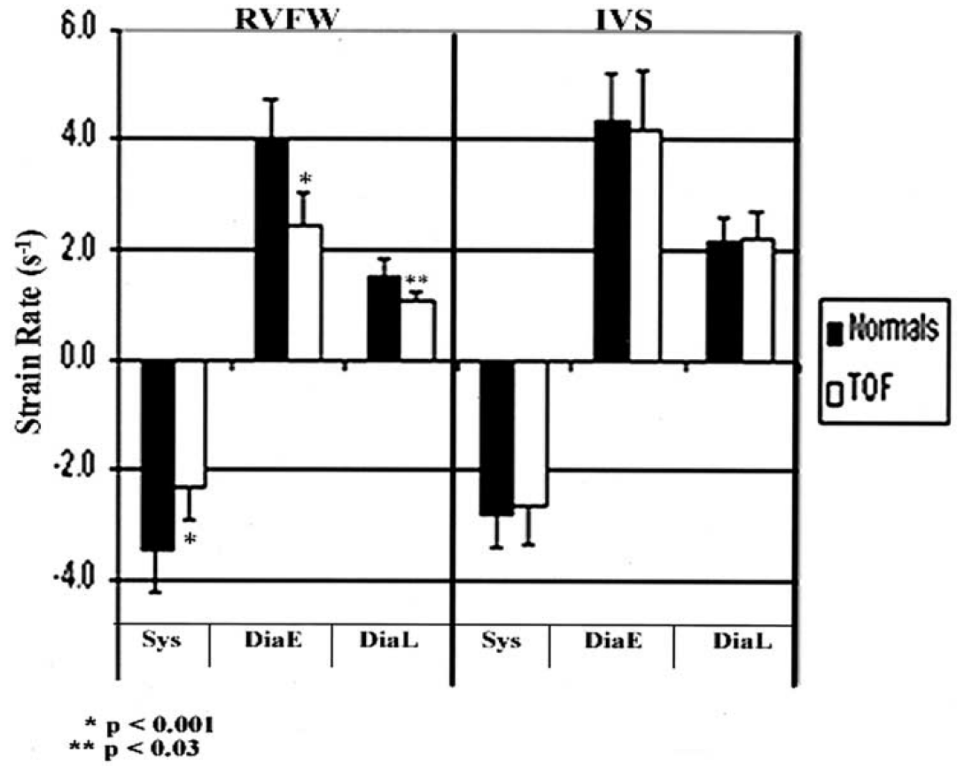
Peak-to-peak delay indicates the maximum time difference between peak strain of the earliest activated myocardial segment and the latest. Postsystolic shortening refers to the number of patients with peak strain postsystolic shortening occurring after aortic valve closure.

Tzemos, AJC 2009; 103:420

RV strain/ SR in TOF

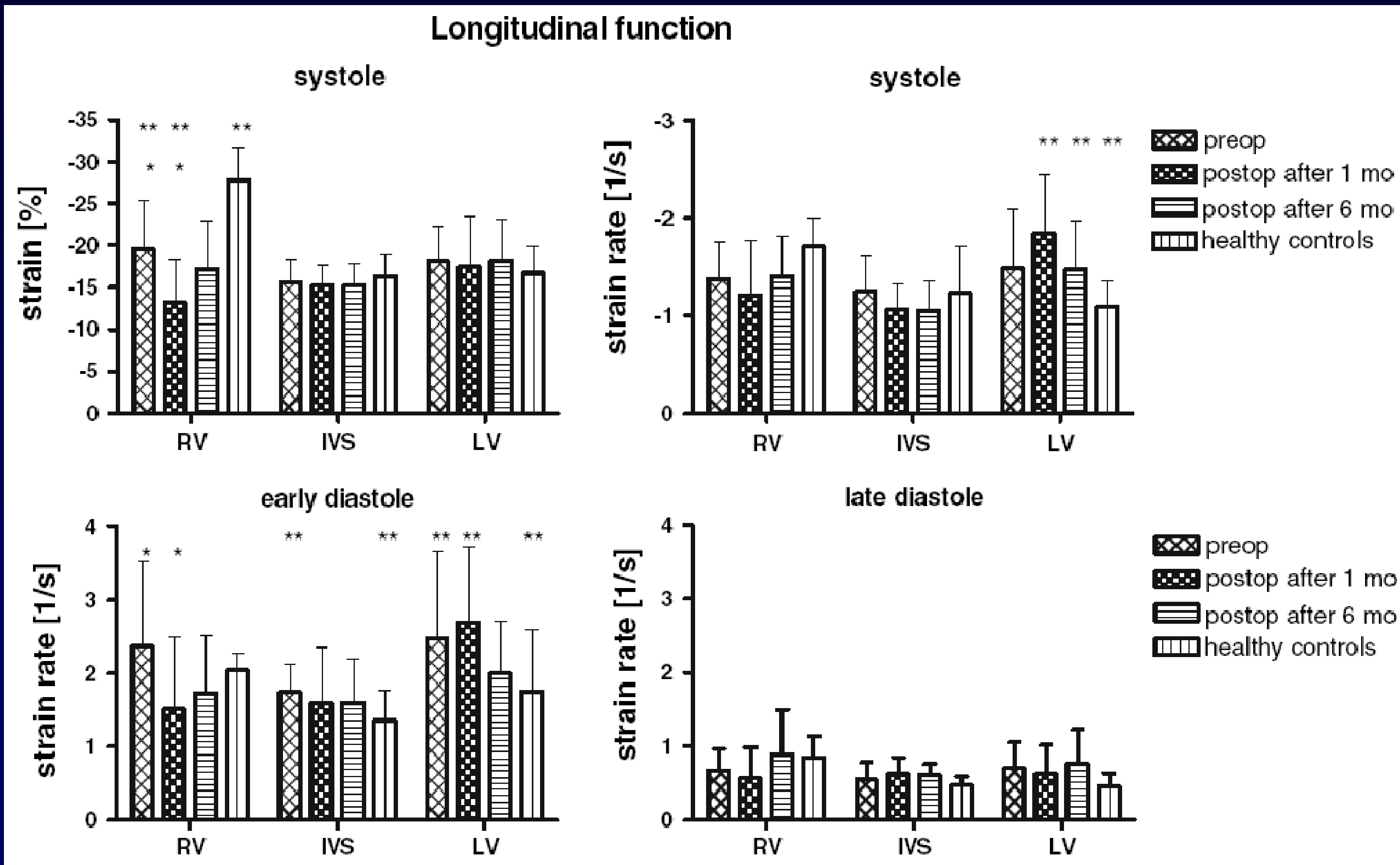
	Patients with TOF (n = 15)	Control subjects (n = 25)	*P*
RVEF1	0.53 ± 0.18 (0.25–0.81)	0.57 ± 0.16 (0.29–0.72)	.75
RVEF2	0.57 ± 0.18 (0.28–0.93)	0.59 ± 0.10 (0.46–0.75)	.59





Solarz, J Am Soc Echocardiogr 2004;17:338-44.

Strain and SR after PVR in TOF

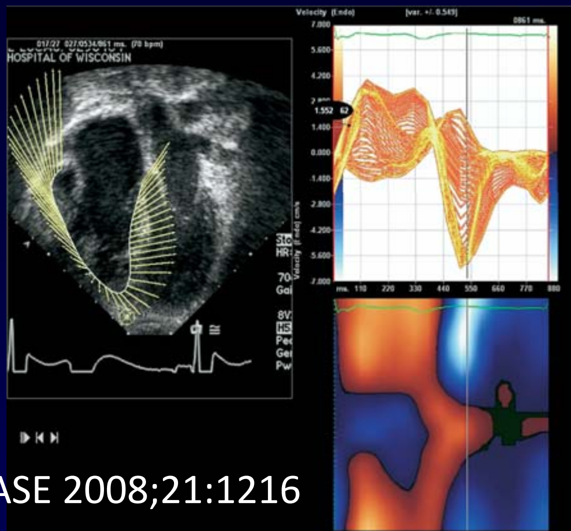


Knirsch, Pediatr Cardiol; 2008 29:718–725

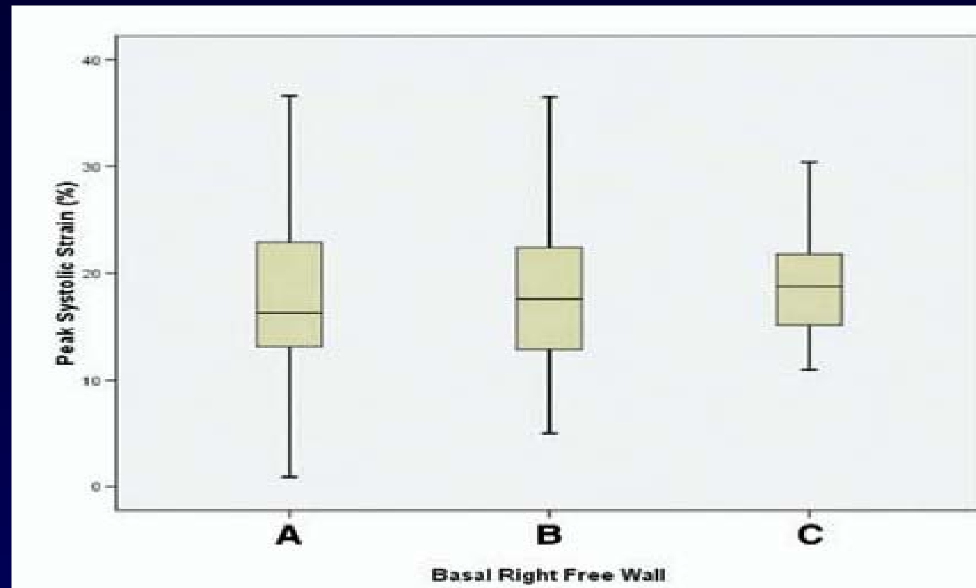
Strain and SR after PVR in TOF

N=58

Echo analysis at median intervals of 2.8 months before and 30 months after PVR.



Kutty, JASE 2008;21:1216



Before After Control

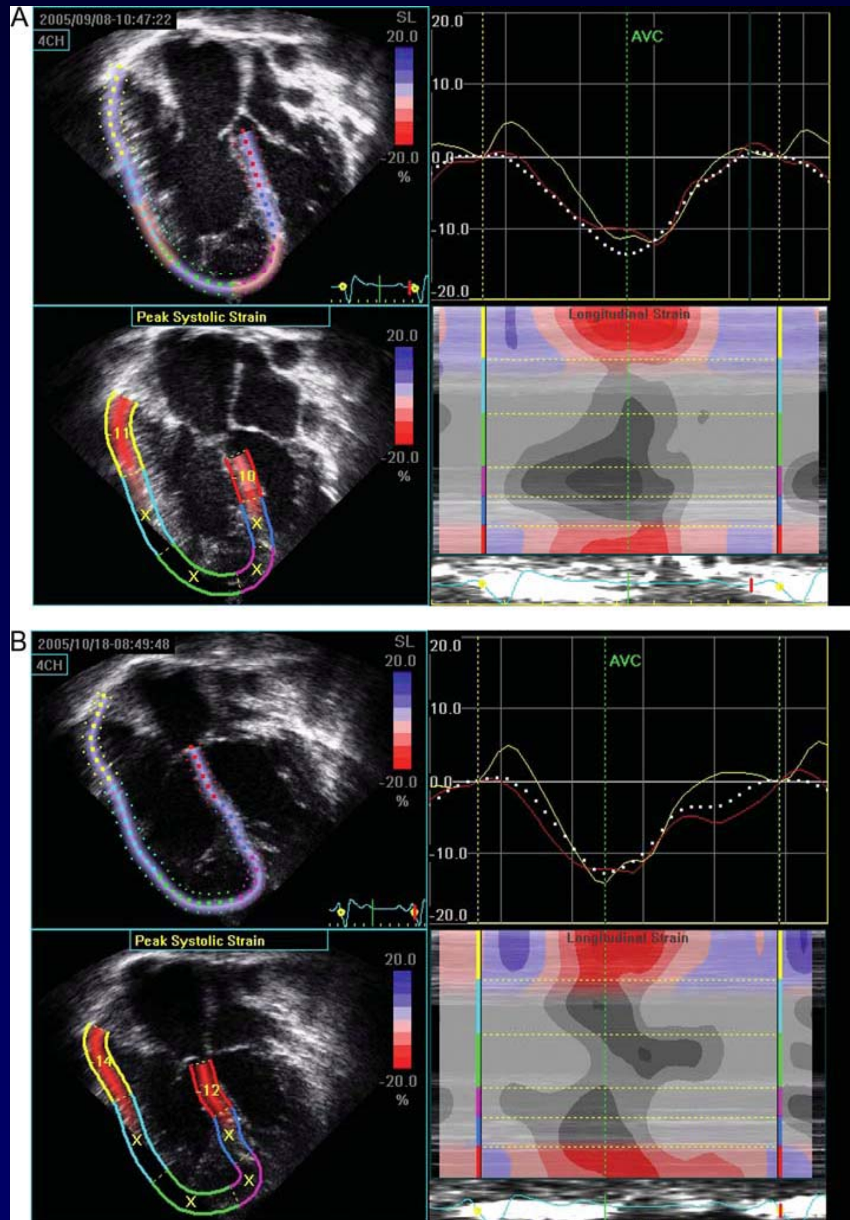
TABLE 3. Myocardial (Tissue) Doppler Measurements in Normal Subjects and in 124 TOF Patients With Different Severity of Pulmonary Regurgitation

	Controls (n=176)	Mild PR (n=34)	Moderate PR (n=22)	Severe PR (n=68)	*P* TOF (ANOVA)
IVA RV, m/s²	1.8±0.5	1.0±0.4	0.9±0.3	0.6±0.4	0.0001
s-velocity, cm/s	11.3±2.0	7.6±1.9	7.3±2.3	7.1±2.0	NS
e-velocity, cm/s	11.9±3.3	7.9±3.2	9.3±3.4	9.4±2.9	NS
a-velocity, cm/s	7.7±3	5.5±2.0	4.6±2.7	4.4±2.2	NS
RV strain, %	−45±13*	−29.6±6.7	−28.4±7.3	−28.2±6.3	NS
RV strain rate/s	2.8±0.7*	2.5±0.7	2.3±0.7	2.3±0.26	NS
IVA LV, m/s²	1.3±0.3	1.2±0.6	1.2±0.4	0.9±0.4	0.002
s-velocity, cm/s	8.7±2.1	6.9±1.8	6.8±2.0	6.4±1.6	NS
e-velocity, cm/s	11.6±4.2	11.7±3.1	11.3±2.5	11.2±2.9	NS
a-velocity, cm/s	4.9±2.3	4.3±1.9	3.9±1.9	3.6±1.8	0.03
LV strain, %	−25±11*	−26.8±4.3	−25.9±4.6	−26.2±3.9	NS
LV strain, rate/s	1.9±0.7*	2.6±0.7	2.5±0.7	2.5±0.5	NS

TOF indicates tetralogy of Fallot; PR, pulmonary regurgitation; n, numbers of subjects; IVA, isovolumic acceleration; RV, right ventricle; LV, left ventricle; *P* in patients with TOF, statistical difference of the mean between groups with different degree of PR (assessed by 1-way ANOVA test).
*Normal values described in the literature.

Frigiola, Circ. 2004;110[suppl II]:II-153–II-157

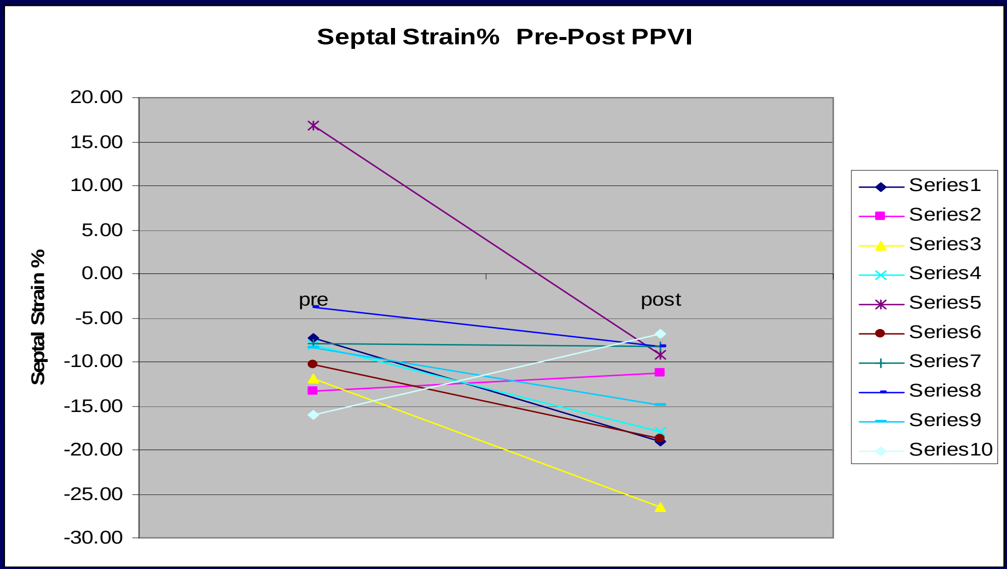
RV strain after catheter PVR



Friedberg, Eur J Echo 2009 10: 585

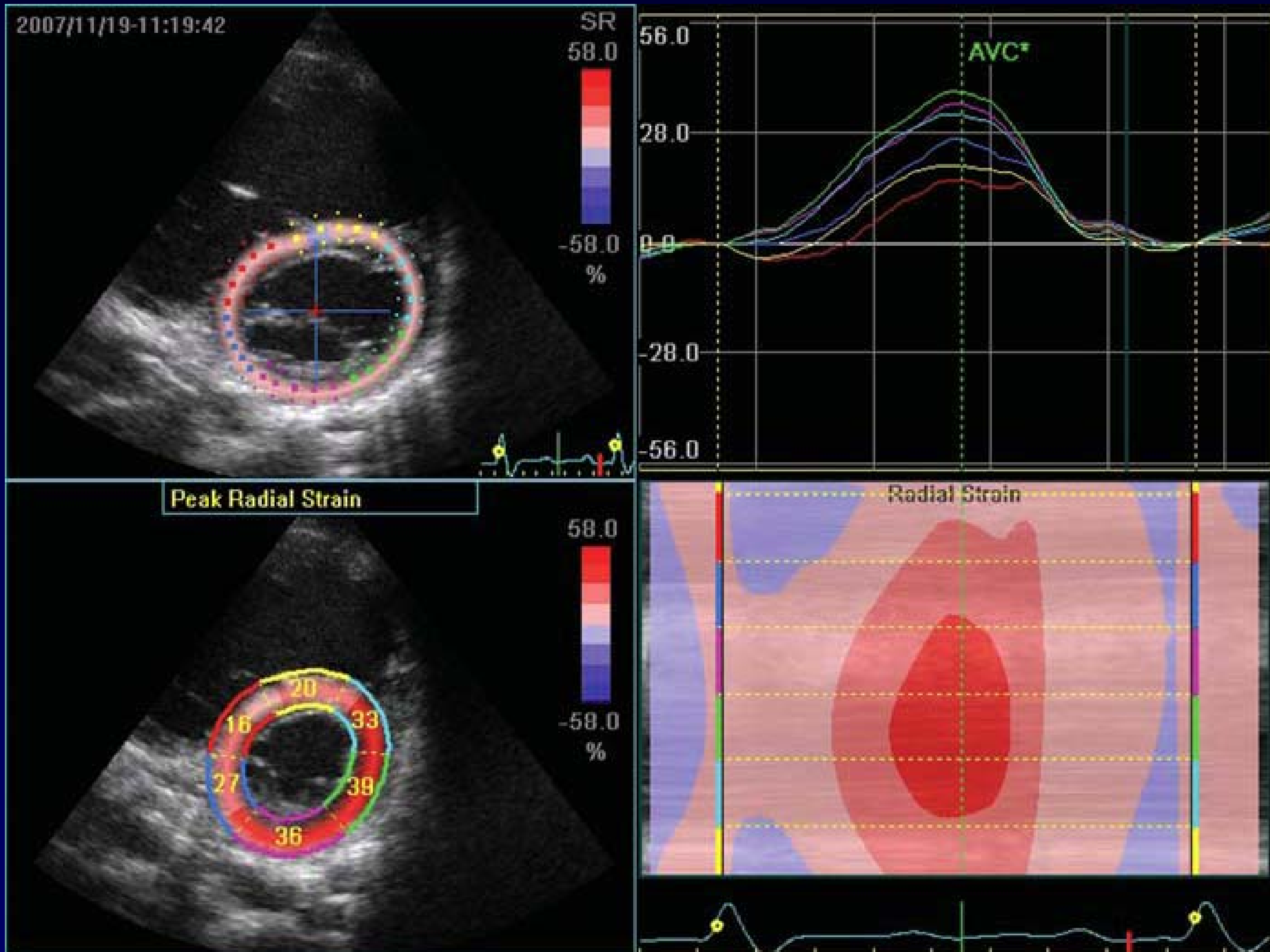
PVR: Short term changes in deformation

	n	Pre PVR (mean ± SD)	Post PVR (mean ± SD)	p- value
Strain LV %	10	-22.37 ± 8.0	-20.02 ± 11.8	0.22
Strain IVS %	10	-7.04 ± 9.1	-14.10 ± 6.4	0.02
Strain RV %	10	-14.56 ± 13.9	-23.53 ± 6.3	0.04
Strain Rate LV (s^{-1})	10	-1.48 ± 0.3	-1.50 ± 0.5	0.47
Strain Rate IVS (s^{-1})	10	-0.29 ± 1.1	-1.06 ± 0.5	0.049
StrainRate RV (s^{-1})	10	-1.53 ± 1.1	-2.07 ± 0.7	0.13



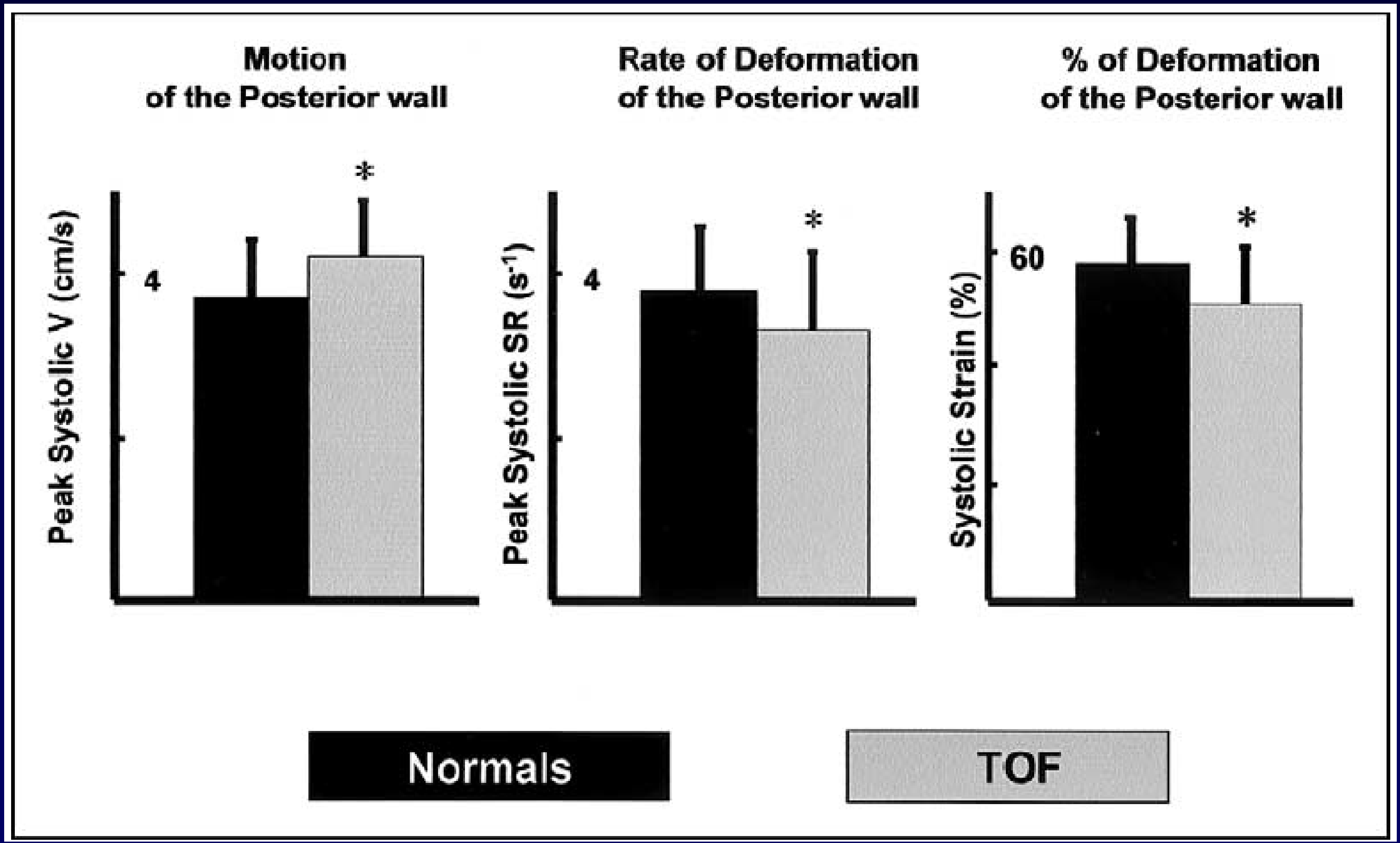
Moiduddin, AJC 2009;104:862

LV function in TOF



Friedberg, Eur J Echo 2009 10, 585

LV deformation after TOF repair

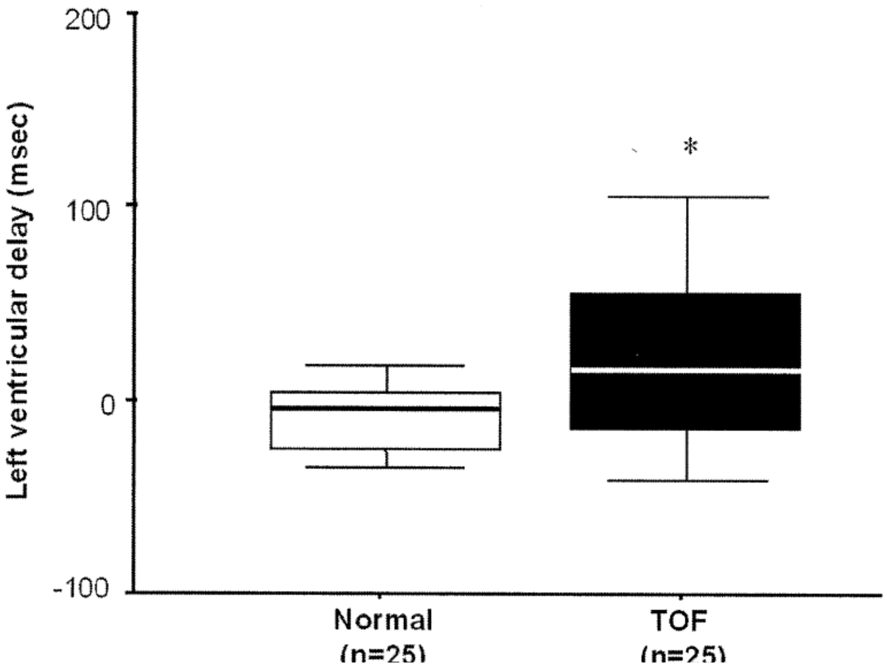


Weidemann, Am J Cardiol 2002;90:133–138

	TOF	Controls	P value
Myocardial Deformation			
LV Radial strain			
base*	30±14	39±20	<0.01
mid*	36±16	50±22	<0.01
apex†	38± 19	54±20	<0.01
LV Radial strain rate			
base*	1.5±0.74	1.9±0.82	<0.01
mid*	1.4±0.39	1.9±0.61	<0.01
apex†	1.6±0.77	2.0±0.65	0.01
LV Circumferential strain			
base*	-16±6	-18±7	0.1
mid*	-16±5	-19±6	<0.01
apex†	-19+/-6	20+/-6	0.4
Longitudinal strain			
RV (base+mid)	-23±5	-27±9	0.03
LV (base+mid)	-16±5	-17±4	0.4

Fernandes, AEPC, 2010

LV dyssynchrony in TOF



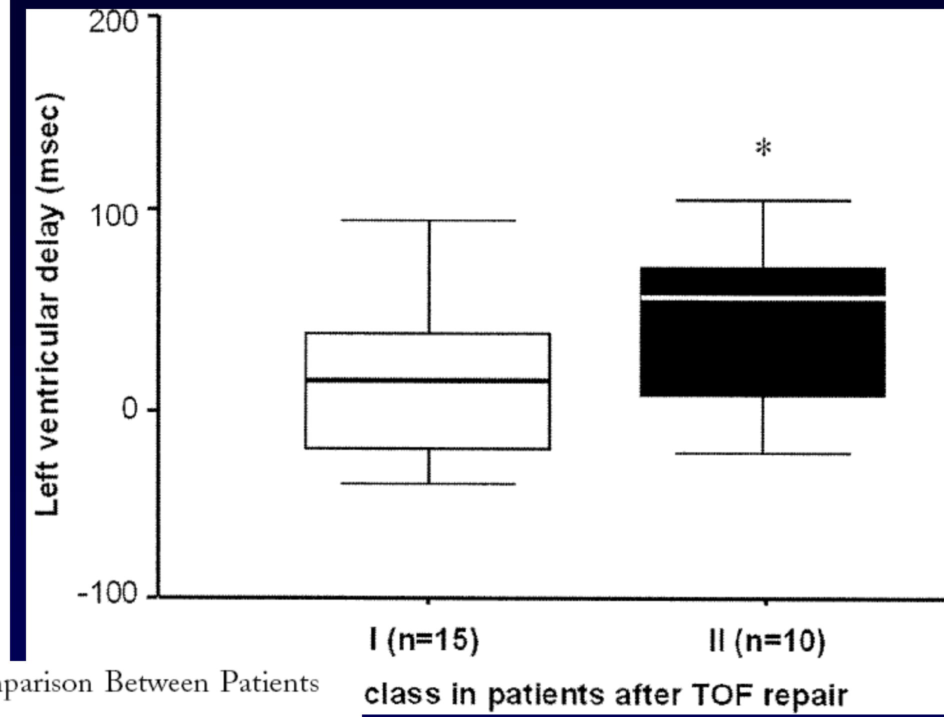


Table 3. Regional Myocardial Deformation and Time Intervals: Comparison Between Patients After TOF Repair Without and Those With LV Asynchrony

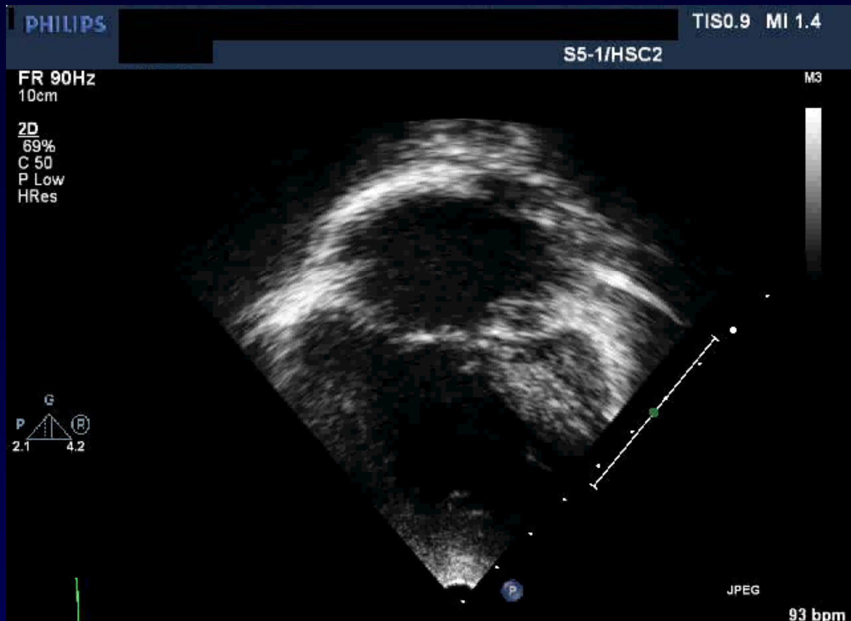
	No LV Asynchrony TOF Group 1 (n = 12)		LV Asynchrony TOF Group 2 (n = 13)	
	Strain (%)	Time Interval (ms)	Strain (%)	Time Interval (ms)
LV basal	21 ± 5.7	372 ± 50	18.6 ± 4.3	366 ± 107
LV middle	22.4 ± 7.7	369 ± 44	20.1 ± 7.1	384 ± 38
LV apex	14.5 ± 8.6	356 ± 49	13.7 ± 6.7	368 ± 47
LV (mean)	19.1 ± 3.6	366 ± 44	17.2 ± 5.2	373 ± 44
Septum basal	20.6 ± 7.5	348 ± 52	15.8 ± 5.8	409 ± 97*
Septum middle	19 ± 5.1	351 ± 43	11.1 ± 6.8*	425 ± 86*
Septum apex	19.8 ± 6.8	351 ± 33	11.1 ± 4.8*	422 ± 84*
Septum (mean)	19.8 ± 4.2	350 ± 44	12.7 ± 3.6*	419 ± 40*
LV delay		−12 ± 19		62 ± 25*

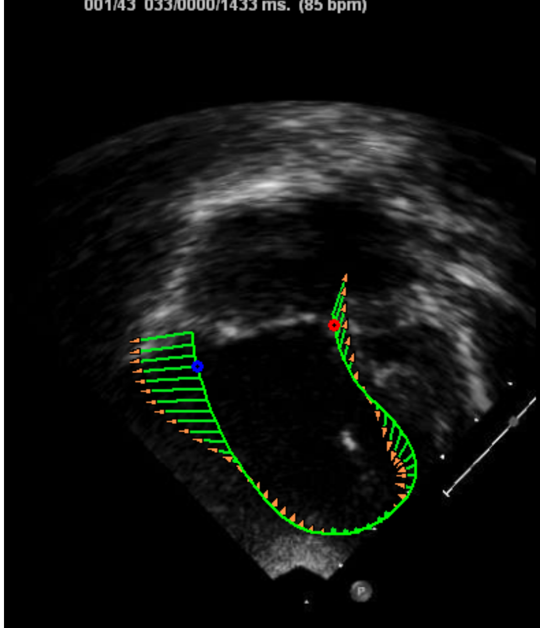
*Patients after TOF repair with LV asynchrony versus patients after TOF repair without left intraventricular asynchrony, $p < 0.05$.

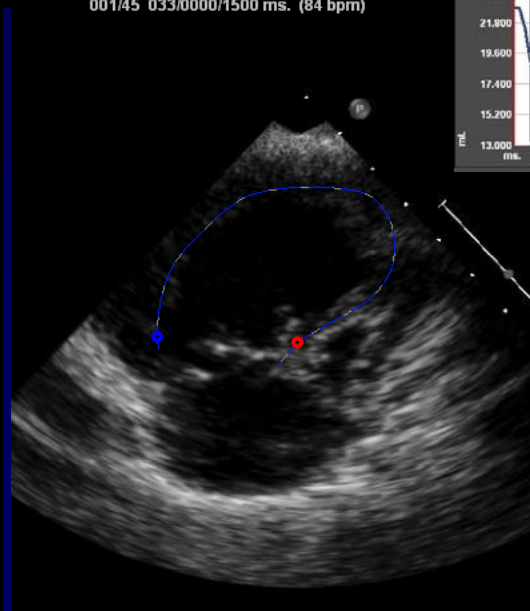
Abdul Khaliq, JACC 2005;45:915

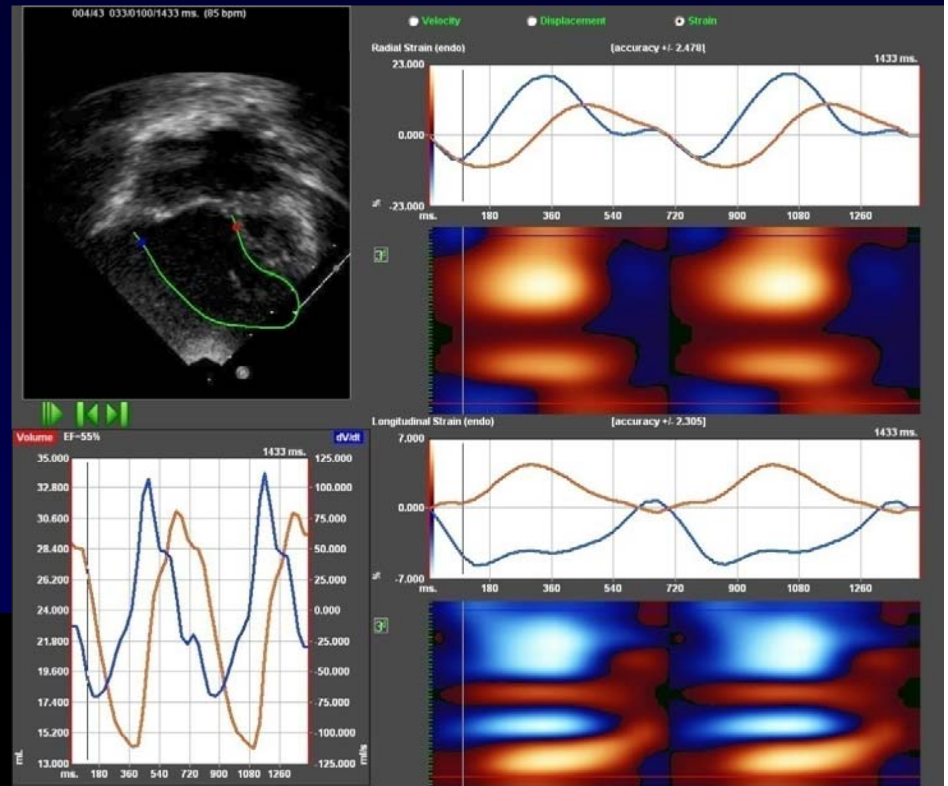
Hypoplastic Left Heart Syndrome

Assessment of function in single ventricles

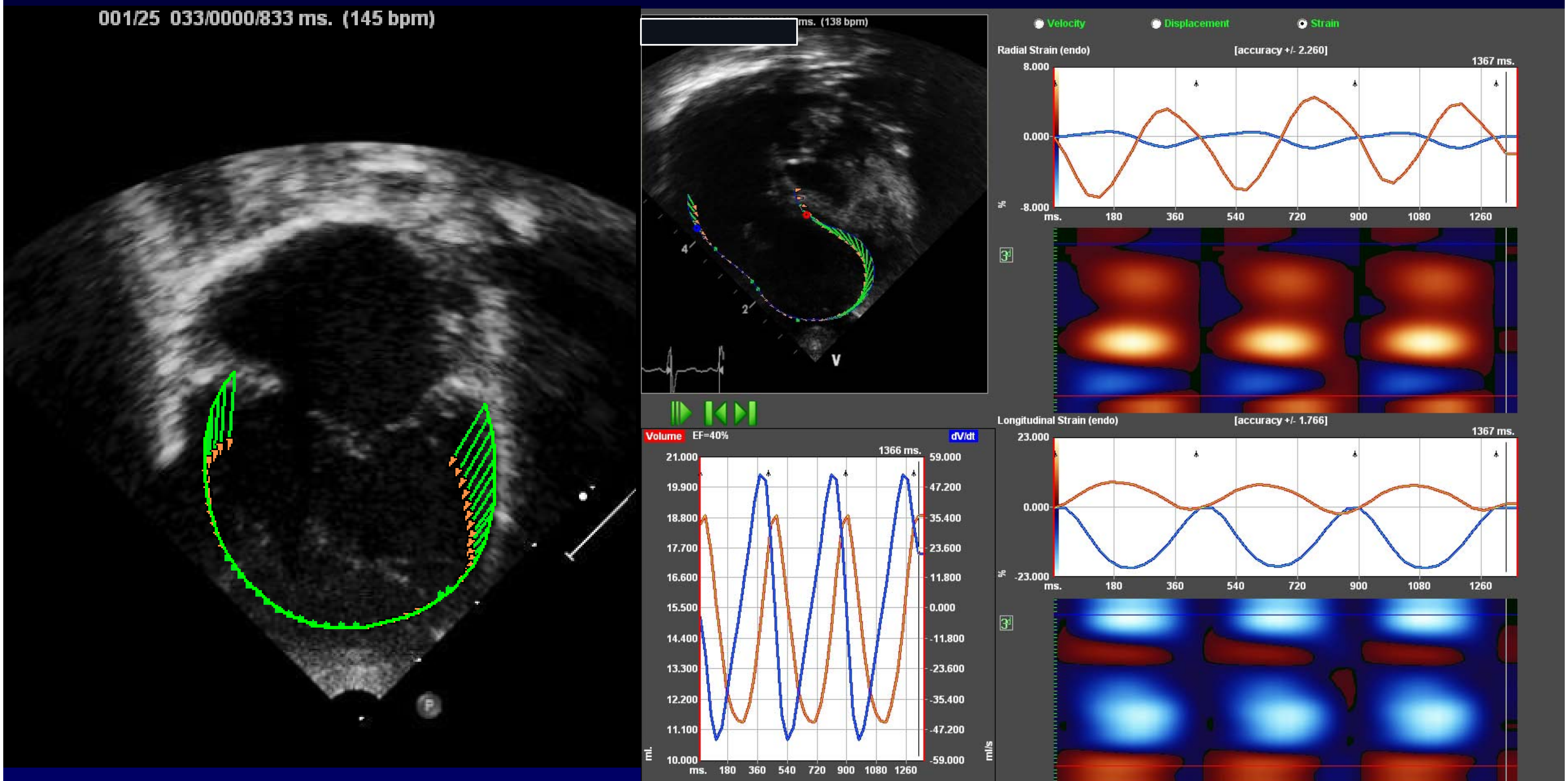








HLHS good RV Deformation



RV-PA conduit vs BTS in Stage 1 Norwood

Table 2 Clinical and echocardiographic characteristics of each patient listed in chronological order of surgery

Patient	Echo post-op (days)	Heart rate (beats/min)	SaO_2 (%)	Inotrope (μg/kg/min)	TR	RV %A-Ch (%)	Peak systolic SR (1/s)	Peak systolic ε (%)	Outcome
S-PA shunt									
1	50	149	80	None	Mod	29	−1.11	−16.2	A
2	47	167	79	None	Mod	25	−0.69	−12.2	A
3	41	136	80	None	Mild	29	−0.77	−11.9	D (60 days)
4	28	177	82	Dobutamine 5	Mild	17	−1.08	−13.4	D (29 days)
Mean (SD)	41.5 (3.4)	157 (18)	80 (1)			25 (6)	−0.91 (0.21)	−13.4 (2.0)	
RV-PA conduit									
5	34	147	85	None	Mild	49	−1.54	−20.4	A
6	27	138	88	None	Mod	62	−1.06	−16.5	A
7	36	154	86	None	Mild	55	−1.18	−16.7	A
8	31	170	85	Dobutamine 2.5	Mild	53	−1.29	−16.5	A
9	32	133	82	None	Mild	62	−1.11	−19.0	A
Mean (SD)	32 (9.7)	148 (15)	85 (2)			56 (6)	−1.24 (0.19)	−17.8 (1.8)	
p Value	0.07	0.4	<0.01			<0.01	0.048	0.01	

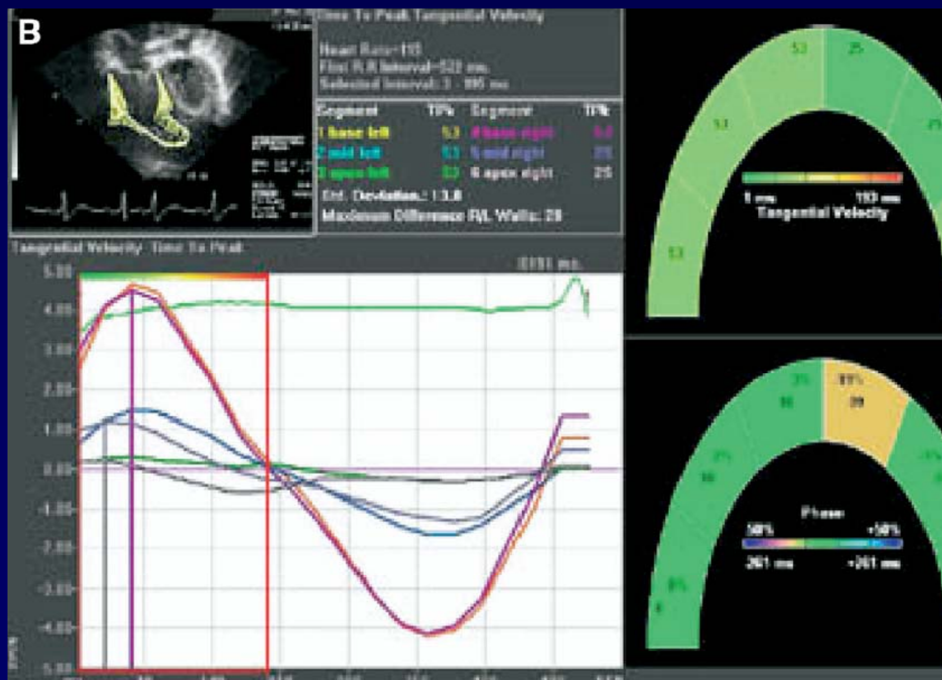
ε, systolic strain; A, alive; D, died; mod, moderate; RV % A-Ch, right ventricle percentage area change; SaO_2, percutaneous oxygen saturation; SR, strain rate; TR, tricuspid valve regurgitation.

Hughes, Heart 2004;90:191–194

Dyssynchrony in HLHS using VVI

Table 2 Mechanical dyssynchrony in the systemic right ventricle of children with hypoplastic left heart syndrome and left and right ventricular mechanical dyssynchrony in healthy age-matched control subjects

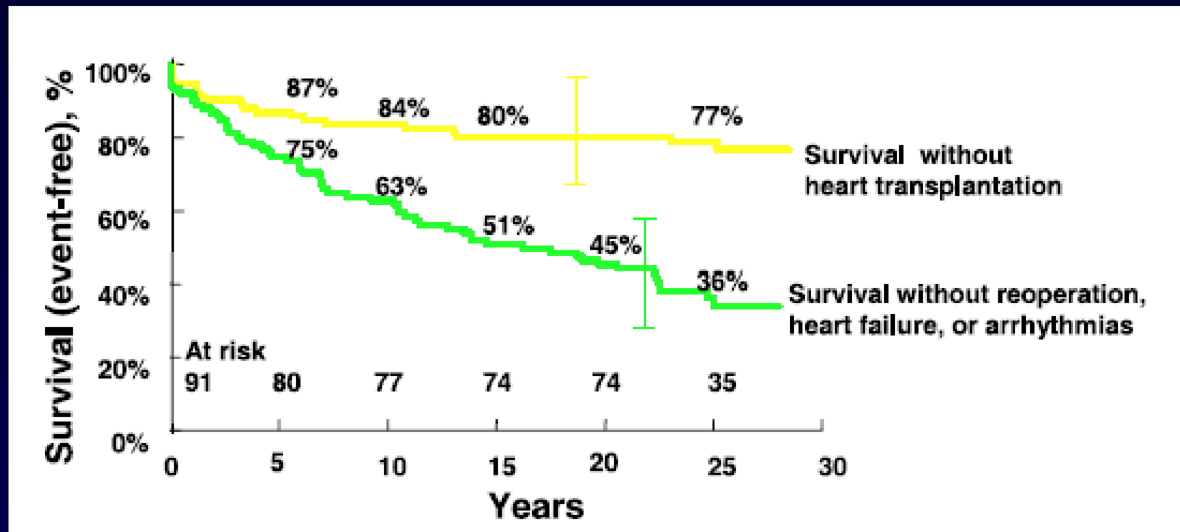
	Hypoplastic left heart syndrome	Control subjects: left ventricle	*P*	Control subjects: right ventricle	*P*
SD of time to peak velocity, ms	43 ± 67	11 ± 6	.07	12 ± 7	.08
SD of time to peak strain, ms	37 ± 35	8 ± 8	<.01	9 ± 11	<.01
SD of time to peak strain rate, ms	31 ± 37	10 ± 13	<.05	14 ± 15	.09



Friedberg, JASE 2007;20:1073-1079

Congenitally corrected transposition of the great arteries

Clinical deterioration in ccTGA is linked to RV failure



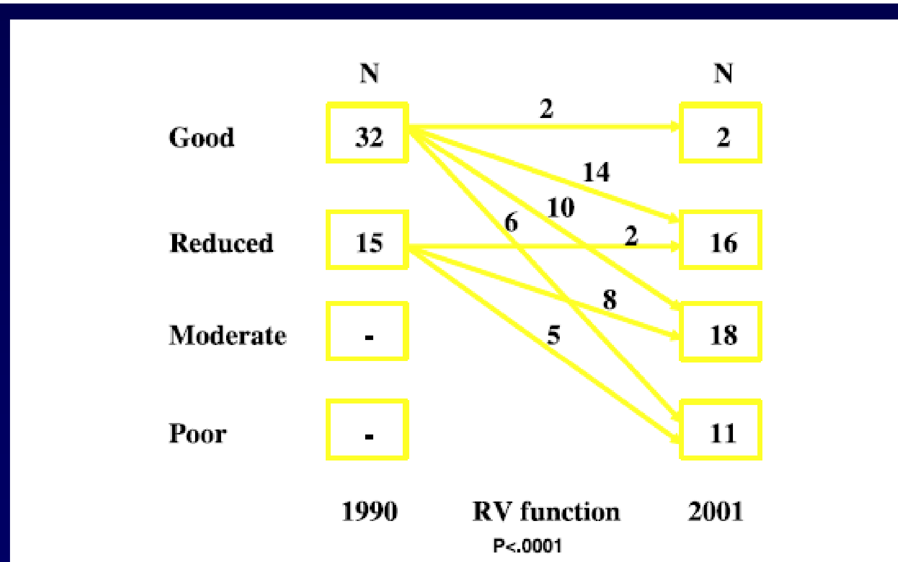
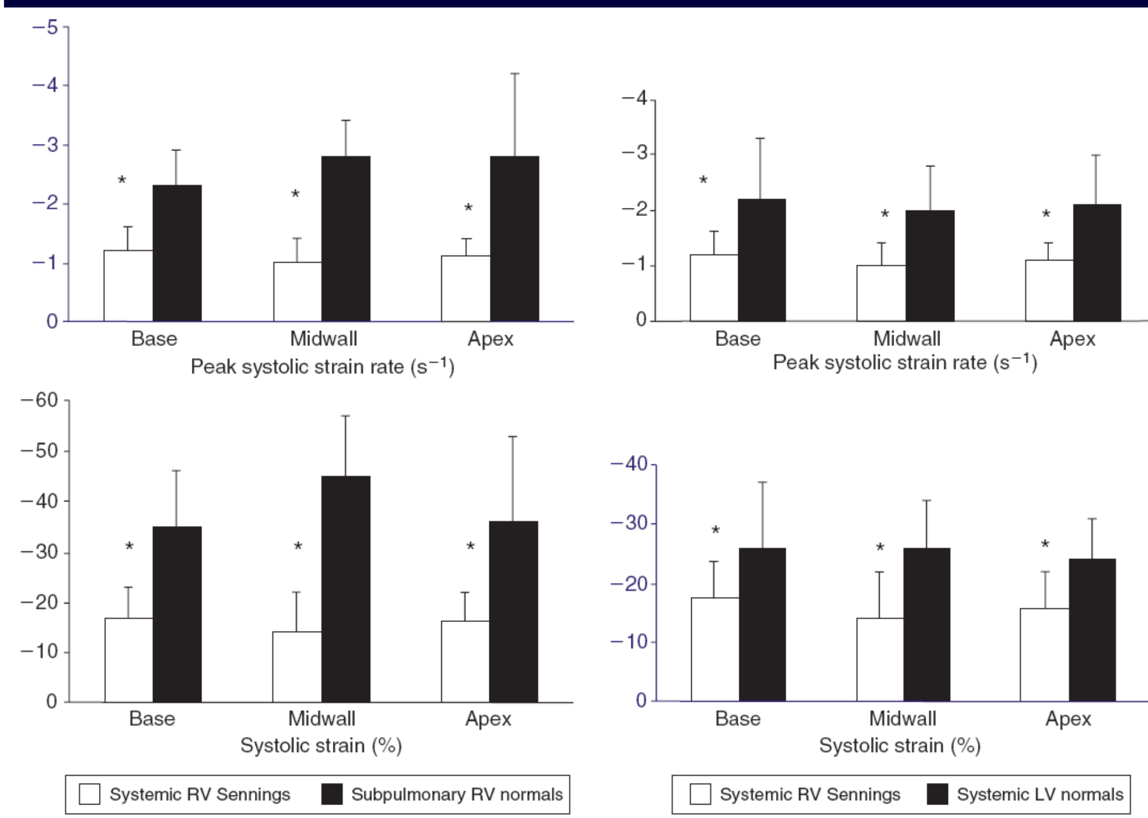
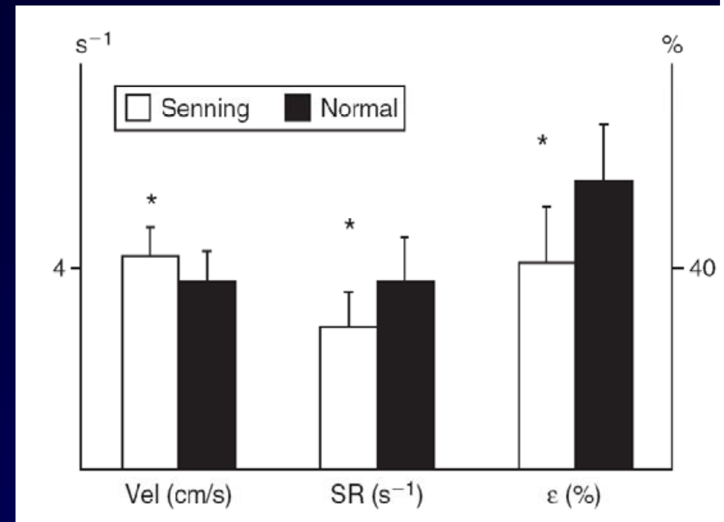


Fig. 5 Decline in systemic ventricular function between 1990 and 2001 measured with echocardiography.

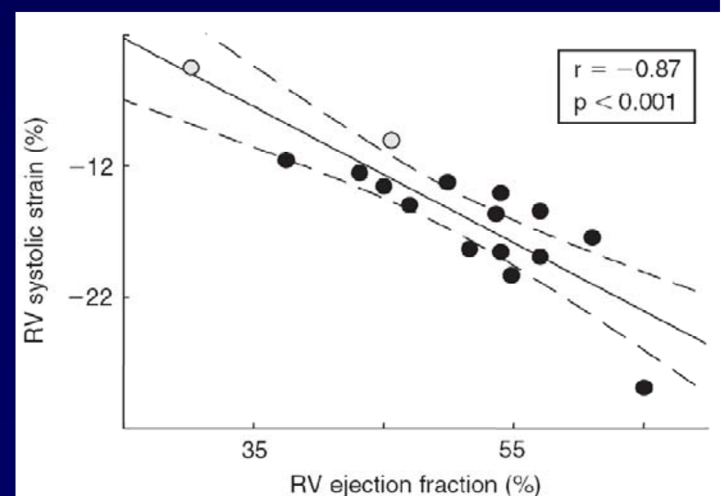
Roos-Hesselink, EHJ 2004; 25, 1264

Strain and SR after Senning in ccTGA



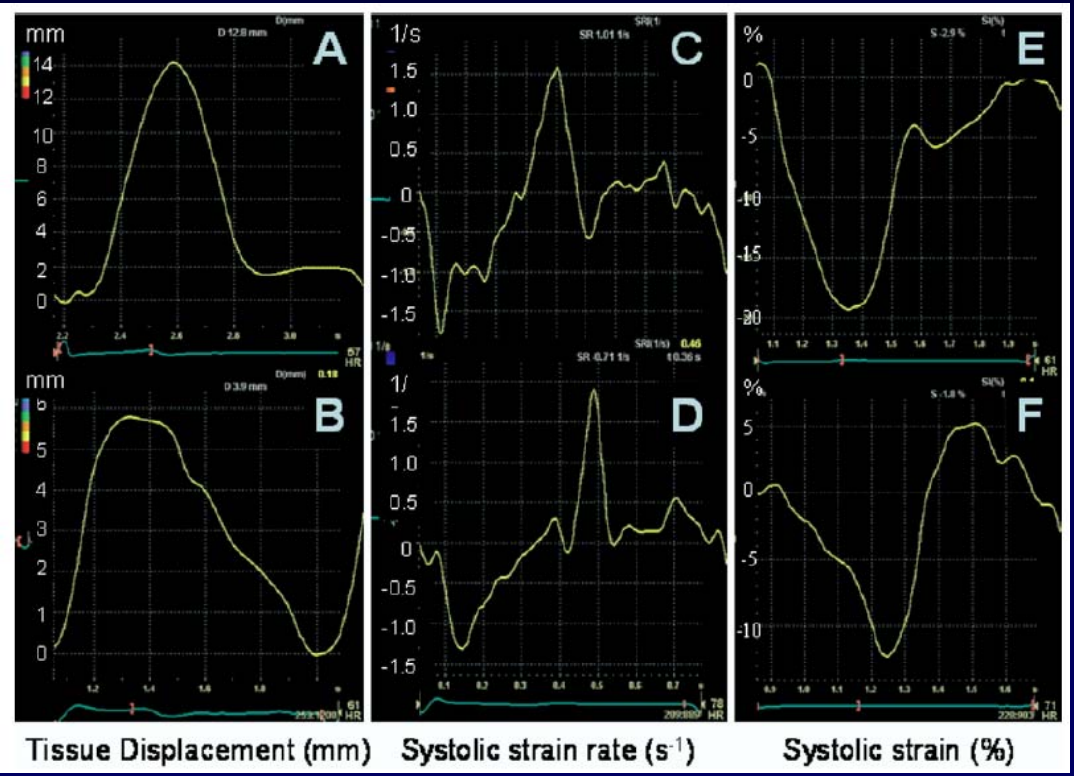


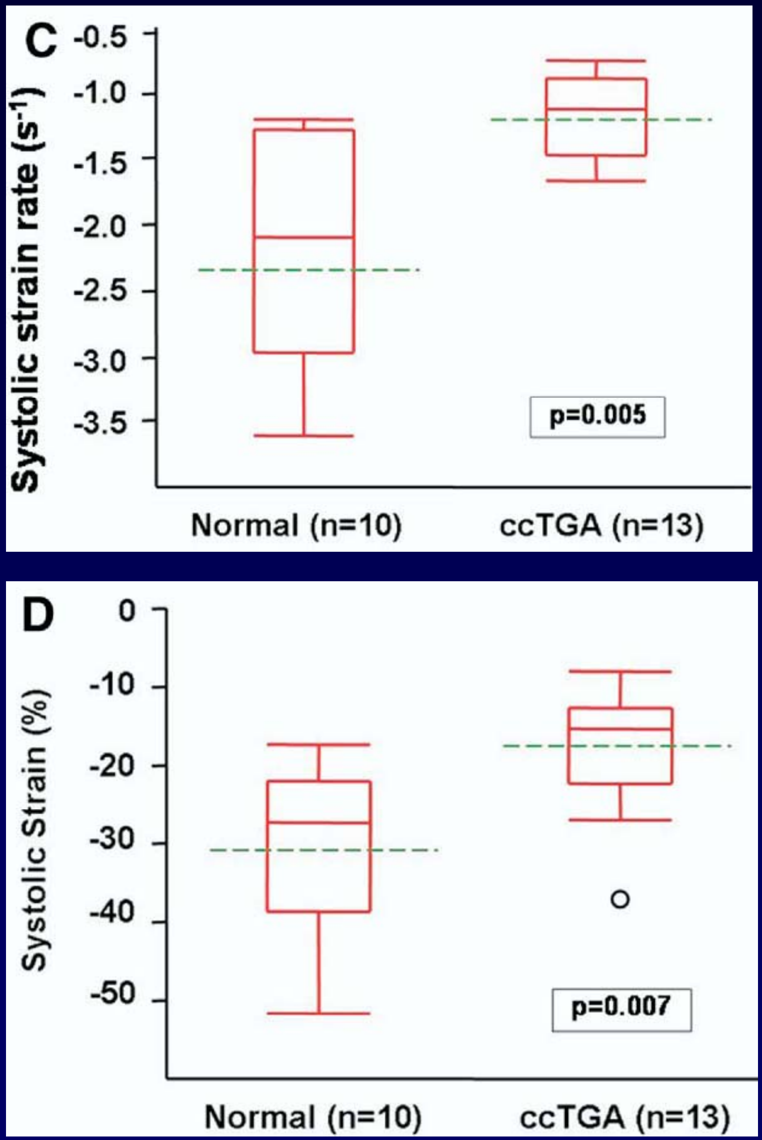
LV posterior wall radial function



Eyskens, Cardiol Young 2004; 14: 255–264

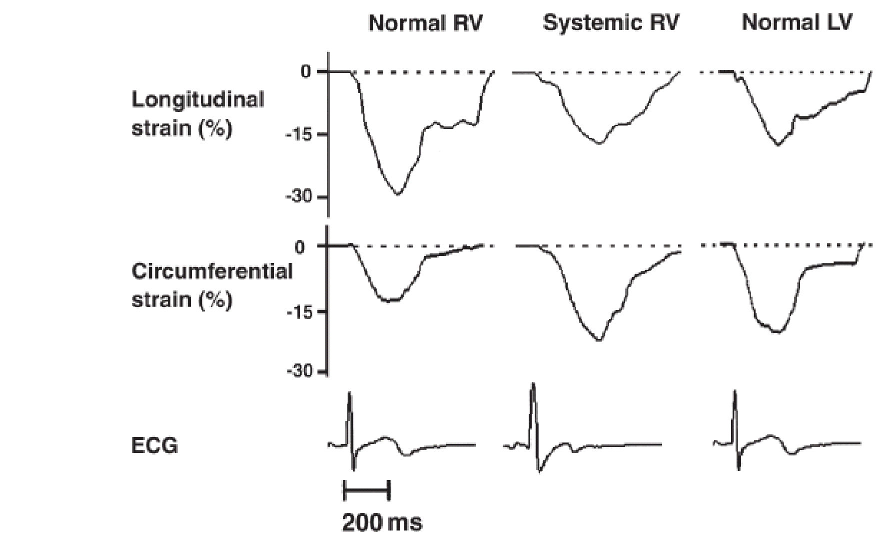
Asymptomatic patients with ccTGA





Bos, JASE 2006;19:1033

RV adaptation after atrial switch



Myocardial Shortening Patterns

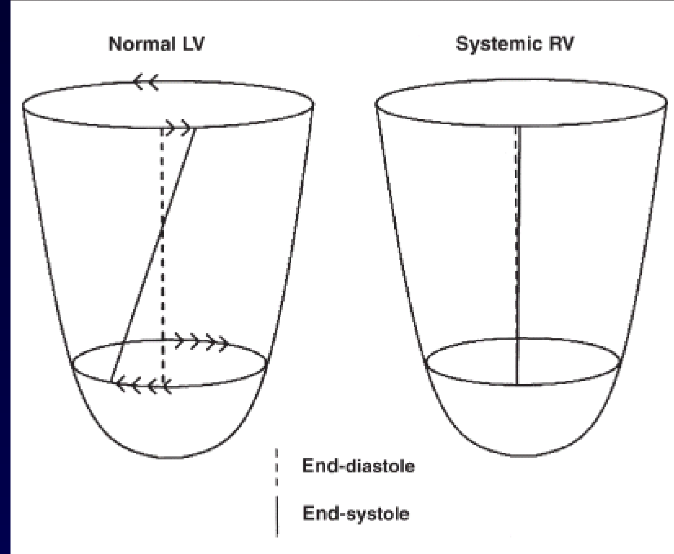


Figure 4 Basal and Apical Systolic Rotation

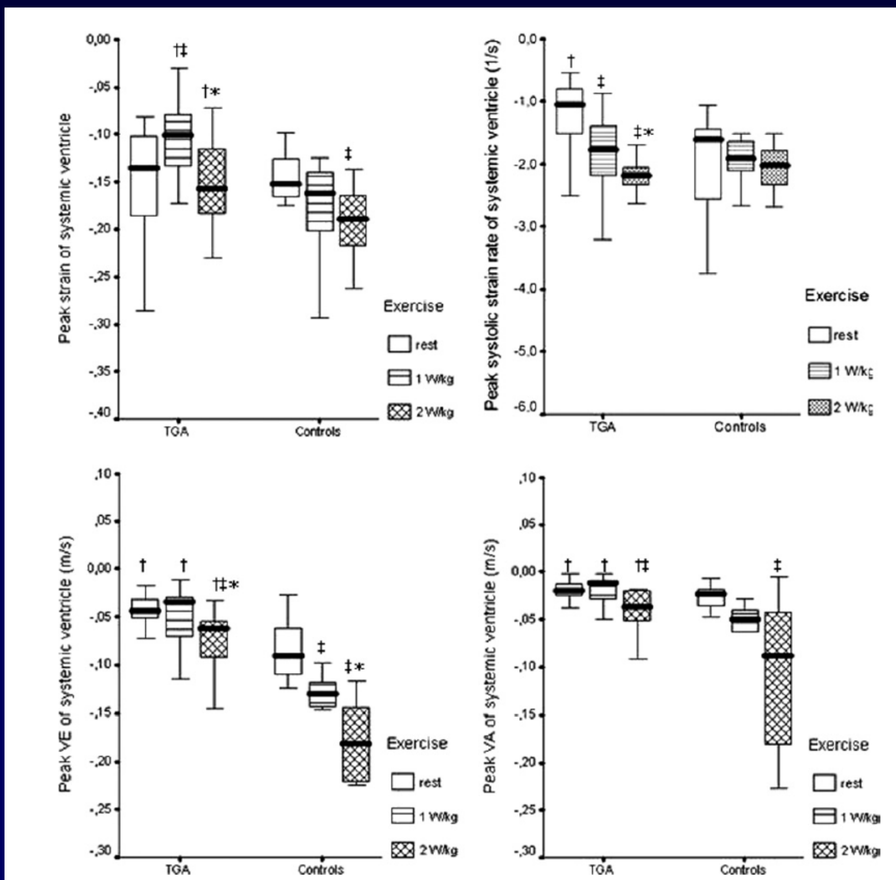
Table 2 Assessment of Regional Myocardial Function in the Systemic RV Free Wall Compared With the RV and LV Free Wall in Healthy and Operated Control Subjects

	RV Control Subjects	RV Operated Control Subjects	Systemic RV	LV Control Subjects	LV Operated Control Subjects
Longitudinal strain (%)					
Apical free wall	−30.6 ± 4.2	−29.7 ± 2.4	−14.7 ± 4.3*	−18.3 ± 4.0	−16.6 ± 1.7
Mid free wall	−30.7 ± 3.3	−28.4 ± 4.3	−15.0 ± 3.0*	−16.5 ± 1.7	−17.1 ± 1.7
Basal free wall	−30.1 ± 4.9	−29.6 ± 2.6	−14.3 ± 4.1*	−16.6 ± 2.7	−16.9 ± 2.1
Circumferential strain (%)					
Mid free wall	−15.8 ± 1.3	−14.4 ± 1.8	−23.3 ± 3.4*	−25.7 ± 3.1	−24.5 ± 2.4
Longitudinal strain rate (s^{-1})					
Apical free wall	−2.5 ± 0.4	−2.4 ± 0.4	−1.0 ± 0.2*†	−1.7 ± 0.4	−1.7 ± 0.3
Mid free wall	−2.3 ± 0.4	−2.1 ± 0.3	−1.1 ± 0.2*†	−1.7 ± 0.3	−1.7 ± 0.4
Basal free wall	−2.2 ± 0.7	−2.3 ± 0.5	−1.1 ± 0.2*‡	−1.6 ± 0.5	−1.6 ± 0.2
Circumferential strain rate (s^{-1})					
Mid free wall	−1.5 ± 0.4	−1.5 ± 0.3	−1.5 ± 0.5†	−2.4 ± 0.5	−2.6 ± 0.2

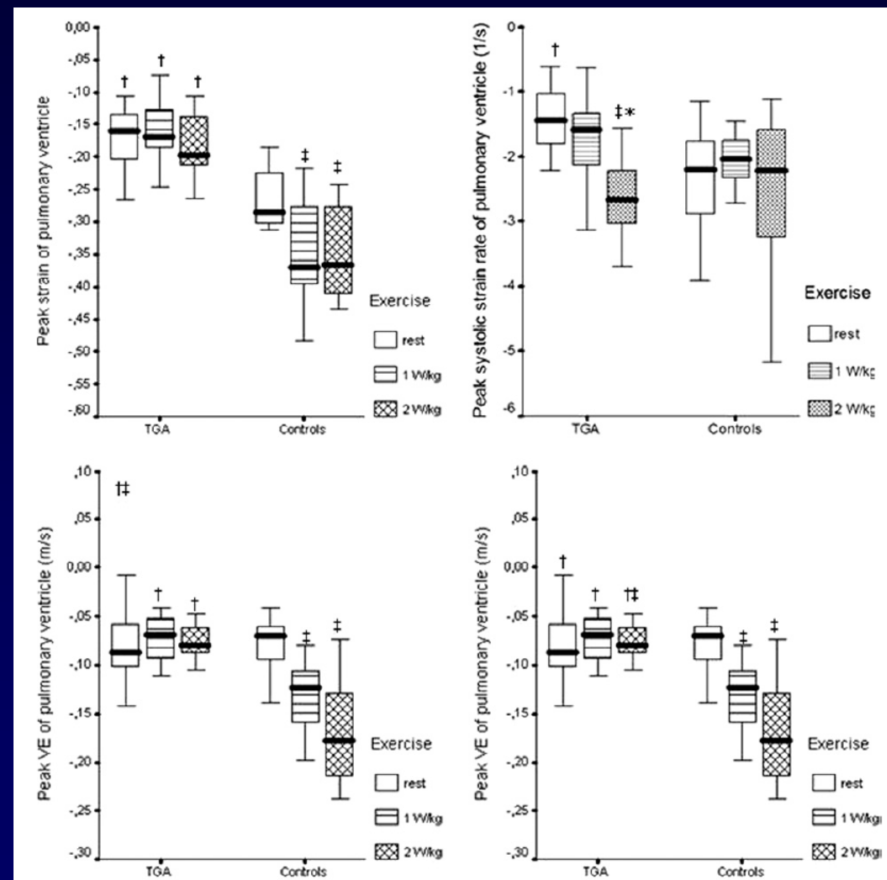
Pettersen, JACC, 2007;49:2450

Impaired Diastolic Reserve in ccTGA

Systemic Ventricle

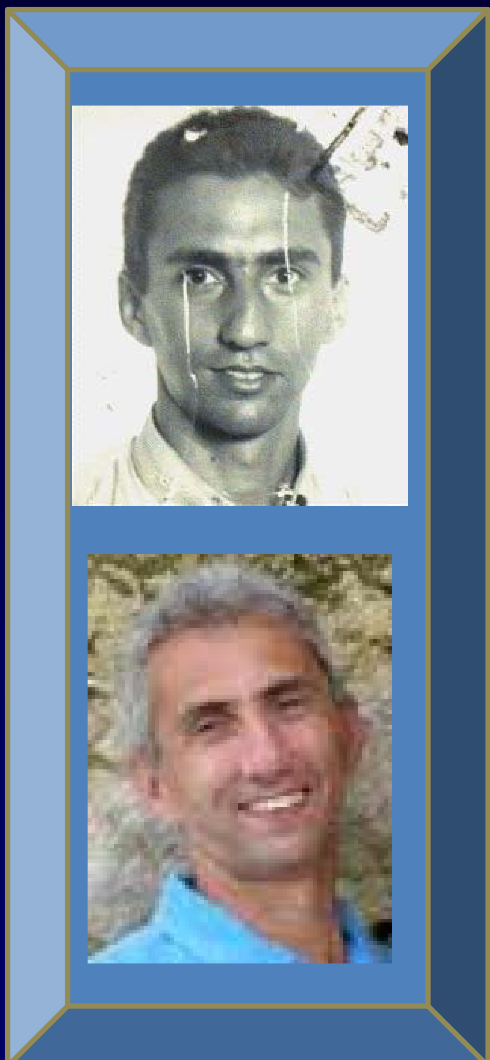


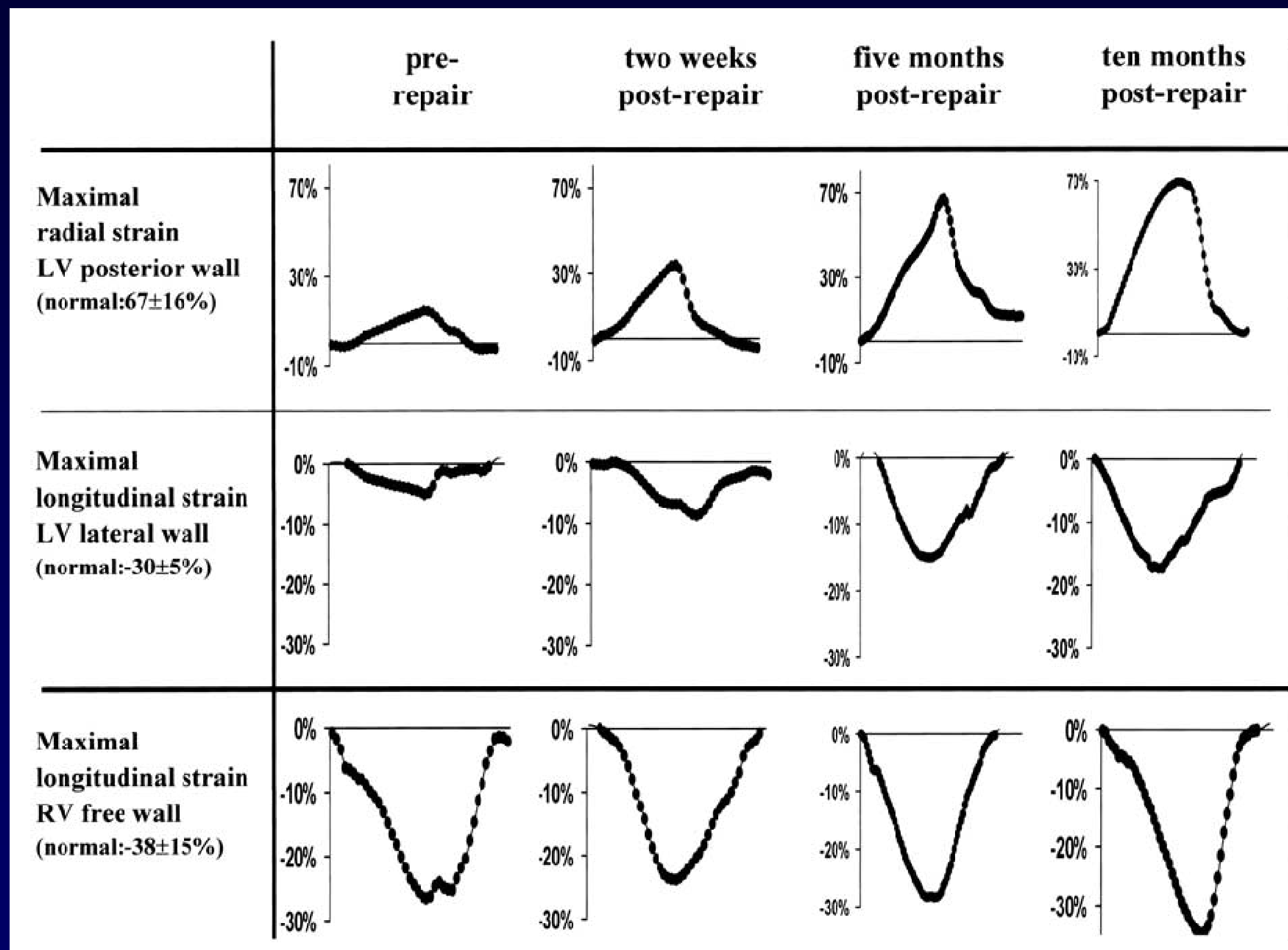
Pulmonary Ventricle



Poerner J Am Soc Echocardiogr 2007;20:1 285

Serial Evaluation of LV function after ALCAPA repair



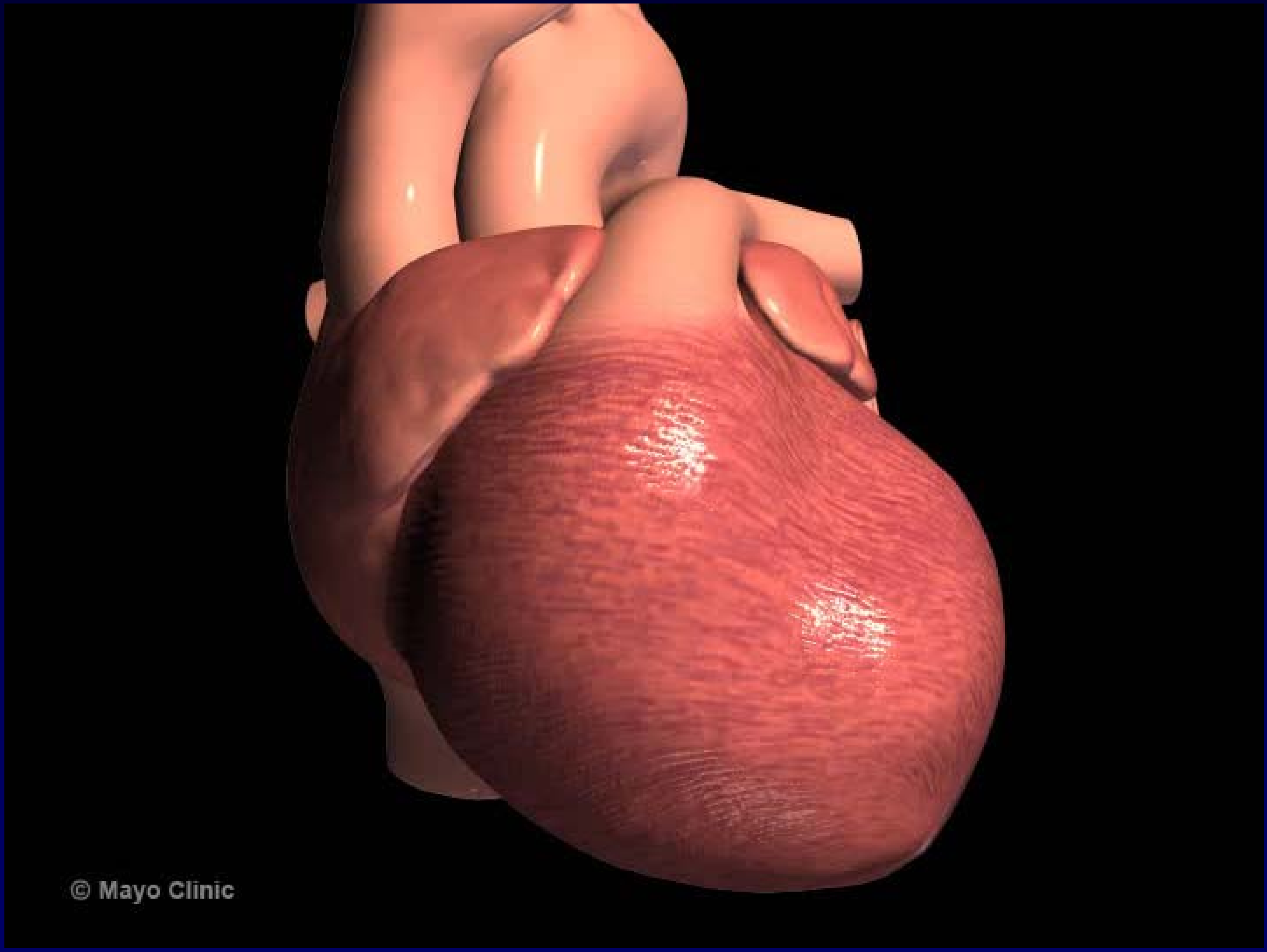


Mertens, Cardiol Young, 2001

Child with ALCAPA

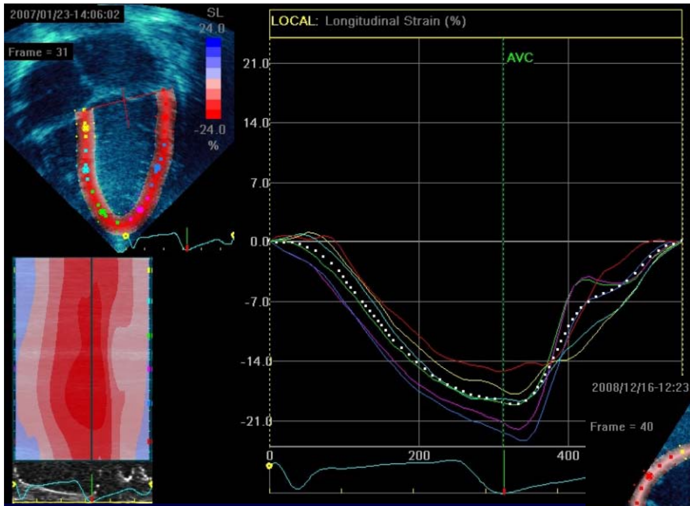
3D strain

Left Ventricular Deformation is 3-dimensional

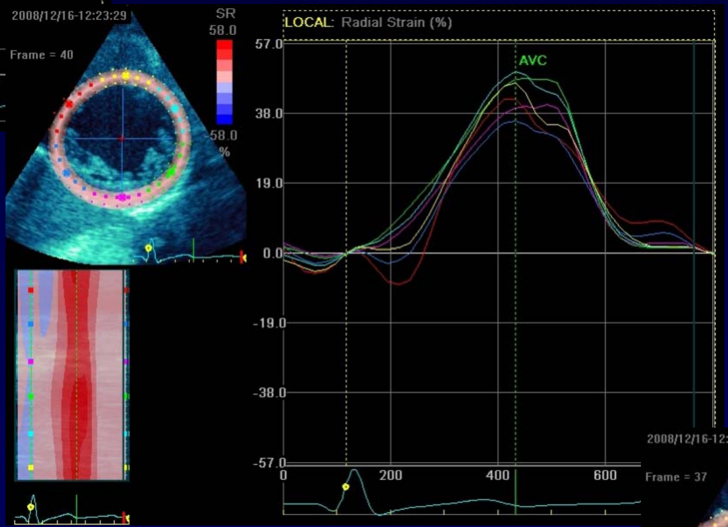


Courtesy of Ben Eidem, MD

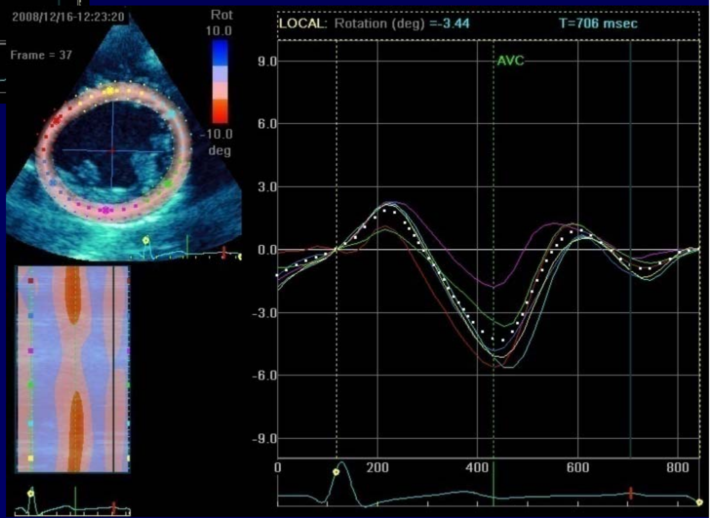
We evaluate strain in 3-dimensions



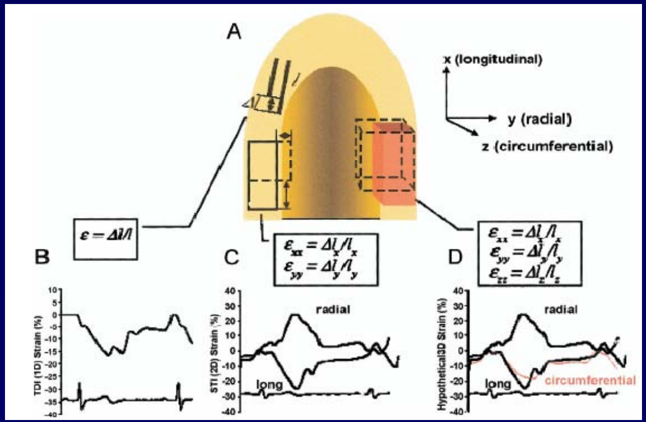
Longitudinal strain



Radial strain



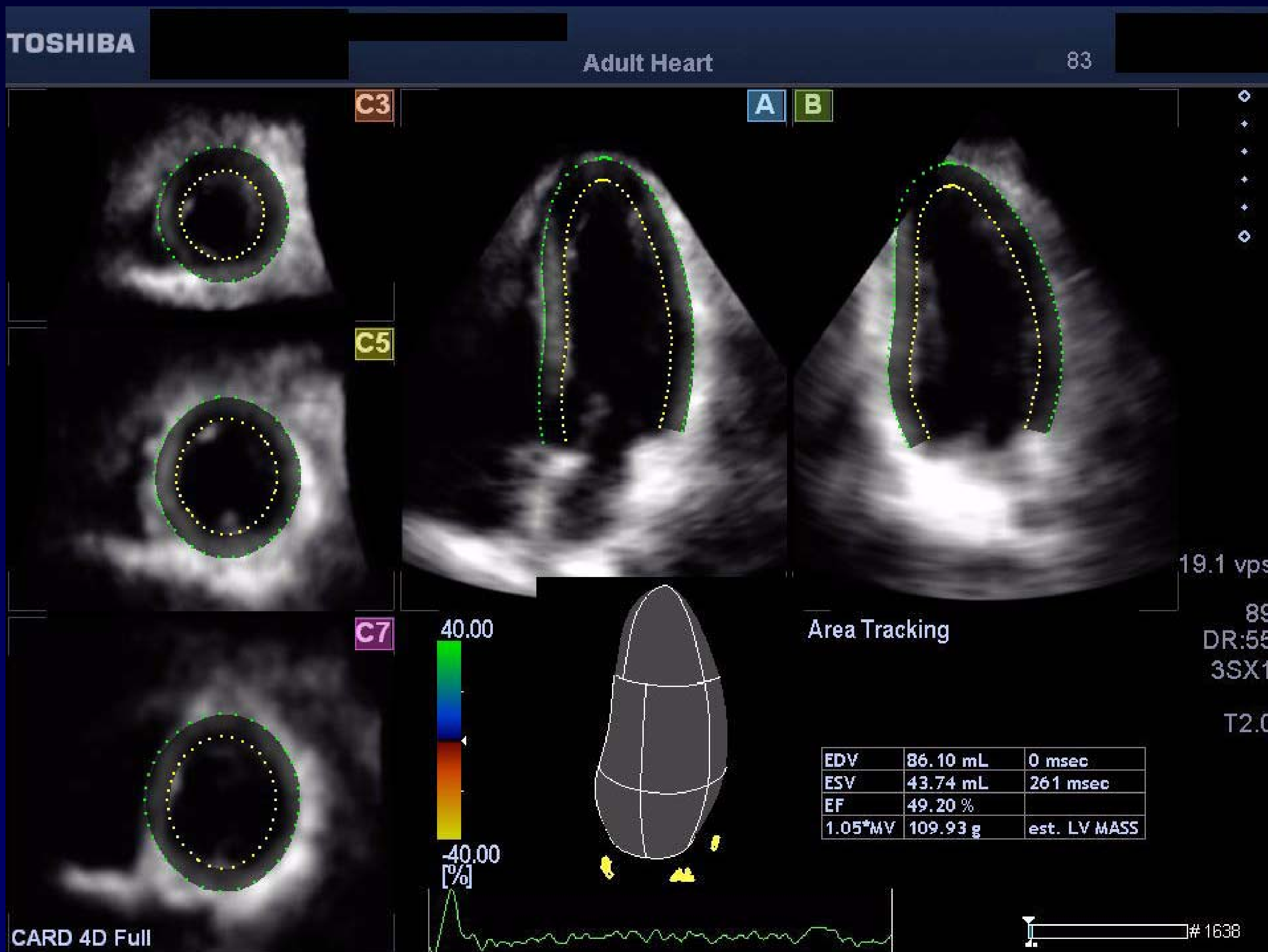
Circumferential strain



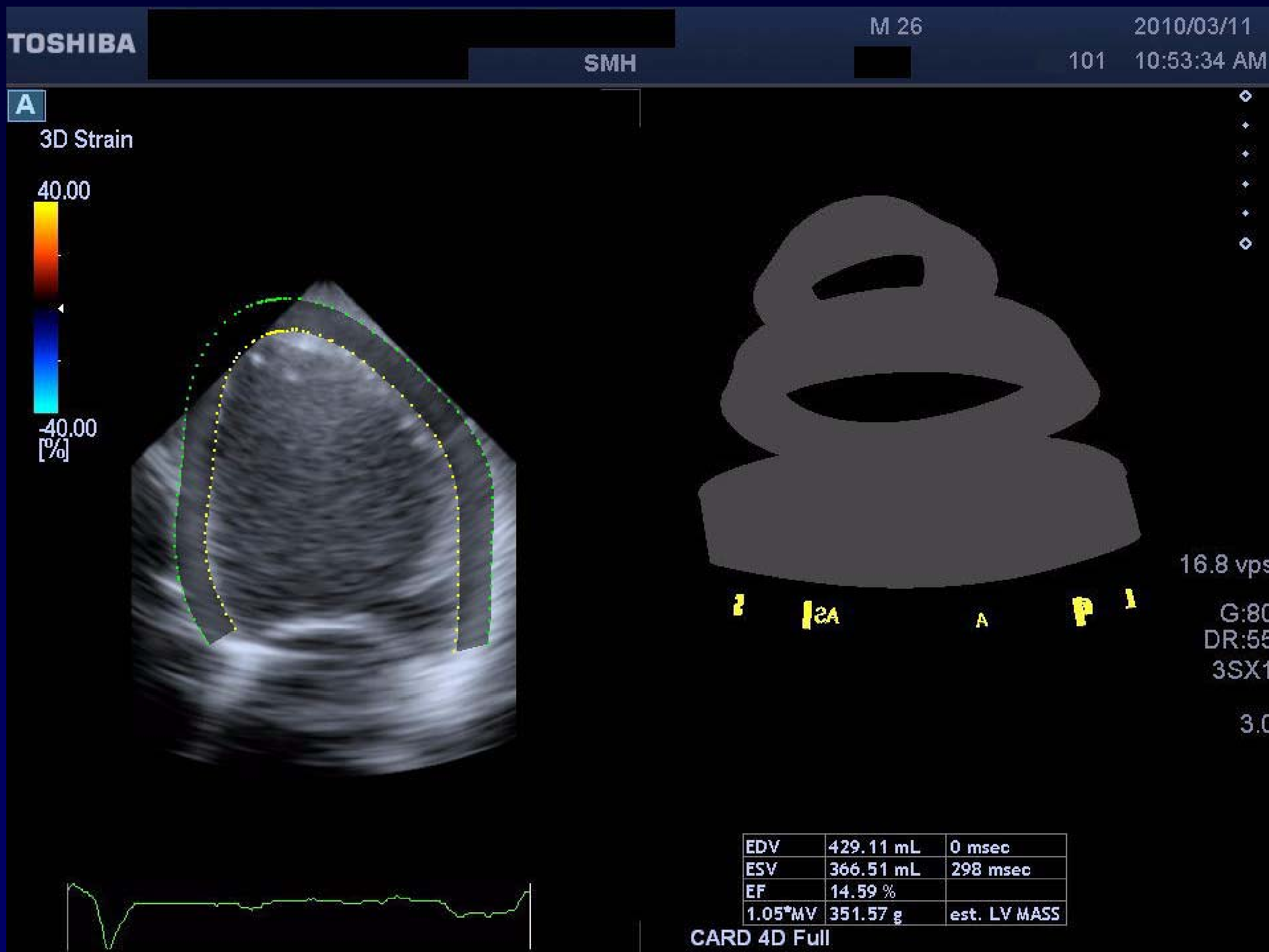
Abstracts at the upcoming AHA

- "Is Left Ventricular Twisting Obtained Using Three-dimensional Ultrasound Speckle Tracking Imaging Useful in Assessing Left Ventricular Function?- Comparison with Invasive Parameters"
- "Left Ventricular Eccentricity Impairs Three-Dimensional Systolic Radial Strain and Torsion in Patients After Repair of Tetralogy of Fallot: A Three-Dimensional Speckle Tracking Analysis"

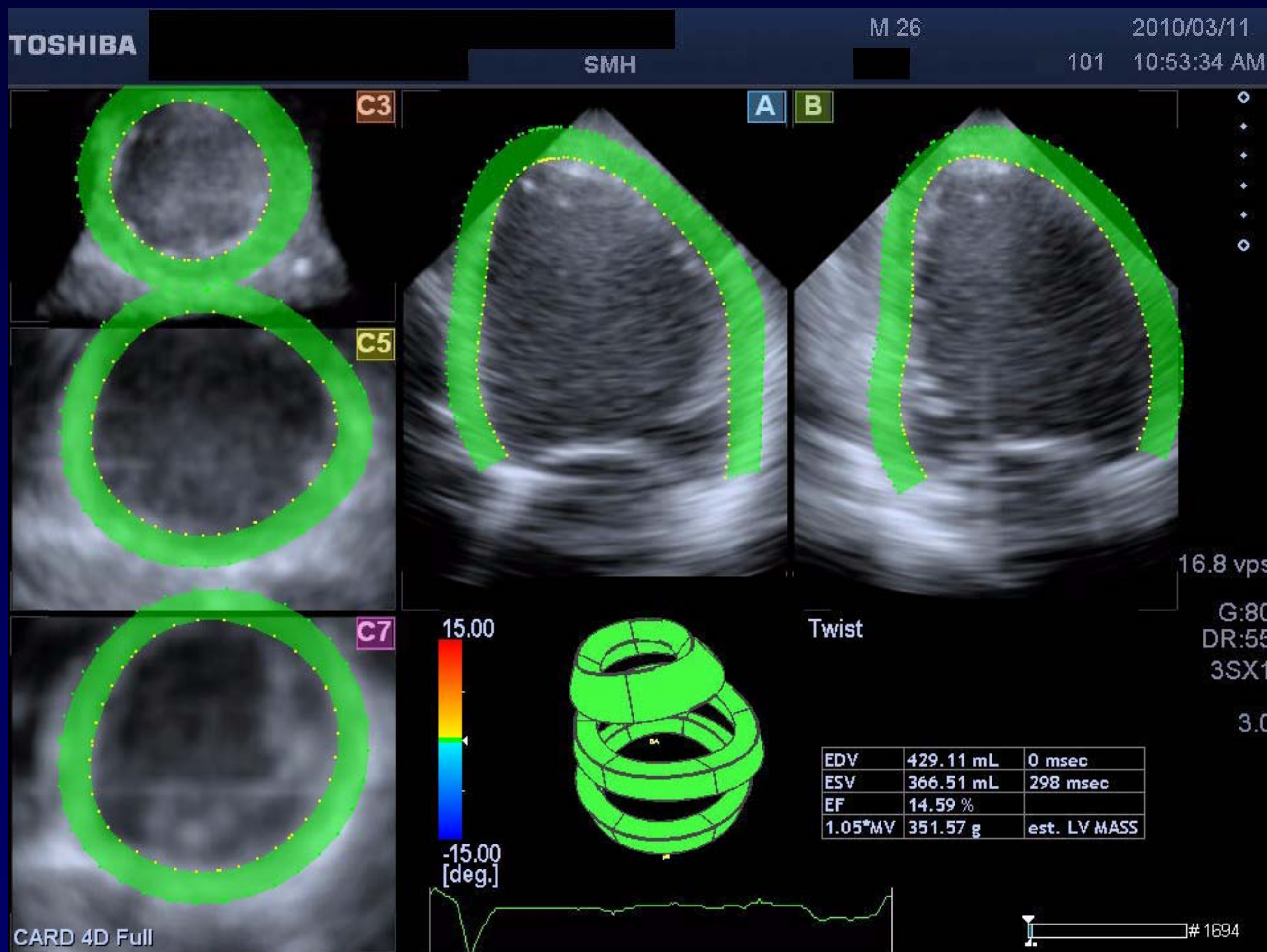
3-D strain


TOSHIBA
[redacted]
Adult Heart
83
[redacted]
C3
C5
C7
A
B
19.1 vps
89
DR:55
3SX1
T2.0
40.00
-40.00
[%]
Area Tracking
EDV 86.10 mL 0 msec
ESV 43.74 mL 261 msec
EF 49.20 %
1.05*MV 109.93 g est. LV MASS
CARD 4D Full
1638

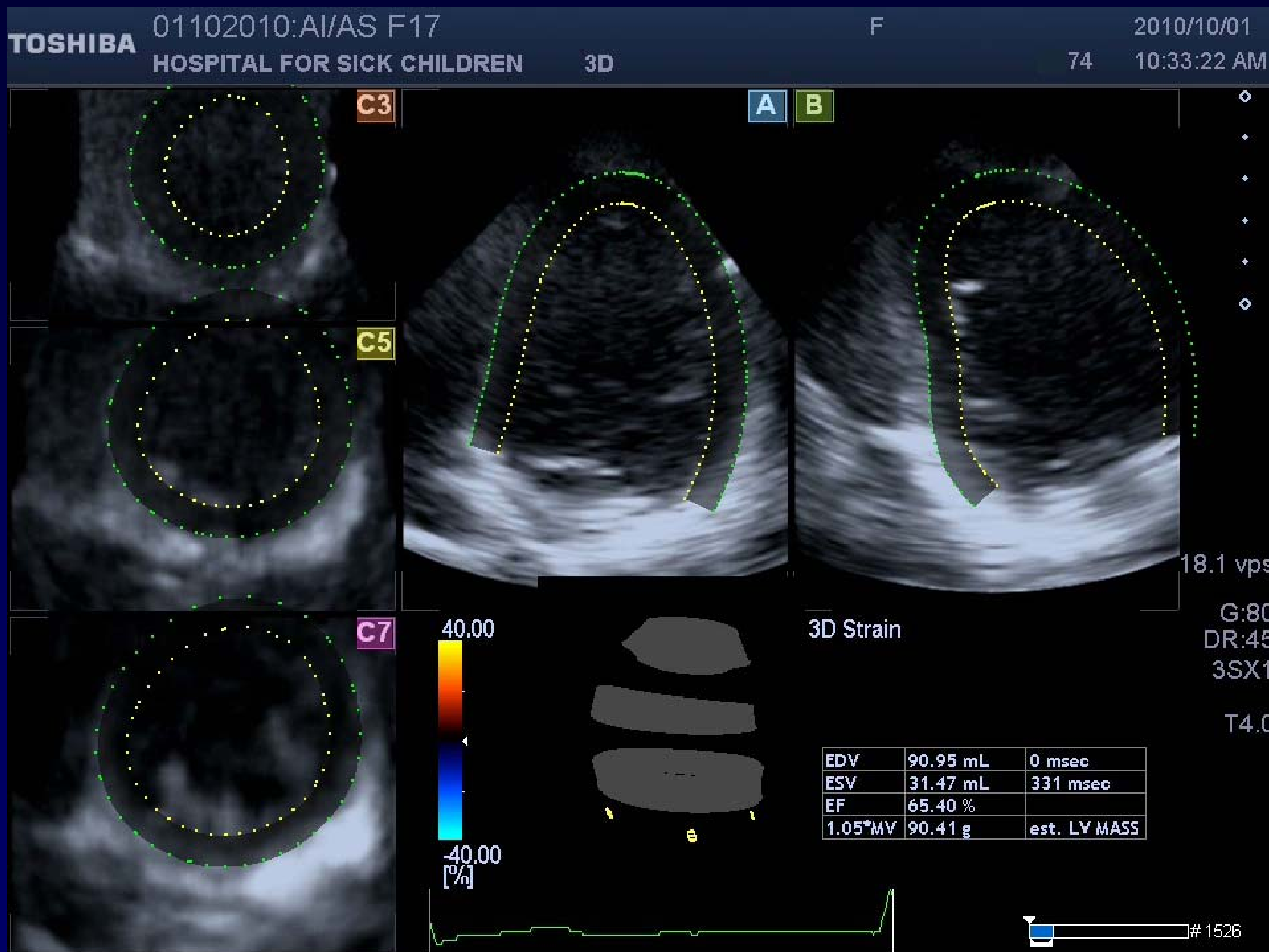
3-D strain


TOSHIBA
[redacted]
M 26
SMH
[redacted]
2010/03/11
101
10:53:34 AM
A
3D Strain
40.00
-40.00
[%]
16.8 vps
G:80
DR:55
3SX1
3.0
EDV 429.11 mL 0 msec
ESV 366.51 mL 298 msec
EF 14.59 %
1.05*MV 351.57 g est. LV MASS
CARD 4D Full

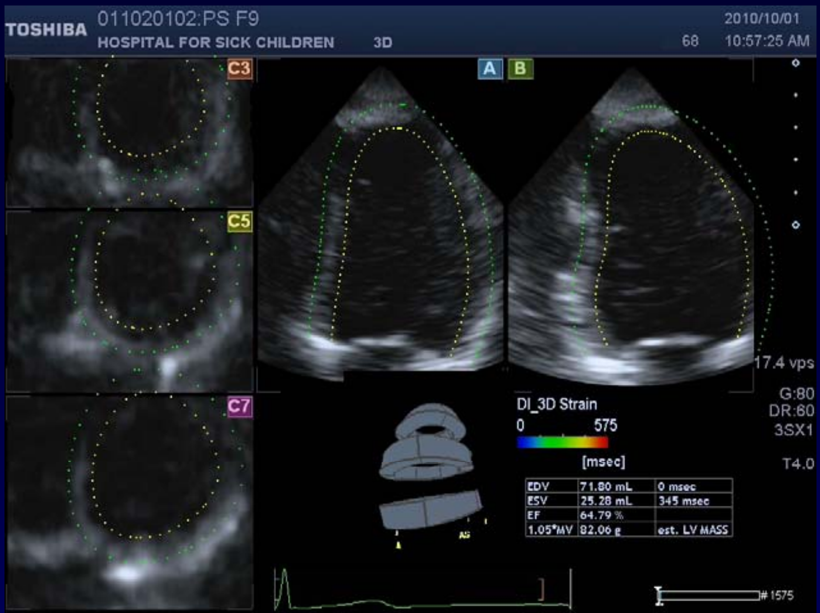
3-D rotation and torsion

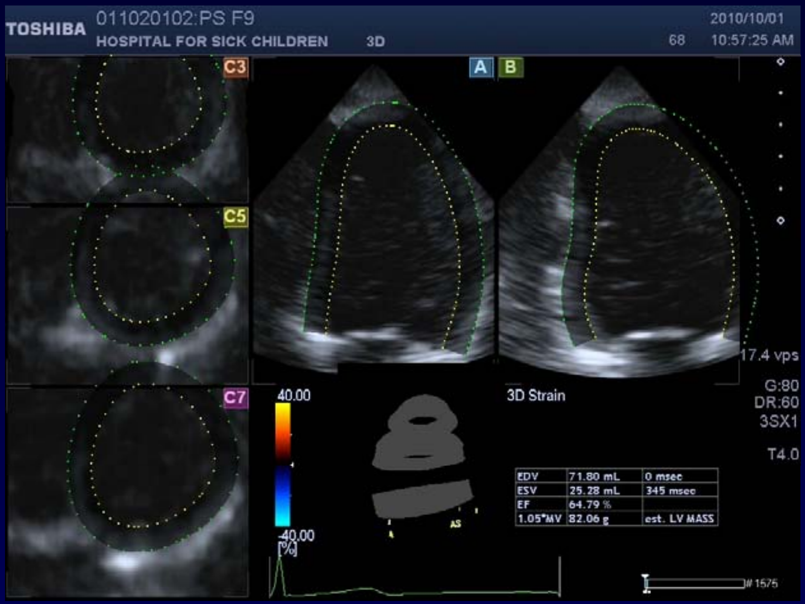


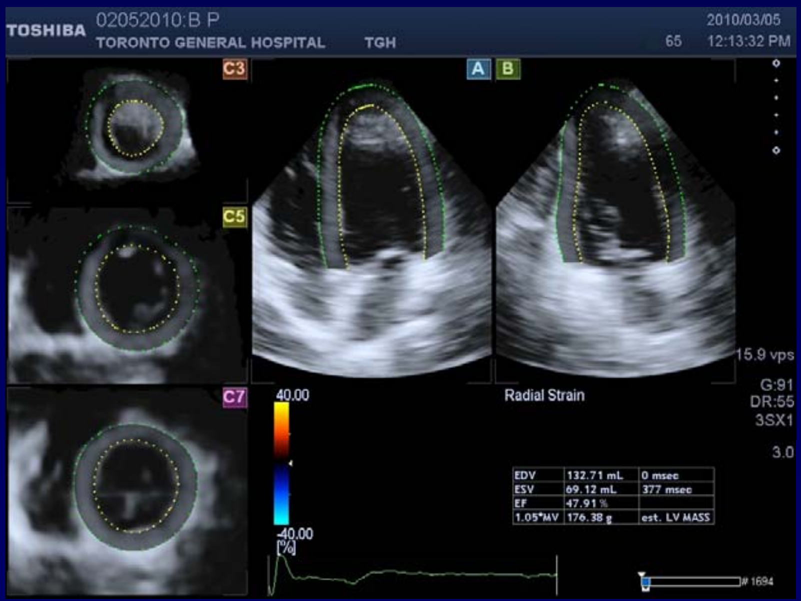
17 year old with AS and AI

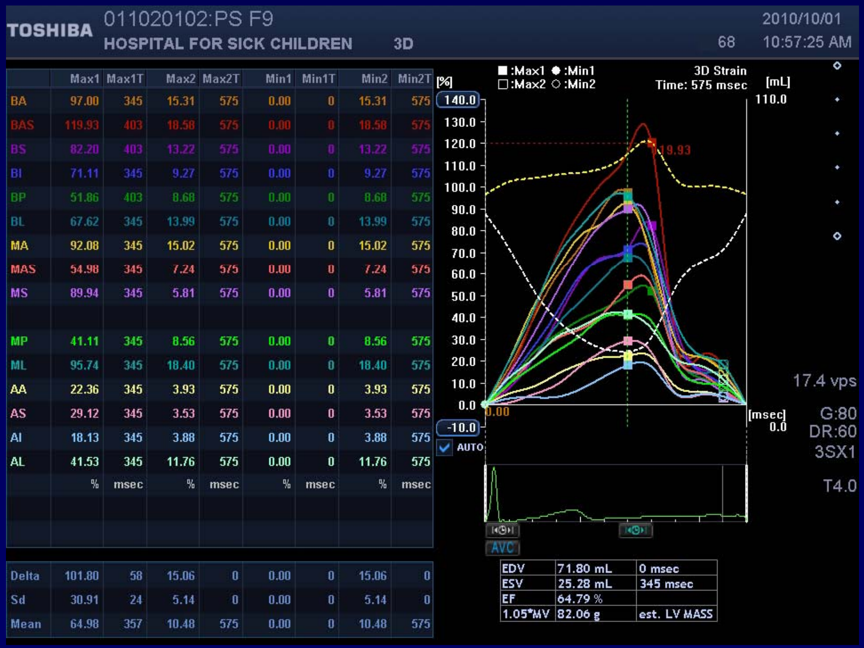


9 yr, girl, pulmonary stenosis









Problems using strain in clinical practice

- Technical acquisition
- Normal values vary between techniques and studies
- Large inter/ intra observer variability
- Large scatter/ variation compared to reference methods
- Conflicting data regarding load-dependency
- Regional vs global function-what and where should we be measuring
- Which method should we be using S/ SR?
- Standardization (eg peak vs mean velocities (colour vs pulsed Doppler)
- Long post-acquisition processing time
- Incorporation of results into clinical decision making
- Data overload but small numbers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CURTIS DEAN
"Yes! That was very loud Sir, but
I said I wanted to hear your *HEART!*"


Thank you!