Strain imaging in pediatric & congenital cardiovascular conditions: Clinical value and utility in decision making

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Conflict of Interest Disclosure

Jamie K. Harrington MD

- I have no financial relationships with a commercial entity producing healthcare-related products and/or services.

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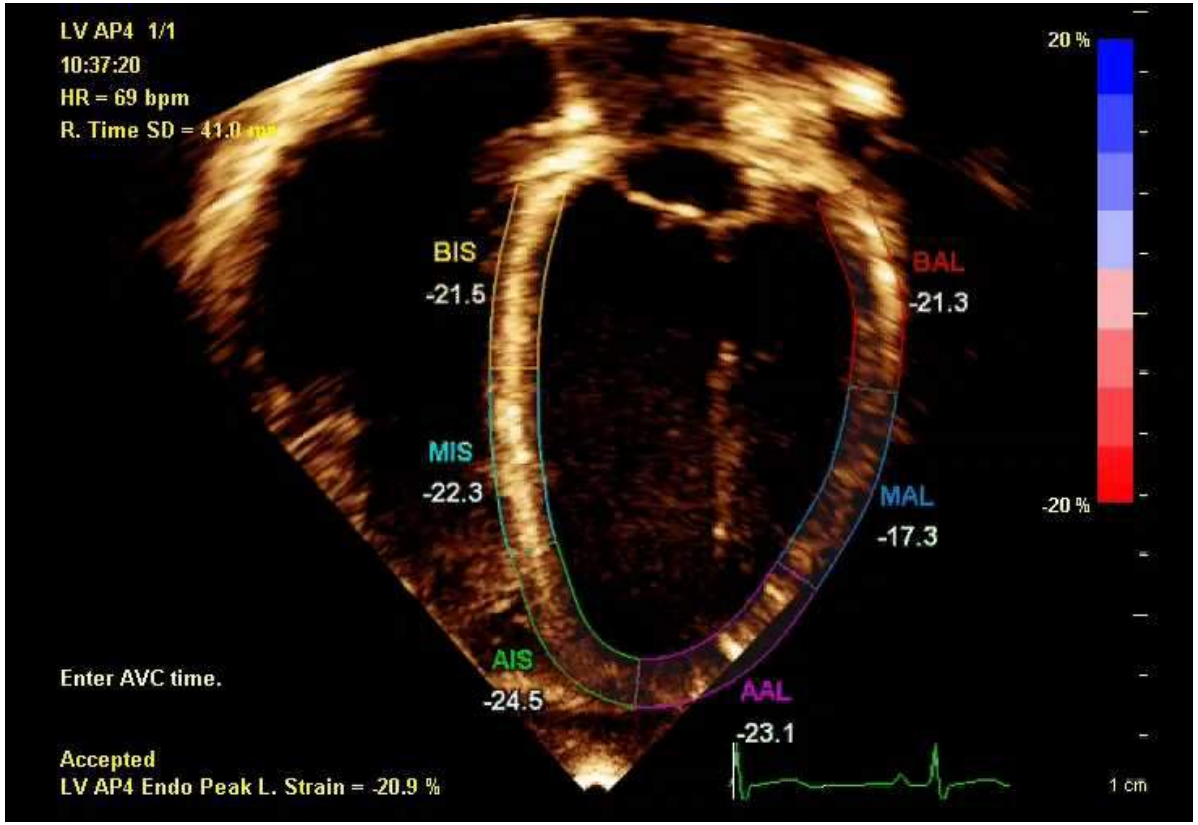
Outline

- Strain Imaging (focus on STE)
  - Advantages
  - Disadvantages
- Adult Guidelines
- Utility in Congenital Heart Disease
  - Tetralogy of Fallot
  - Single Ventricle
- Utility in Acquired Heart Disease
  - Cardiotoxicity
  - Inherited Cardiomyopathy
  - Pulmonary Hypertension



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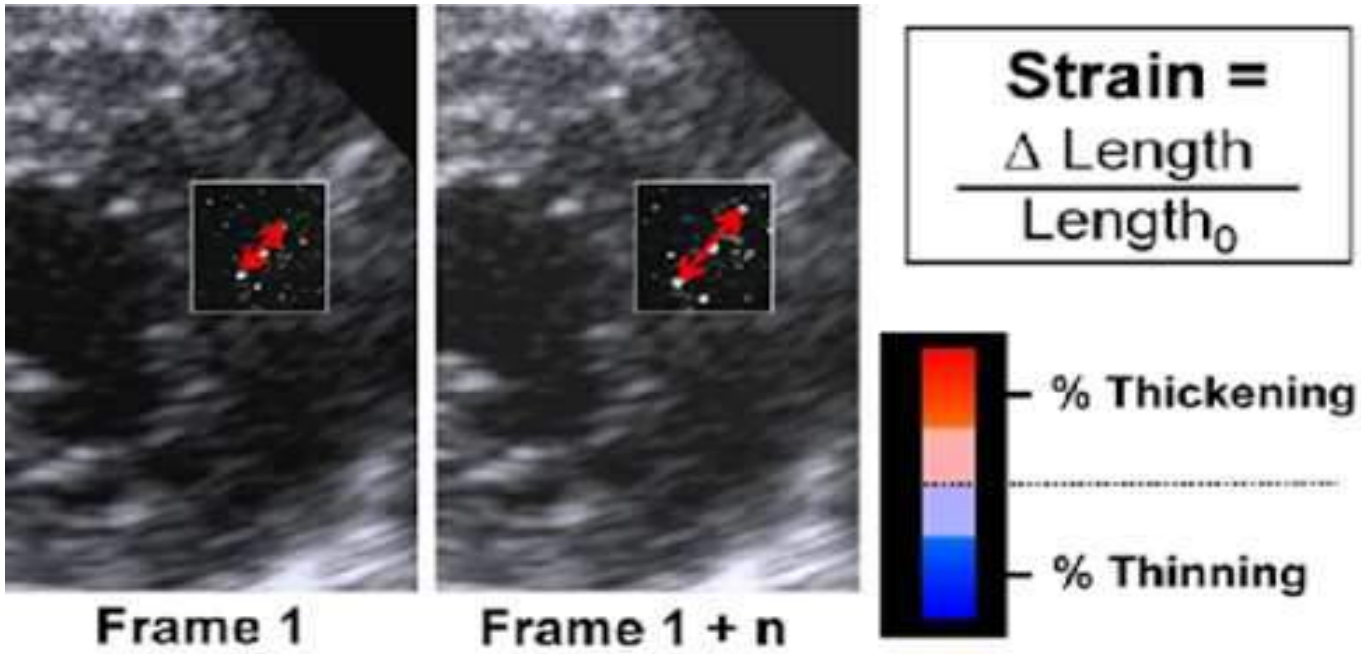
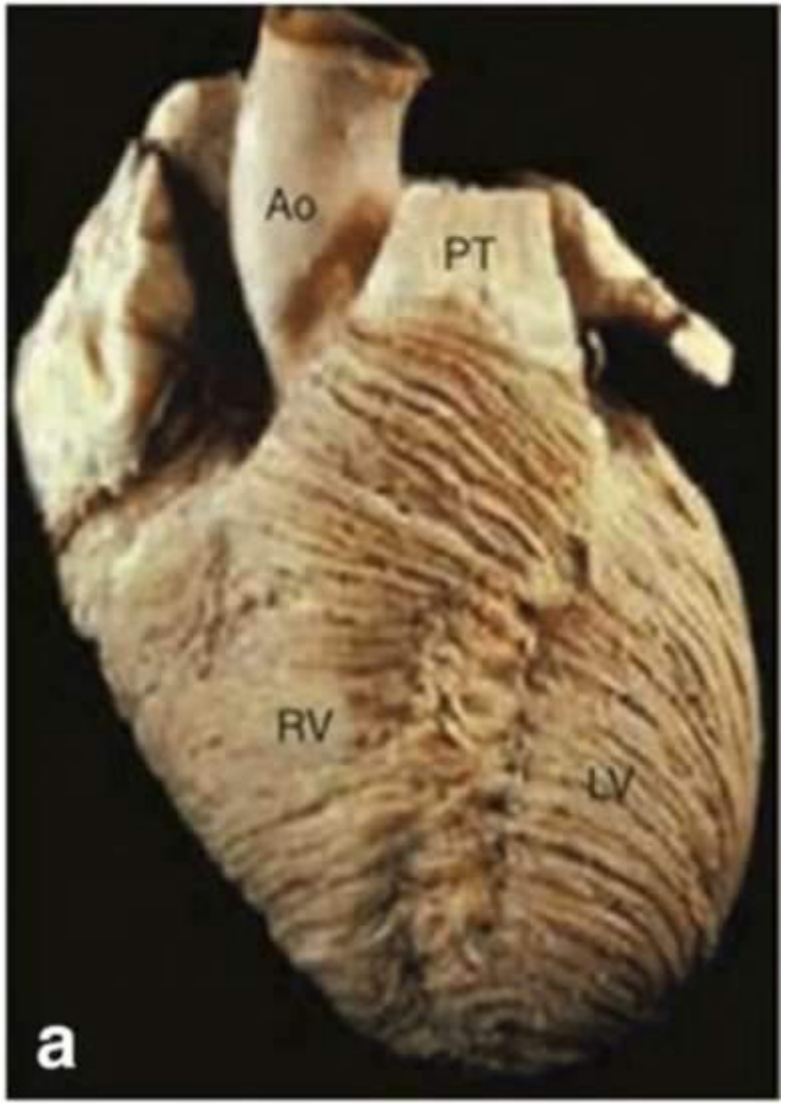
Advantages: Directly Measures Myocardial Fiber Changes



Myocardial speckles in a gray-scale image can be tracked frame-to-frame



Ho et al. Heart 2006

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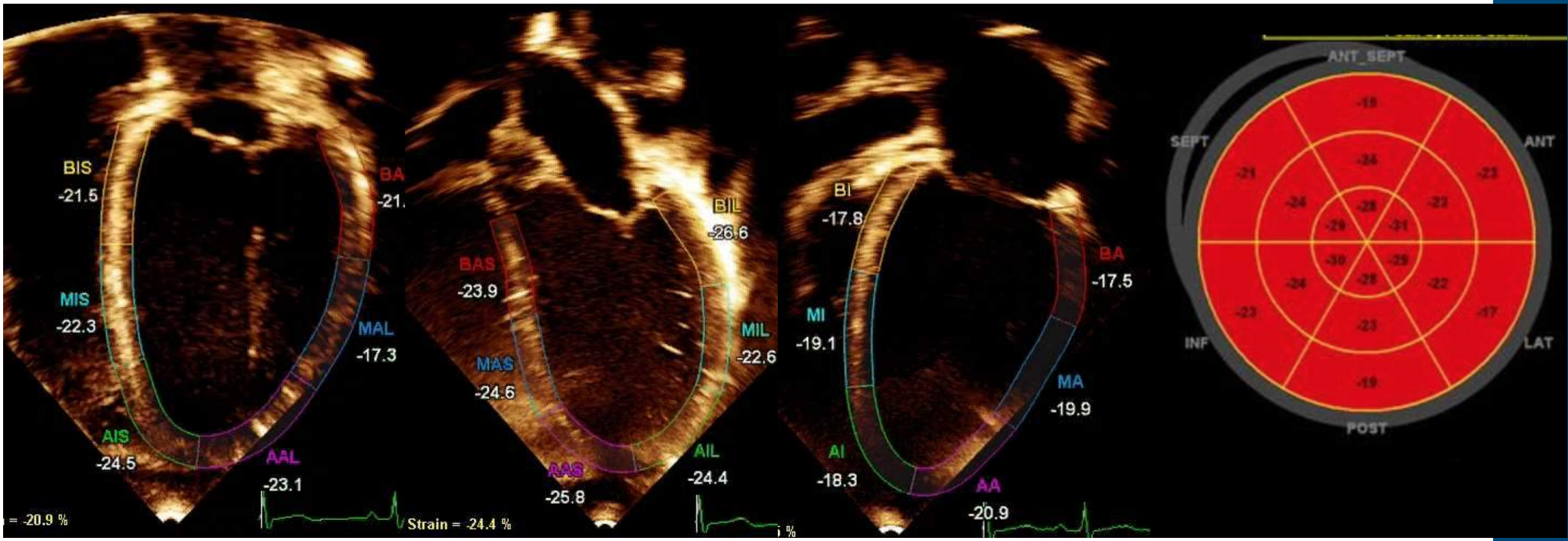
Gorcsan et al. JACC 2011

Advantages: Global & Segmental Strain by STE



4-Chamber **3-Chamber** **2-Chamber** **Bullseye**

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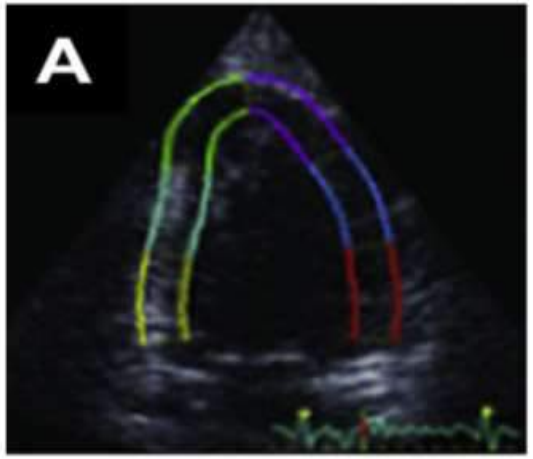
Advantages: Regional Myocardial Mechanics

Segmental Strain

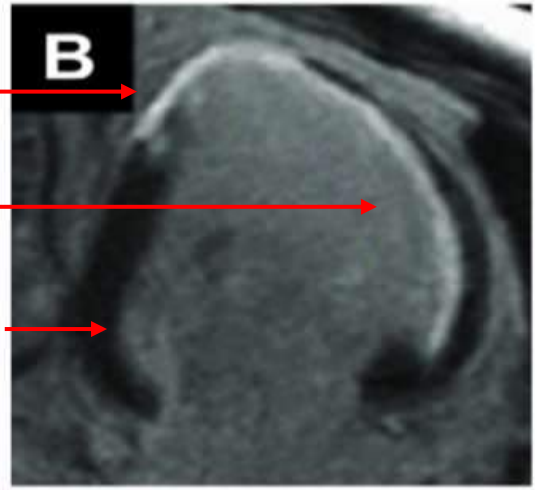


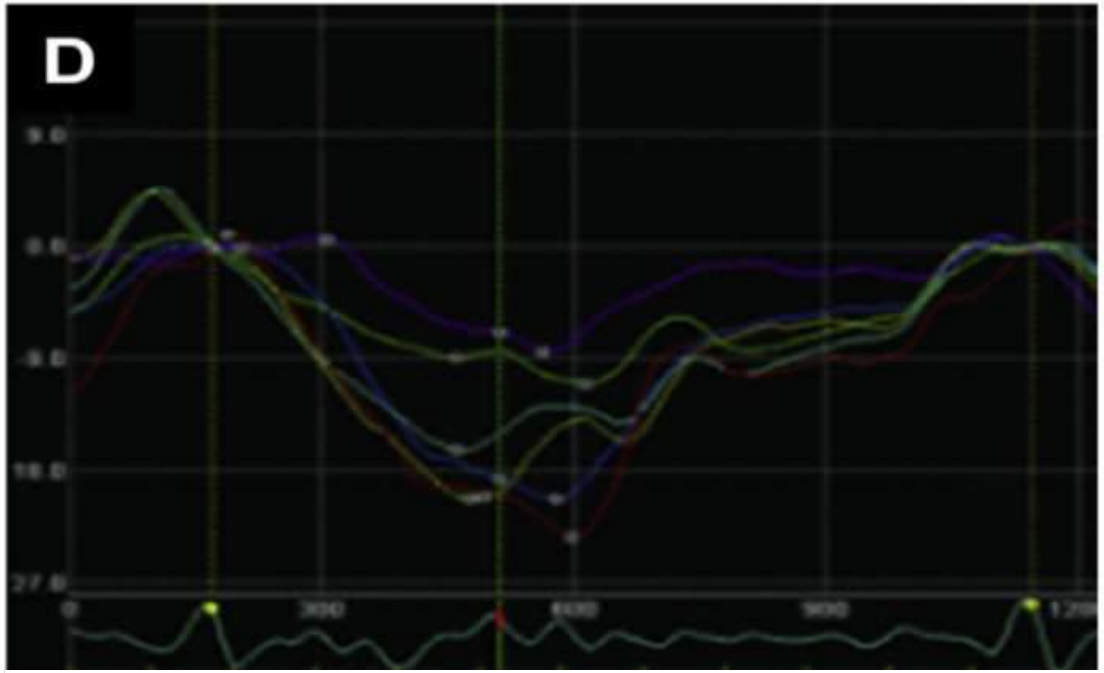
LGE - MRI

Transmural infarct

Subendocardial infarct

Normal myocardium





Green & purple = transmural infarct

Blue & red = subendocardial infarct

Yellow & cyan = normal myocardium

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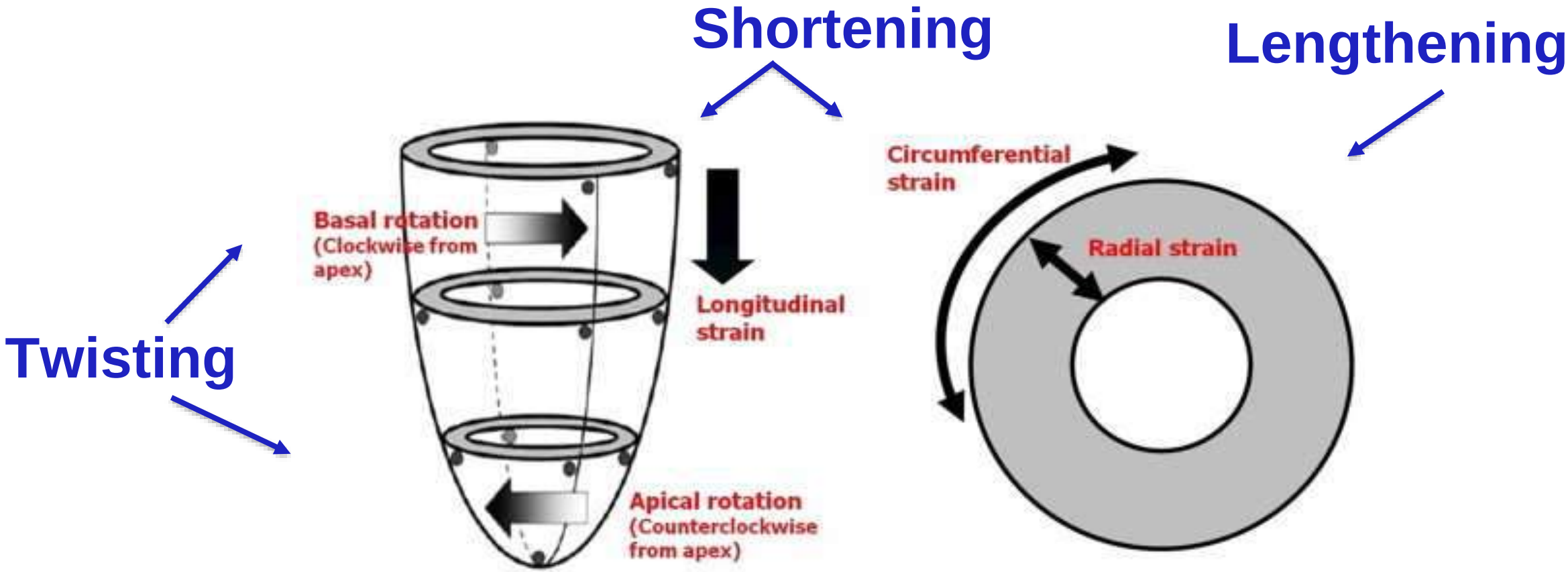
Mor-Avi et al. JASE 2011

Advantages: Can Assess Complex Myocardial Mechanics



EF overlooks these complex mechanics

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Bansal et al. Indian Heart J. 2013

Disadvantages STE

- Good quality 2D gray-scale images are required
- Frame rate must be adequate
  - Ideal 50-90 Hz
  - Most PACS systems store DICOM images at default 30 Hz
- Vendor specific software
  - Different post-processing algorithms from different vendors

Efforts to Reduce Inter-Vendor Variability

European Heart Journal – Cardiovascular Imaging (2015) **16**, 1–11
doi:10.1093/ehjci/jeu184

CONSENSUS PAPER

Definitions for a common standard for 2D speckle tracking echocardiography: consensus document of the EACVI/ASE/Industry Task Force to standardize deformation imaging

Jens-Uwe Voigt[1†], Gianni Pedrizzetti[2,3†], Peter Lysyansky[4†], Tom H. Marwick[5], Helen Houle[6], Rolf Baumann[7], Stefano Pedri[8], Yasuhiro Ito[9], Yasuhiko Abe[10], Stephen Metz[11], Joo Hyun Song[12], Jamie Hamilton[13], Partho P. Sengupta[3], Theodore J. Kolias[14], Jan d'Hooge[1], Gerard P. Aurigemma[15], James D. Thomas[16‡], and Luigi Paolo Badano[17‡*]

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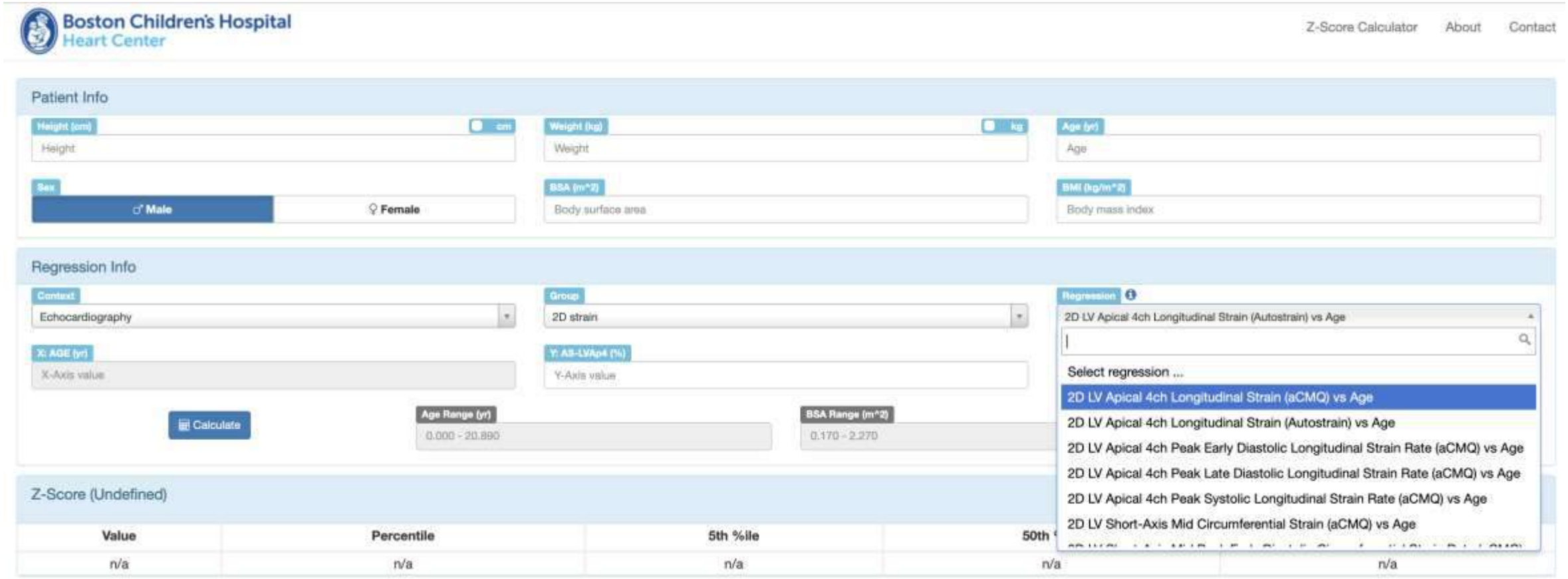
Widespread Use and Interpretation



https://zscore.chboston.org/

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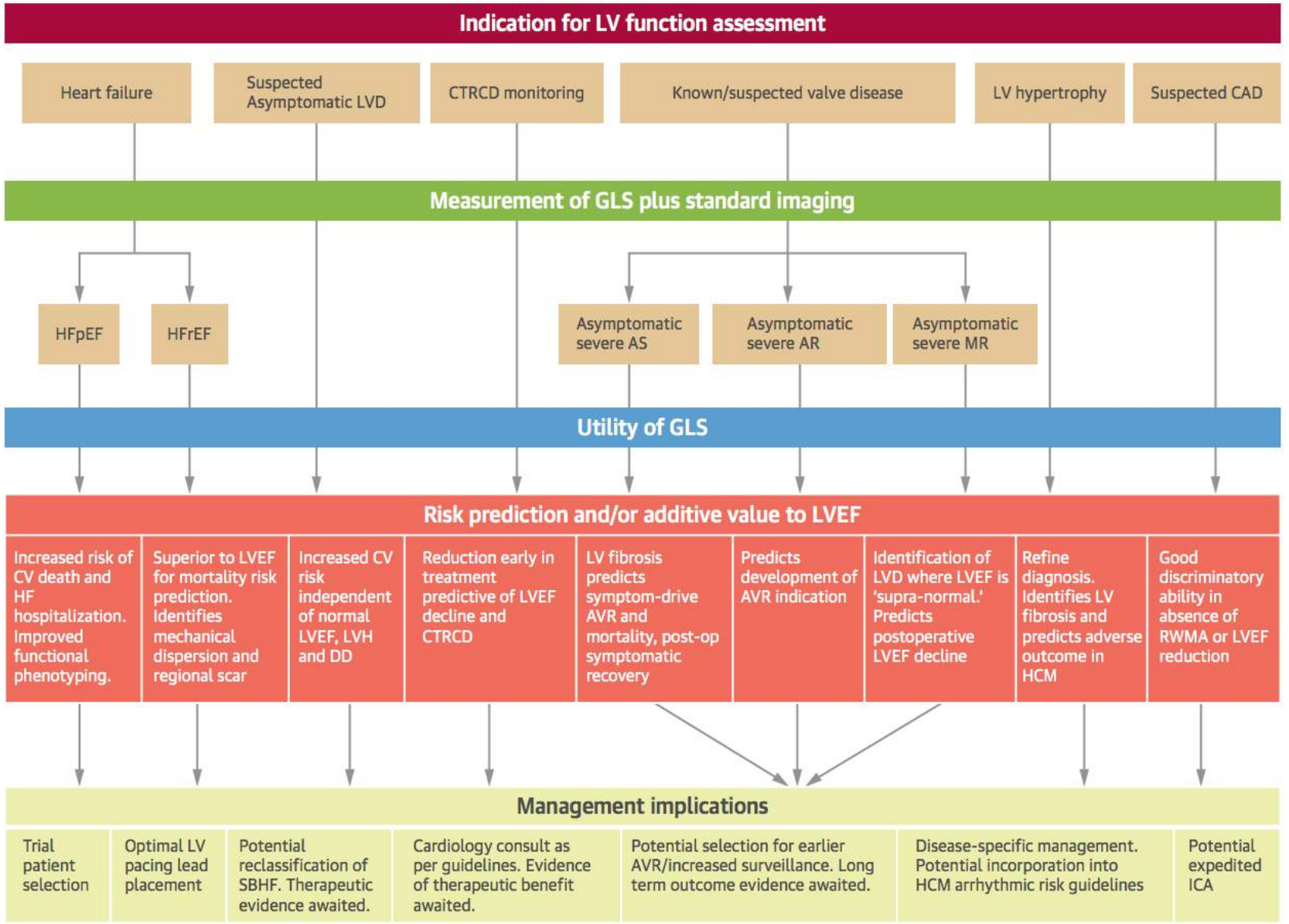
CENTRAL ILLUSTRATION **Prognostic and Management Implications of Abnormal Strain Measurement in Common Clinical Scenarios**



Potter, E. et al. J Am Coll Cardiol Img. 2018;11(2):260-74.

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Repaired Tetralogy of Fallot

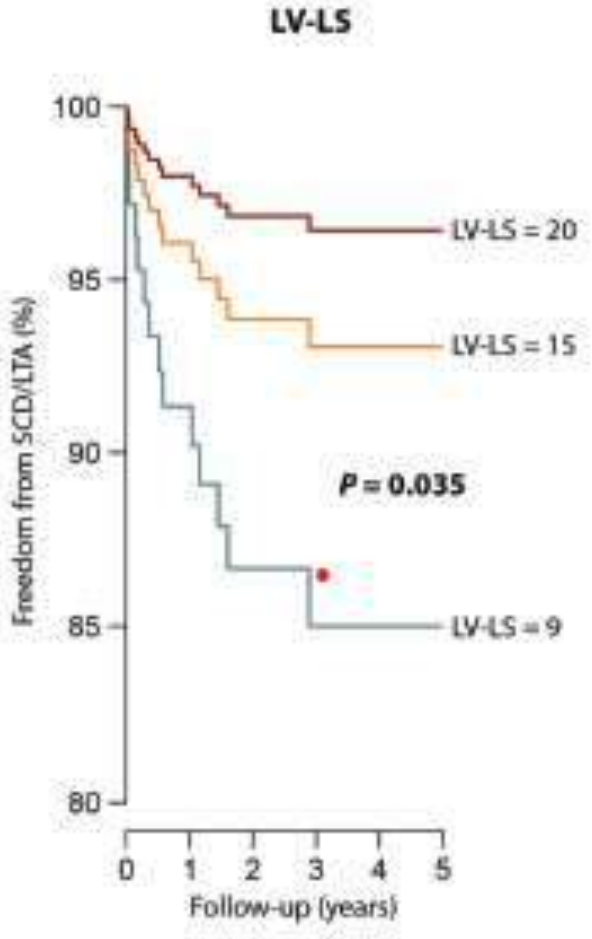
- Strain imaging shows impaired cardiac mechanics in rTOF
  - Reduction in strain prior to reduction in EF
  - Abnormal rotational mechanics
  - Abnormal VV interaction
  - Abnormal atrial mechanics
- Ventricular myocardial mechanics are associated with EF and dyssynchrony
- Emerging data suggests a prognostic value of strain imaging in rTOF

Li et al. JASE 2020;33:788-801

Strain in rTOF: Clinical Utility

Adverse Cardiovascular Events

- Diller et al. Circulation 2012
  - LV GLS (2DSTE) related to composite endpoint of SCD/life-threatening arrhythmia
  - LV EF not significant on univariate analysis
  - LV GLS a/w significantly greater risk of endpoint
  - LV GLS <15%, RA area >20cm2, RV FAC <32%
    (HR per unit, 2.74; 95%CI, 1.75–4.30; P<0.0001)



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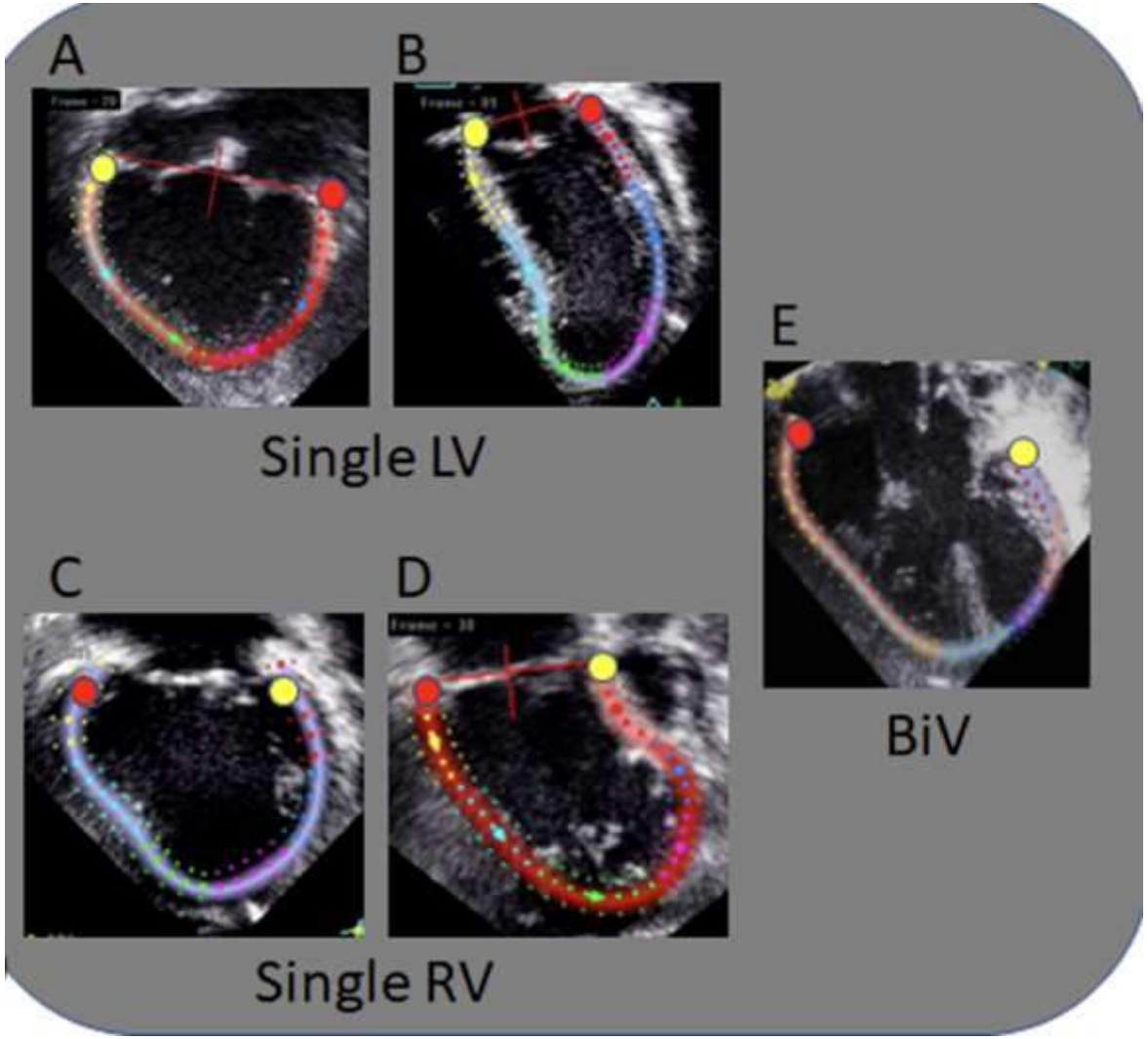
Strain in rTOF: Clinical Utility

Exercise Performance

- Alghamdi et al. Eur Heart J Cardiovasc Imaging 2013
  - RV LS (2DSTE) had strongest correlation with maximum O2 consumption (r = 0.66, P = 0.0001)
  - Correlation with RV/LV EF, RV vol, RV SV, RV OT vol and EF were weak or absent

Single Ventricle Patients

- Appealing method for serial function assessment
  - abnormal SV geometry
  - ability to assess RV and LV global and regional function
- Characterization of SV mechanics throughout SV palliation
- Minimal work on prognostic value



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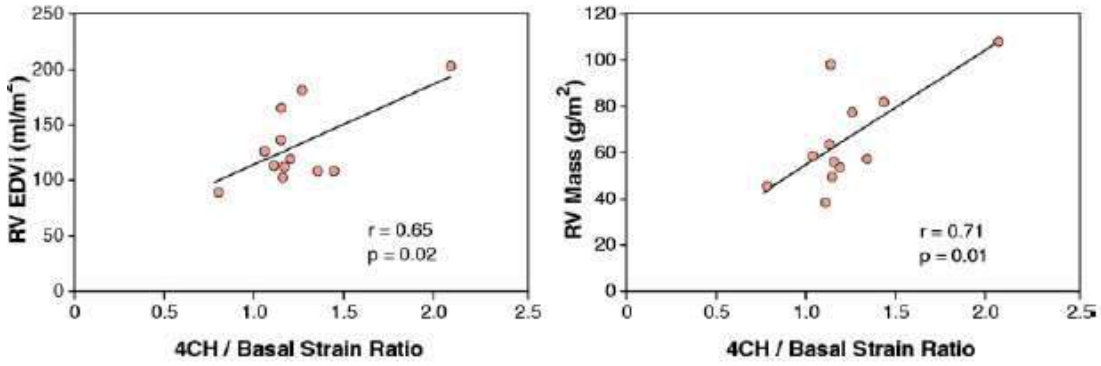
Goudar et al. Cardiology in the Young 2022

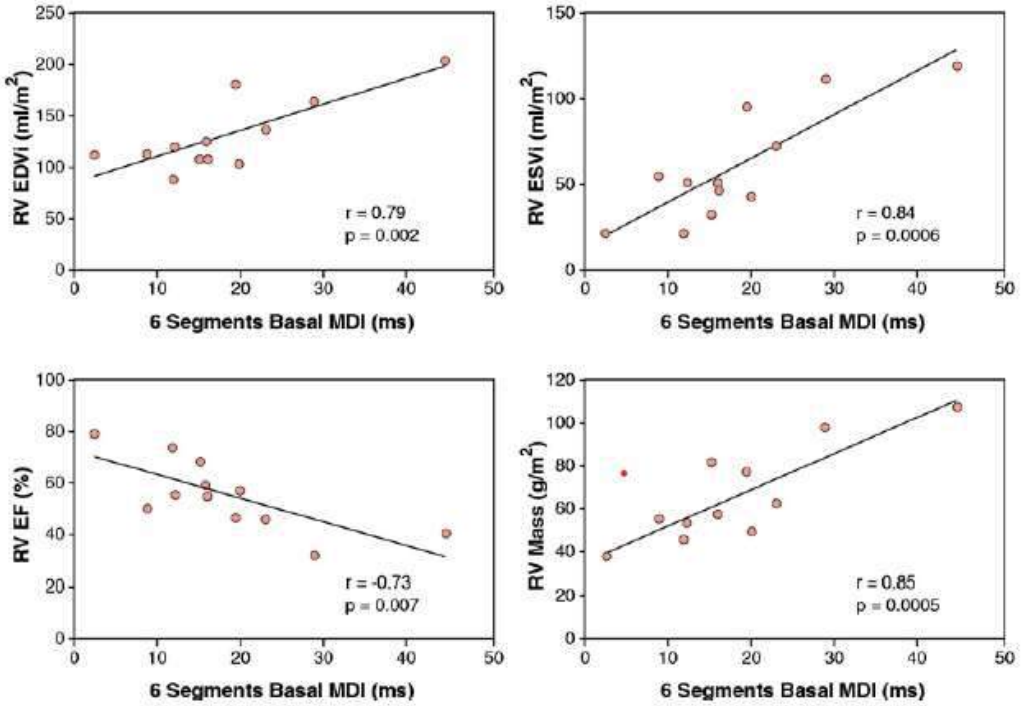
Strain in HLHS: RV Function Adaptation

- RV contraction becomes more circumferential (more similar to LV)
- This correlates with decreased dyssynchrony, RV mass and volume.



Less circumferential adaptation

Positive correlation: MDI with RV size and mass
Negative correlation: MDI with RV EF



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Khoo et al. JACC Imaging 2011;4:128-37

Strain in Cardiotoxicity in Children 2022 Systemic Review and Meta-Analysis

1

LV strain is impaired in children during treatment and among long-term survivors.

- RV strain changes are not well characterized.

2

Cumulative anthracycline dose and chest RT are associated with impaired myocardial strain.

3

Limited data suggests impaired LV contractile mechanics during stress in CCS.

4

Predictive value of early reduction in strain in development of cardiotoxicity is unknown.

Li et al. JASE 2022;35:629-56.

Strain in Inherited Cardiomyopathies in Children 2021 Systemic Review

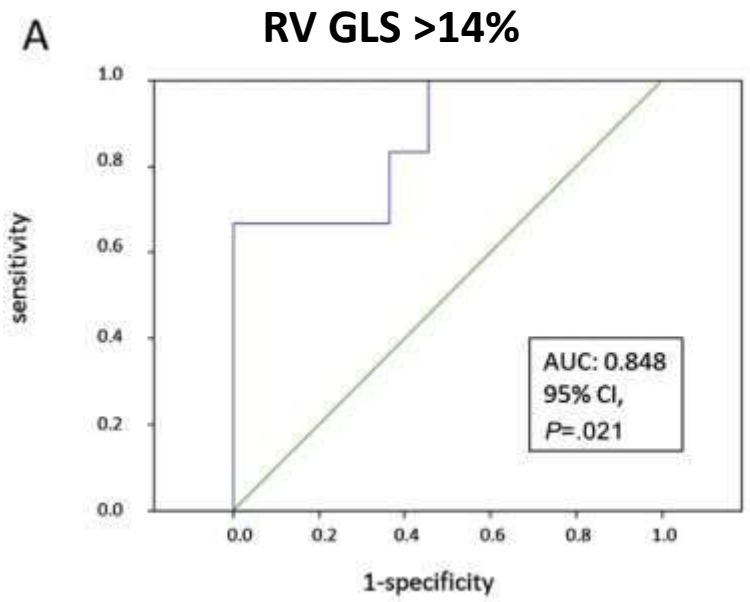
- Overall limited data on the use of STE.
- Early changes measurable by STE w/wo abnormal systolic/diastolic function by non-STE methods.
- Need for protocol standardization in measurements and reporting.
- Reasonable to report longitudinal strain aside conventional systolic function parameters.
- Stringent need for prospective, longitudinal studies in children to determine exact benefit of adding STE to SOC.

Dorobantu et al., Diagnostics 2021, 11, 635

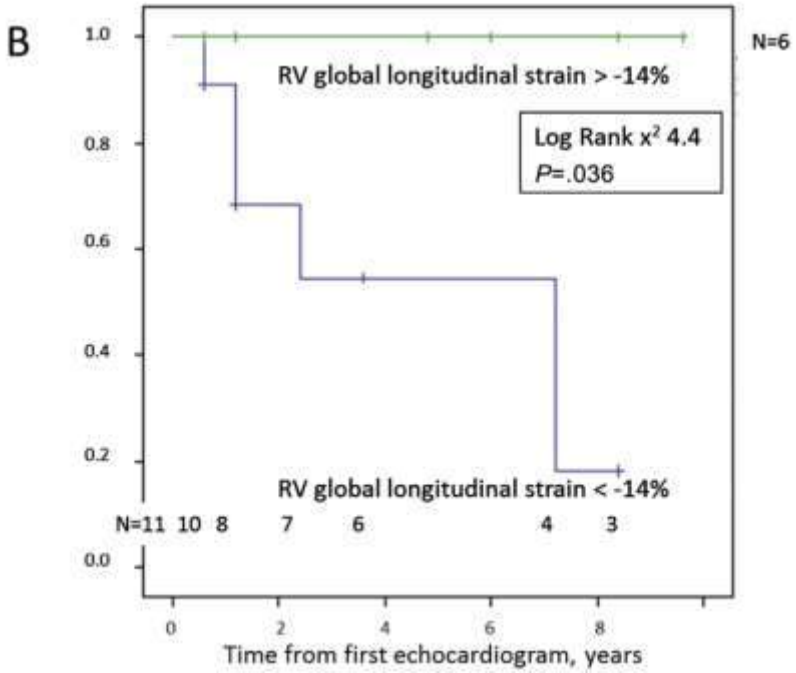
Pulmonary Hypertension

RV GLS > 14% predicted transplantation-free survival with 100% sensitivity and 54.5% specificity

55% specificity



100% sensitivity



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Okumura et al. JASE 2014;27:1344-51.

Summary

Strain can provide a more comprehensive assessment of cardiac mechanics than other functional measures.

Strain parameters provide additional insight into mechanism of dysfunction.

Strain has been shown to reliably monitor function and is increasingly being used as a routine part of functional assessment.

More work is needed to show prognostic value and clinical utility to current SOC function assessment.

Future Directions

- Routine use in more types of congenital and acquired heart disease
- Research about prognostic implications of strain in children
- Incorporation into imaging guidelines in children
- Reduce inter-vendor variability & standardize normal values in children

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Thank You!
Questions?

SRV

Table 3. Comparison of STI Parameters at Pre-Norwood and Pre-BCPA Examinations

Variables	Pre-Norwood Median {25th, 75th Quartile}	Pre-BCPA Median {25th, 75th Quartile}	p Value
Basal circumferential variables			
Peak strain, %	−10.8 {−13.9, −8.5}	−13.6 {−15.2, −11.3}	NS
Peak systolic strain, %	−10.6 {−13.4, −7.6}	−10.8 {−14.8, −8.2}	NS
Time-to-peak strain, %	106 {95, 117}	114 {108, 129}	0.006
Post-systolic strain index	0.01 {0.00, 0.08}	0.08 {0.03, 0.25}	0.005
Peak strain rate, %/s	−1.26 {−1.44, −0.91}	−0.92 {−1.03, −0.78}	0.0003
Basal 6 segment MDI, %	21 {16, 32}	16 {12, 23}	0.009
4CH longitudinal variables			
Peak strain, %	−18.3 {−20.7, −16.2}	−16.2 {−18.3, −13.5}	<0.05
Peak systolic strain, %	−18.1 {−20.6, −15.9}	−14.5 {−16.5, −12.4}	0.009
Time-to-peak strain, %	101 {98, 104}	112 {106, 119}	0.0002
Post-systolic strain index	0.01 {0.00, 0.02}	0.05 {0.01, 0.12}	<0.0001
Peak strain rate, %/s	−1.63 {−2.00, −1.27}	−0.90 {−1.13, −0.76}	<0.0001
4CH 6-segment MDI, (%)	23 {15, 26}	16 {11, 18}	<0.0001
4CH/basal strain ratio	1.56 {1.47, 2.10}	1.15 {1.10, 1.40}	0.001

MDI = mechanical dyssynchrony index; STI = speckle tracking imaging; 4CH = 4-chamber; 4CH/basal strain = ratio of longitudinal/circumferential strain; other abbreviations as in Table 1.

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Khoo et al. JACC Imaging 2011;4:128-37

SRV vs. SLV

Table 5 Circumferential strain variables showing comparisons between the patients with SRVs and those with SLVs of the whole group (boldface) and at each surgical stage

Variable	SRV	SLV	*P*
Strain (%)	**−13.4 (−25.2 to −4.3)**	**−14.9 (−28.3 to −7.6)**	**NS**
Pre-BCPA	−15.1 (−19.2 to −9.2)	−14.2 (−28.3 to −7.6)	NS
Pre-Fontan	−13 (−19.5 to −10.3)	−14.4 (−20.1 to −7.9)	NS
Post-Fontan	−10.7 (−25.2 to −4.3)	−16.0 (−24 to −9.6)	NS
SR (%/sec)	**−1.0 (−1.8 to −0.7)**	**−1.2 (−2.0 to −0.6)**	**.01**
Pre-BCPA	−1.0 (−1.4 to −0.9)	−1.3 (−2.0 to −0.6)	NS
Pre-Fontan	−0.9 (−1.4 to −0.7)	−1.2 (−1.4 to −0.7)	NS
Post-Fontan	−1.0 (−1.8 to −0.7)	−1.3 (−1.6 to −0.9)	NS
PSSi (%)	**8 (0 to 33)**	**0 (0 to 12)**	**<.0001**
Pre-BCPA	8 (2 to 33)	0 (0 to 11)	.01
Pre-Fontan	8 (0 to 22)	3 (0 to 9)	NS
Post-Fontan	7.5 (0 to 25)	0 (0 to 12)	NS
MDI (%)	**19.5 (2.4 to 38.5)**	**15.2 (7.0 to 38.0)**	**NS**
Pre-BCPA	15.0 (2.4 to 23.6)	13.8 (7.0 to 38.0)	NS
Pre-Fontan	18.9 (15.2 to 38.5)	15.6 (10.5 to 37.0)	NS
Post-Fontan	26 (3.0 to 37.7)	19.9 (7.7 to 27.4)	NS
EDSR (%/sec)	**1.4 (0.4 to 2.3)**	**1.9 (0.7 to 3.4)**	**.03**
Pre-BCPA	1.6 (1.1 to 2.2)	1.7 (0.8 to 3.4)	NS
Pre-Fontan	1.3 (0.9 to 2.0)	1.8 (0.7 to 2.9)	NS
Post-Fontan	1.3 (0.4 to 2.3)	2.0 (0.7 to 3.3)	NS

MDI, Myocardial dyssynchrony index.
Data are expressed as median (range).

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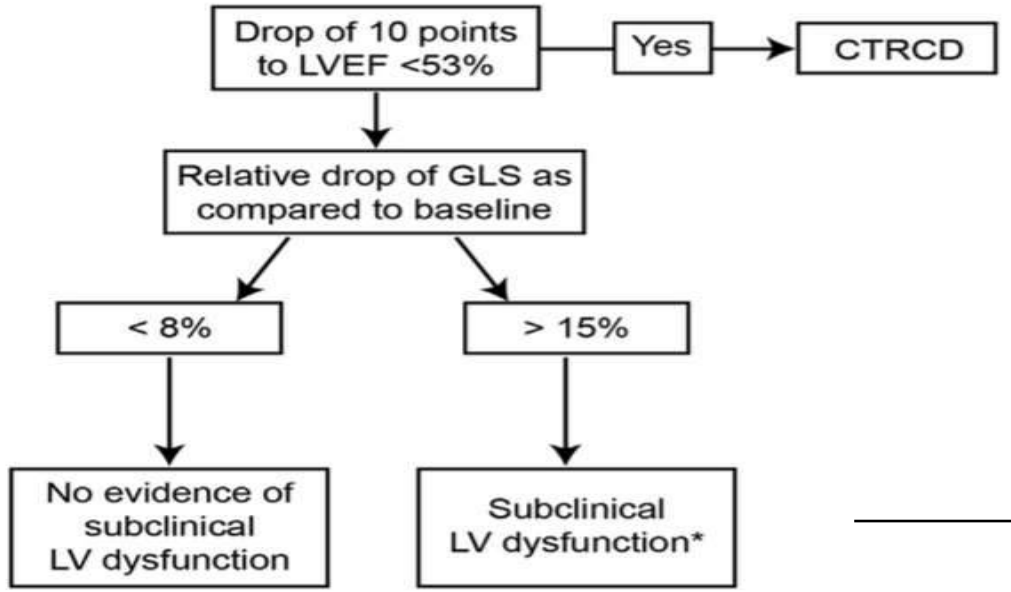
Kaneko et al. JASE 2012;25:1222-30

Adult Imaging in Cancer Therapy Consensus Statement

Plana JC et al. Expert consensus for multimodality imaging evaluation of adult patients during and after cancer therapy: a report from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr* 2014;27:911-939.



Cardiology Consultation

* The data supporting the initiation of cardioprotection for the treatment of subclinical LV dysfunction is limited.

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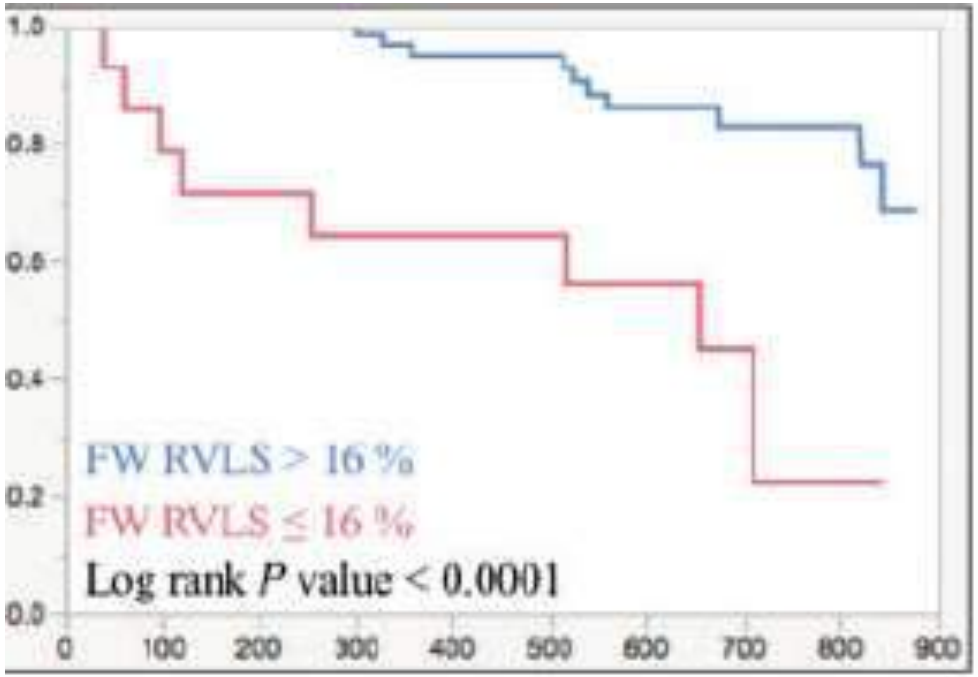
RV FWS Predicts Adverse Events in Pediatric PH

RV FWS ≤ 16%



RV FWS ≤ 16% as significant associated with increased risk of clinical events.

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Jone et al., Eur Heart J. 2018;19:1026-1033