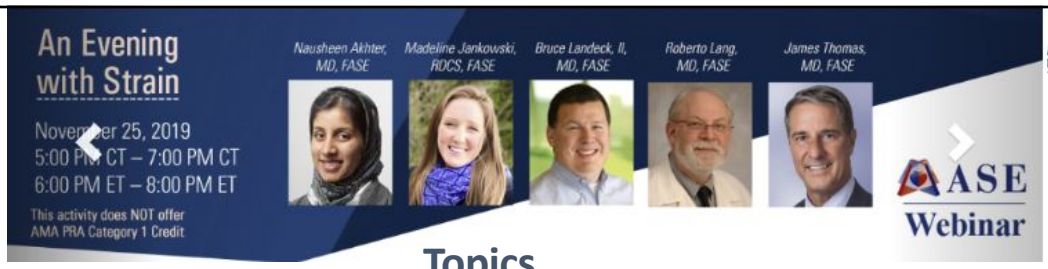
An Evening with Strain

Expert Advice on How and When to Integrate Strain into an Echocardiography Study

James D. Thomas, Madeline Jankowski, Nausheen Akhter, Roberto Lang, Bruce Landeck, II

1



Topics

- Physics and instrumentation
- Intervendor agreement
- Tips & tricks for acquisition
- Q&A
- Cardio-oncology
- Coronary disease & heart failure
- Q&A
- Valvular heart disease
- RV & pulmonary hypertension
- Pediatrics and congenital heart disease
- Q&A
- Concluding remarks

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Physical Meaning and Principles of Strain

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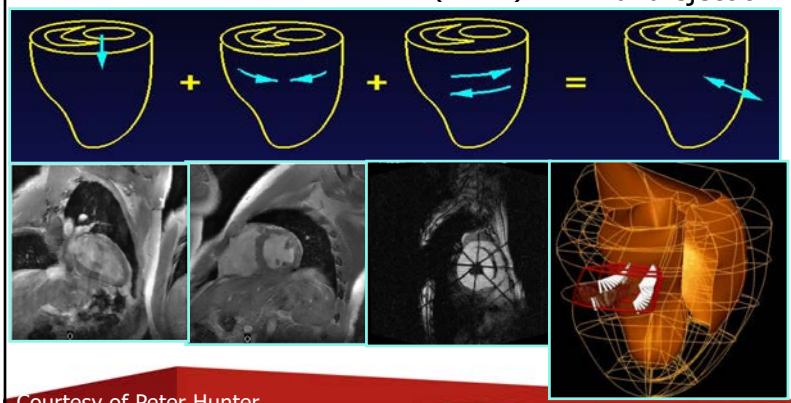
Conflicts of interest: GE, Abbott, Edwards, Caption Health (honoraria)
Caption Health (spouse employment)

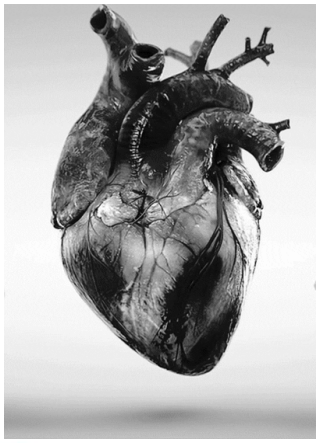
3

Mechanics of the Heart

Complex combination of deformation (strain) to produce ejection

base-apex shortening | circumferential shortening | axial twist (shear) | wall thickening and ejection





Courtesy of Peter Hunter

Nash MP and Hunter PJ. *J. Elasticity.* 61(1-3):113-141, 2001

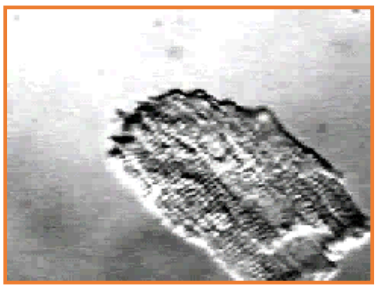
4

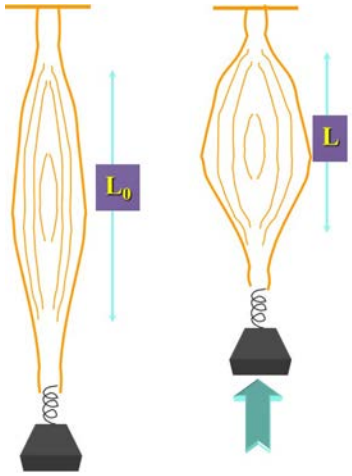
Myocardial Strain: What is It??

Strain: dimensionless index of change in length

Strain (ε) = $L-L_0/ L_0$

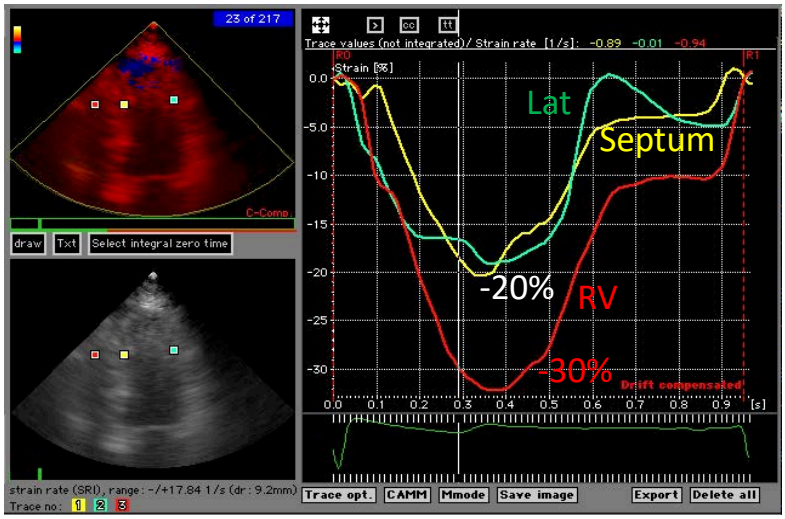
LV strain may offer a pure index of regional LV function but is difficult to measure





5

Strain Can be Calculated from Tissue Doppler



Limitations of TDI Strain

Detects only single component of strain

Limited scope of imaging

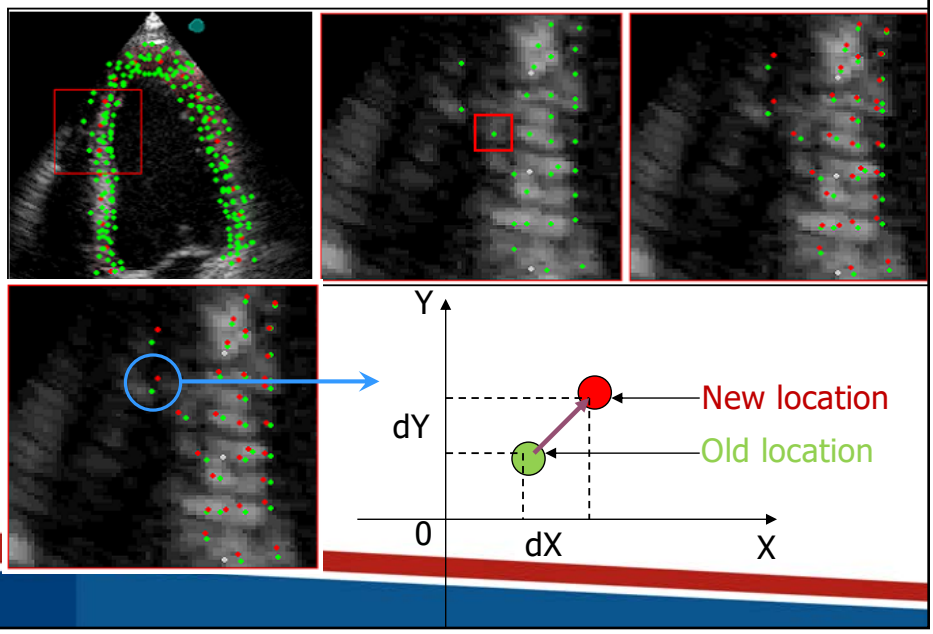
Subject to noise, particularly strain rate

Very tedious to perform

6

Deriving strain directly from the B-mode image

Tracking patterns of speckles caused by ultrasound interference with small structures



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Not a New Idea, Just Better Implementation

COMPUTERS IN CARDIOLOGY 1988

LOCAL MYOCARDIAL DEFORMATION COMPUTED FROM SPECKLE MOTION

Jean Meunier, Michel Bertrand, Guy E. Mailloux and Robert Petitclerc

Ecole Polytechnique, C.P. 6079, Station "A"
and Institut de Cardiologie, 5000 Belanger E.,
Montreal, H1T 1C8, CANADA

Fig. 2 A typical echocardiographic image (short axis view) and two successive frame ROI after lowpass filtering near end-diastole.

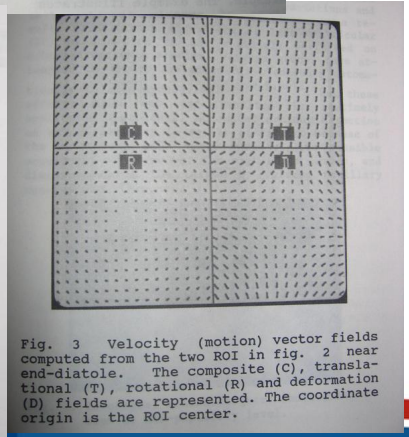

Fig. 3 Velocity (motion) vector fields computed from the two ROI in fig. 2 near end-diatole. The composite (C), translational (T), rotational (R) and deformation (D) fields are represented. The coordinate origin is the ROI center.

You just couldn't make this work on video tape at 30 Hz. You needed digital images at higher frame rates

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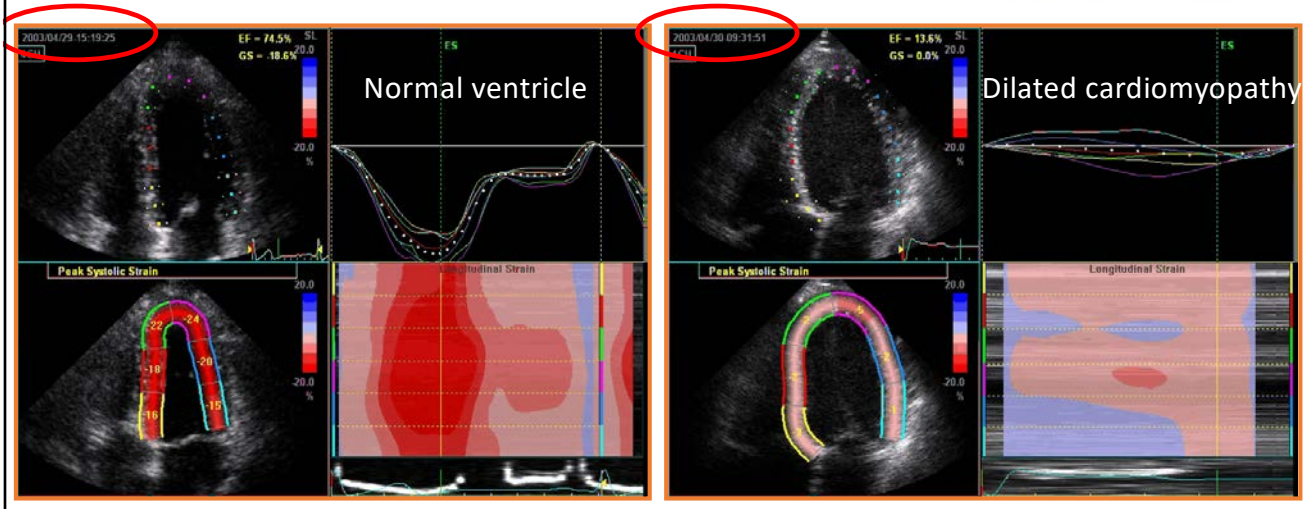
Longitudinal Strain from B-Mode Echoes



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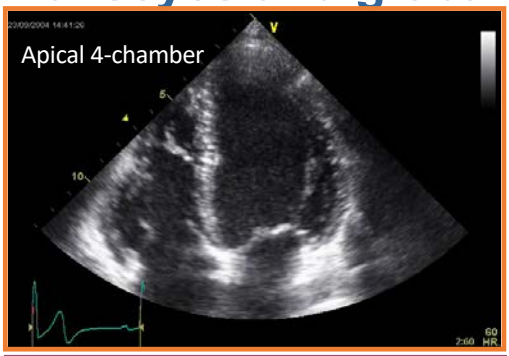
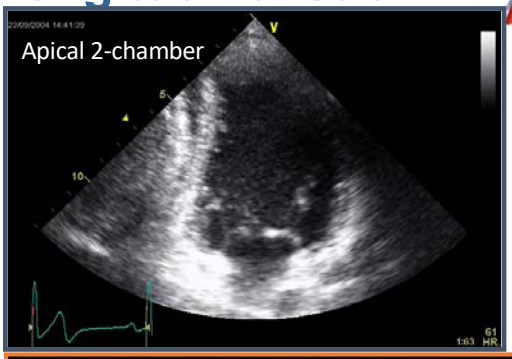
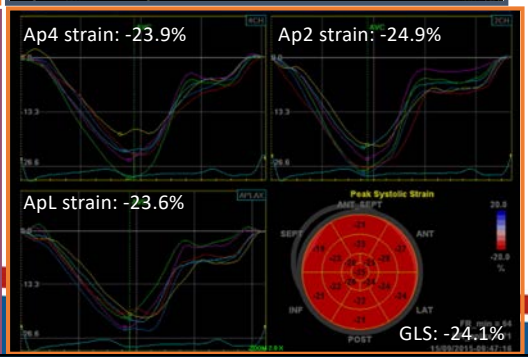
Bullseyes and global longitudinal strain







Global longitudinal strain (aka GLS) reflects the average shortening from the three views and is the most commonly reported strain parameter. It is a negative number but "increase" or "decrease" by convention refers to distance from zero.

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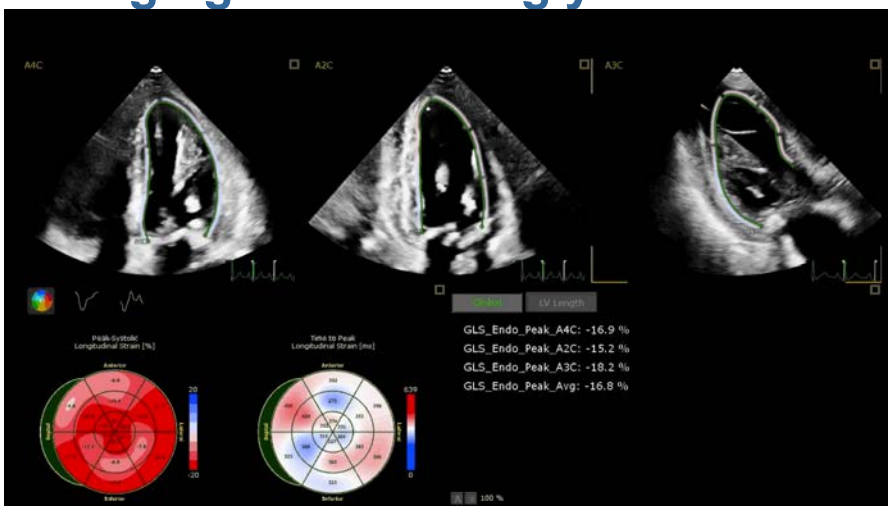
Strain imaging is increasingly automated



Identify 3 apical views, and the software does the rest

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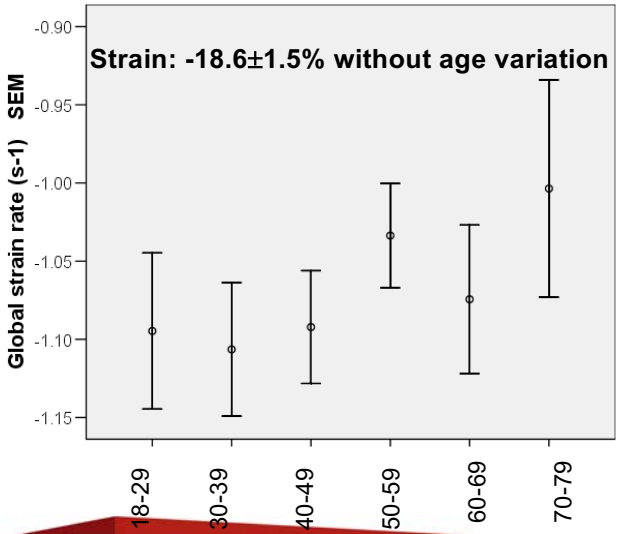
Normal Global Strain and Strain Rate by Age

242 Patients in Cleveland, Brisbane, and Aachen



Marwick et al. JACC Imaging 2009; 2: 80-84

From the Chamber Quantification Guideline

Recommendations. LV systolic function should be routinely assessed using 2DE or 3DE by calculating EF from EDV and ESV. LV EFs of <52% for men and <54% for women are suggestive of abnormal LV systolic function. Two-dimensional STE-derived GLS appears to be reproducible and feasible for clinical use and offers incremental prognostic data over LV EF in a variety of cardiac conditions, although measurements vary among vendors and software versions. To provide some guidance, a peak GLS in the range of −20% can be expected in a healthy person, and the lower the absolute value of strain is below this value, the more likely it is to be abnormal.

- **GLS below -16% is abnormal in most circumstances**
- **Between -16% and -17% borderline**
- **It's a continuum so cut-offs are less meaningful**

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Can We Estimate EF from Strain?
Kinda Sorta, but Why Would We Want To?

Several papers have tried to generate regression equations for EF from GLS

But why not just measure the EF?

- Lots of progress making LV volumes more accurate and reproducible (3D, contrast)

GLS is most interesting when it tells us something different from EF

- Predicting future cardiotoxicity
- Asx valve patients needing intervention

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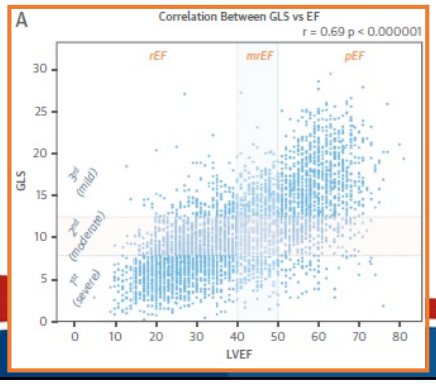
Global Longitudinal Strain to Predict Mortality in Patients With Acute Heart Failure

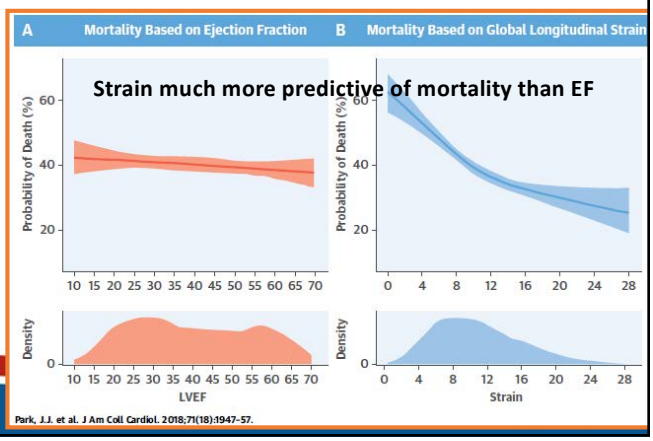
JACC 2018; 71: 1947-57

Jin Joo Park, MD, PhD,[a] Jun-Bean Park, MD, PhD,[b] Jae-Hyeong Park, MD, PhD,[c] Goo-Yeong Cho, MD, PhD[a]

- ***4172 consecutive patients admitted with ADHF***
  - **53% HFrEF, 15% HFmEF, 32% HFpEF**
  - **40% overall mortality at 5 years**

EF and GLS clearly correlated but LOTS of scatter





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Achilles Heel:
Intervendor Reproducibility

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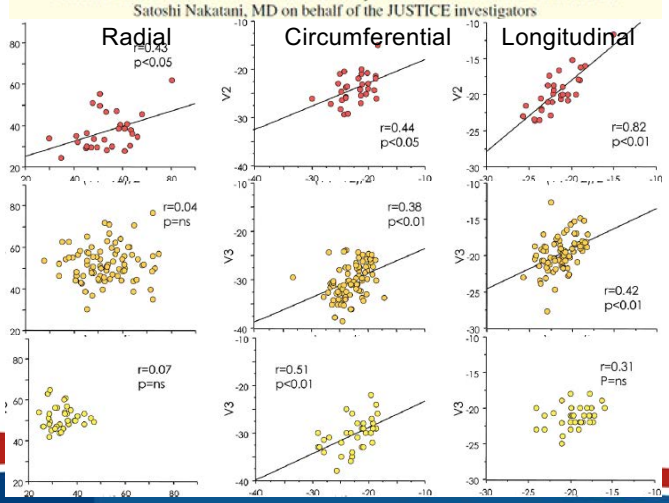
Intervendor Reproducibility in Normals

V1: GE
V2: Philips
V3: Toshiba

Normal Range of Left Ventricular 2-Dimensional Strain
– Japanese Ultrasound Speckle Tracking of the Left Ventricle (JUSTICE) Study –

Kiyohiro Takigiku, MD; Masaaki Takeuchi, MD; Chisato Izumi, MD; Satoshi Yuda, MD; Konomi Sakata, MD; Nobuyuki Ohte, MD; Kazuaki Tanabe, MD; Satoshi Nakatani, MD on behalf of the JUSTICE investigators



Circ J 2012; 76: 2623-32

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Task Force on Strain Standardization

European Association on CardioVascular Imaging

American Society on Echocardiography

Dr. Luigi Badano

Dr. Jim Thomas

- *Academics*
  - Technical
  - Biomedical / clinical
- *Societies*
  - Japanese Society on Echocardiography
  - Korean Society on Echocardiography
- *Industrial stakeholders*
  - Hardware/software vendors: Esaote, GE VingMed, Hitachi-Aloka, Mind Ray, Philips, Siemens, Toshiba, (Samsung Medison)
  - Software only vendors: Epsilon Imaging, TomTec

Task force

1) Reach consensus on definitions
2) Reach consensus on a set of tools for QA

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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,[†] Gianni Pedrizzetti,[†] Peter Lysyansky,[†] Tom H. Marwick, Hélène Houle, Rolf Baumann, Stefano Pedri, Yasuhiro Ito, Yasuhiko Abe, Stephen Metz, Joo Hyun Song, Jamie Hamilton, Partho P. Sengupta, Theodore J. Kolias, Jan d'Hooge, Gerard P. Aurigemma, James D. Thomas,[‡] and Luigi Paolo Badano[‡], *Leuven, Belgium; Trieste, Genova, and Padova, Italy; New York, New York; Haifa, Israel; Hobart, Australia; Mountain View, California; Unterschleissheim, Germany; Tokyo and Tochigi-ken, Japan; Andover and Worcester, Massachusetts; Seoul, Korea; Ann Arbor, Michigan; and Cleveland, Ohio*

- *Agreement on*
  - Nomenclature
  - Display
  - Timing of end-diastole
  - Timing of end-systole
  - Mathematical definition of strain
  - Regions of interest

JASE 2015; 28: 183-93

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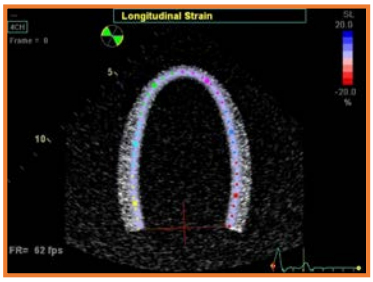
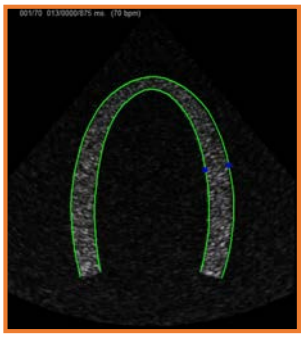
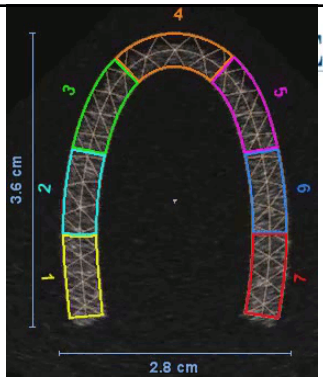
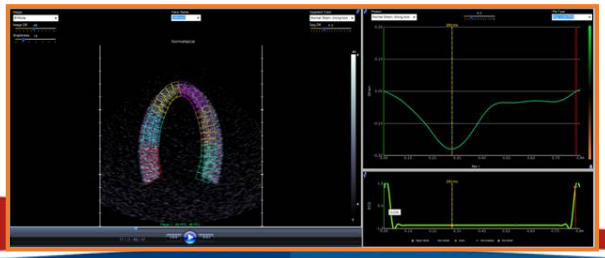
Tracking examples
In silico simulations









D'Hooge et al. EHJ– CVI 2016; 17: 693–701

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Head-to-Head Comparison of Global Longitudinal Strain Measurements among Nine Different Vendors
The EACVI/ASE Inter-Vendor Comparison Study

Konstantinos E. Farsalinos, MD, Ana M. Daraban, MD, Serkan Ünlü, MD, James D. Thomas, MD, PhD, Luigi P. Badano, MD, PhD, and Jens-Uwe Voigt, MD, PhD, *Leuven, Belgium; Chicago, Illinois; and Padua, Italy*

One week:	**22nd - 26th April 2013, Leuven**	
7 machines:	**Esaote**	**MyLab Alpha**
	GE	**Vivid E9**
	Hitachi-Aloka	**Prosound Alpha7 CV**
	Philips	**iE 33**
	Samsung	**EKO 7**
	Siemens	**SC 2000**
	Toshiba	**Artida**
2 independent softwares:	**Epsilon**	**EchoInsight**
	Tomtec	**Image Arena**

JASE 2015; 28: 1171-81

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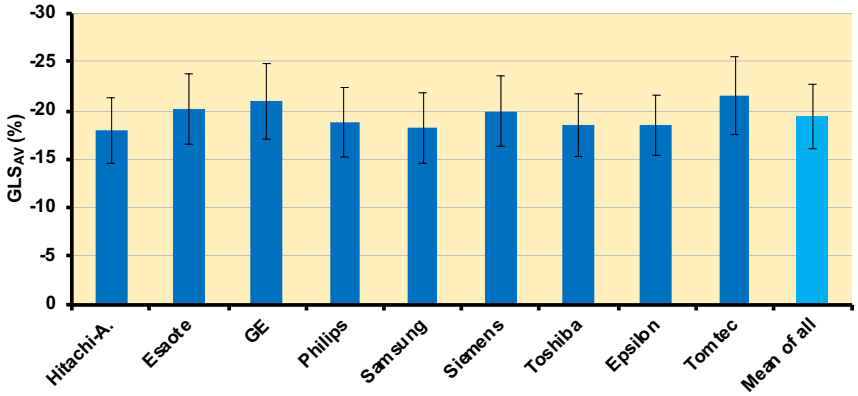
Mean GLS Values
All Vendors



JASE 2015; 28: 1171-81

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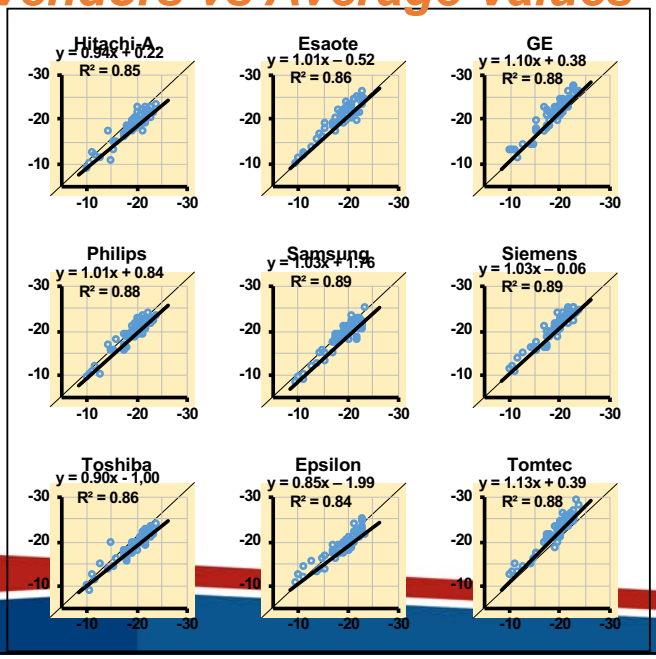
Regression Analysis
All Vendors vs Average Values



JASE 2015; 28: 1171-815

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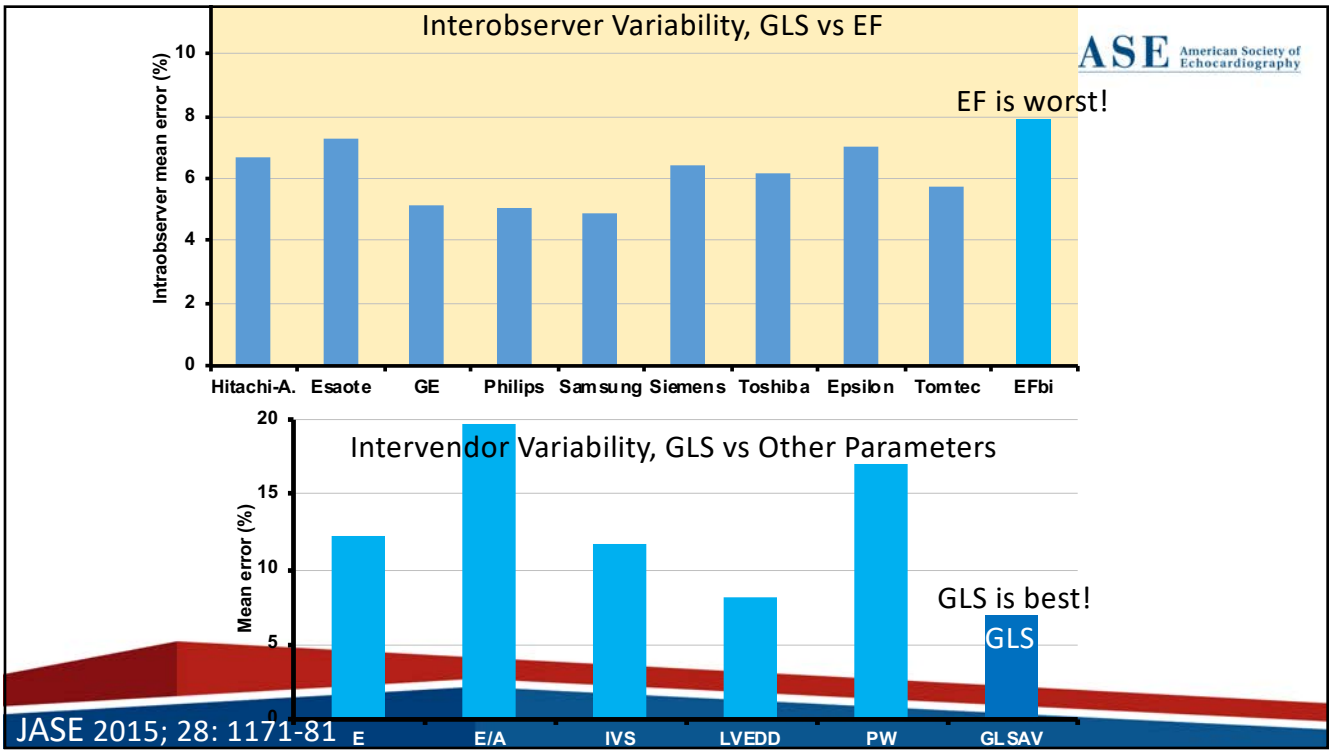

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93356: New add-on CPT code for strain

Strain has been a Category III (tracking) code for several years

Now announced as Category I (reimbursable) as of 1/1/2020

H		Private office			Non-Facility				
		CY2020 wRVU	CY2020 Payment	CY2020 PE RVU	CY2020 Payment	CY2020 MPI	CY2020 Payment	CY2020 Total RVU	CY2020 Payment
+93556	Myocrd strain img spckl trck	0.24	$ 8.66	0.87	$ 31.40	0.02	$ 0.72	1.13	$ 40.78
		Hospital OPD			Facility				
		CY2020 wRVU	CY2020 Payment	CY2020 PE RVU	CY2020 Payment	CY2020 MPI	CY2020 Payment	CY2020 Total RVU	CY2020 Payment
+93556	Myocrd strain img spckl trck	0.24	$ 8.66			0.01	$ 0.36	0.25	$ 9.02

PE not reimbursed in HOPD yet, but bill, so you can support higher APC in future

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Strain Imaging: Acquisition and Analysis Tips and Tricks

Madeline Jankowski, BS, RDCS, FASE
Northwestern Memorial Hospital
Chicago, IL

@maddiejane25

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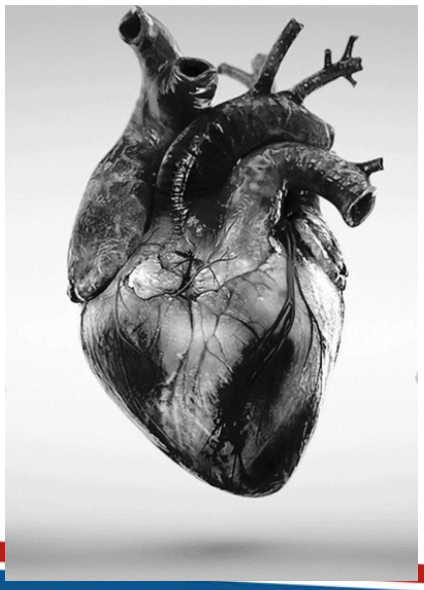
Introduction and Background

- Strain is used to improve our assessment of LV systolic function
- Measures deformation of the ventricle
- Looks at regional and global function
- Research tool as well as used in everyday practice



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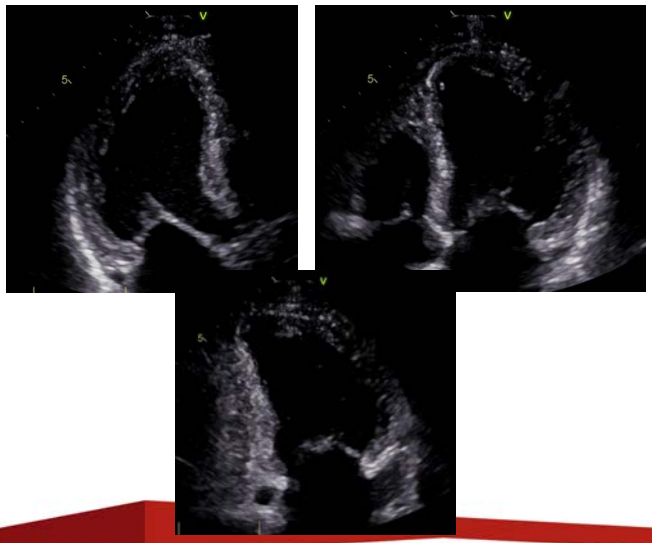
How – To: Strain!



Tips to start:

- Image quality is key, good quality images, good strain tracking
- Optimize your image – endocardial border and FR
- Good EKG tracing to record 3 beats
- Patient breath holding to stabilize image

Focus on Global Longitudinal Strain (GLS)

- Views you need:
  - Apical 3ch (APLAX)
  - Apical 4ch
  - Apical 2ch
- Be aware to have similar heart rates
- Optimal frame rates usually **40-80 fps**

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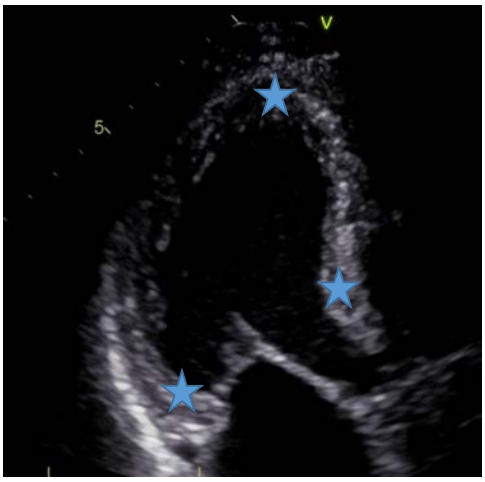
How – To: Strain!



Newest Versions on the ultrasound cart and EchoPac have automated ROI placement

- You can look at the preliminary tracking on the "yo-yo", where it flickers during systole

3 Click Method:

- Place your three points
  - First on basal posterolateral segment (at the mitral annulus in
  - Second on the basal anteroseptum (just proximal to the LVOT)
  - Third at the apex

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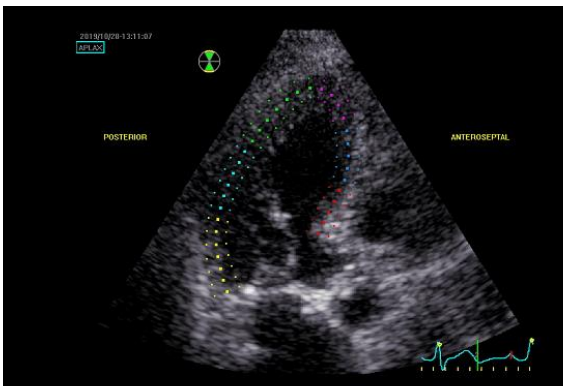
How – To: Strain!



- ROI drawn around the endocardial border, set by the points that you plotted
- Adjust the ROI by clicking and dragging the inner line of dots until it fits the LV wall
- Adjust wall thickness as needed with ROI width
- The ROI should include the endocardium/myocardium within the lines, excluding the pericardium

Once you have it set, hit "Process"!

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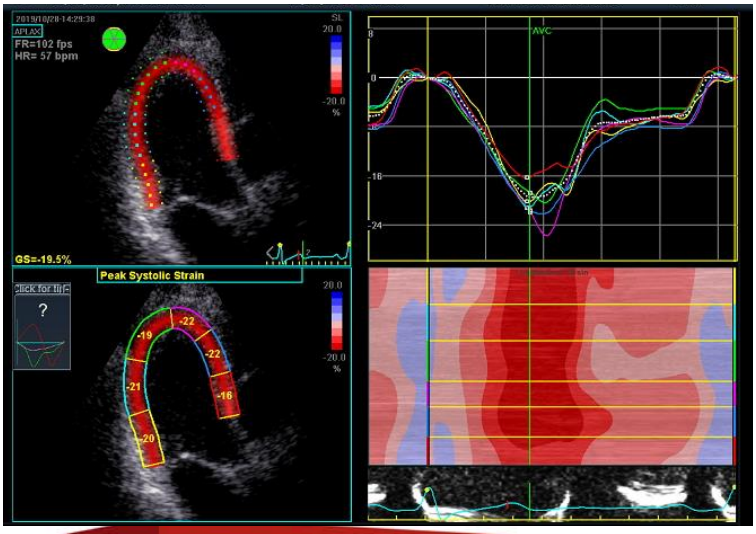
How – To: Strain!



Top left – "single" view Movie to inspect tracking

Bottom left – segmental strain breakdown showing peak strain values – color coding matches strain curves

Top right – strain curves for 6 segments (color coded). Dotted white line is global strain for that view.

Bottom right – M-Mode strain map

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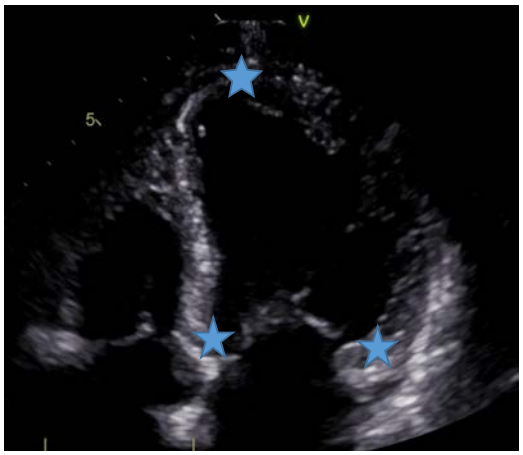
How – To: Strain!



Next select the **4-ch view.**

For 3-click method, repeat putting in the points for your four chamber.

- First point on the basal inferoseptum, at the insertion of the mitral annulus
- Second point on the basal anterolateral wall, at the insertion of the mitral annulus
- Third at the apex

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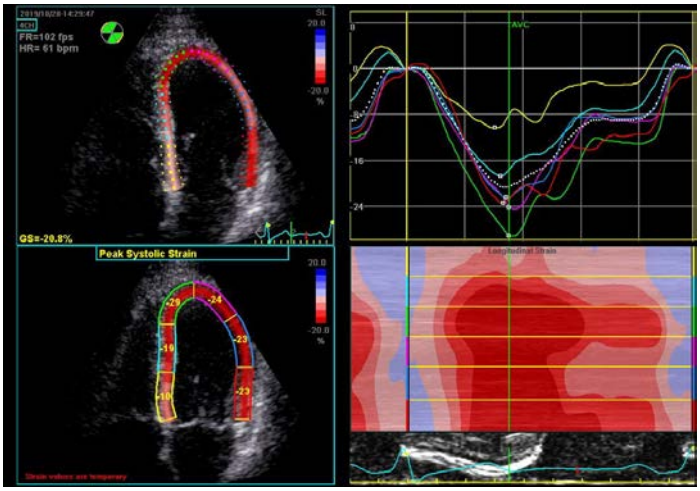
How – To: Strain!



4-ch view

Top left – "single" view Movie to inspect tracking

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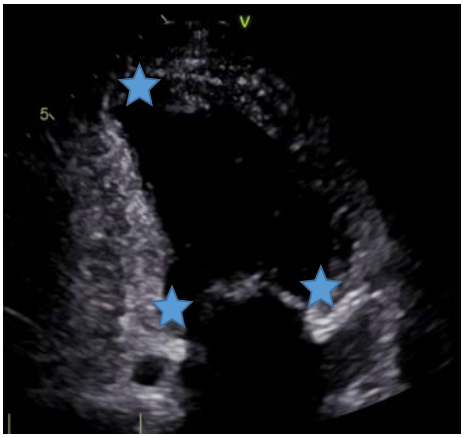
How – To: Strain!



Next select the **2-ch view.**

You know the drill ☺

For 3-click method, repeat putting in the points for your four chamber.

- First point on the basal posterior wall at the mitral annulus insertion
- Second point on the basal anterior wall at the mitral annulus insertion
- Third at the apex

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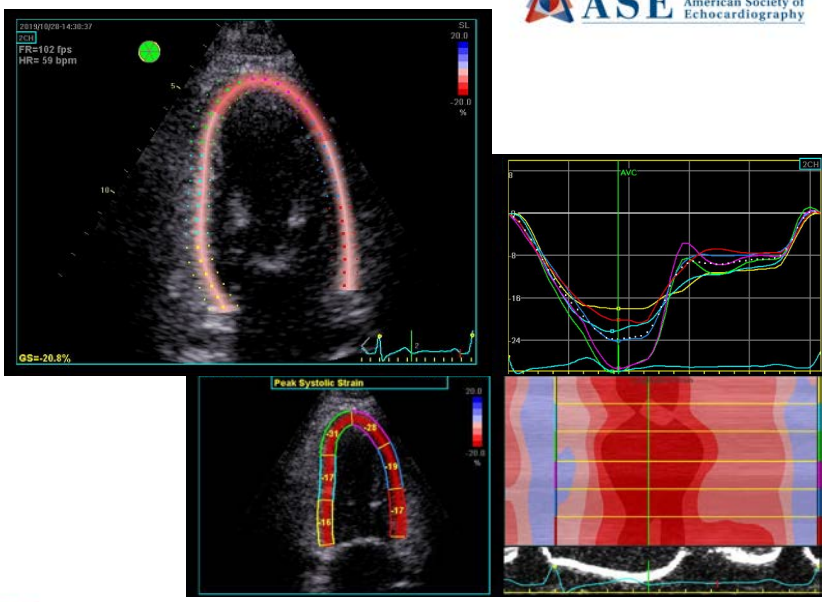
How – To: Strain!

- Plot your points
- Adjust the ROI if needed
- "Approve" to get strain curves



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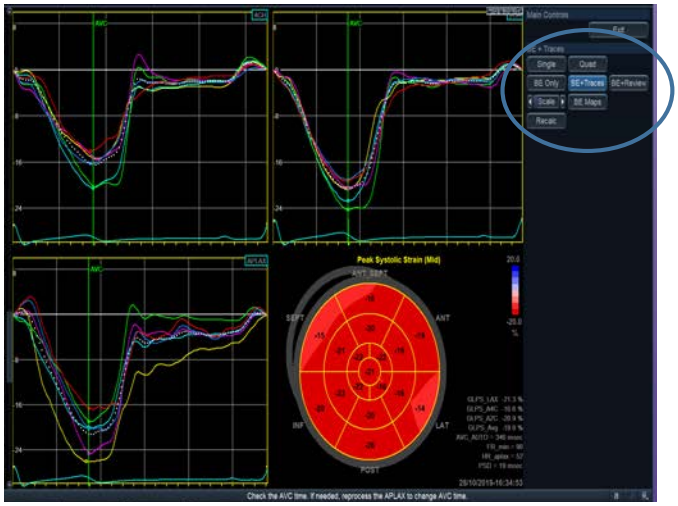
How – To: Strain!

- The bullseye and GLS is now available!
  - On the cart – select on the touch screen
  - On EchoPac – options available on the side
- Press the "BE + Traces" to get all strain curves and the bullseye
- BE = Bullseye



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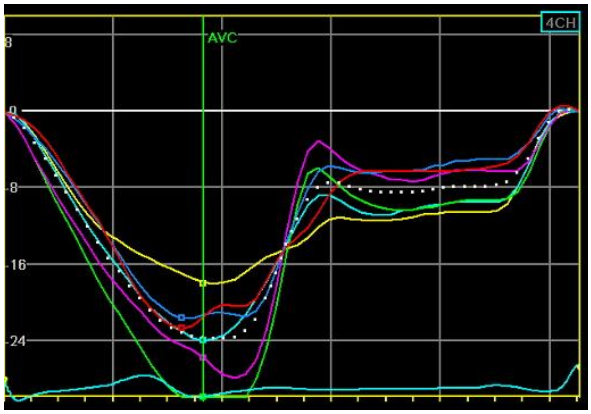
How – To: Strain!

Strain curves uncovered!

- Follows the cardiac cycle
- Systole – muscle is shortening – longitudinal strain curve goes down
- Diastole – muscle is elongating and relaxing – Longitudinal strain goes up
- Atrial contraction seen
- Colors represent segments



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How – To: Strain!

And the final step…the big bullseye

- Peak segmental strain on the bullseye
- Averages for each view
- **Global Longitudinal Peak Strain Average** is the number we report, average of all the segments

- Different vendors may have different approaches to peak segmental strain on bullseye (end-systolic, peak systolic or peak throughout).
- Software may allow you to pick this option in configuration.

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How – To: Strain!

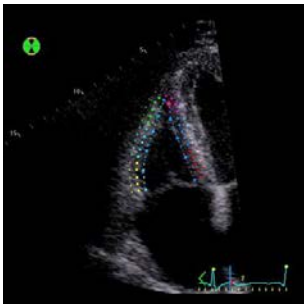
Review of important points

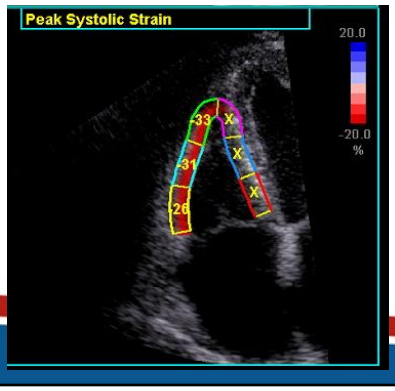
- **Quality images = quality tracking**
- **Software package will guide you**
- **Use the software AND your eyeball to assess tracking**
- **Make sure it makes sense and don't report if it doesn't!**

41

RV strain

- **Focused RV view with visualization of the free wall**
- **Dedicated RV strain software or "trick" the software with APLAX or 4ch**
- **Report the free wall values as an average**

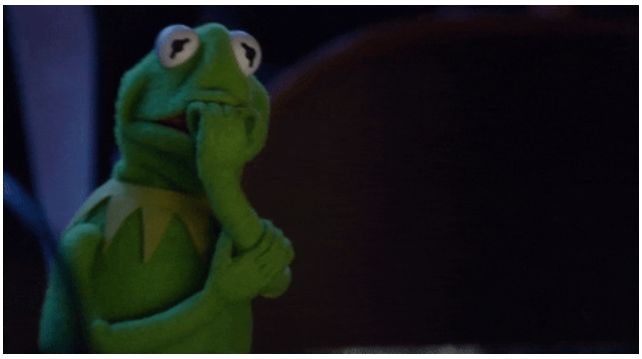




42

Trouble Shooting

Cases

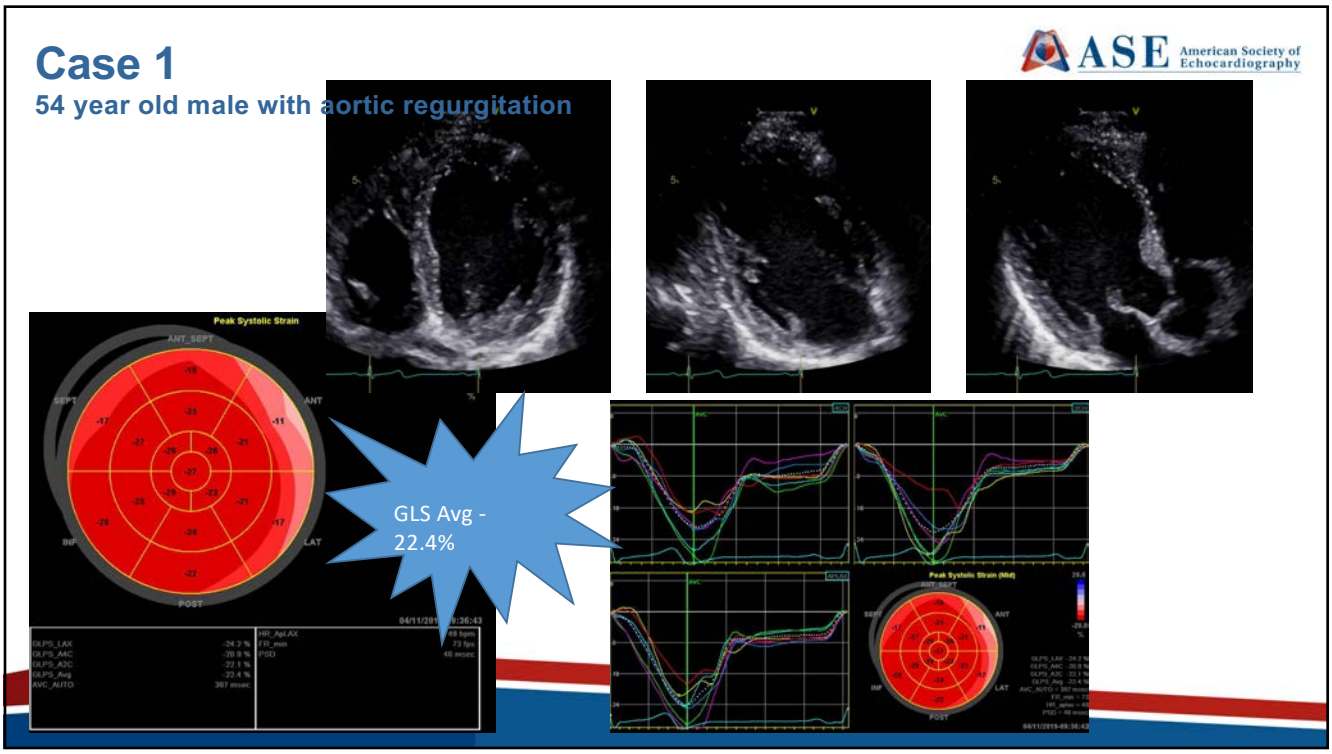


- Isn't tracking with your eye
- ROI does not track endocardium, artifact, shadowing, etc.
- Strain curves look off
- Technically difficult patients
- Not producing bullseye
- Low/positive strain numbers
- Red Xs

43

Case 1

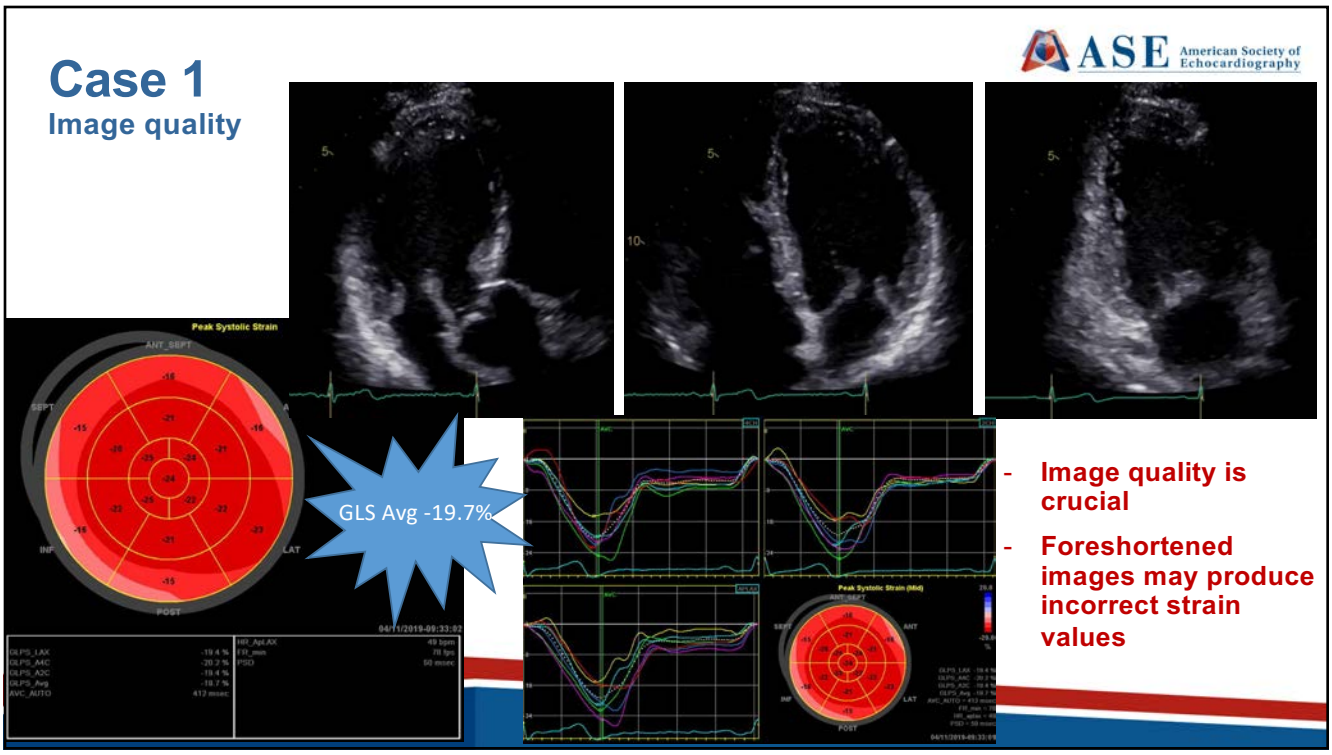
54 year old male with aortic regurgitation



44

Case 1

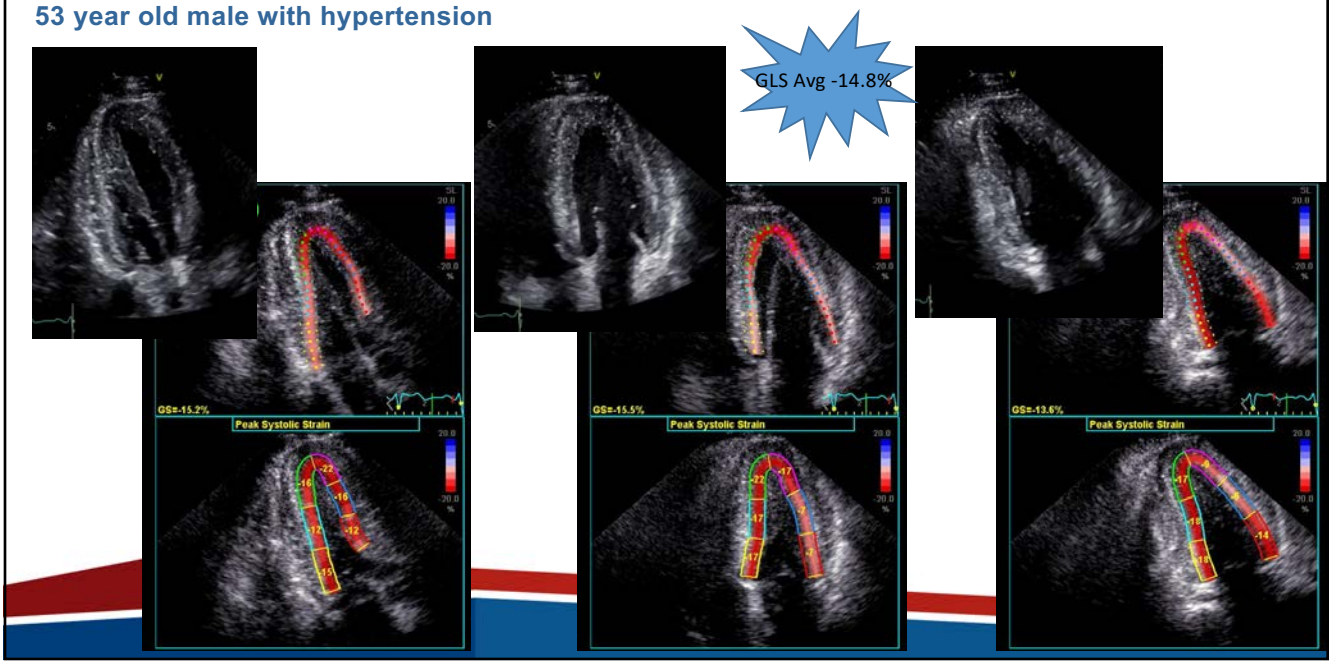
Image quality



45

Case 2

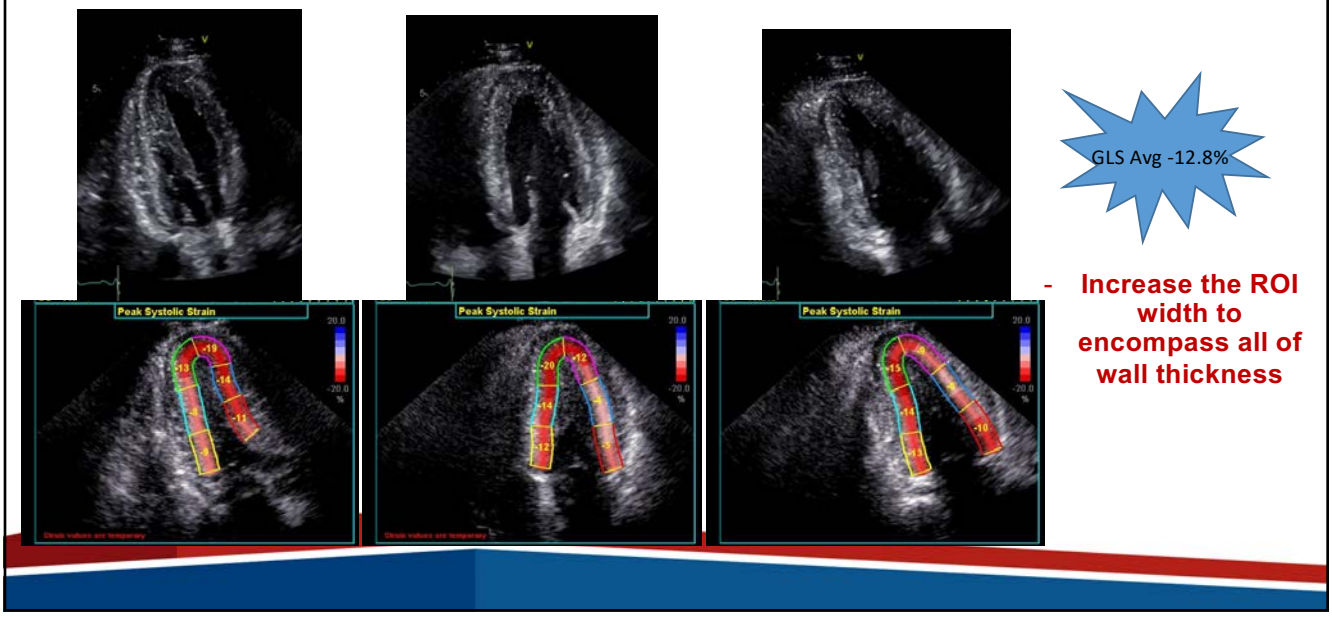
53 year old male with hypertension



46

Case 2

Adjustments to ROI – increased width

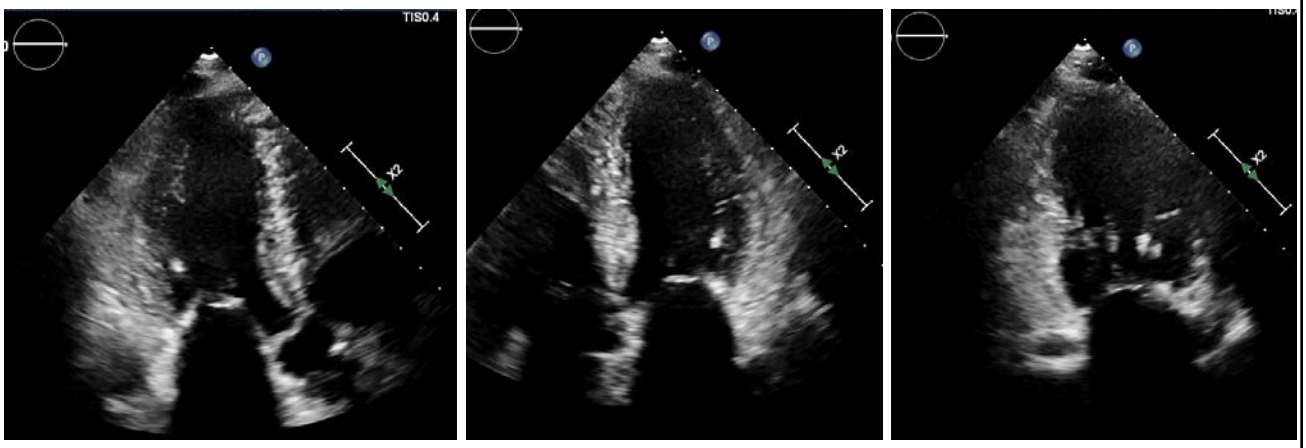


- **Increase the ROI width to encompass all of wall thickness**

47

Case 3

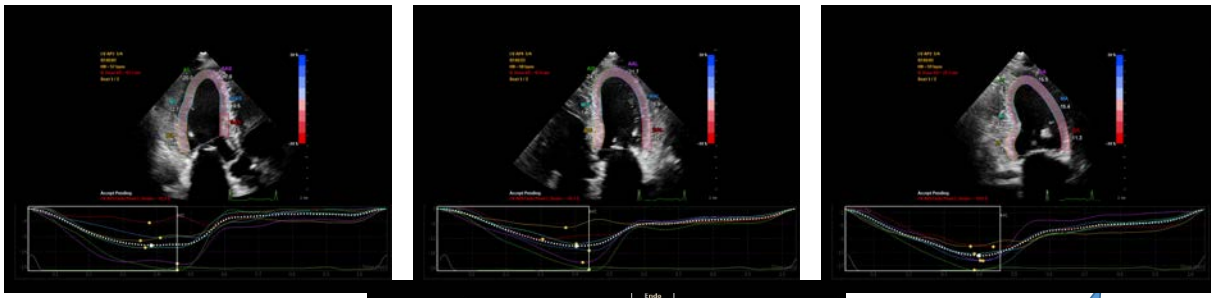
69 year old female presents with SOB and concern for PE



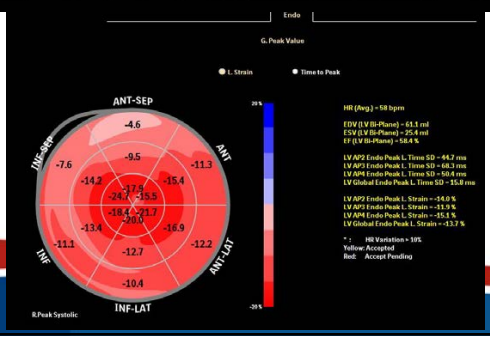
48

Case 3

Low/positive strain numbers



- Strain can uncover underlying heart disease and add diagnostic information to LVEF
- Understand the curves and the colors

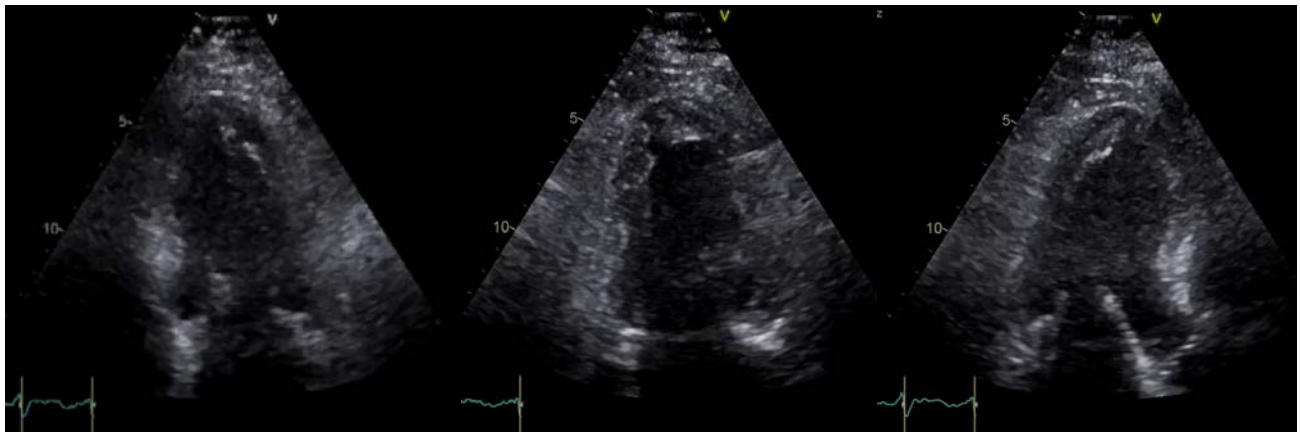


Auto LVEF 58.4%
GLS -13.7%

49

Case 4

72 year old man with HFpEF presents with edema and worsening HF symptoms

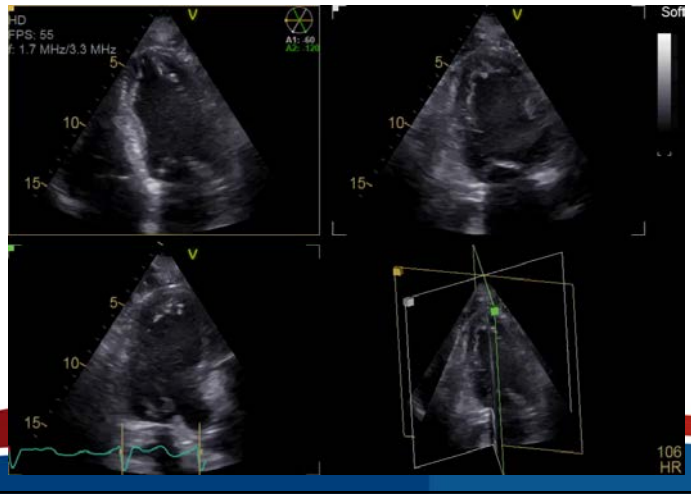


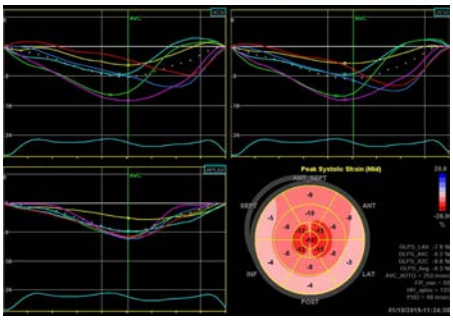
50

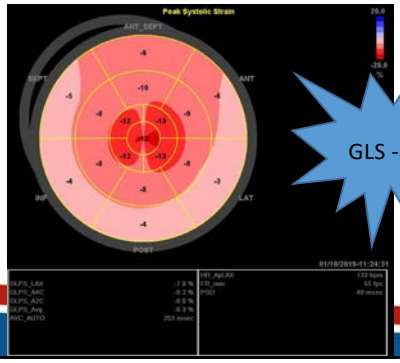
Case 4

Atrial Fibrillation – can we do strain? YES!

- **Multiplane imaging can be used with A-Fib to record the same cardiac cycle**





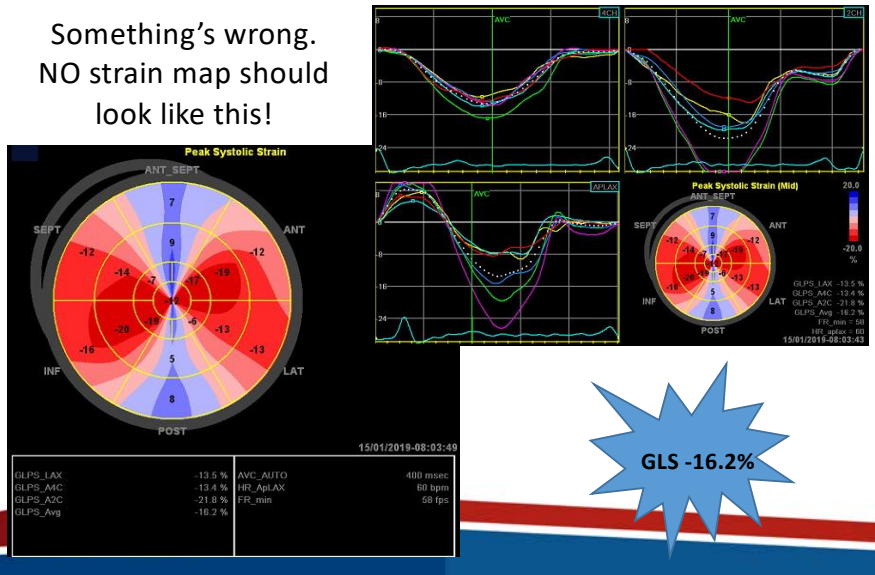


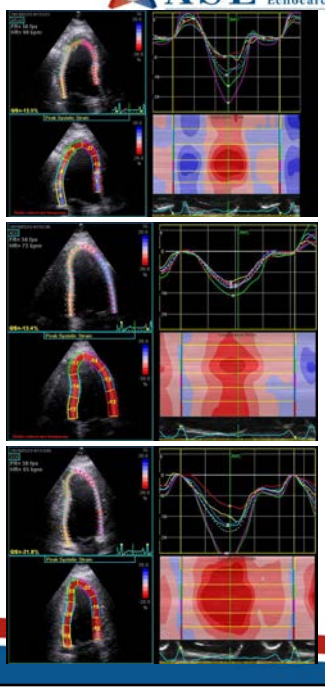
51

Case 5

50 year old male with history of hypertension

Something's wrong.
NO strain map should look like this!



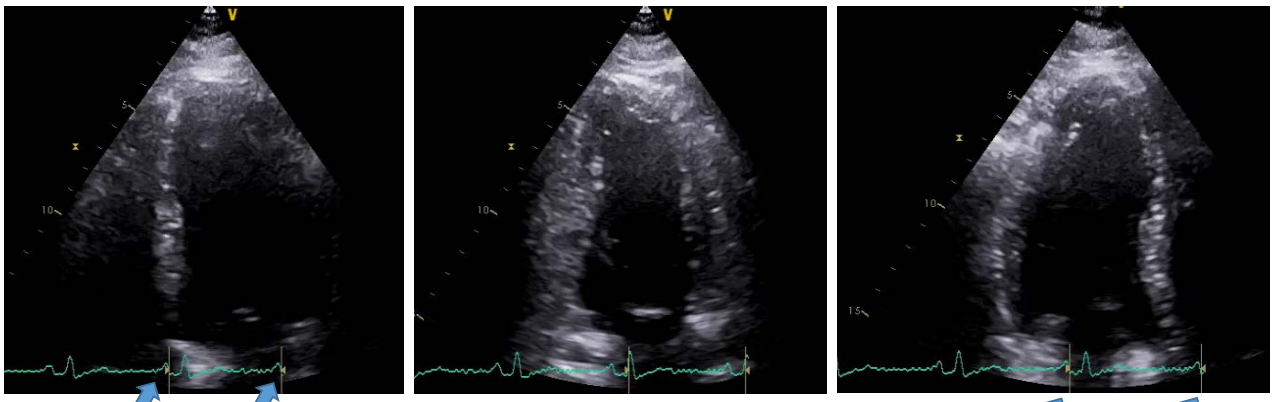


GLS -16.2%

52

Case 5

50 year old male with history of hypertension



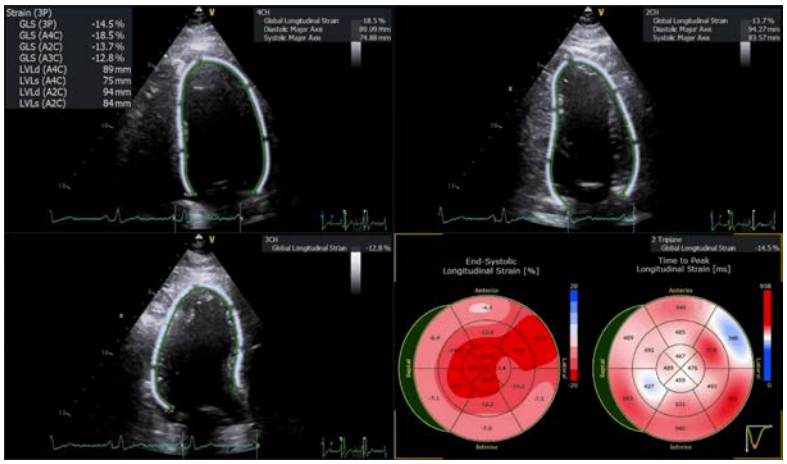
Beware triggering off the P-wave!

53

Case 5

Bullseye doesn't look right

- **Trust your eye!**
- **Understand the curves and the colors**
- **Try a different image or other software**



54

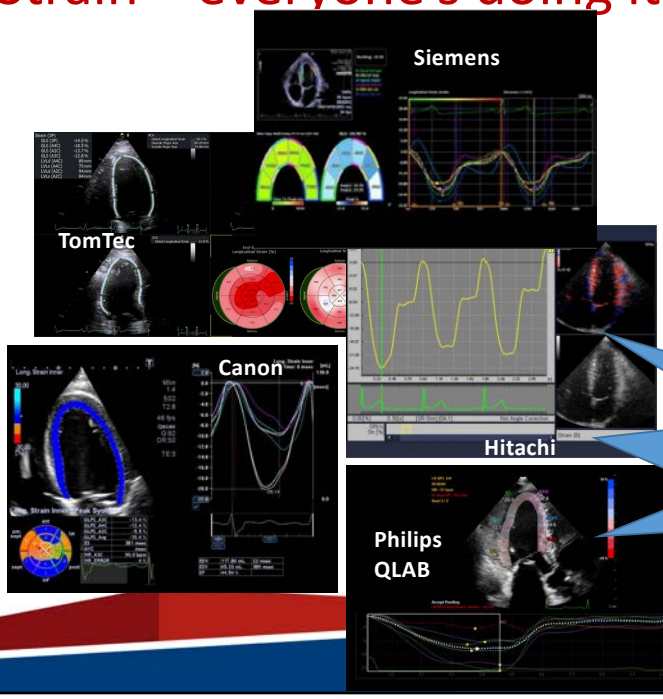
Trouble Shooting

Technically difficult patients

- Sometimes just can't get the pictures or the strain to track
- **Speckle tracking does not work with echo enhancing agents**
- Have a colleague try and obtain images
- Garbage in, GARBAGE OUT!

55

Strain – everyone's doing it!



- There are several other software programs that helps with the interpretation and analysis of echo images for strain.
- Vendor specific
- Vendor neutral

*Only showed **one** vendor in these slides as an example.*

Please ask your applications specialists for tips and advice for each strain software

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Thank you!

@maddiejane25

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Questions & Answers

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How Do I Use Strain in a Cardio-Oncology Clinic?

Nausheen Akhter, MD, FASE, FACC
Director of Cardio-Oncology
Northwestern Medicine

November, 25 2019

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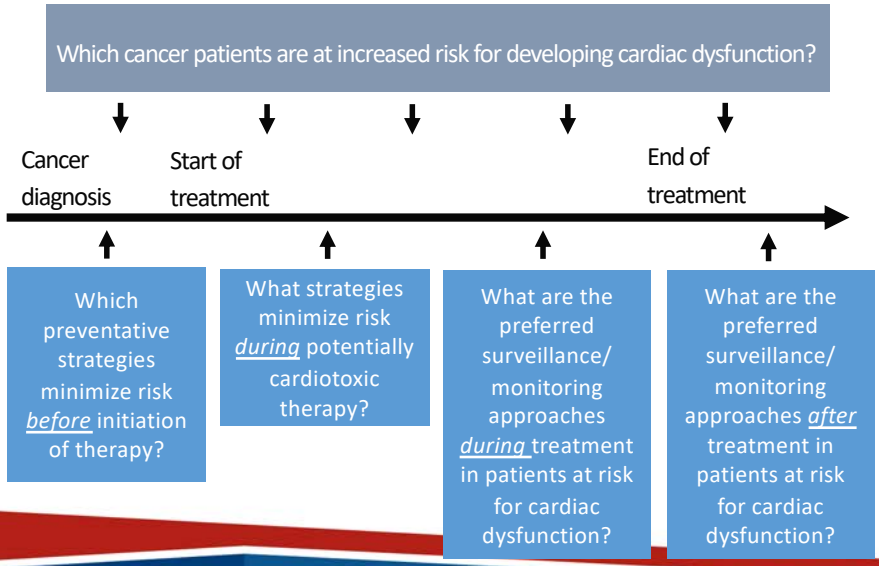
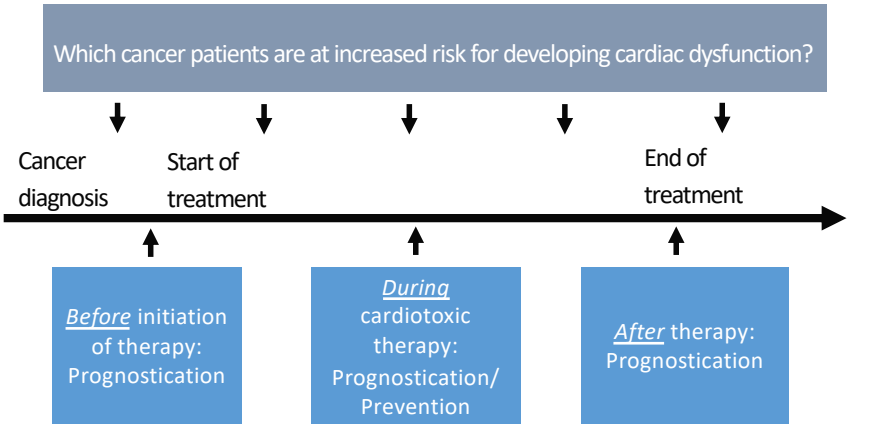
Cancer Care Continuum: ASCO Guidelines



Armenian JCO 2016; 35: 893-911

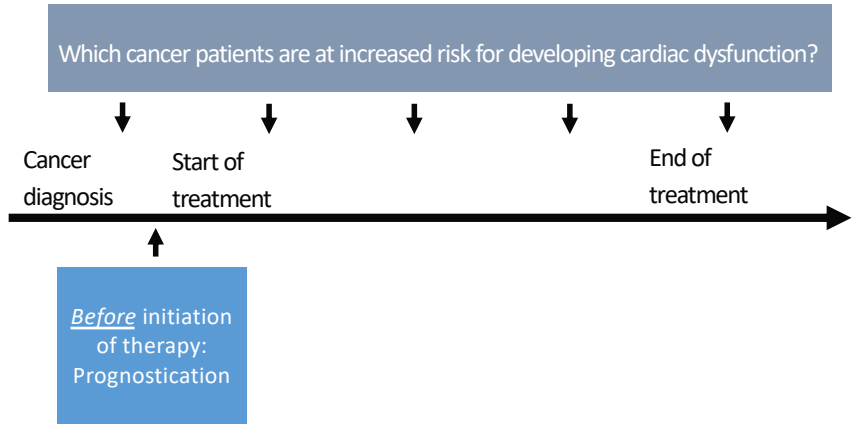
60

What is the Role of Strain in Cardiotoxicity?



61

What is the Role of Strain in ***Before*** initiation of Anti-Cancer Therapy?



62

Baseline GLS & CV Outcomes in Hematologic Malignancies

- N = 450 patients with Leukemia or Lymphoma
- Treated with anthracycline
- Follow-up 4-5 years
- 6% cardiac events (death/symptomatic HF
- DM, HTN were primary risk factors
- Pre-chemo GLS was independently associated with CE (P<0.0001)

Cut-off Baseline GLS < -17.5% was associated with 6x increase in cardiac events.

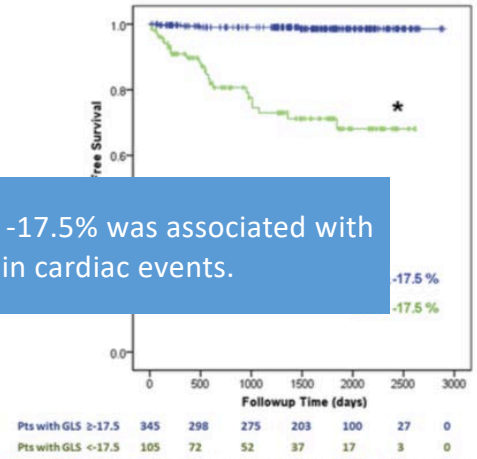


Figure 2 CE-free survival according to GLS. Kaplan-Meier curves depicting event-free survival in patients with GLS above or below the absolute value of −17. %. *Pts*, Patients. *P < .0001.

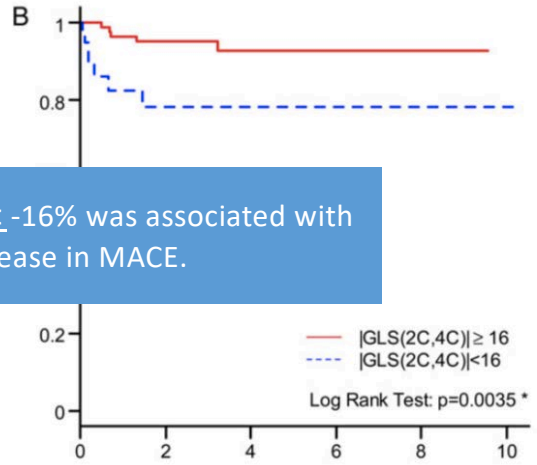
Ali et al. J Am Soc Echocardiogr 2016; 29: 522-27.

63

Baseline GLS & MACE in Breast & Hematologic Malignancies

- N = 158 patients treated with anthracyclines (25% Breast Ca, 57% Blood Ca, 18% other cancer)
- Pre-chemo LVEF
- Follow up 173 d
- Primary outcome (MACE): heart failure class III or IV, cardiac arrest or cardiac death.

Cut-off Baseline GLS ≤ -16% was associated with 4.7 x increase in MACE.

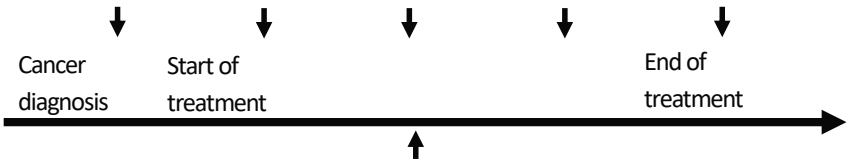


Mousavi et al. EHJ - Cardiovascular Imaging, 2015; 16, 977-984

64

What is the Role of Strain ***During*** Administration of Anti-Cancer Therapy?

Which cancer patients are at increased risk for developing cardiac dysfunction?



During cardiotoxic therapy: Prognostication/ Prevention

66

Case A

48 yo F with h/o L-sided breast cancer (ER+, PR-, HER2-) dx in April 2009

- Cancer Treatment:
  - Bilateral mastectomy in 4/09
  - Adjuvant AC-T, adjuvant post-mastectomy radiation
    - AC-T: Adriamycin (total dose 240 mg/m2), Cyclophosphamide, taxol
  - Bilateral implant reconstructions
  - Started adjuvant tamoxifen in 1/10

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Case A

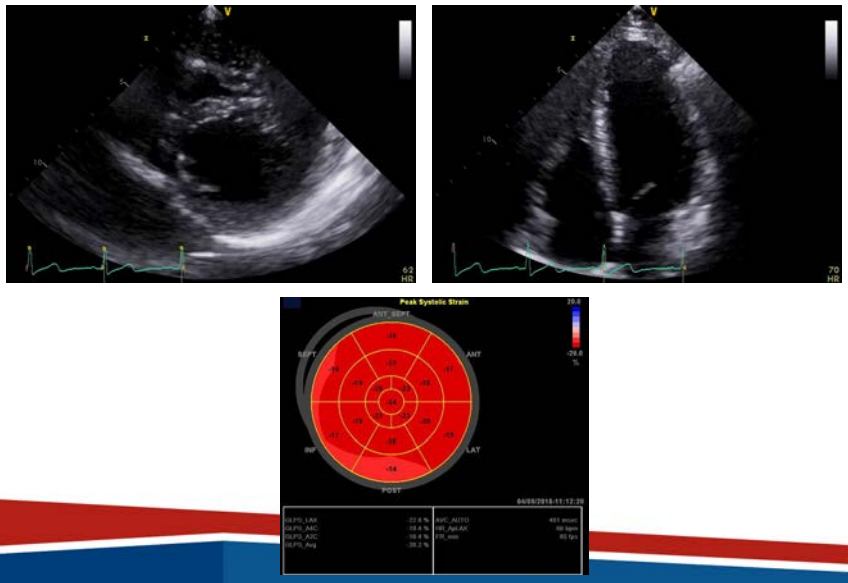
- **She is found to have a new primary at the lateral aspect of her L breast reconstruction in July 2018 (ER +, PR -, HER2+)**

- Cancer Treatment:
  - Wide excision, including skeletal muscle on 8/13/18 with negative margins
  - Started adjuvant TCHP x 6 cycles (9-12-18 to 12-26-18)
    - TCHP: Docetaxel, carboplatin, trastuzumab, pertuzumab

68

Baseline Echo: EF 70%, GLS -20.2%

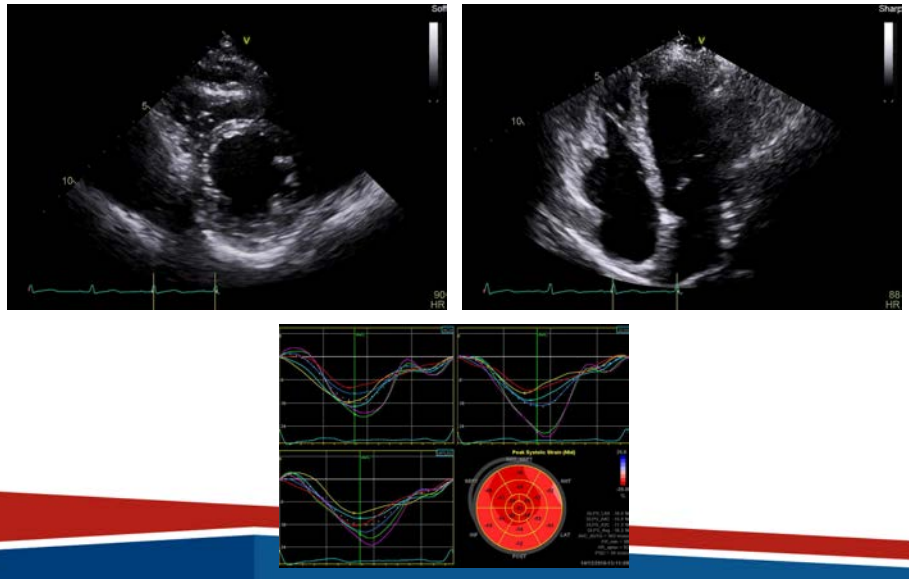
Sept 4, 2018



69

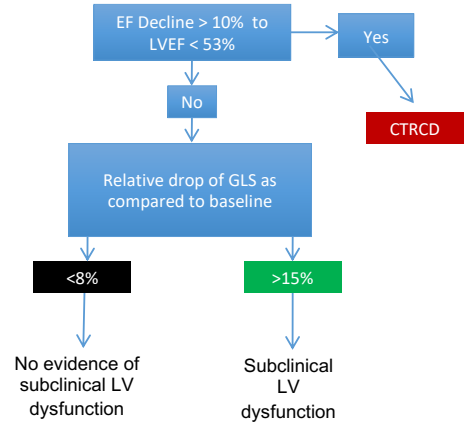
3 Month Echo: EF 58%, GLS -16.3%

December 14, 2018



70

Subclinical LV Dysfunction



EXPERT CONSENSUS STATEMENT

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

Juan Carlos Plana, MD, FASE, Chair, Maurizio Galderisi, MD, FESC, Co-Chair, Ana Barac, MD, PhD, Michael S. Ewer, MD, JD, Bonnie Ky, MD, FASE, Marielle Scherrer-Crosbie, MD, PhD, FASE, Javier Ganame, MD, PhD, FASE, Igal A. Sebag, MD, FASE, Deborah A. Agler, RCT, RDCS, FASE, Luigi P. Badano, MD, PhD, FESC, Jose Banchs, MD, FASE, Daniela Cardinale, MD, PhD, FESC, Joseph Carver, MD, Manuel Cerqueira, MD, Jeanne M. DeCara, MD, FASE, Thor Edvardsen, MD, PhD, FESC, Scott D. Flamm, MD, MBA, Thomas Force, MD, Brian P. Griffin, MD, Guy Jerusalem, MD, PhD, Jennifer E. Liu, MD, FASE, Andreia Magalhães, MD, Thomas Marwick, MBBS, PhD, MPH, Lisa Y. Sanchez, RCS, FASE, Rosa Sicari, MD, PhD, FESC, Hector R. Villarraga, MD, FASE, and Patrizio Lancellotti, MD, PhD, FESC, *Cleveland, Ohio; Naples, Padua, Milan, and Pisa, Italy; Washington, District of Columbia; Houston, Texas; Philadelphia, Pennsylvania; Boston, Massachusetts; Hamilton, Ontario and Montreal, Quebec, Canada; Chicago, Illinois; Oslo, Norway; Liège, Belgium; New York, New York; Lisbon, Portugal; Hobart, Australia; Rochester, Minnesota*

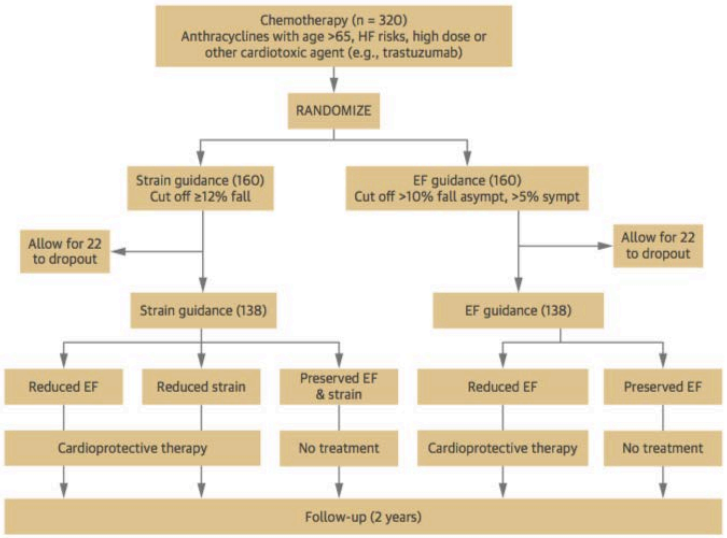
(J Am Soc Echocardiogr 2014;27:911-39.)

Keywords: Chemotherapy, Doxorubicin, Trastuzumab, Left ventricular dysfunction, Three-dimensional echocardiography, Early detection, Strain, Biomarkers

Plana, JC et al. JASE 2014; 27: 911-39

71

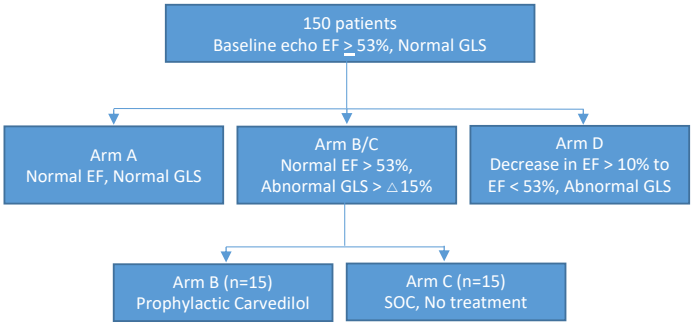
SUCCOUR



Negishi T. et al. JACC 2018; 11: 1098-105

72

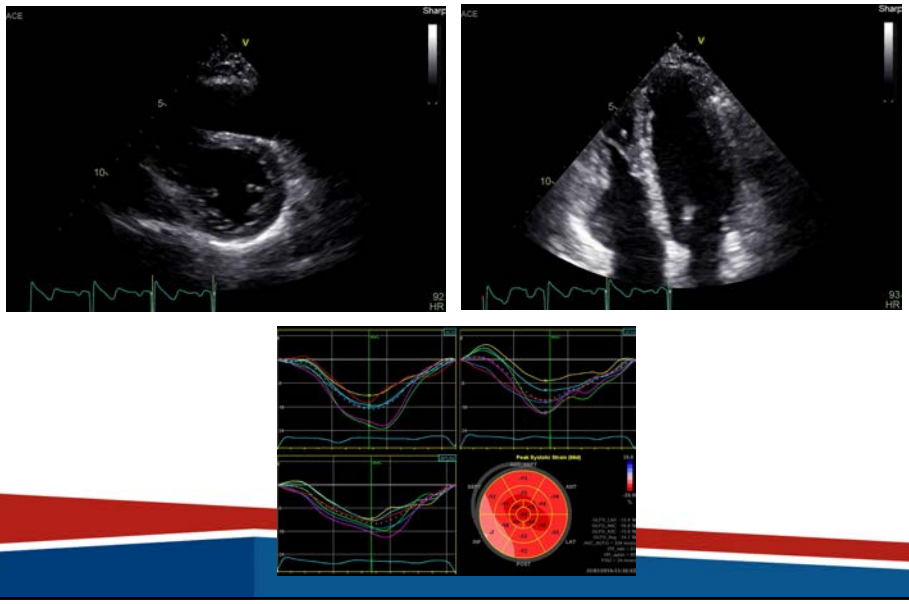
NU Strain-Surveillance Study



73

5 month Echo: EF 47%, GLS -14.7%

January 31, 2019



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Case A

48 yo F with h/o L-sided breast cancer (ER+, PR-, HER2-) s/p AC-T and RT in 2009; new recurrent L breast cancer in 2018 on TCHP

- Pt endorsed dyspnea with stairs and chest tightness.
- Chemotherapy was stopped.
- Started coreg 3.125 BID – GDMT limited by hypotension.
- Stress test done as next EF assessment, due to history of prior L-sided radiation history in 2009 which demonstrated no ischemia, EF improved to 50-55%

77

Case A

48 yo F with h/o L-sided breast cancer (ER+, PR-, HER2-) s/p AC-T and RT in 2009; new recurrent L breast cancer in 2018 on TCHP

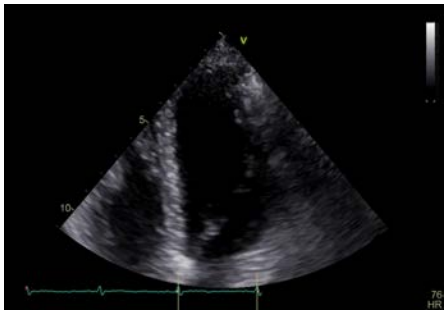
- Pt re-challenged on treatment with ado-trastuzumab (T-DM1) on March 13, 2019 every 21 days to complete 1 year.
  - Ado-trastuzumab is an antibody-drug conjugate consisting of the humanized monoclonal antibody trastuzumab covalently linked to the cytoxic agent DM1.

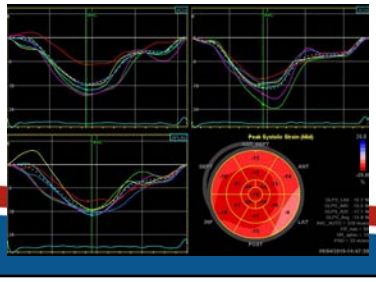
78

7 month Echo: EF 54%, GLS -15.9%

ASE American Society of Echocardiography

April 8, 2019





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Trastuzumab Cardiotoxicity

ASE American Society of Echocardiography

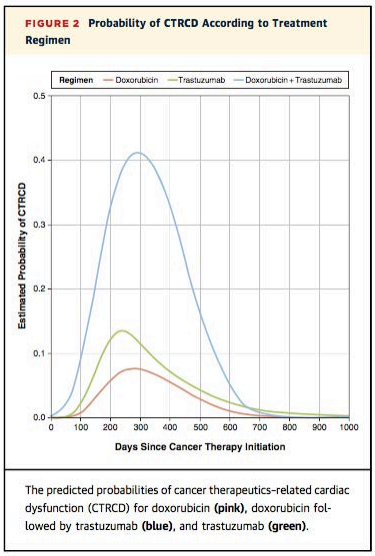


FIGURE 2 Probability of CTRCD According to Treatment Regimen

The predicted probabilities of cancer therapeutics-related cardiac dysfunction (CTRCD) for doxorubicin **(pink)**, doxorubicin followed by trastuzumab **(blue)**, and trastuzumab **(green)**.

LV dysfunction 7-18%

Clinical HF 2-4%

Not related to cumulative dose

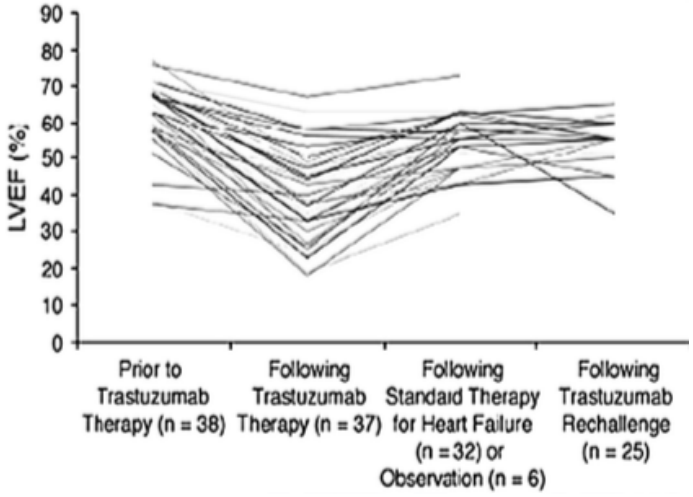
Largely reversible

Higher rates when used sequentially with anthracyclines

Narayan et al, JACC Imaging. 2016; 9: 1131-41

80

OK to Re-challenge?

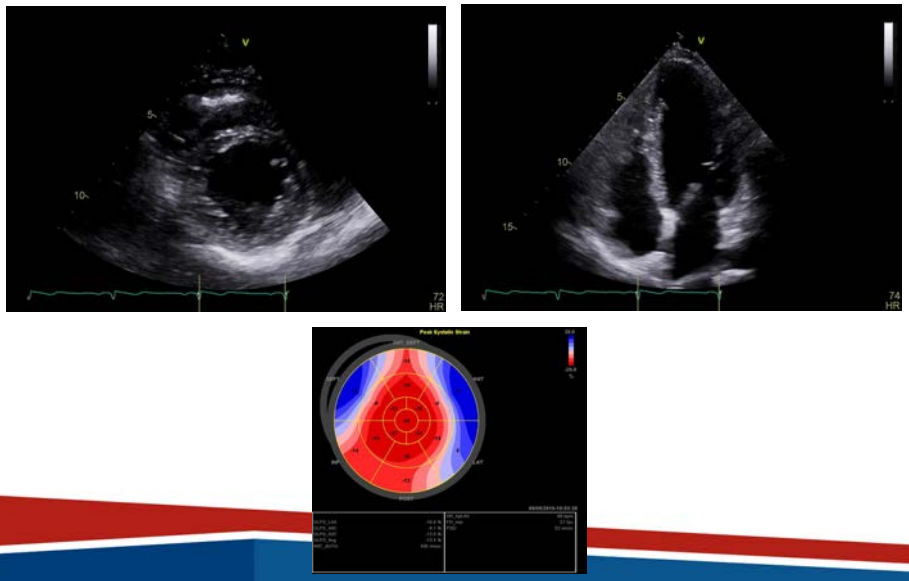


Circ HF 2016; J Card Fail 2008; 14: 437

82

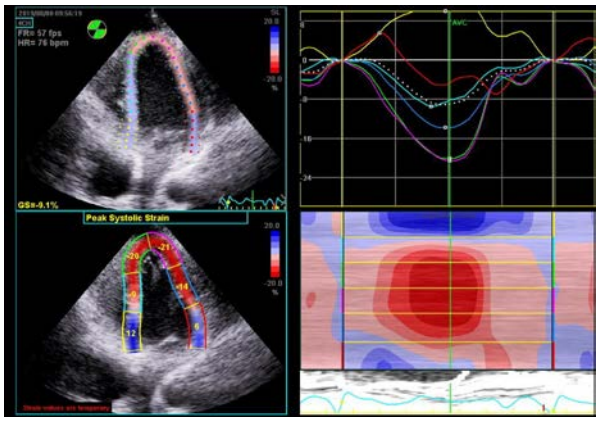
11 month Echo: EF 55%, GLS ??

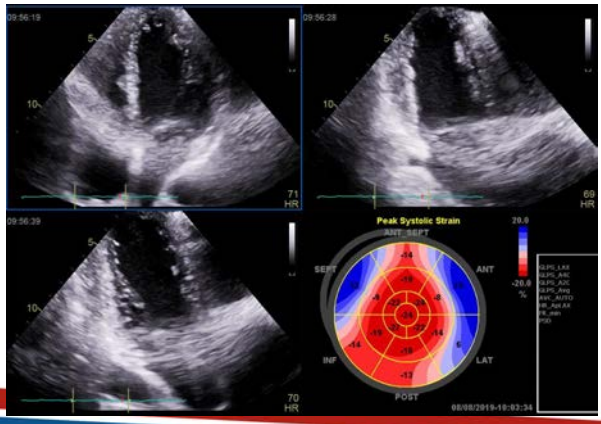
August 8, 2019



83

Breast Implant Artifact





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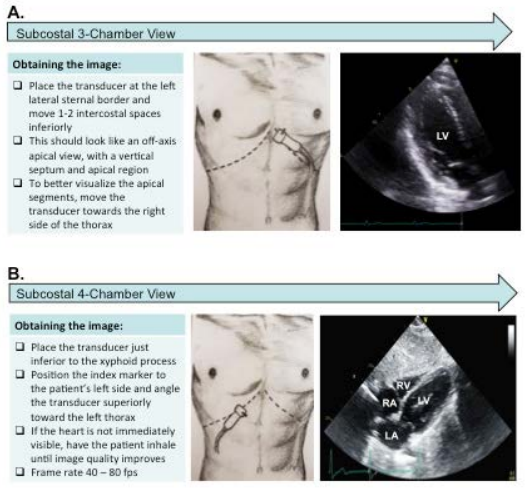
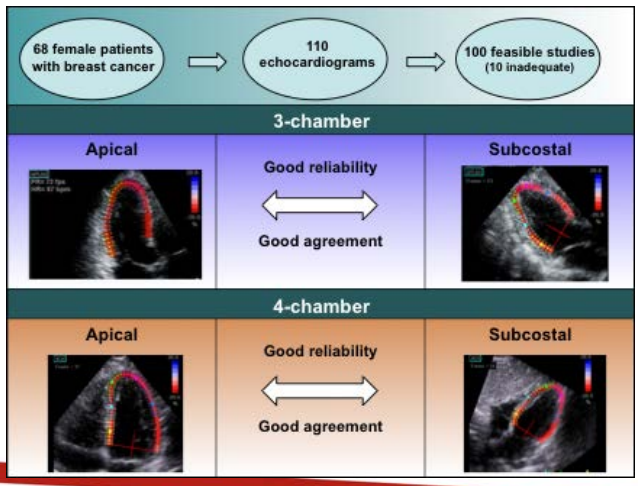
Subcostal Strain in Breast Cancer: Feasibility & Novel Clinical Utility





Chuzi, S… Akhter, N. JASE 2019 Apr; 32(4): 514-520

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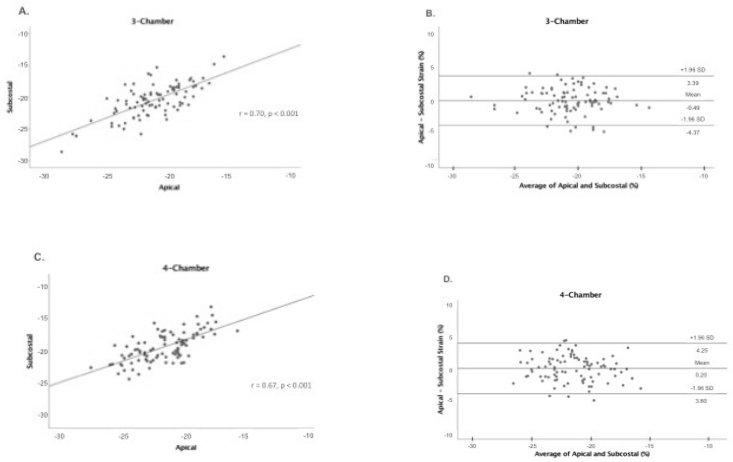
Subcostal Strain in Breast Cancer: Feasibility & Novel Clinical Utility



Chuzi, S… Akhter, N. JASE 2019 Apr; 32(4): 514-520

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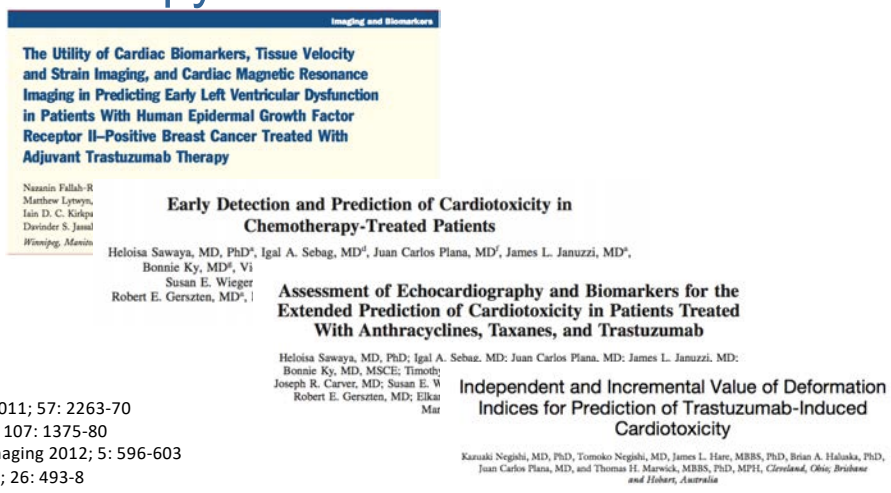
Prognostic Utility of GLS ***During*** Breast Cancer Therapy


Imaging and Biomarkers

The Utility of Cardiac Biomarkers, Tissue Velocity and Strain Imaging, and Cardiac Magnetic Resonance Imaging in Predicting Early Left Ventricular Dysfunction in Patients With Human Epidermal Growth Factor Receptor II–Positive Breast Cancer Treated With Adjuvant Trastuzumab Therapy

Nazanin Fallah-R
Matthew Lytwyn,
Iain D. C. Kirkpa
Davinder S. Jassal
Winnipeg, Manito

Early Detection and Prediction of Cardiotoxicity in Chemotherapy-Treated Patients

Heloisa Sawaya, MD, PhD[a], Igal A. Sebag, MD[d], Juan Carlos Plana, MD[f], James L. Januzzi, MD[a],
Bonnie Ky, MD[g], Vi
Susan E. Wieger
Robert E. Gerszten, MD[e],

Assessment of Echocardiography and Biomarkers for the Extended Prediction of Cardiotoxicity in Patients Treated With Anthracyclines, Taxanes, and Trastuzumab

Heloisa Sawaya, MD, PhD; Igal A. Sebag, MD; Juan Carlos Plana, MD; James L. Januzzi, MD;
Bonnie Ky, MD, MSCE; Timoth
Joseph R. Carver, MD; Susan E. W
Robert E. Gerszten, MD; Elkan
Mar

Independent and Incremental Value of Deformation Indices for Prediction of Trastuzumab-Induced Cardiotoxicity

Kazuaki Negishi, MD, PhD, Tomoko Negishi, MD, James L. Hare, MBBS, PhD, Brian A. Haluska, PhD, Juan Carlos Plana, MD, and Thomas H. Marwick, MBBS, PhD, MPH, *Cleveland, Ohio; Brisbane and Hobart, Australia*

Fallah-Rad, JACC 2011; 57: 2263-70
Sawaya, AJC 2011; 107: 1375-80
Sawaya, Circ CV Imaging 2012; 5: 596-603
Negishi, JASE 2013; 26: 493-8

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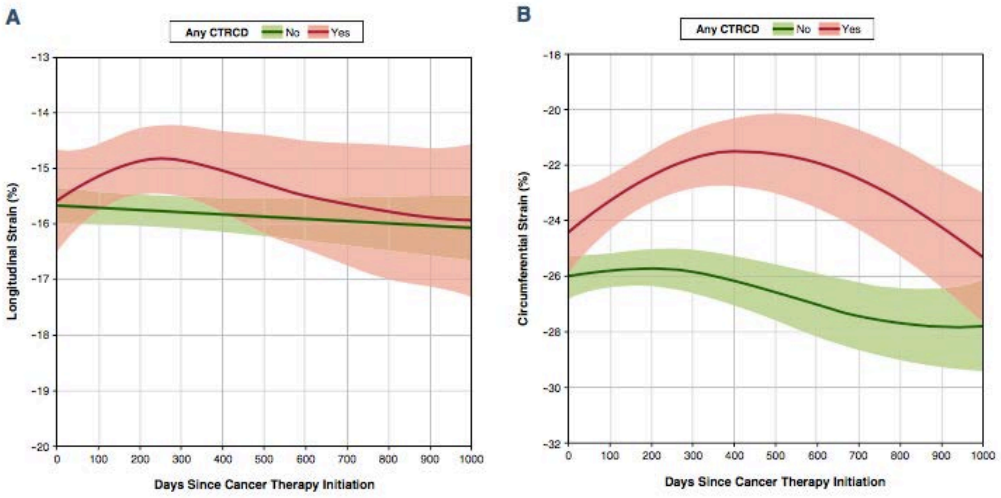
Patterns of Myocardial Mechanics



Narayan et al, JACC Imaging. 2016; 9: 1131-41

89

GLS is an Early Predictor of Cardiotoxicity

Table 3 Early Predictors of Cardiotoxicity

Studies/First Author (Ref. #)	Sensitivity	Specificity	PPV	NPV
Fallah-Rad et al. (44)*				
2% absolute (10.1% relative) decrease in LS	79%	82%	60%	92%
0.8% decrease in RS	86%	81%	60%	95%
Sawaya et al. (41)†				
10% decrease in GLS	78%	79%	50%	93%
Elevated hsTnI	67%	82%	50%	90%
10% decrease in GLS and elevated hsTnI	55%	97%	83%	89%
10% decrease in GLS or elevated hsTnI	89%	65%	40%	97%
Sawaya et al. (40)†				
GLS <19%	74%	73%	53%	87%
hsTnI >30 pg/ml	48%	73%	44%	77%
LS <19% and usTnI >30 pg/ml	35%	93%	67%	77%
LS <19% or usTnI >30 pg/ml	87%	53%	43%	91%
Negishi et al. (42)†				
11% reduction in global GLS	65%	95%	—	
3.6% reduction in global GLSR early diastole	82%	67%	—	—
6.4% reduction in global GLSR	73%	67%	—	—
Absolute GLS at 6 months <−20.5%	96%	66%	—	—

Thavendiranathan et al. JACC 2014; 63: 2751-68

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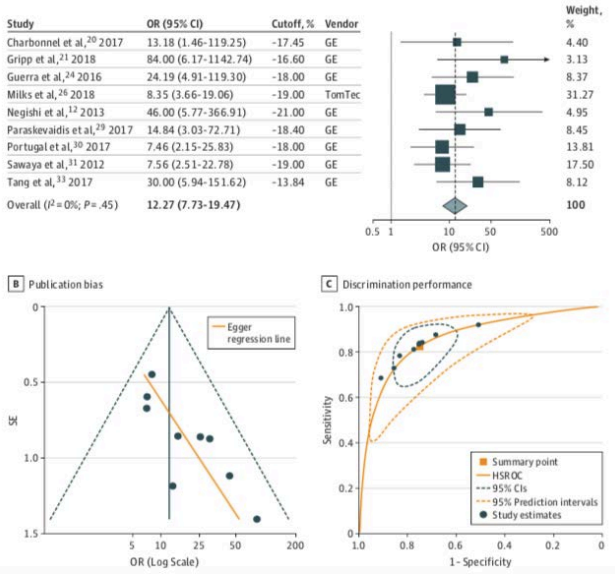
Figure 2. Prognostic and Discriminatory Performance of Absolute Left Ventricular Global Longitudinal Strain (GLS) Measured After Initiation of Cardiotoxic Chemotherapy for Cancer Therapy-Related Cardiac Dysfunction



Oikonomou E et al. JAMA Cardiology 2019; 4(10):1007-1018

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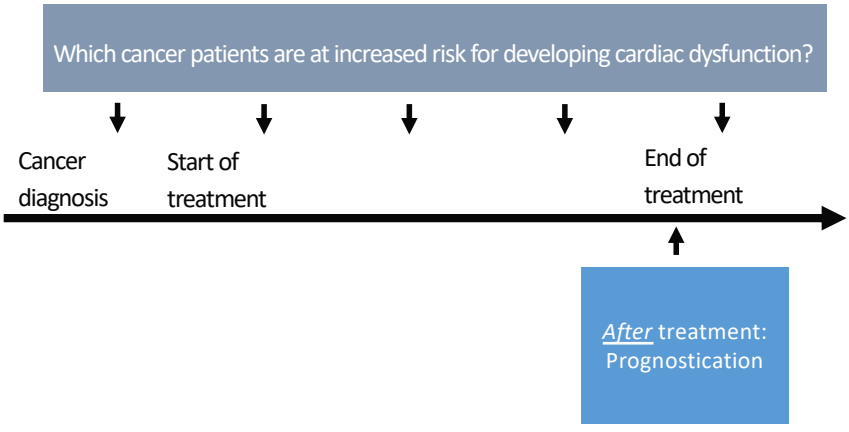
What is the Role of Strain ***After*** Completion of Anti-Cancer Therapy?



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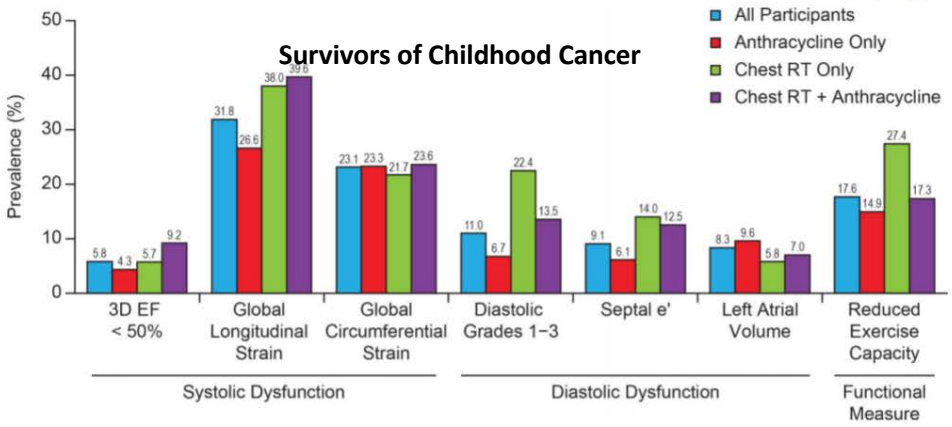

- 1,820 adult, median age 31
- Median time from diagnosis of cancer : 23 years
- Anthracycline and/or radiotherapy
- Only 5.8% of survivors had an abnormal 3D LVEF <50%
- 28 % of patients with preserved 3D LVEF had a reduced GLS

Armstrong et al. , J Am Coll Cardiol. 2015

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Post-Treatment GLS Predicts LV Recovery in Breast Cancer

- N = 95 patients with breast cancer treated with AC and TRZ
- Follow-up: 17-month (13-28 months) , ≥ 5 echocardiograms/patient
- 19 patients (20%) developed cardiotoxicity. Of these patients, the LVEF partially or fully recovered in 13 (68%).
- GLS at the time of cardiotoxicity diagnosis was associated with subsequent recovery of LVEF (p = 0.004).

Fei HW et al. Echocardiography 2016; Apr; 33(4): 519-26.

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Summary

Prognostication

- Pre-chemotherapy GLS may have a discriminatory ability to identify patients at risk for cardiac dysfunction
- Strain can be trended for prognostication of LV dysfunction during treatment in patients with breast cancer, but may be useful across cancer subtypes with anthracyclines +/- trastuzumab
- Post-chemotherapy GLS may be used for prediction of LV dysfunction/recovery, but more work is needed

Prevention

- Prophylactic medication based on strain-surveillance is currently being studied: SUCCOUR Trial, NU Strain-Surveillance Study

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Thank You

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GLS and CAD
GLS and Heart Failure

Roberto M Lang, MD
University of Chicago Medicine

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GUIDELINES AND STANDARDS

Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults:

Global Longitudinal Peak Systolic Strain (GLS) "in the range of -20%"

- "Optimize image quality, maximize frame rate and minimize foreshortening".
- "When regional tracking is suboptimal in more than two myocardial segments in a single view the calculation of GLS should be avoided".

to eliminate several minor discrepancies that existed between previously published guidelines. (J Am Soc Echocardiogr 2015;28:1-39.)

Keywords: Adult echocardiography, Transthoracic echocardiography, Ventricular function, Normal values

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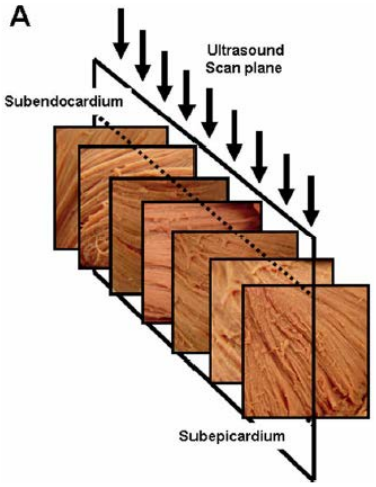
Fiber Orientation

In the subendocardium, the fibers are longitudinally oriented contributing to longitudinal LV mechanics.

In the mid-wall, the fibers are oriented in the circumferential direction, changing to an oblique orientation in the sub-epicardium.

Both the mid-wall and sub-epicardium contribute to circumferential and rotational mechanics



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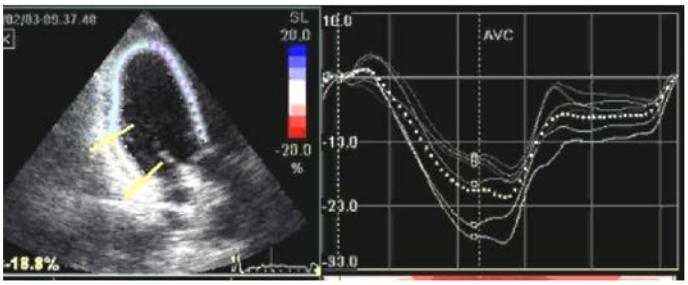
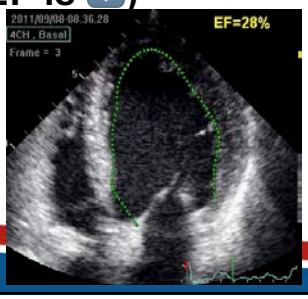
Myocardial ischemia affects the subendocardial fibers and therefore primarily longitudinal strain.



Mid-wall fibers with a circumferential orientation are afected when there is transmural ischemia (LVEF is ⬇️)



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Global Longitudinal Peak Systolic Strain

1. Timing of Aortic Valve Closure
2. Avoid LVOT
3. Avoid the Atrium
4. ROI to Wide
5. Foreshortened Images

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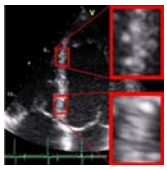
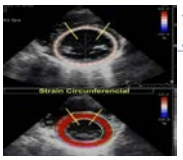
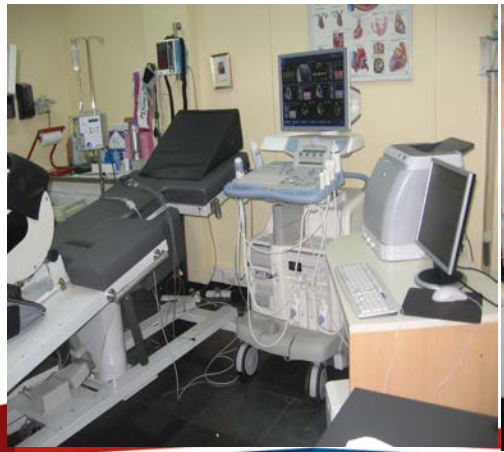
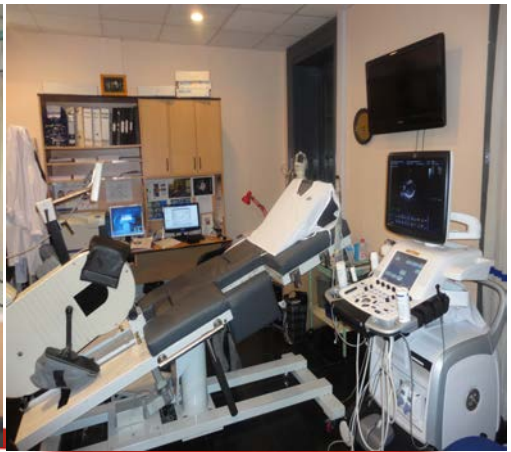


Strain 2 D







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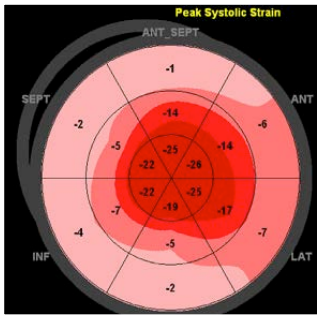
CAD by Coronary Artery Distribution

Cardiac Amyloidosis



Apex strain > 2x Rest of heart

- Territorial analyses to assess CAD by coronary artery distribution.
- Lower absolute regional GLS in the LAD distribution detected CAD with 91% sensitivity and 45% specificity.
- Decreased absolute GLS in the RCA CAD with 79% sensitivity and 76% specificity.

Phelan, Collier et al. Heart 2012; 98: 1442-1448

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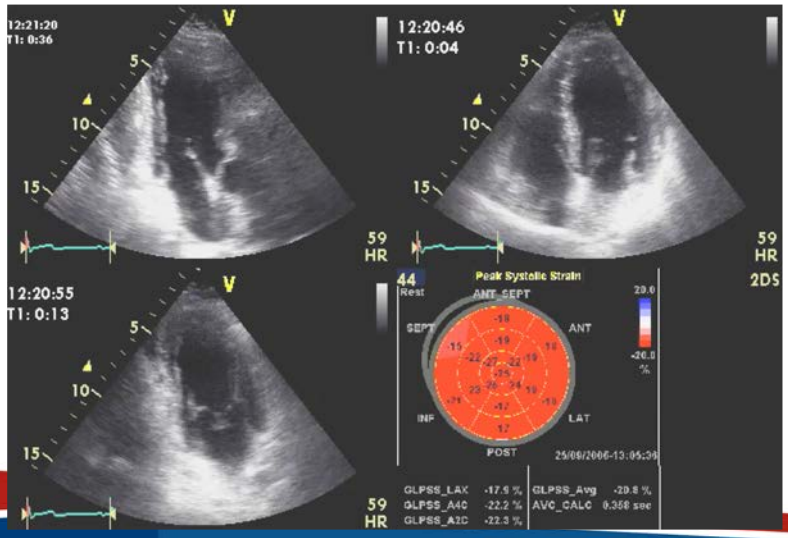
Specific Patterns of GLS in Coronary Artery Disease

Normal Coronaries



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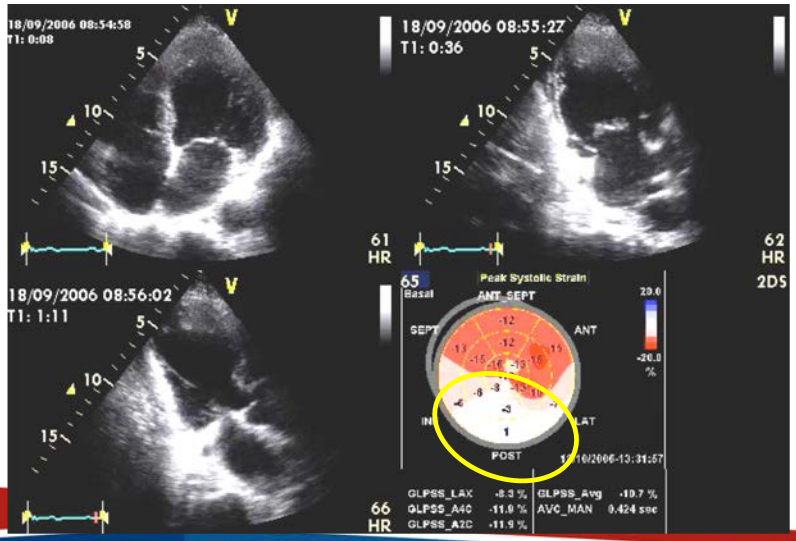
Inferoposterior and lateral Ischemia



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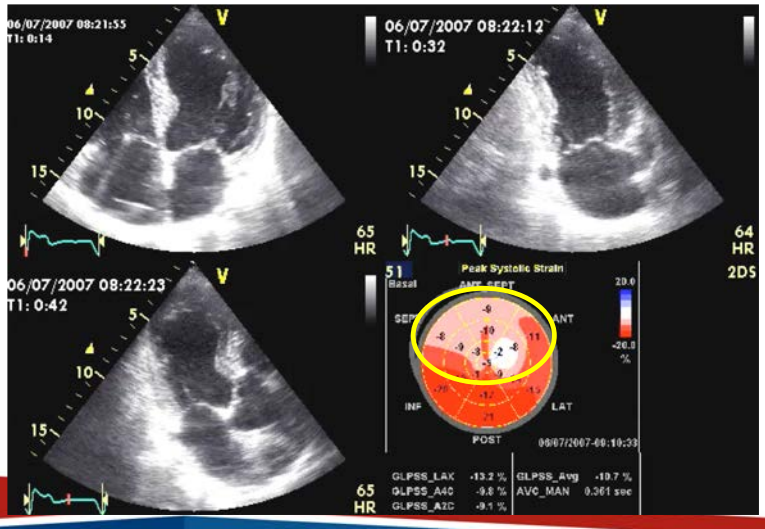
Septal, Apical and Anterior



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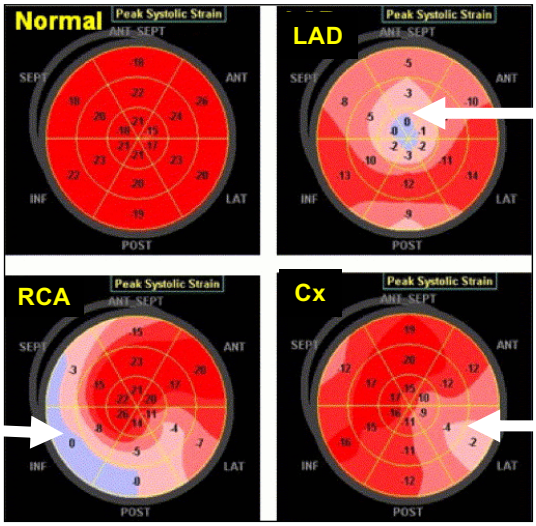

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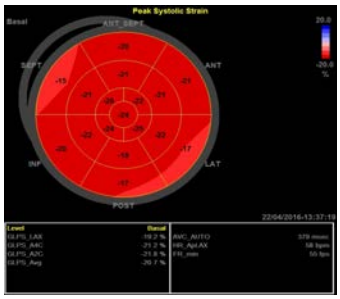
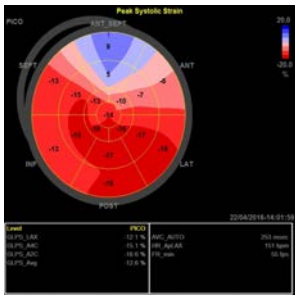
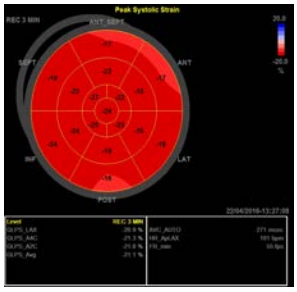
What happens to Strain 3 minutes post-stress?



Rest –20%



Stress –13%



3 min post-recovery –21.1 %

65 yo. Positive stress in the apical, septal anterior, anterior and inferior segments

Severe lesion on the LAD and RCA

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Longitudinal 2D strain at rest predicts the presence of left main and three vessel coronary artery disease in patients without regional wall motion abnormality

GLS was lower in 108 patients with left main or triple vessel disease in patients without RWMA (**-17.9 %)** with a sensitivity and specificity of 79% with respect to normals
No patient with triple vessel disease had normal GLS
GLS was more sensitive compared to visual analysis

A GLS cutoff value of -17.4% identified obstructive CAD with high sensitivity and specificity (83% and 77%, respectively), [3] and patients with obstructive CAD demonstrated a reliable decrease in absolute GLS with increasing number of diseased coronaries

Jin-Oh Choi et al Eur J Echocardiogr (2009) 10(5): 695-701. Korea.

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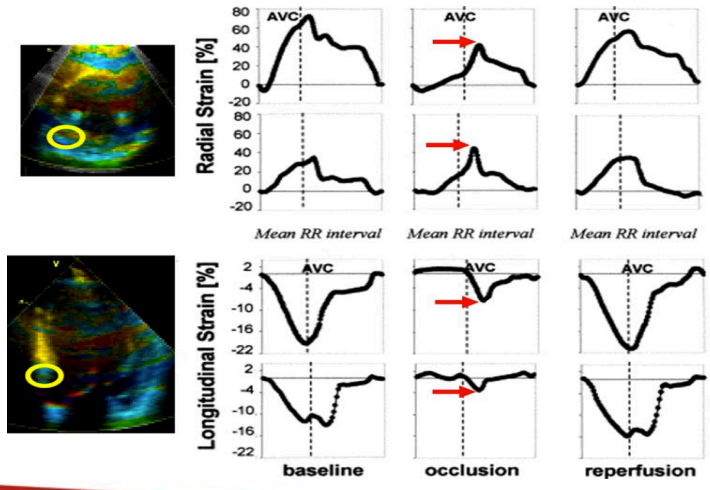
Post Systolic Thickening after Acute Ischemia



(J Am Coll Cardiol 2011;58:1401–13)

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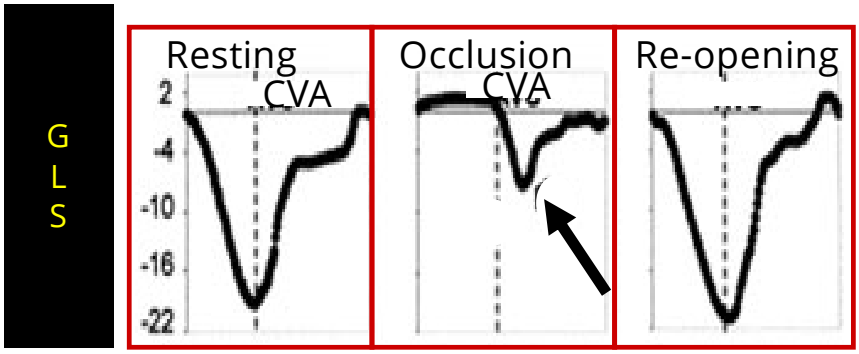
Myocardial Ischemia: Post Systolic Thickening



Post-Systolic Contraction

Effect of acute ischemia on regional strain (intracoronary balloon)

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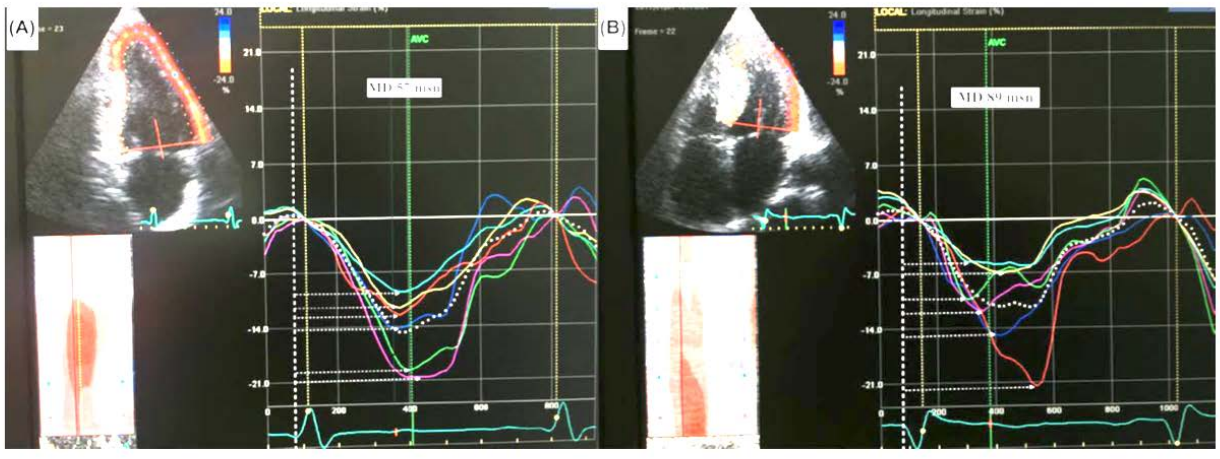
Mechanical Dispersion index is SD of the time to peak of each of the 16 regions and expressed as a percentage of the R-R interval.



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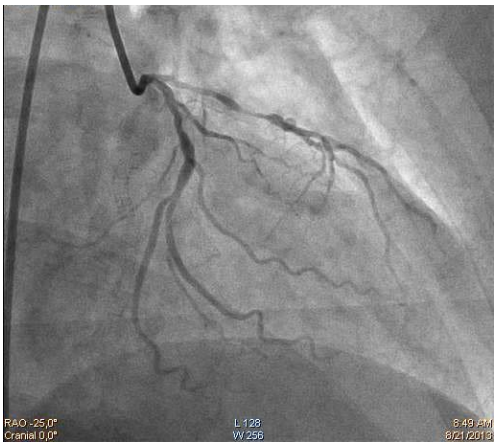
Exercise Echocardiography



Rest | Stress

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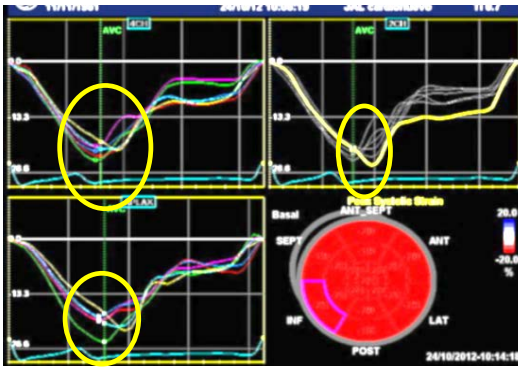
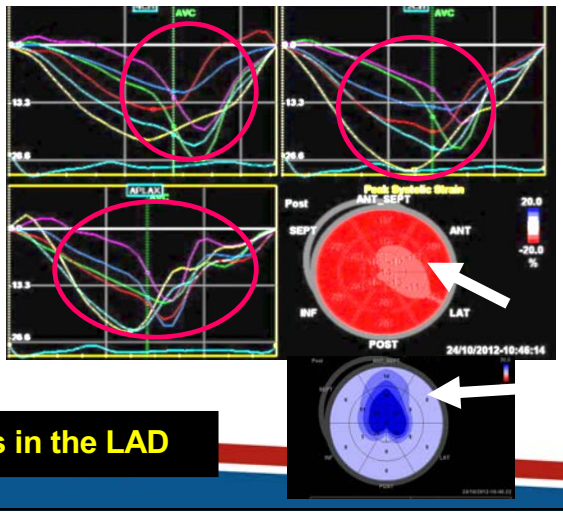
GLS, post-systolic contraction, mechanical dispersion index

Rest



Stress



2 severe lesions in the LAD

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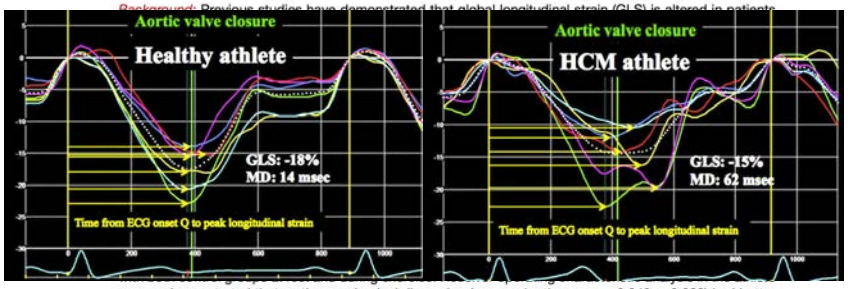
ASE American Society of Echocardiography

Mechanical Dispersion by Strain Echocardiography: A Novel Tool to Diagnose Hypertrophic Cardiomyopathy in Athletes

Frédéric Schnell, MD, PhD, David Matelot, PhD, Magalie Daudin, MD, Gaelle Kervio, PhD, Philippe Mabo, MD, PhD, François Carré, MD, PhD, and Erwan Donal, MD, PhD, *Rennes, France*



groups demonstrated that resting mechanical dispersion (area under the curve = 0.949 ± 0.023) had better ability to identify HCM compared with GLS at rest (area under the curve = 0.644 ± 0.069) ($P < .001$) or during exercise (area under the curve = 0.706 ± 0.066) ($P < .005$).

Conclusions: In athletes, normal resting GLS does not rule out the diagnosis of HCM. Mechanical dispersion of longitudinal strain seems to be a promising tool for the diagnosis of HCM in athletes. (J Am Soc Echocardiogr 2016;■:■-■.)

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JACC: CARDIOVASCULAR IMAGING
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http://dx.doi.org/10.1016/j.jcmg.2013.03.005

American Society of Echocardiography

Strain Echocardiography Improves Risk Prediction of Ventricular Arrhythmias After Myocardial Infarction

Kristina H. Haugaa, MD, PhD,*† Bjørnar L. Grenne, MD, PhD,‡ Christian H. Eek, MD, PhD,* Mads Ersbøll, MD,§ Nana Valeur, MD, PhD,‖ Jesper H. Svendsen, MD, PhD,§¶ Anca Florian, MD,# Benthe Sjøli, MD, PhD,‡ Harald Brunvand, MD, PhD,‡ Lars Køber, MD, PhD,§ Jens-Uwe Voigt, MD, PhD,# Walter Desmet, MD, PhD,# Otto A. Smiseth, MD, PhD,*† Thor Edvardsen, MD, PhD*†
Oslo and Arendal, Norway; Copenhagen and Gentofte, Denmark; and Leuven, Belgium

In this prospective multicentric study in pts
Post AMI days the combination of LGS and the mechanical dispersion index predicted arrythmic events independently of LVEF.
This may aid in the selection of implantable cardioverter defibrillation in patientes post AMI

$p < 0.001$) in patients with arrhythmias compared with those without. Mechanical dispersion was an independent predictor of arrhythmic events (per 10-ms increase, hazard ratio: 1.7; 95% confidence interval: 1.2 to 2.5; $p < 0.01$). Mechanical dispersion and global strain were markers of arrhythmias in patients with non–ST-segment elevation MIs ($p < 0.05$ for both) and in those with LVEFs > 35% ($p < 0.05$ for both), whereas LVEF was not ($p = 0.33$). A combination of mechanical dispersion and global strain showed the best positive predictive value for arrhythmic events (21%; 95% confidence interval: 6% to 46%).

CONCLUSIONS Mechanical dispersion by strain echocardiography predicted arrhythmic events independently of LVEF in this prospective, multicenter study of patients after MI. A combination of mechanical dispersion and global strain may improve the selection of patients after MI for implantable cardioverter-defibrillator therapy, particularly in patients with LVEFs > 35% who did not fulfill current implantable cardioverter-defibrillator indications. (J Am Coll Cardiol Img 2013;■:■–■) © 2013 by the American College of Cardiology Foundation

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Strain and GLS: Conclusion

- **Strain aids in the detection of CAD, assessment of myocardial changes after revascularization, and prognosis.**
- **Lack of improvement in GLS after coronary revascularization are associated with negative LV remodeling at 6 months in patients with non-ST elevation myocardial infarction.**
- **In patients with an acute AMI, strain and strain rate were significantly and independently correlated with all-cause mortality, reinfarction, revascularization, and heart failure hospitalization at 3-year follow up.**

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Strain and Heart Failure

- **Risk Assessment**
  - Association of strain with outcome
- **Diagnosis**
  - Etiology of LV dysfunction
  - HFpEF vs noncardiac dyspnea
- **Management**
  - CRT implantation
  - VAD vs BiVAD
- **Follow-up**
  - Cardiotoxicity
  - F/U of Increased Filling pressures and TX

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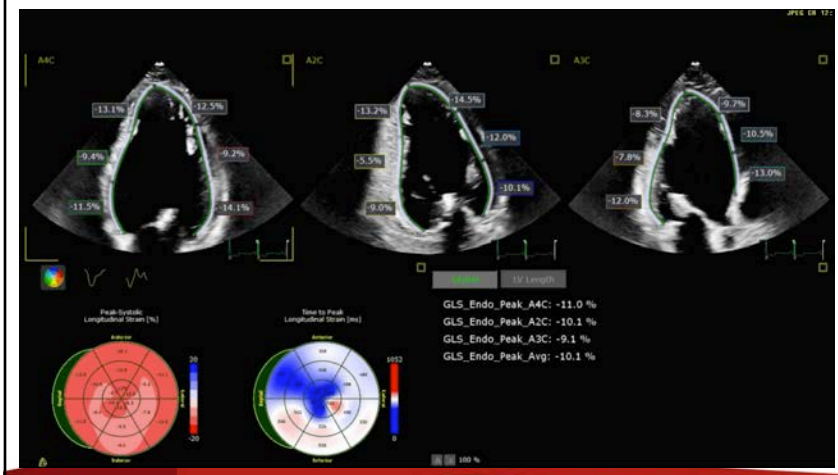
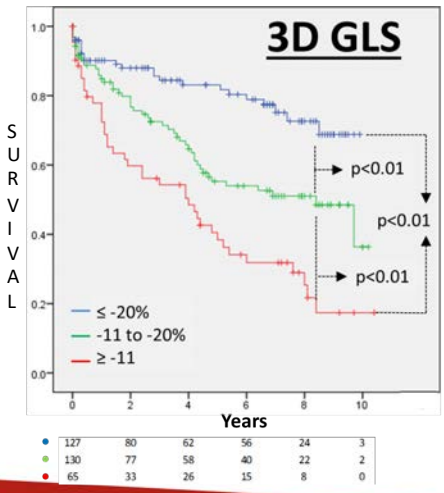
In HF with reduced EF, LGS adds value in stratifying the outcomes of patients with an EF less than 22%.





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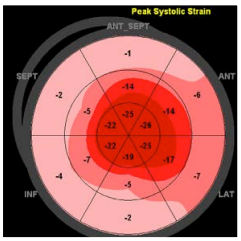
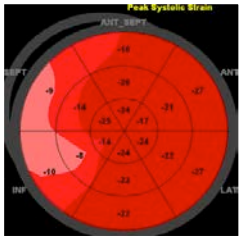
Etiology

Cardiac Amyloidosis	Hypertensive Heart Disease	Hypertrophic Cardiomyopathy
		
14mm	14mm	13mm

Mean Wall Left Ventricular Thickness

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Strain and Heart Failure

- **Risk Management**
  - CRT implantation
  - VAD vs BiVAD
- **Follow-up**
  - Cardiotoxicity
  - F/U of Increased Filling pressures and TX

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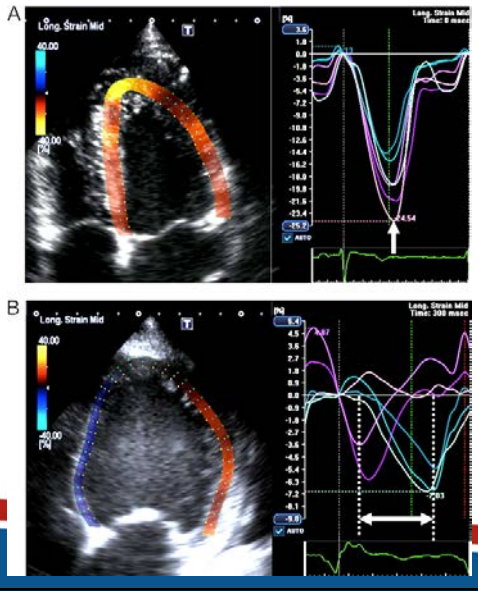
LS in a Normal Subject and a Patient with CHF and CLBBB



Early septal peak strain followed by late lateral wall peak strain

(J Am Coll Cardiol 2011;58:1401–13)

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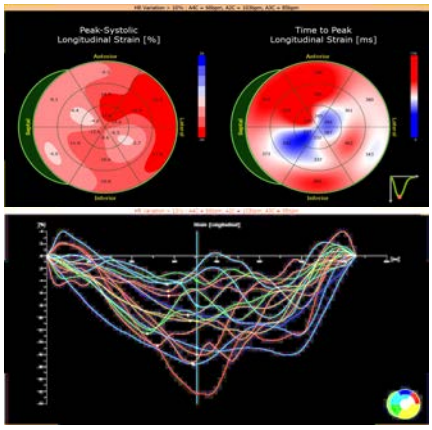
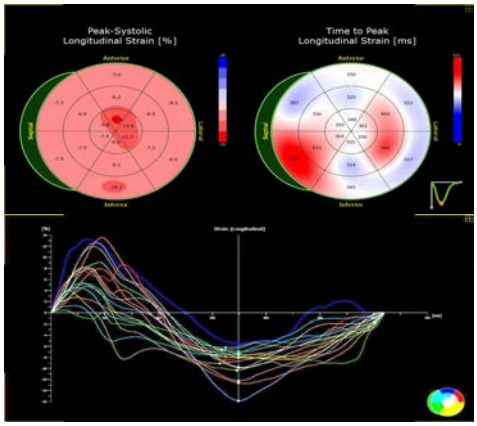
Bundle of His Pacing

Baseline



6 month



131

Thanks for your attention

132

Questions & Answers

133

Applications of Strain in Valvular Heart Disease

James D. Thomas, MD, FASE, FACC, FESC
Northwestern University
Chicago, IL

@JamesDThomasMD1

Conflicts of interest: GE, Abbott, Edwards, Caption Health (honoraria)
Caption Health (spouse employment)

134

Strain in Valvular Heart Disease

What Do the Guidelines Say?

Number of words in 2014 valve guideline

- 104,645

Number of strain mentions

- 4

Number of strain references

- 2/939 (both of them mine)

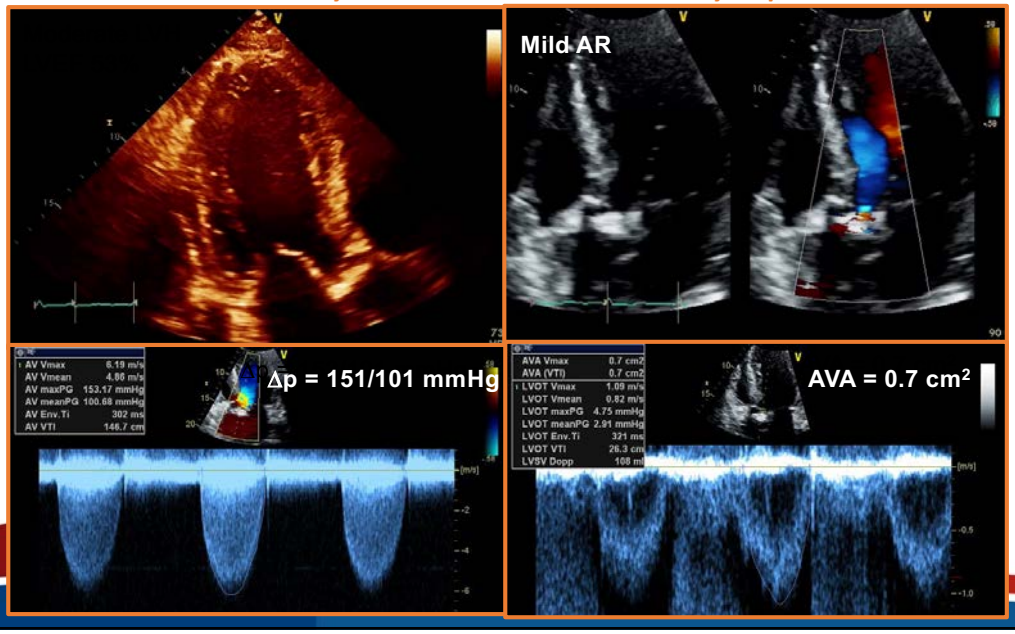
Number of guidelines that use strain

- 0

135

61 yo Man with Severe AS

Known AS x 2 years, claims to be asymptomatic



136

Asymptomatic Aortic Stenosis
General Teaching

Do NOT operate on the asymptomatic patient with AS and normal LV function

"The leading cause of death in asymptomatic AS is premature surgery."

--Eugene Braunwald

137

Aortic Stenosis: Timing of Intervention

Recommendations	COR	LOE
AVR is recommended with severe high-gradient AS who have symptoms by history or on exercise testing (stage D1)	I	B
AVR is recommended for asymptomatic patients with severe AS (stage C2) and LVEF <50%	I	B
AVR is indicated for patients with severe AS (stage C or D) when undergoing other cardiac surgery	I	B

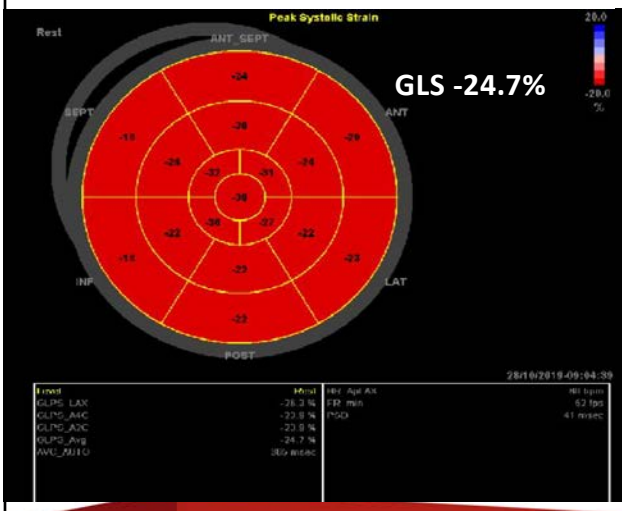
Are there other factors that should be considered??

ACCF/AHA Valve Guidelines

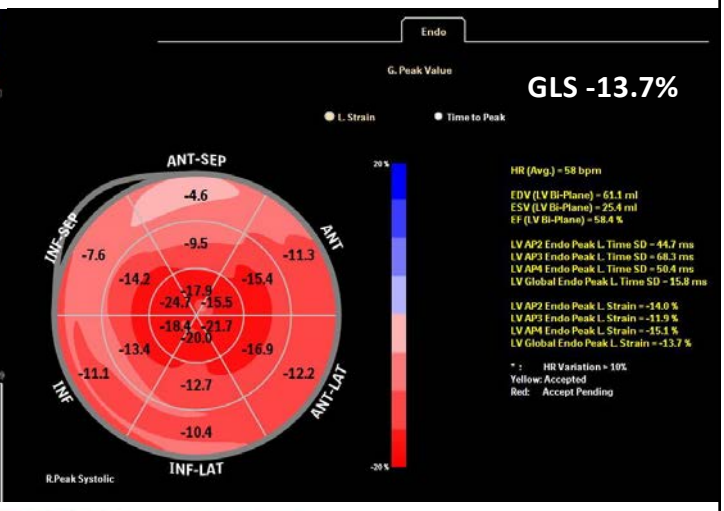
138

Should it matter if your strain looks like…

This?



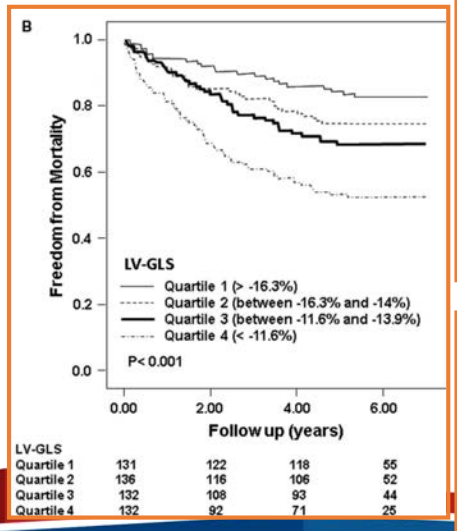
Or THIS?



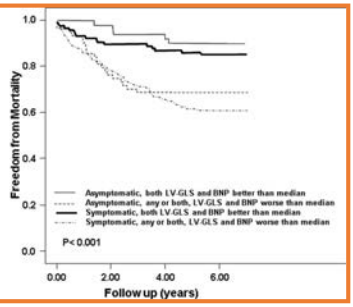
139

Impact of Strain and BNP on Survival in AS

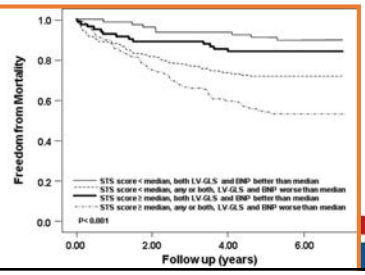
531 Pts w/ AVA<1.3 cm² and LVEF>50%



vs symptoms



vs STS score



Goodman et al. JAHA 2016; 5: e002561

140

JAMA Cardiology | Original Investigation

Association of Left Ventricular Global Longitudinal Strain With Asymptomatic Severe Aortic Stenosis

Natural Course and Prognostic Value

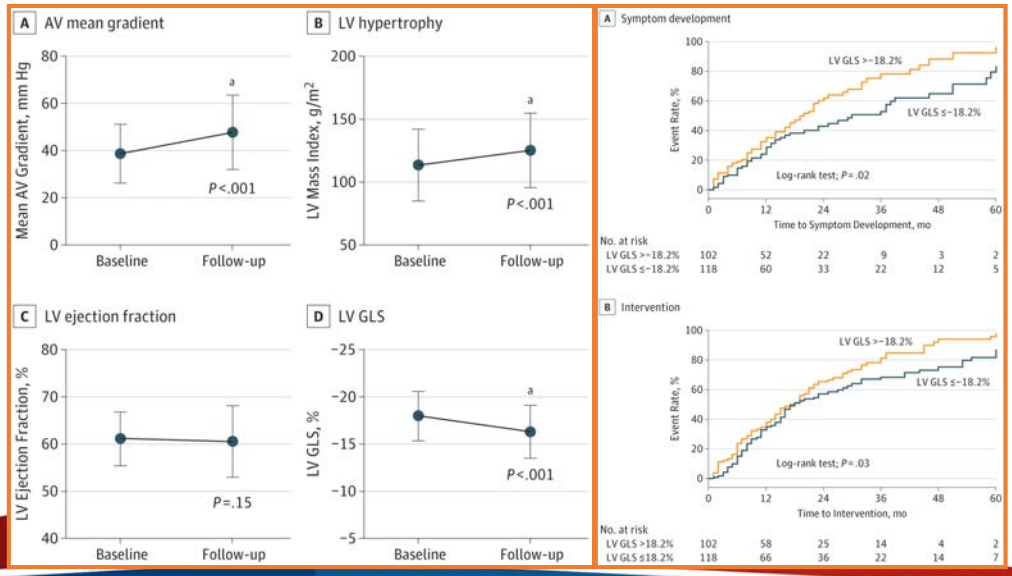
E. Mara Vollema, MD; Tadafumi Sugimoto, MD; Mylène Shen, MSc; Lionel Tastet, MSc, MS; Arnold C. T. Ng, MD, PhD; Rachid Abou, MD; Nina Ajmone Marsan, MD, PhD; Bart Mertens, PhD; Raluca Dulgheru, MD; Patrizio Lancellotti, MD, PhD; Marie-Annick Clavel, DVM, PhD; Philippe Pibarot, DVM, PhD; Philippe Genereux, MD; Martin B. Leon, MD; Victoria Delgado, MD, PhD; Jeroen J. Bax, MD, PhD

Vollema EM et al. JAMA Cardiol 2018; 3(9): 839-847

141

Impact of Strain on Survival in ASx Severe AS

220 Pts w/ AVAi<0.6 cm²/m² and LVEF>50%



Vollema EM et al. JAMA Cardiol 2018; 3(9): 839-847

142

Moving Past Ejection Fraction in Timing of Aortic Stenosis Intervention

James D. Thomas, MD

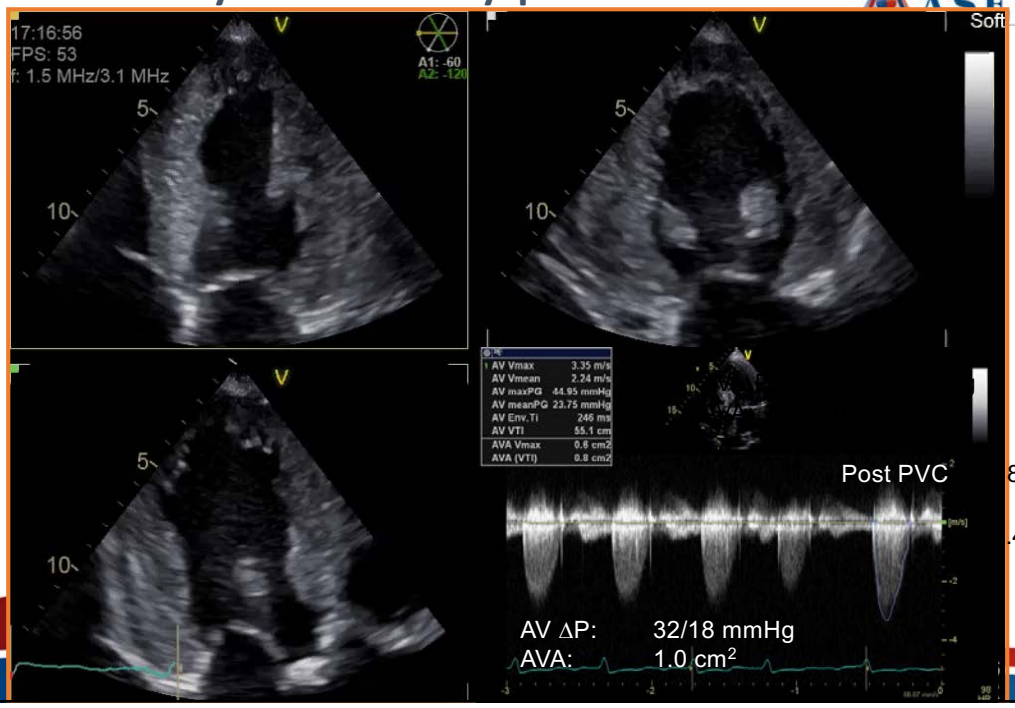
American Society of Echocardiography

Perhaps it is time to organize a clinical trial of asymptomatic severe AS with randomization between those whose care is guided in part by GLS and those using current guidelines to time intervention.

Thomas JD et al. JAMA Cardiol 2018; 3(9): 847-8

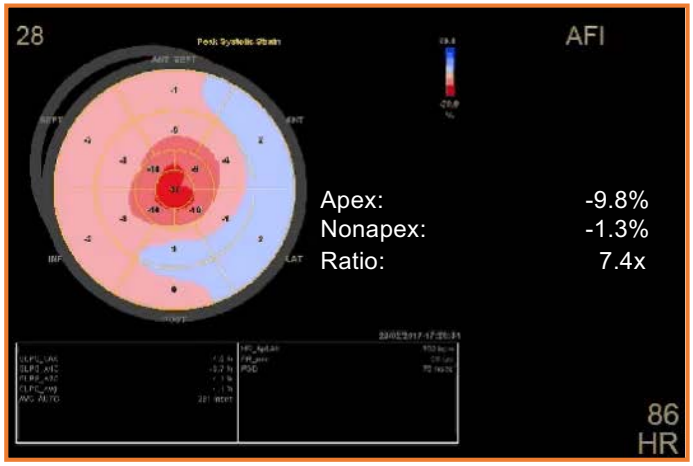
143

Don't Miss This! 91yo Man with Dyspnea and ?LFLGAS



144

91yo Man with Dyspnea and ?LFLGAS

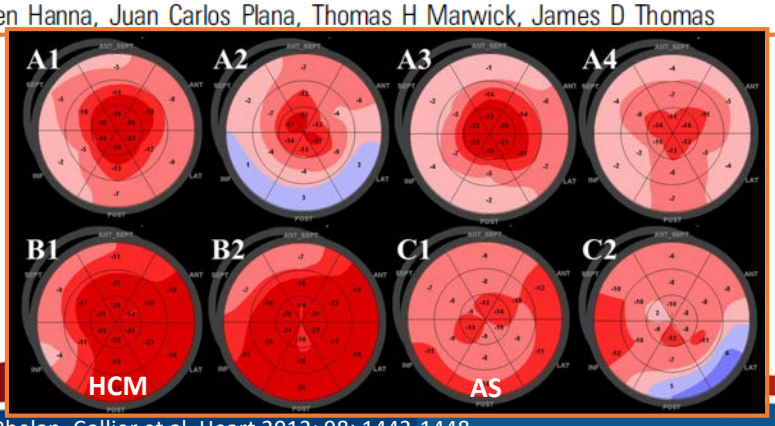


145

ORIGINAL ARTICLE

Relative 'apical sparing' of longitudinal strain using two-dimensional speckle-tracking echocardiography is both sensitive and specific for the diagnosis of cardiac amyloidosis

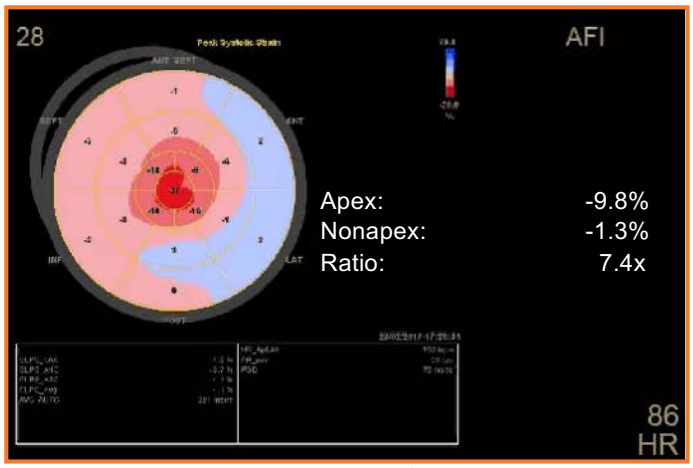
Dermot Phelan, Patrick Collier, Paaladinesh Thavendiranathan, Zoran B Popović, Mazen Hanna, Juan Carlos Plana, Thomas H Marwick, James D Thomas



Phelan, Collier et al. Heart 2012; 98: 1442-1448

146

91yo Man with Dyspnea and ?LFLGAS



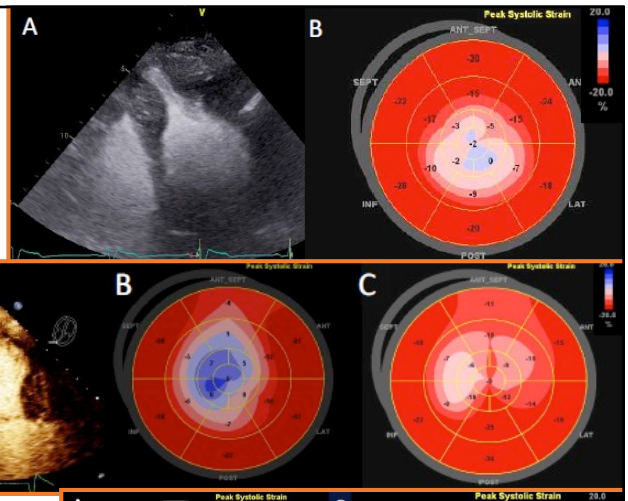
Strong suspicion for amyloid confirmed with pyrophosphate scan

No TAVR

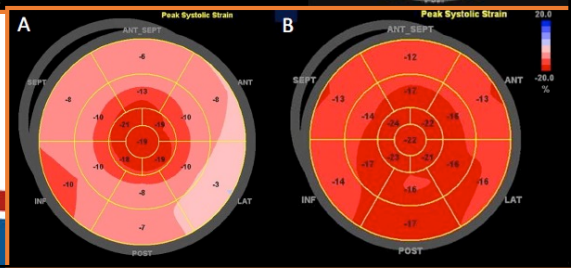
147

Apical HCM

Keep your eyes open for other typical strain patterns



Takotsubo



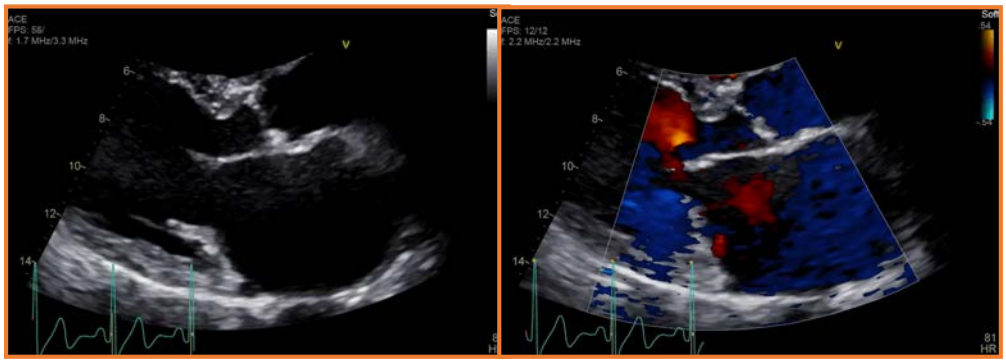
Reverse Takotsubo

Singh et al. JAMA Cardiol 2019

148

Organic Mitral Regurgitation
When to Intervene???

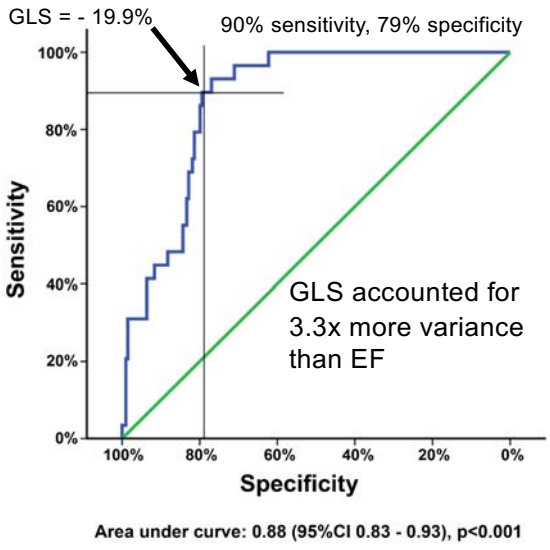
Organic MR: The valve makes the ventricle sick



Flail PML, severe anteriorly-directed MR

149

Impact of Strain on Post MVr LV function
233 Pts, Prediction of 12+ month LVEF<50%



Predictors of LV dysfunction

	OR	*p*
|GLS|<19.9%	*23.2*	*<0.001*
LVESD>40mm	*6.7*	*0.003*
EF<60%	*2.6*	*0.069*
Symptoms	*2.4*	*0.165*
AF	*2.0*	*0.210*

χ^2 = 69.1, p<0.001

Closer to zero = Bad

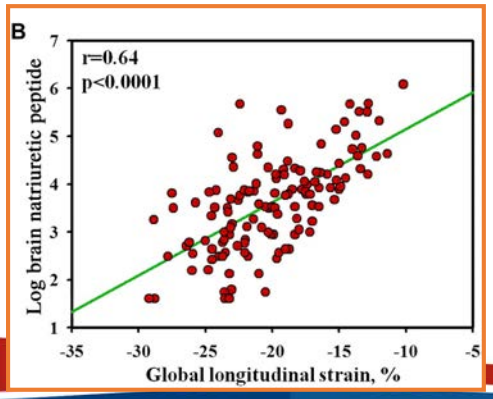
Witkowski et al. EHJ-CVI 2013; 14 :69-76

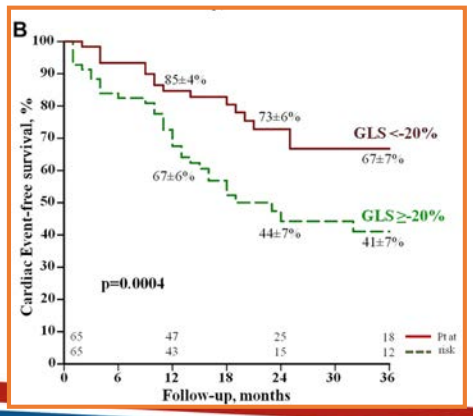
150

Prognostic importance of brain natriuretic peptide and left ventricular longitudinal function in asymptomatic degenerative mitral regurgitation

Julien Magne,[1] Haifa Mahjoub,[2] Luc A Pierard,[1] Kim O'Connor,[1,2] Charles Pirlet,[1] Philippe Pibarot,[2] Patrizio Lancellotti[1]

- *135 asx mod-severe MR patients followed x 2 years*





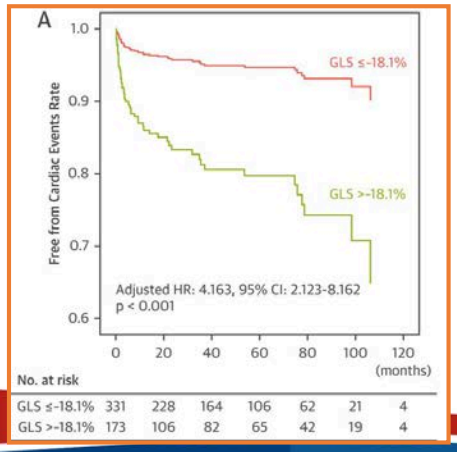
Magne et al. Heart 2012; 98: 584-91

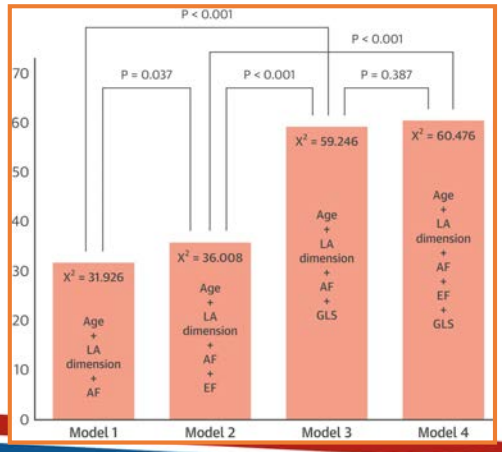
151

Myocardial Strain in Prediction of Outcomes After Surgery for Severe Mitral Regurgitation

Hyue Mee Kim, MD,[a,b] Goo-Yeong Cho, MD, PhD,[a] In-Chang Hwang, MD,[a,b] Hong-Mi Choi, MD,[a] Jun-Bean Park, MD, PhD,[b] Yeonyee E. Yoon, MD,[a] Hyung-Kwan Kim, MD, PhD[b]

- *506 surgical MR patients over a 10 year period*





Kim et al. JACC Imaging 2018; 11: 1235-44

152

EDITORIAL COMMENT

The Prognostic Role of Global Longitudinal Strain in Severe Primary Mitral Regurgitation

Moving Past the Proof-of-Concept Era*

James D. Thomas, MD, Menhel Kinno, MD, MPH

ASE American Society of Echocardiography

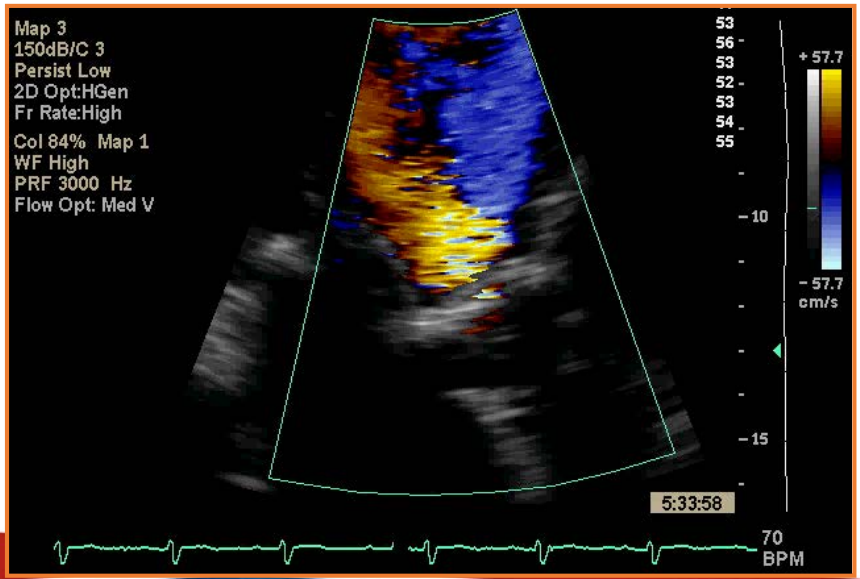
Regardless, the bulk of evidence indicates that GLS is useful in MR patients, and practitioners are encouraged to measure this parameter on a routine basis in patients with severe MR.

Thomas and Kinno. JACC Imaging 2018; 11: 1245-47

153

What About AR???

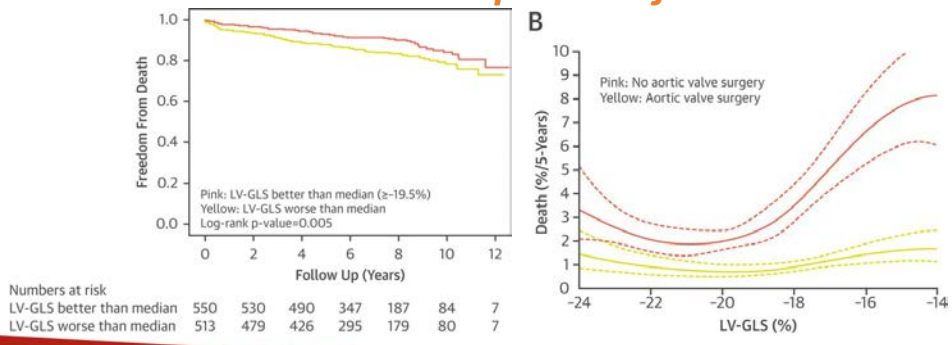
ASE American Society of Echocardiography



154

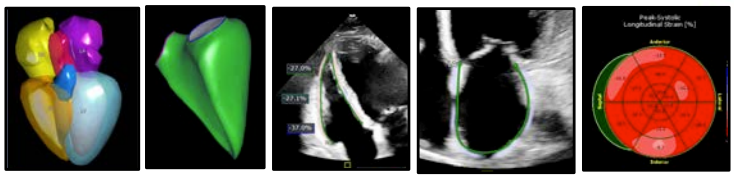
Incremental Prognostic Utility of Left Ventricular Global Longitudinal Strain in Asymptomatic Patients With Significant Chronic Aortic Regurgitation and Preserved Left Ventricular Ejection Fraction

- *1063 asx mod-severe AR patients followed x 7*



Alashi et al. JACC Imaging 2018

155



Role of RV Strain

Roberto M Lang, MD

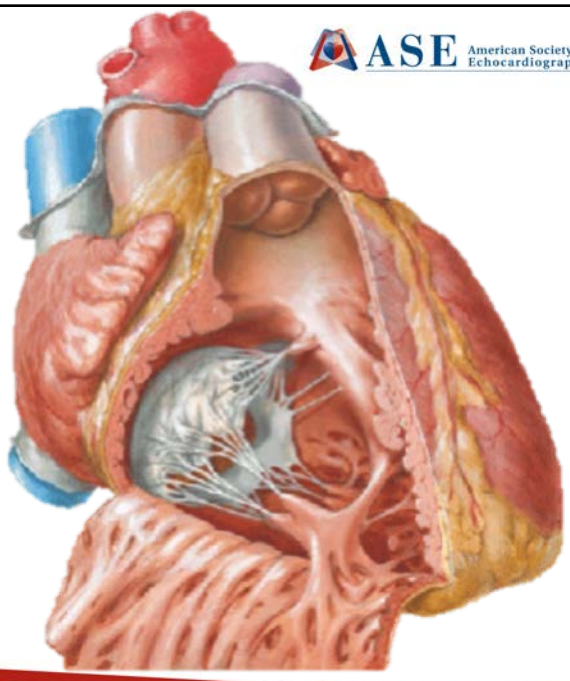
University of Chicago

@robertomlang

156

RV Anatomy

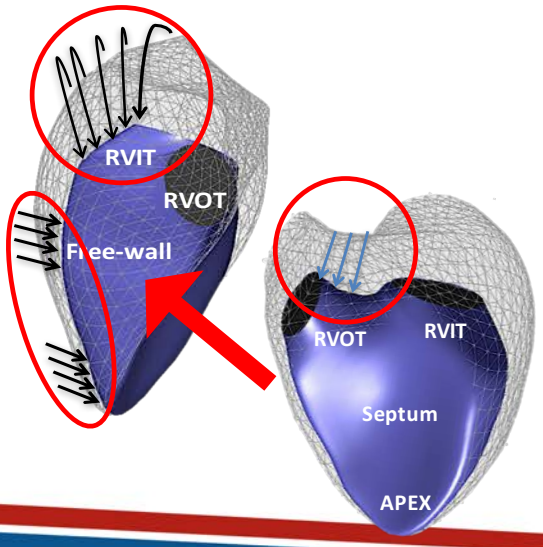
- Behind the sternum
- *Complex* crescent shape
- Thin-walled
- Anatomically made up of:
  - *Outlet* (conus) – accounts for ~20% of the EDV
  - Trabeculated *apex*
  - *Inflow* tract
- Low pulmonary resistance /afterload



157

Right Ventricular Contraction

1. Long-axis shortening drawing the TV towards the apex
2. Inward movement of the free-wall (bellows effect)
3. Bulging of the IVS into the RV during LV contraction



159

ASE American Society of Echocardiography
Heart & Circulation Ultrasound Specialists

EACVI EUROPEAN ASSOCIATION OF CARDIOVASCULAR IMAGING

Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

Roberto M. Lang, MD, FASE, FESC, Luigi P. Badano, MD, PhD, FESC, Victor Mor-Avi, PhD, FASE, Jonathan Afilalo, MD, MSc, Anderson Armstrong, MD, MSc, Laura Ernande, MD, PhD, Frank A. Flachskampf, MD, FESC, Elyse Foster, MD, FASE, Steven A. Goldstein, MD, Tatiana Kuznetsova, MD, PhD, Patrizio Lancellotti, MD, PhD, FESC, Denisa Muraru, MD, PhD, Michael H. Picard, MD, FASE, Ernst R. Rietzschel, MD, PhD, Lawrence Rudski, MD, FASE, Kirk T. Spencer, MD, FASE, Wendy Tsang, MD, and Jens-Uwe Voigt, MD, PhD, FESC, *Chicago, Illinois; Padua, Italy; Montreal, Quebec and Toronto, Ontario, Canada; Baltimore, Maryland; Créteil, France; Uppsala, Sweden; San Francisco, California; Washington, District of Columbia; Leuven, Liège, and Ghent, Belgium; Boston, Massachusetts*

J Am Soc Echocardiogr 2015;28:1-39 Eur Heart J Cardiovasc Imaging 2015;16:233-71

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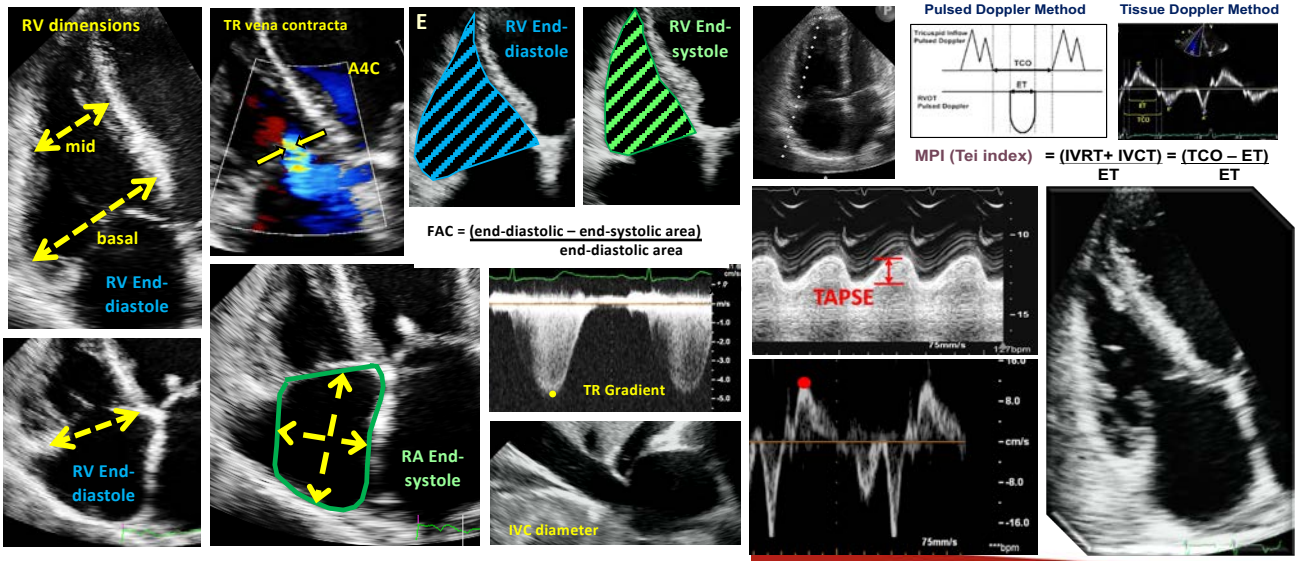
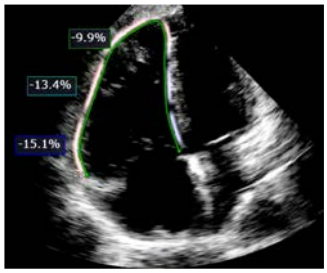
RV Assessment on 2D Echocardiography

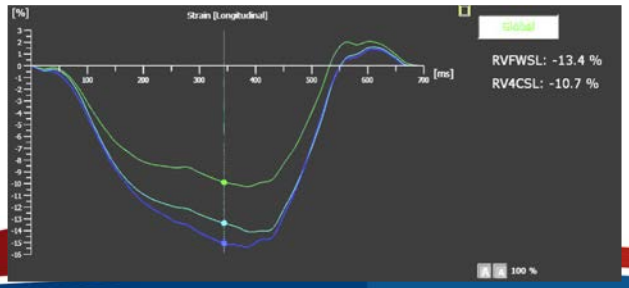
ASE American Society of Echocardiography



161

What's New in 2019?





Importance of deformation imaging emphasized

J Am Soc Echocardiogr 2015;28:1-39

162

The Right Ventricle on 2D Echocardiography

Obtain a good RV-focused apical 4-chamber view

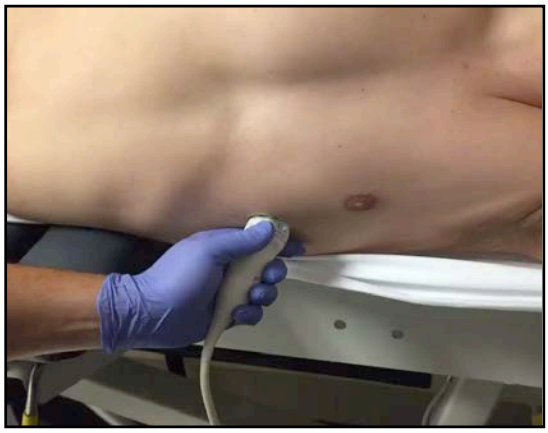
RV should be positioned centrally in the imaging sector

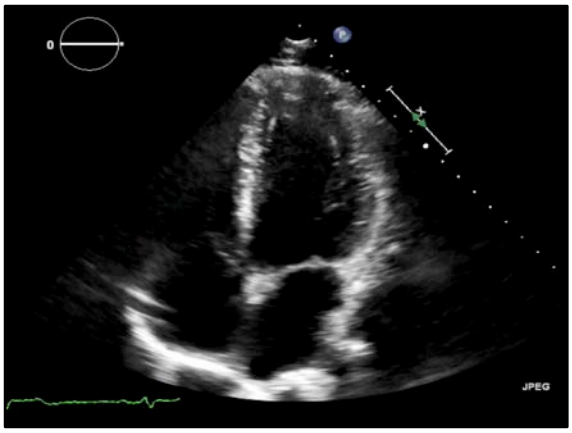
RV should not be fore-shortened. LVOT should not be visible

Frame rate should optimized to >40 frames/s by ↓ the imaging sector and ↓ depth to focus on the RV

163

Limitations of 2D Assessment of the RV



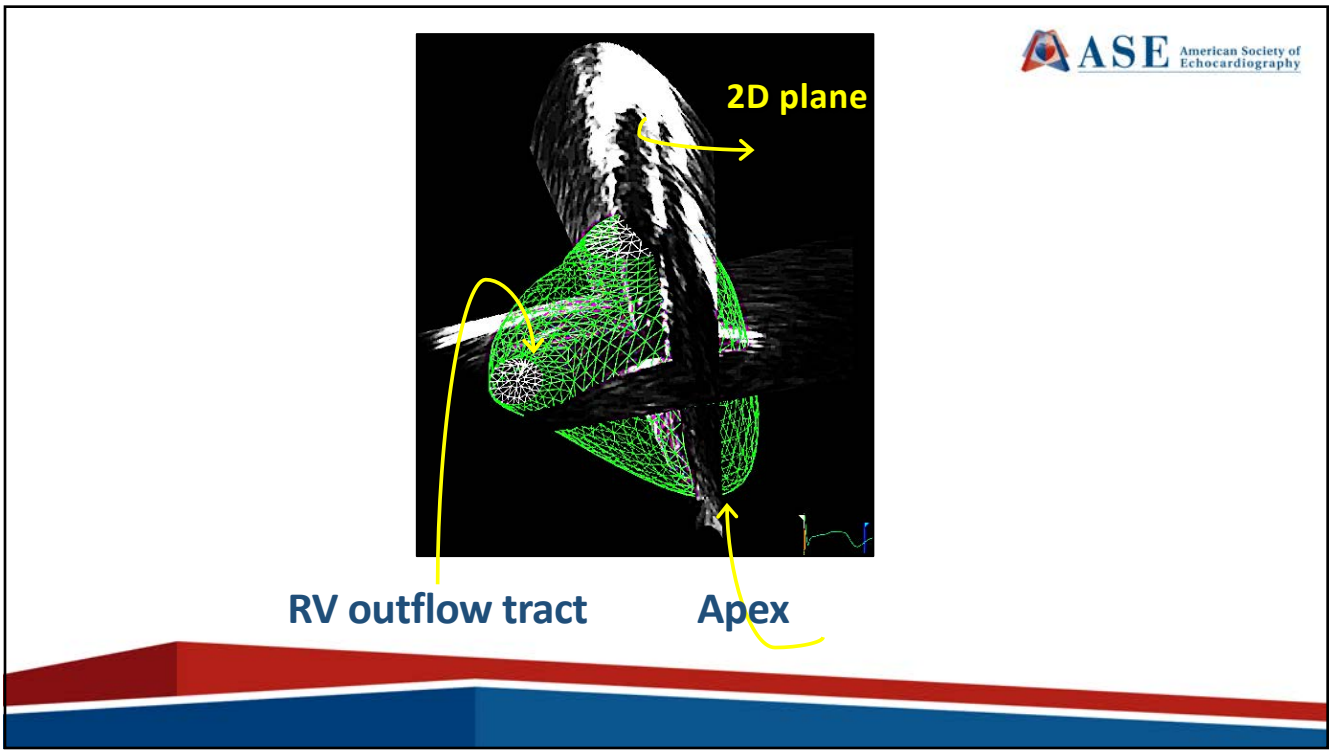


164

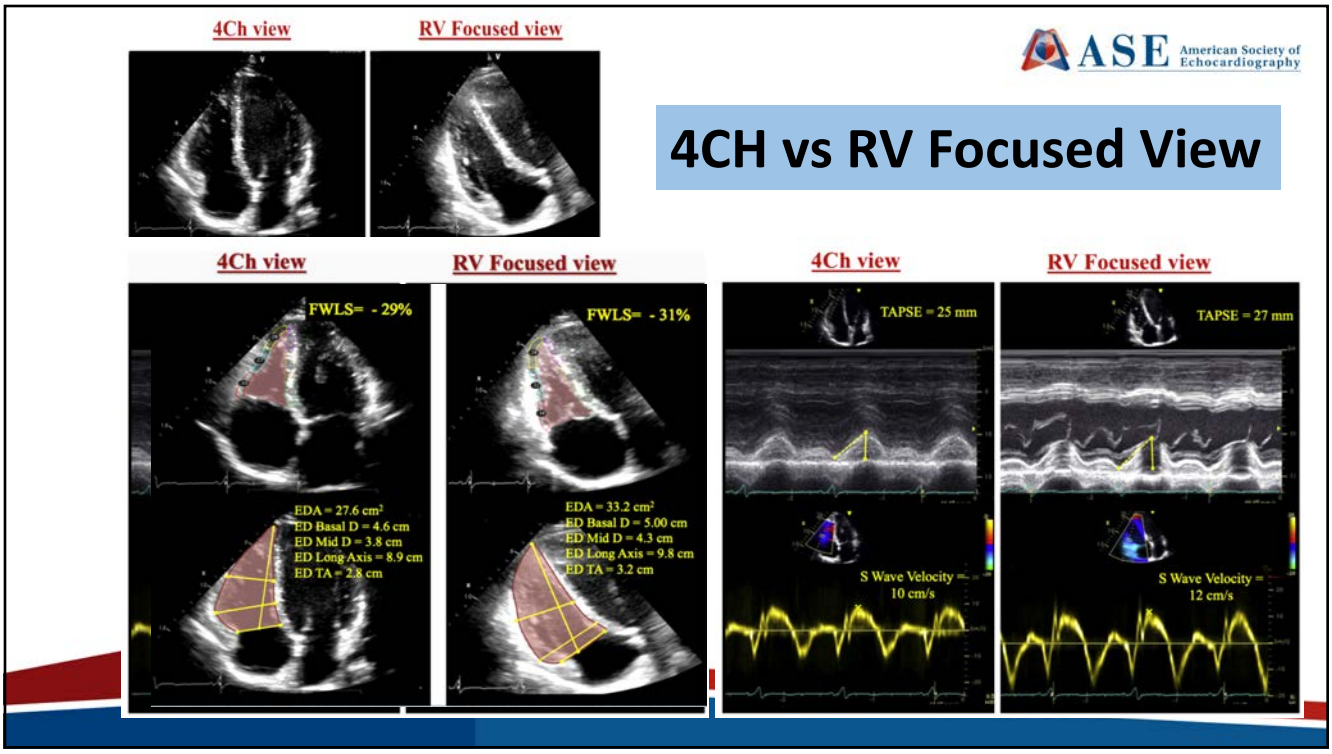
The RV focused view is like the 'tip of the iceberg'

Pectus excavatum

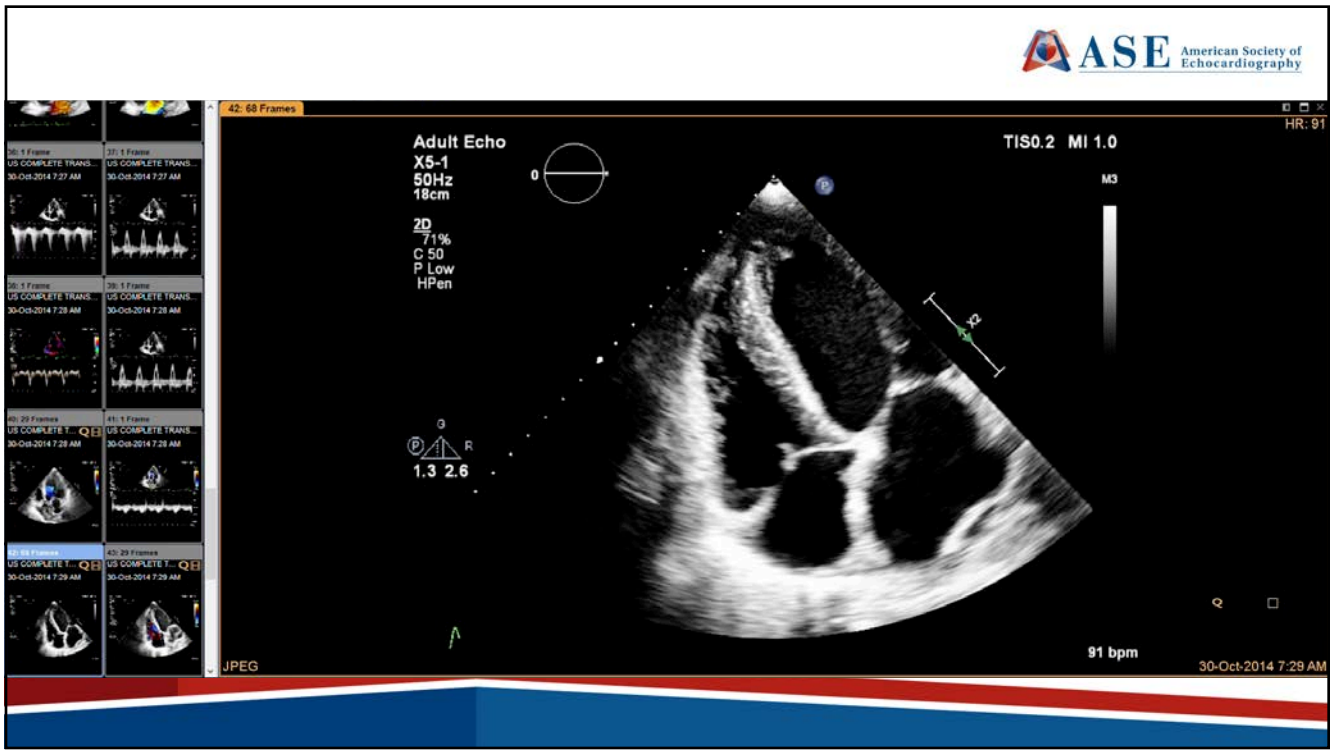
165


ASE American Society of Echocardiography
2D plane
RV outflow tract
Apex

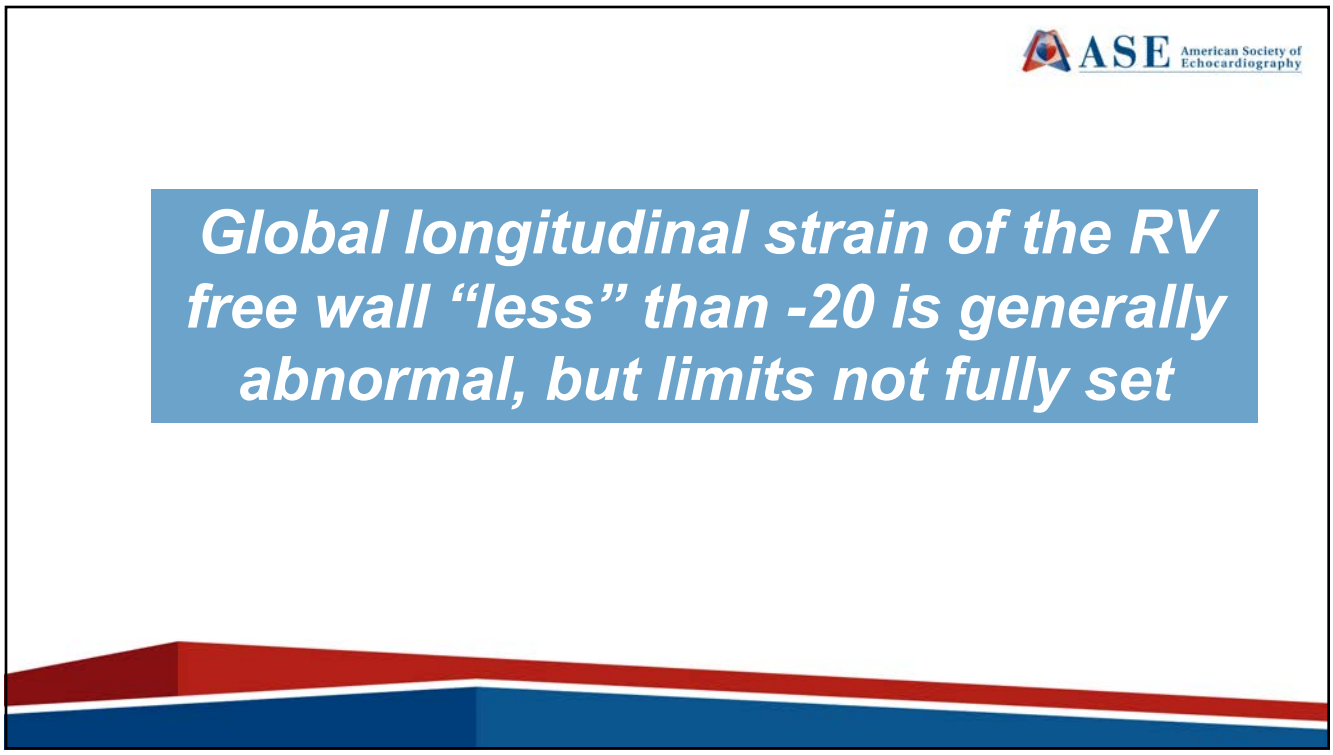
166


4Ch view
RV Focused view
ASE American Society of Echocardiography
4CH vs RV Focused View
4Ch view
RV Focused view
FWLS= - 29%
EDA = 27.6 cm²
ED Basal D = 4.6 cm
ED Mid D = 3.8 cm
ED Long Axis = 8.9 cm
ED TA = 2.8 cm
FWLS= - 31%
EDA = 33.2 cm²
ED Basal D = 5.00 cm
ED Mid D = 4.3 cm
ED Long Axis = 9.8 cm
ED TA = 3.2 cm
4Ch view
RV Focused view
TAPSE = 25 mm
S Wave Velocity = 10 cm/s
TAPSE = 27 mm
S Wave Velocity = 12 cm/s

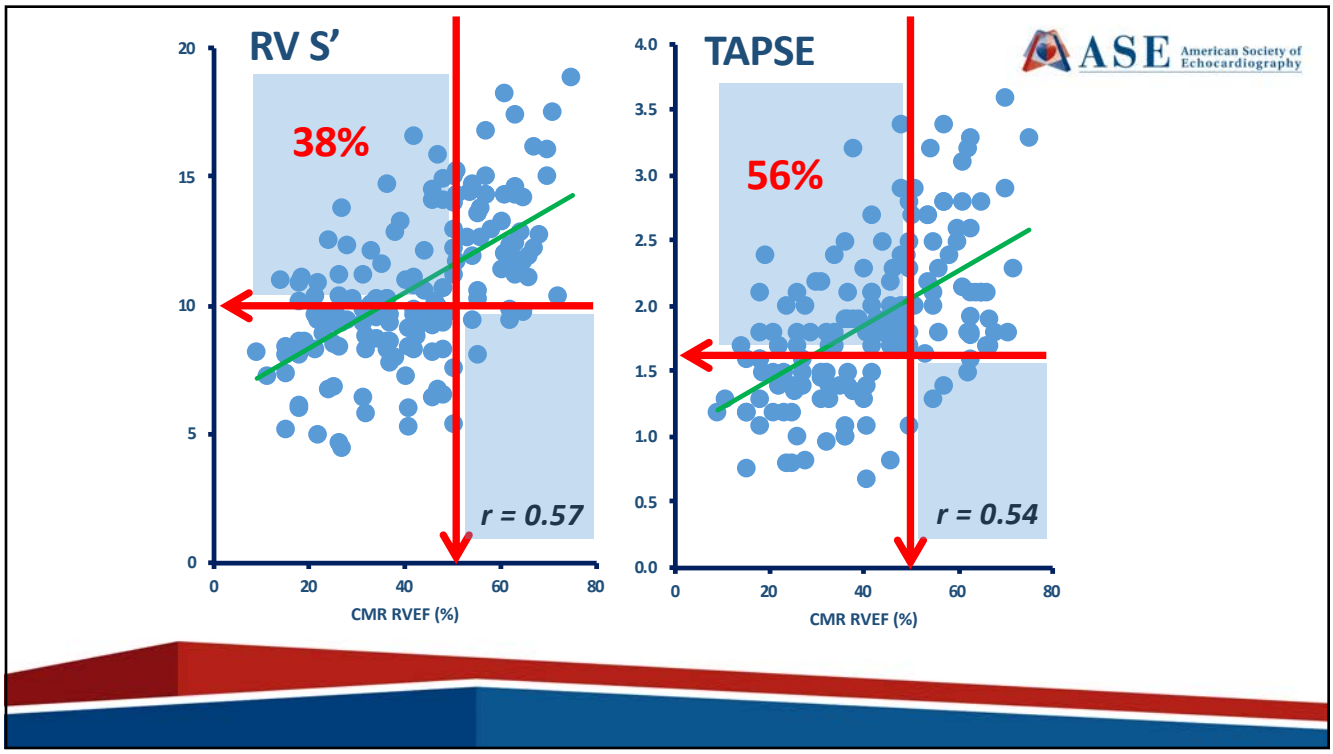
167


ASE American Society of Echocardiography
42: 68 Frames
Adult Echo
X5-1
50Hz
18cm
2D
71%
C 50
P Low
HPen
TIS0.2 MI 1.0
M3
HR: 91
1.3 2.6
91 bpm
JPEG
30-Oct-2014 7:29 AM

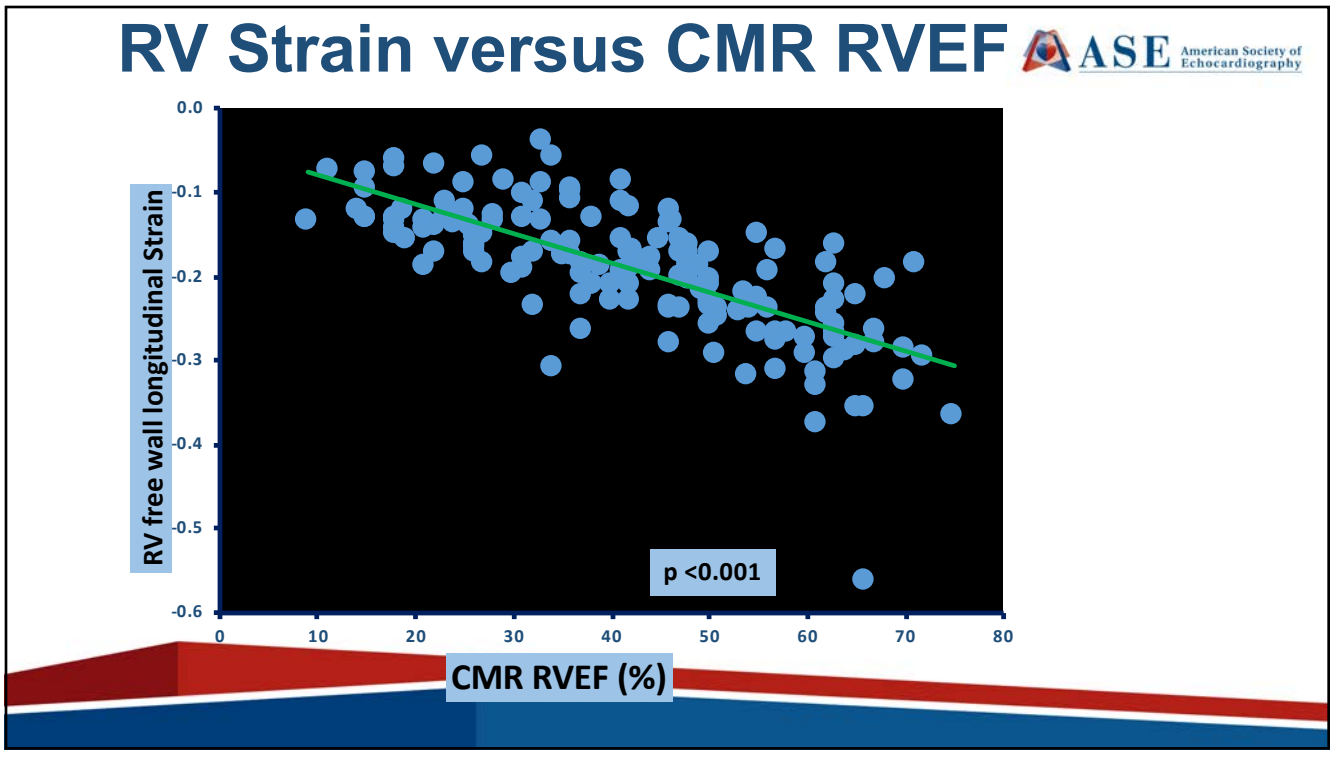
168


ASE American Society of Echocardiography
Global longitudinal strain of the RV free wall "less" than -20 is generally abnormal, but limits not fully set

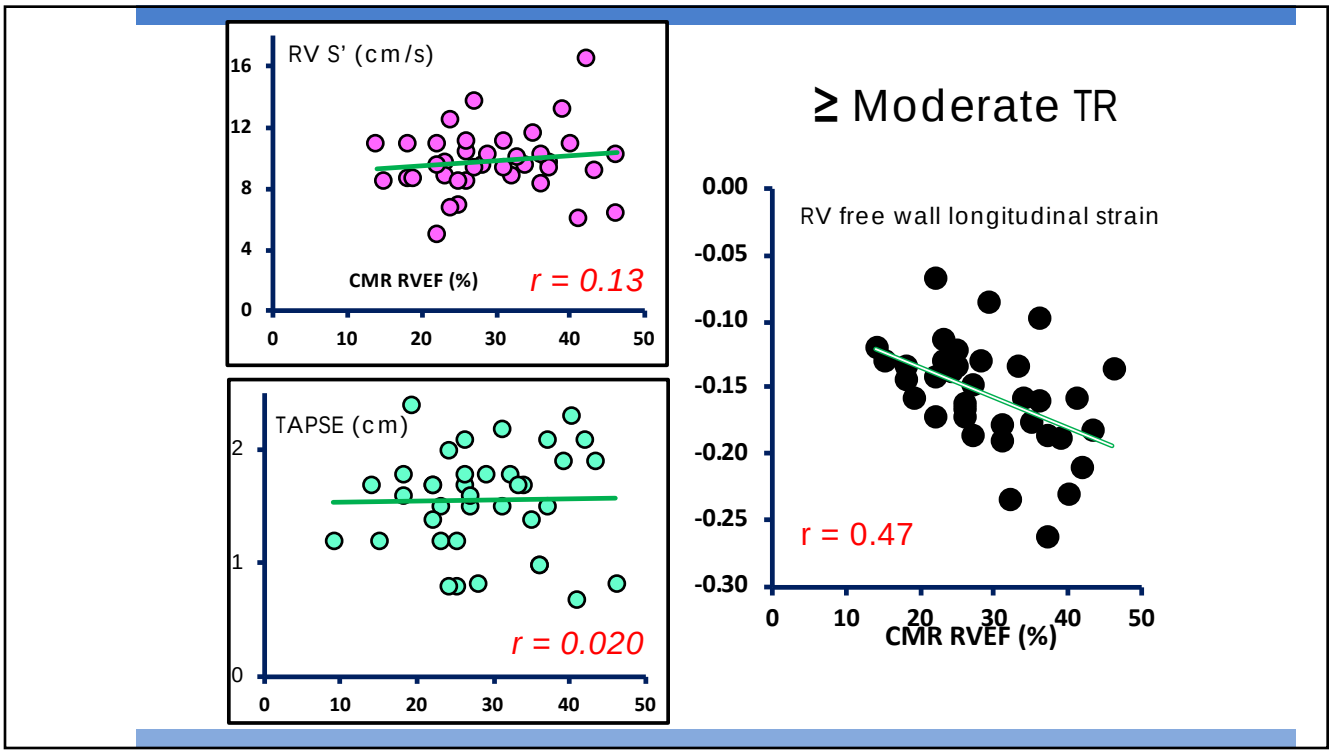
169


RV S'
38%
r = 0.57
CMR RVEF (%)
TAPSE
56%
r = 0.54
CMR RVEF (%)
ASE American Society of Echocardiography

170


RV Strain versus CMR RVEF
ASE American Society of Echocardiography
RV free wall longitudinal Strain
p <0.001
CMR RVEF (%)

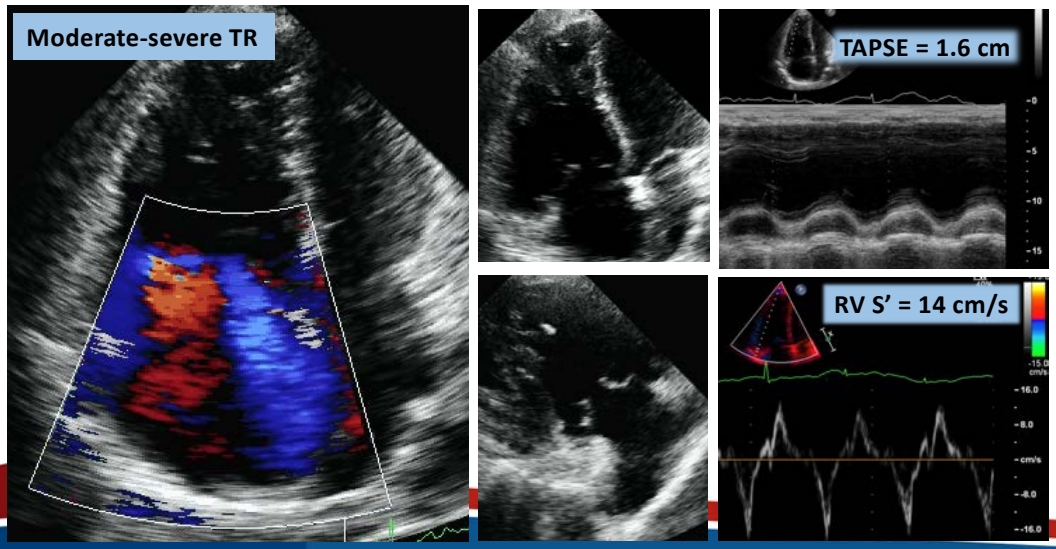
171



172

Added value of RV strain imaging

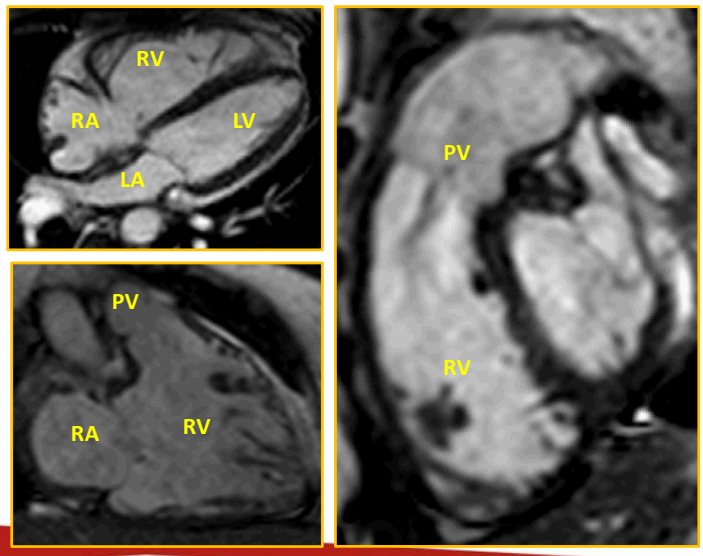
Sometimes the 2D measurements are just wrong….



173

Added value of RV strain imaging

CMR



RVEF 27%

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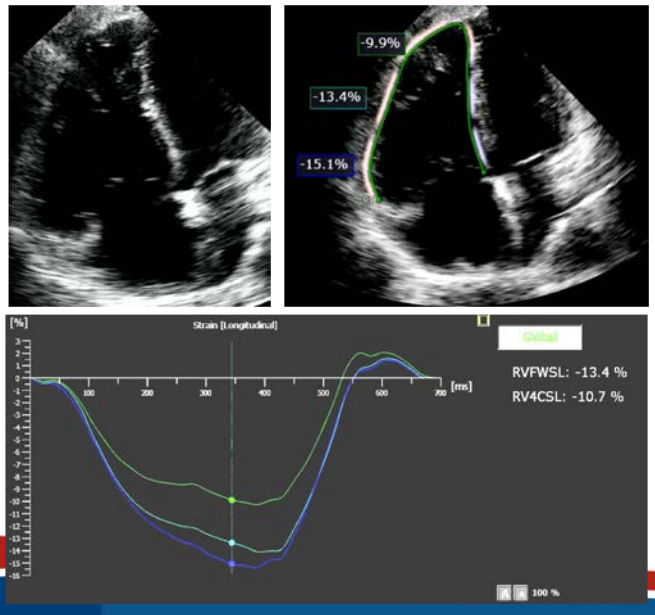
Added value of RV strain imaging



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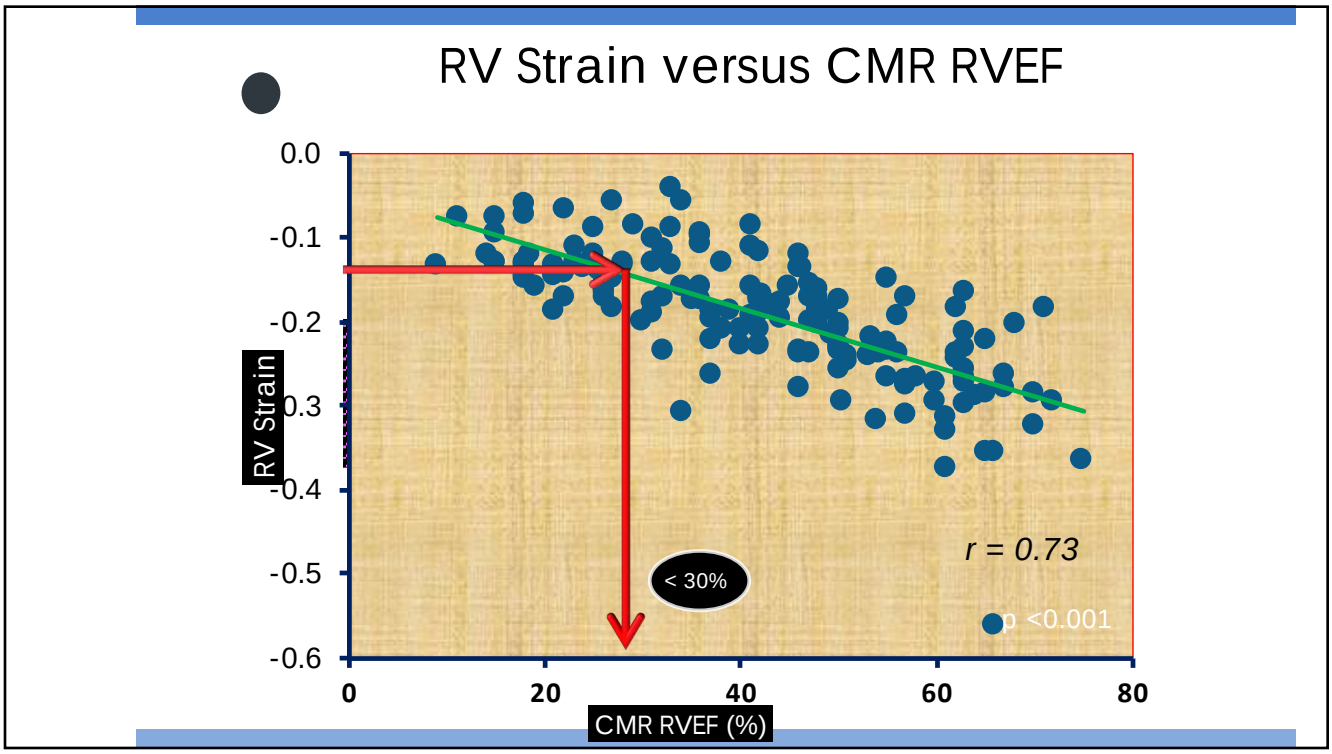

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Summary

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1. **TAPSE and S'**
   - Correlate moderately with CMR RVEF
   - In the presence of moderate or more TR TAPSE and RV S' probably should not be used
2. **RV free wall longitudinal strain**
   - ? better index of RV function than TAPSE or RV S'
   - Correlates better with CMR RVEF

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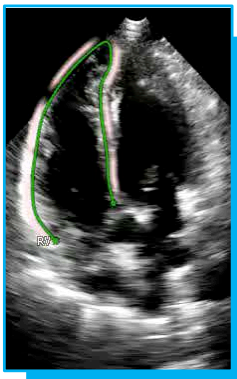
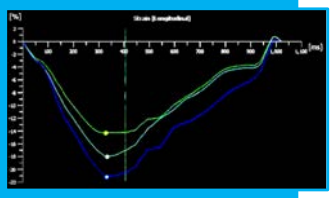
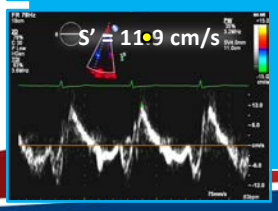
Added value of RV strain imaging

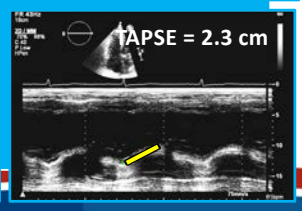


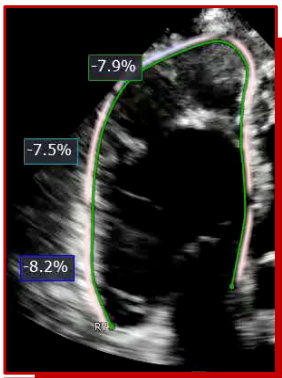
RV parameters in 2018

RVFWSL: -17.8 %



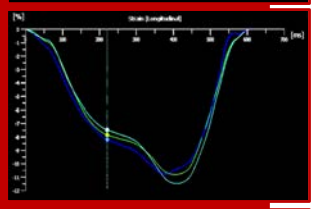


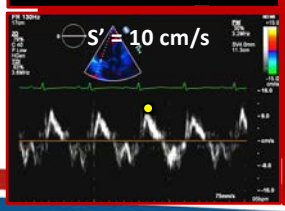


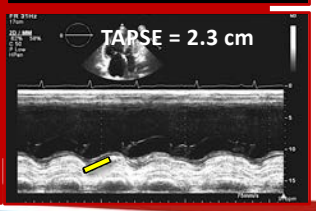


RV parameters in 2019

RVFWSL: -11.2 %







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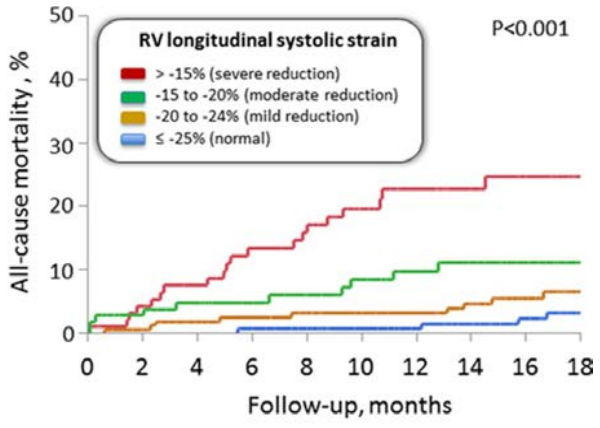

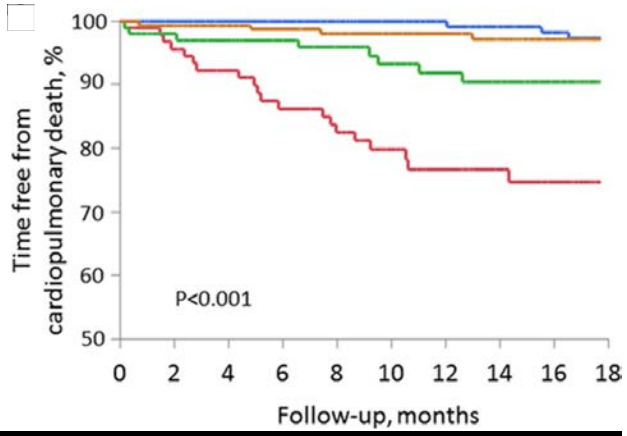

Consecutive patients referred for evaluation of known or suspected PH at the Mayo Clinic between October 2010 and July 2011. Cohort of n = 575 patients

Fine NM, Circ Cardiovasc Imaging. 2013 Sep;6(5):711-21

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Conclusion

- RV free wall LS correlates better with CMR RVEF and is a better index of RV function than TAPSE or RV S'
- RV GLS has prognostic value in pulmonary hypertension, acute pulmonary thromboembolism
- In patients with heart failure with LV systolic dysfunction, abnormal RV GLS was predictive of adverse events after adjusting for LVEF and diastolic dysfunction.
- In patients undergoing cardiac transplant, global RV GLS and RV free-wall LS were more strongly associated with future cardiovascular events than LV GLS, LV CS, LVEF, and N-terminal brain natriuretic peptide levels.

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Thanks for your attention

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Applications in the Pediatric Population

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Associate Professor, Pediatric Cardiology
University of Colorado School of Medicine
Children's Hospital Colorado Heart Institute

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No disclosures

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Challenges to Strain Analysis in Pediatric Patients

Selected Applications for Strain in Pediatric Patients

- Kawasaki Disease
- Pediatric Pulmonary Hypertension
- Single Ventricle Hearts

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Challenges to Strain Analysis in Pediatric Patients

- Higher heart rate
  - Frame rates may need to be higher than in adults to accommodate for normal pediatric heart rates as high as 180-200bpm
  - If performing strain analysis on DICOM images, those images should be pushed from the echo machine to the PACS system at frame rate of acquisition, not compressed to 30fps

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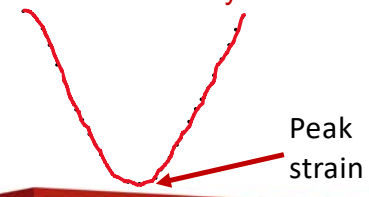
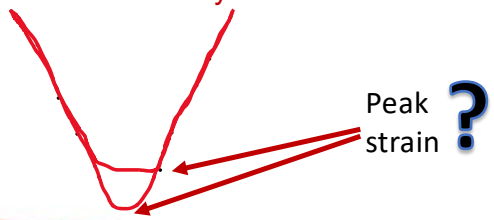
Why Frame Rate Matters

- **Example 1:**
  - Adult with HR 60bpm, frame rate 30fps
  - 30 frames/second x 60 seconds/minute = 1800 frames/minute
  - 1800 frames/minute ÷ 60 beats/minute = 30 frames/cardiac cycle



- **Example 2:**
  - Infant with HR 180bpm, frame rate 30fps
  - 30 frames/second x 60 seconds/minute = 1800 frames/minute
  - 1800 frames/minute ÷ 180 beats/minute = 10 frames/cardiac cycle



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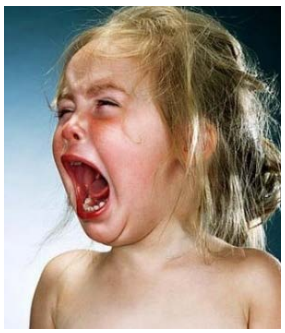
Challenges to Strain Analysis in Pediatric Patients

- **Smaller hearts**
  - **Typical left ventricular wall thickness may be as thin as 3mm in diameter, which places challenges on contouring, particularly when measuring endocardial strain**
- **Higher frequency transducers**
  - **Need for validation testing**
- **Patient factors (agitation, uncooperative toddler, etc.)**
  - **User must recognize improper tracking due to translation**



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Selected Applications for Strain in Pediatric Patients

- Kawasaki Disease
- Pediatric Pulmonary Hypertension
- Single Ventricle Hearts

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Kawasaki Disease

- KD is a systemic vasculitis affecting the heart by causing coronary dilation/aneurysm formation
- KD can also promote myocarditis with diminished function
- Frank et al found diminished longitudinal strain in the left ventricle in patients with KD during the acute (inflammatory) phase of the disease, which resolved during the convalescent phase
  - Mean difference in strain between baseline (acute) and 6 weeks out from diagnosis (convalescent) was -2.3% for all patients, but was more pronounced in patients with worse baseline strain
  - This did correlate with an increase in procalcitonin but did not correlate with coronary artery diameter z-score

Frank B et al. *J Clin Exp Cardiolog* 2016 7: 432.

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Kawasaki Disease - A Case Study Where Strain Helped Treatment Decisions

- 3 month old boy hospitalized for fever, truncal rash, red hands and feet, dry lips, and conjunctivitis
- Septic work up done, given antibiotics, discharged after 4 days
- 2 weeks later arrived in ED after out-of-hospital cardiac arrest with bystander CPR
- Transthoracic echo showed diminished function (EF 41%) and multiple coronary artery aneurysms
- Treated with IVIG and infliximab for Kawasaki Disease

Jone PN et al. *Semin Cardiothorac Vasc Anesth* 2015 Sep; 19(3): 255-9.

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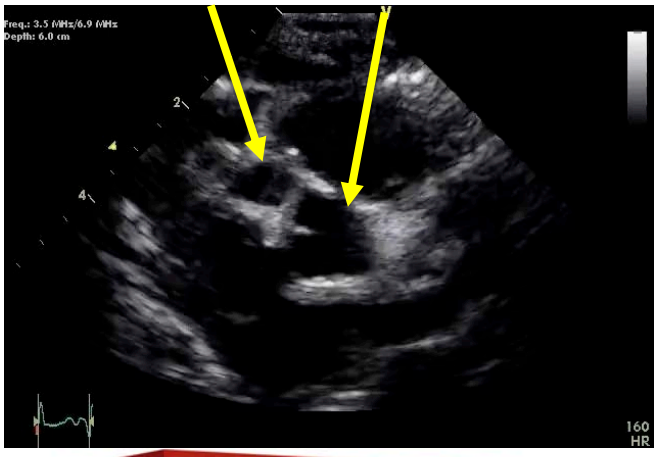
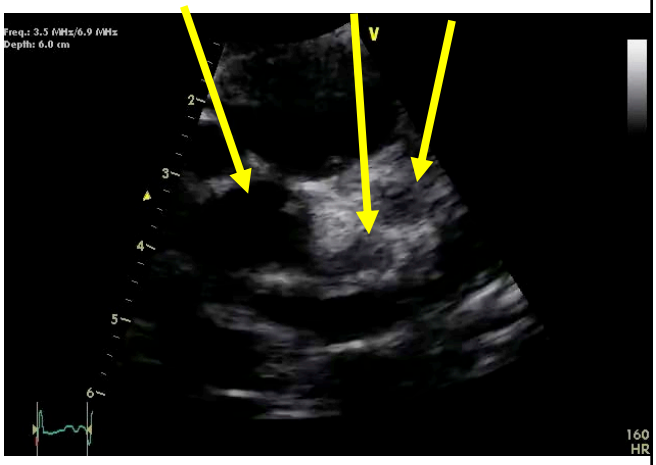
Giant Aneurysms of the Right Coronary and Left Main and Anterior Descending Coronary Arteries

RCA Aneurysm Aortic Valve



Aortic Valve LMCA & LAD Aneurysms



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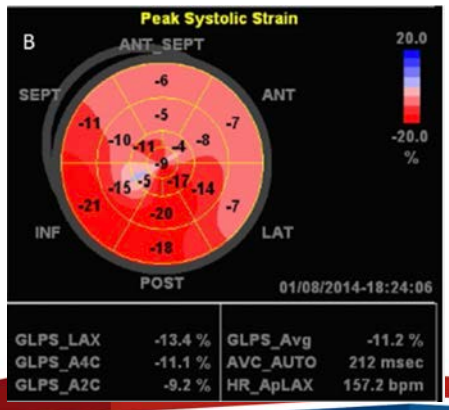
- Speckle tracking analysis showed diminished global longitudinal strain with severely diminished antero-lateral, antero-septal, and septal regional strain



- CT angiography was then performed, showing giant aneurysms with an unopacified LAD, suggesting complete occlusion
- The patient was then taken to the cath lab for intracoronary thrombolysis with alteplase (TPA)
- Continued to receive alteplase in CICU followed by administration of abciximab

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Kawasaki Disease - A Case Study Where Strain Helped Treatment Decisions

- 48 hours after abciximab flow in the antegrade flow was demonstrated by echo in the LAD, and the patient was discharged
- 2 weeks later the patient was asymptomatic in clinic and all echocardiographic markers of function had returned to normal
- Patient continues on clopidogrel, aspirin, and enoxaparin at home
- Now almost 6 years old and doing well at home

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Pediatric Pulmonary Hypertension

- **Right ventricular free wall strain has been shown to be a predictor of adverse clinical events in pediatric pulmonary hypertension, both for idiopathic PAH and PAH secondary to congenital heart disease**
- **Jone PN et al found that RVFW strain is decreased in those with PAH who had adverse events (-18% +/- 5) compared with those who didn't (-21% +/- 4)**
- **ROC analysis cutoff of -16% has 48% sensitivity and 93% specificity in detecting those who did have adverse events from those who didn't (AUC 0.68)**

Jone PN et al. *Eur Heart J Cardiovasc Imaging* 2018 Sep 1; 19(9): 1026-1033.

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Single Ventricle Hearts

- **Single ventricles have unique ventricular geometry which precludes many traditional echocardiographic measures of function**
- **Speckle tracking is angle independent, allowing for accurate tracking of myocardium in patients with abnormal ventricular geometry or cardiac position (i.e. dextrocardia)**
- **Strain analysis can provide an objective measure of function which can be tracked over time, potentially identifying deterioration of function prior to development of clinical symptoms**

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Single Ventricle Hearts – RV Morphology

- **Wu et al evaluated single ventricles of right ventricular morphology (such as hypoplastic left heart system) and found that these patients have decreased septal and lateral regional strain values compared with controls**

		Strain (%)	
		Controls	Single RV
Septal (adjacent to rudimentary chamber)	Basal	−19.07 ± 3.37	−8.06 ± 4.74
	Mid	−19.65 ± 3.90	−8.35 ± 5.18
	Apical	−19.90 ± 8.08	−8.85 ± 4.77
Lateral (opposite rudimentary chamber)	Basal	−19.64 ± 3.45	−13.62 ± 3.64
	Mid	−18.84 ± 3.35	−13.00 ± 3.85
	Apical	−18.17 ± 4.15	−10.95 ± 4.26

Wu et al. *Pediatr Cardiol* 2014 April 27; 35; 1147-54.

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Single Ventricle Hearts – RV Morphology

- **Lin et al evaluated RV function in patients with HLHS prior to bidirectional Glenn operation, including FAC, strain, strain rate**
- **Those who eventually died or underwent transplant (within the median follow up of 5.0 years) had lower strain pre-Glenn than those who survived (p=0.02).**

Lin et al. *J Am Soc Echocardiog* 2018; 31; 831-42.

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Single Ventricle Hearts – RV Morphology

- **Longitudinal strain rate appeared to be able to differentiate survivors from death/transplant in a subset with normal FAC (>35%) although numbers are low (future studies needed)**

Table 6 Speckle-tracking echocardiographic variables before BCPA surgery compared by outcome groups in a subcohort group with RVFAC ≥ 35%

RVFAC ≥ 35% subcohort speckle-tracking variable	Alive, median (IQR; *n* = 44)	Death or transplantation, median (IQR; *n* = 7)	*P*
Longitudinal strain (%)	−18.2 (−20.0 to −16.3)	−15.3 (−19.8 to −10.7)	.09
Longitudinal SR (1/sec)	−1.2 (−1.3 to −1.0)	−1.0 (−1.1 to −0.8)	.03
Circumferential strain (%)	−13.3 (−15.6 to −11.1)	−12.1 (−14.1 to −11.9)	.56
Circumferential SR (1/sec)	−1.1 (−1.2 to −0.9)	−0.9 (−1.1 to −0.7)	.11

Lin et al. *J Am Soc Echocardiog* 2018; 31; 831-42.

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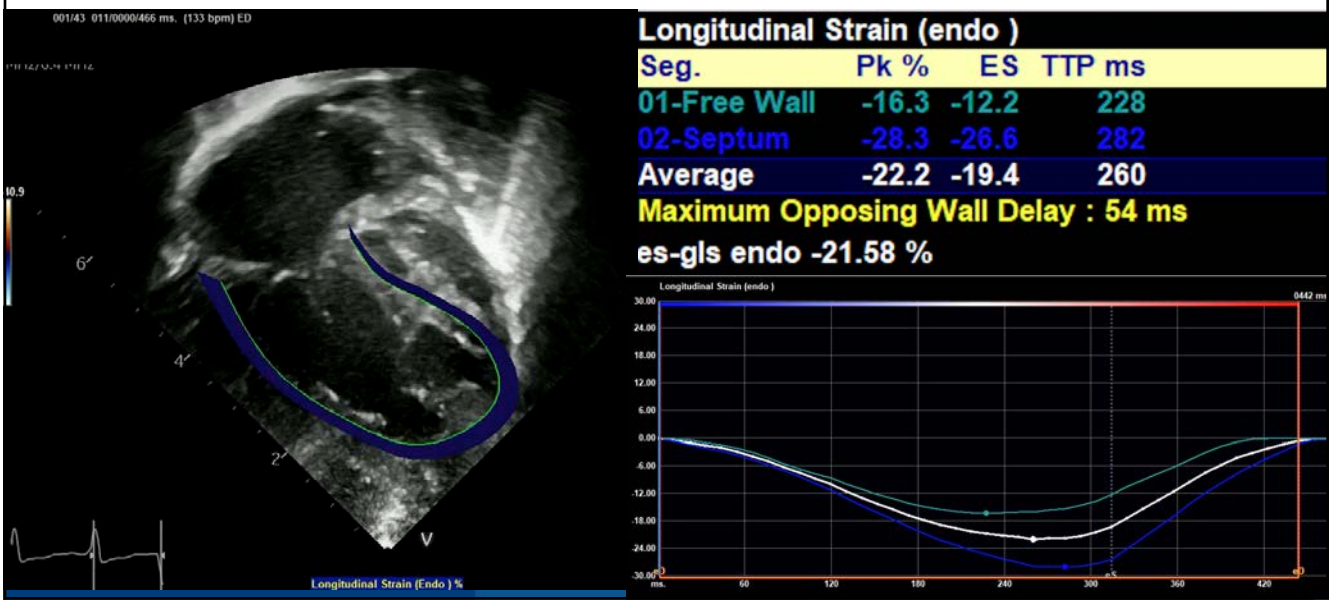
Hypoplastic Left Heart Syndrome – RV Strain



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Single Ventricle Hearts – LV Morphology

- **Lopez et al compared myocardial mechanics by echo in children with single ventricle of left ventricular morphology after Fontan operation to age-matched controls**
- **The Fontan cohort had normal longitudinal strain but reduced basal mean circumferential strain compared with controls**
- **They also had higher apical rotation but lower basal rotation**
- **These findings could be related to abnormal myocardial fiber orientation and fibrosis compared with normal anatomy hearts**

Lopez et al. *J Am Soc Echocardiog* 2018; 31; 1297-306.

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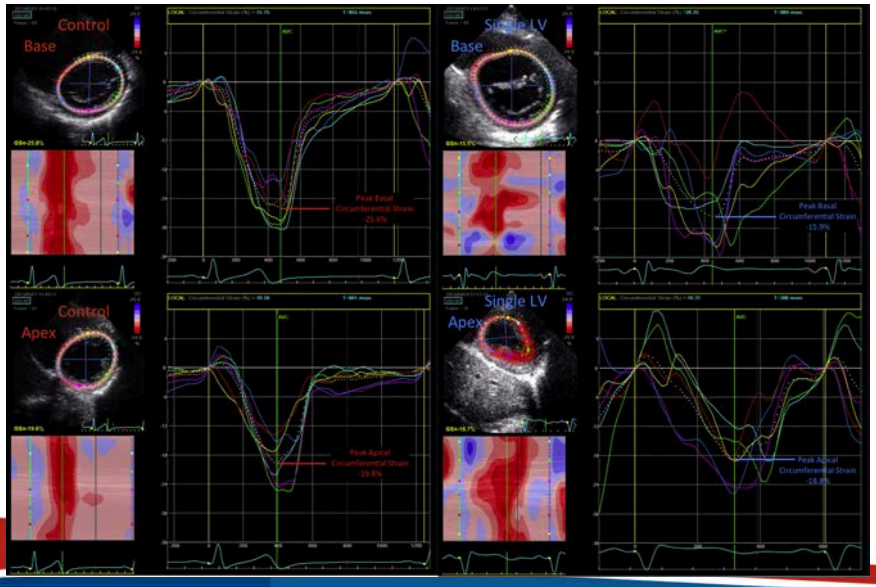
Single Ventricle Hearts – LV Morphology

Controls



Single LV

Lopez et al. *J Am Soc Echocardiog* 2018; 31; 1297-306.

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Other Uses in the Pediatric Population

- Cardio-oncology patients
- Transplant population
- Exercise stress echo
  - S/P coronary manipulation (Ross, arterial switch, etc.)
  - LVOT obstruction (aortic stenosis, coarctation, etc.)
  - Pulmonary hypertension
- Dilated or hypertrophic cardiomyopathy

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Thank You

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Questions & Answers

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Where Do We Use Strain Imaging?

Subclinical LV dysfunction (GLS)
- Cancer chemotherapy (prior or current)
- Unexplained dyspnea (HFpEF vs pulmonary)
- Valvular heart disease (AS, AR, MR)

LV hypertrophy (bullseye pattern)
- Highly predictive for cardiac amyloid

CAD
- Localize infarct, predict arrhythmias
- ??role in stress and dobutamine echo

Assessment of RV function
- ANY suspicion for RV enlargement or dysfunction
- Pulmonary hypertension

Pediatrics and congenital heart disease
- Same as above + single ventricles, Kawasaki, TGV, PH

Don't forget to code 93356!!

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Strain Imaging from ASE

Free for ASE Members

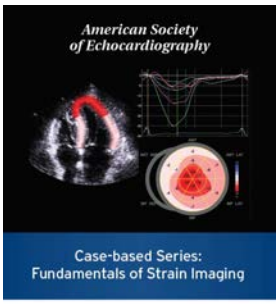
- Focuses on the emerging field of strain echocardiography
- Discusses the implementation of the new category 1 CPT Code for myocardial strain +93356
- Brief lectures will be interspersed with plenty of panel discussions, illustrative cases, and Q&A time

Case-based Series: Fundamentals of Strain Imaging

Purchase yours today at the ASE Registration table and receive a 20% discount.

Activities Include:

1.A Introduction to Strain Imaging
1.B Technical Considerations for Strain Imaging
2.0 Strain Imaging: Tips for Acquisition and Analysis
3.1 Case: Normal Left Ventricular Function (GE Echopac v 203)
3.2 Case: Ischemic Cardiomyopathy with Aortic Stenosis (GE Echopac v 203)
3.3 Case: Dilated Cardiomyopathy Suboptimal Images (GE Echopac v 203)
3.4 Case: Managing a Timing Artifact (GE Echopac v 203)
4.1 Case: Dyspnea Normal Left Ventricular Function (Philips QLAB 13)
4.2 Case: Dilated Cardiomyopathy (Philips QLAB 13)
4.3 Case: Hypertrophic Cardiomyopathy (Philips QLAB 13)
5.0 Case Studies of Strain Imaging in Cardio-Oncology
5.1 Case: Cardio-Oncology (Siemens/TOMTEC)
6.1 Case: Baseline Pre-chemotherapy (Canon Aplio i900)
6.2 Case: Heart Failure Preserved Ejection Fraction (Canon Aplio i900)
7.1 Case: Palpitations and Normal Left Ventricular Function (TOMTEC Arena)
7.2 Case: Cardiomyopathy-Aortic Valve Replacement (TOMTEC Arena)
8.0 Strain Imaging in Cardiac Amyloidosis
8.1 Case: Cardiac Amyloidosis (GE Echopac v 203)



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