

From Imaging to Ambulatory Hemodynamic Monitoring: How Technology is Impacting Clinical Practice

Moderator:

Sujeen Adhikari, MD

Clinical Applications of Strain Imaging - Ready for Prime Time or Just Hype

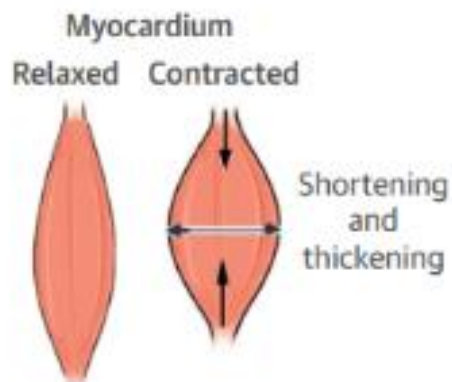
Michael Longo, MD



TALKING ABOUT STRAIN IMAGING IN 15 MINUTES



STRAIN = DEFORMATION

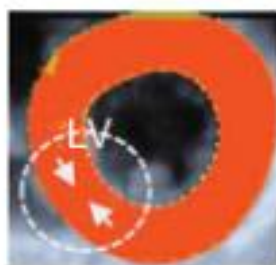


Myocardial Shortening

Longitudinal strain



Circumferential strain



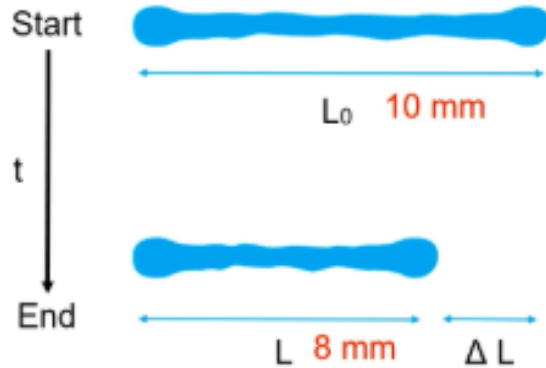
Myocardial Thickening

Radial strain



STRAIN CALCULATION

CALCULATED AS A CHANGE IN LENGTH
Reference is end diastolic length



$$\text{Strain } \epsilon = \frac{L - L_0}{L_0} = \frac{\Delta L}{L_0}$$

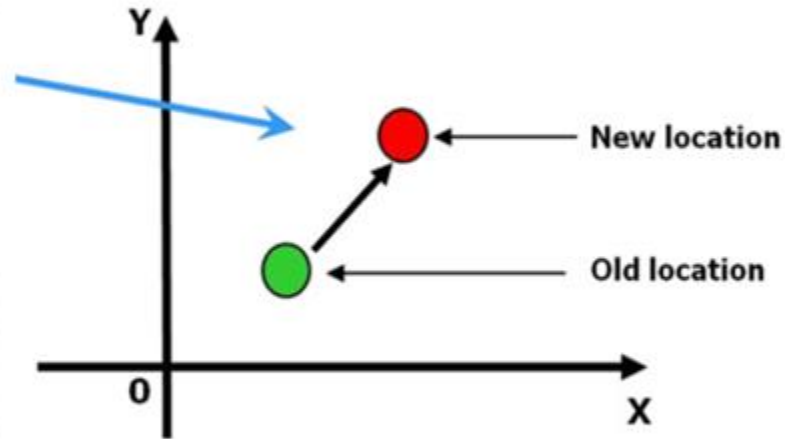
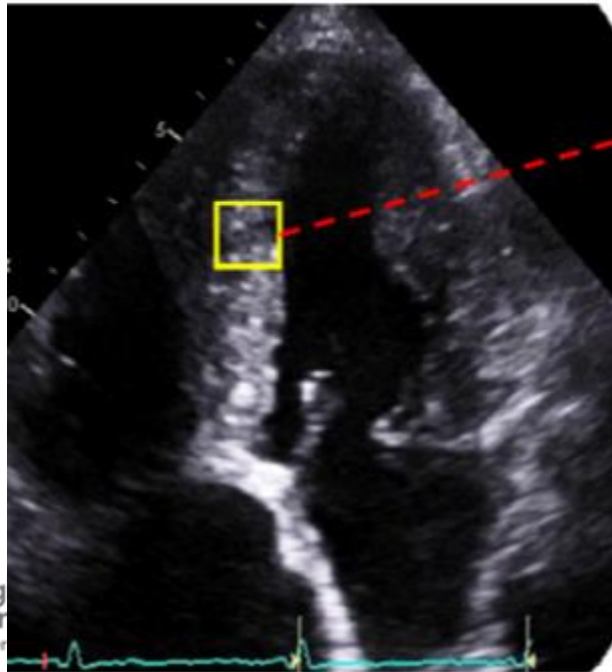
$$\text{Strain } \epsilon = \frac{8 - 10}{10} = \frac{-2}{10} = -20\%$$

$$\text{SR}(t) = \frac{d\epsilon(t)}{dt} \quad \text{or} \quad \frac{V1 - V2}{d}$$

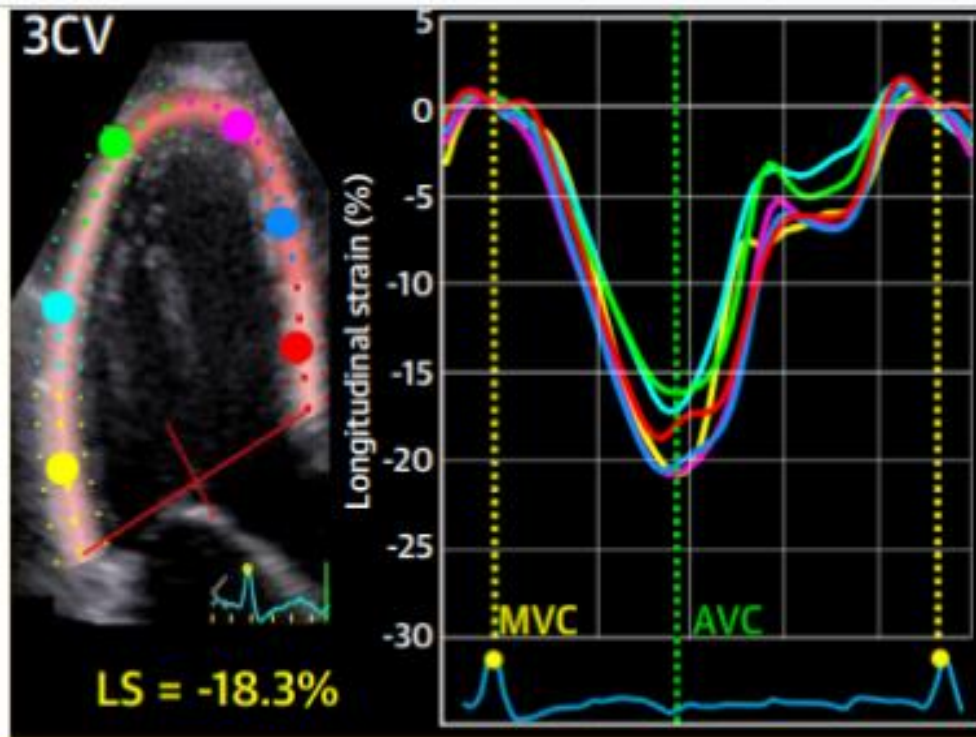
Contraction or shortening → negative
Stretching or lengthening → positive

SPECKLE TRACKING (STE)

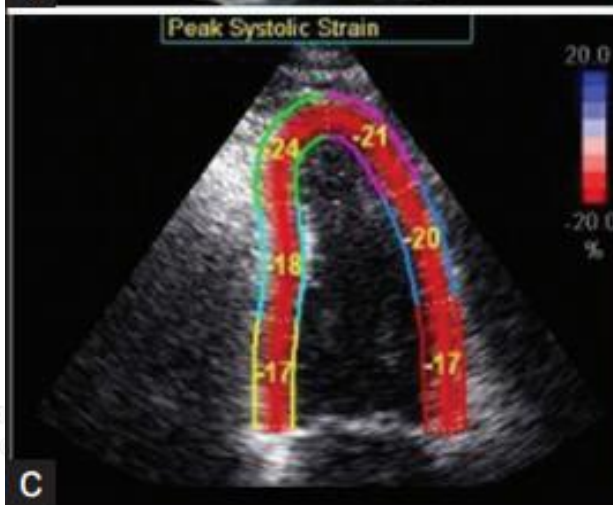
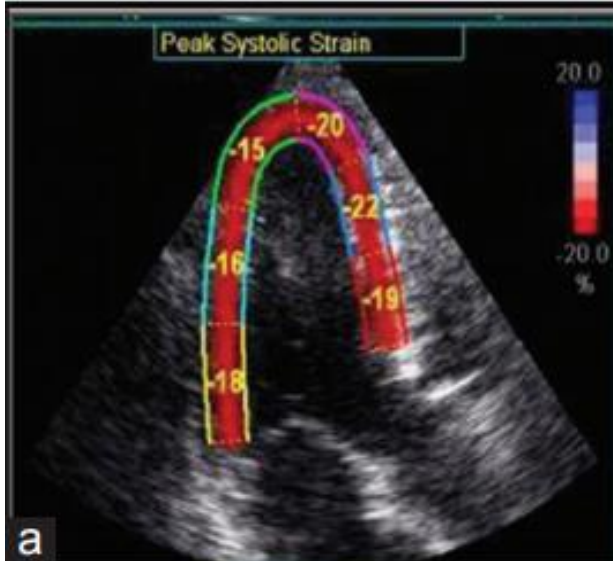
Speckles: granular patterns of bright/dark spots due to scatter of the US beam in tissue (fingerprint)



speckles are tracked frame by frame to determine the change in size and shape



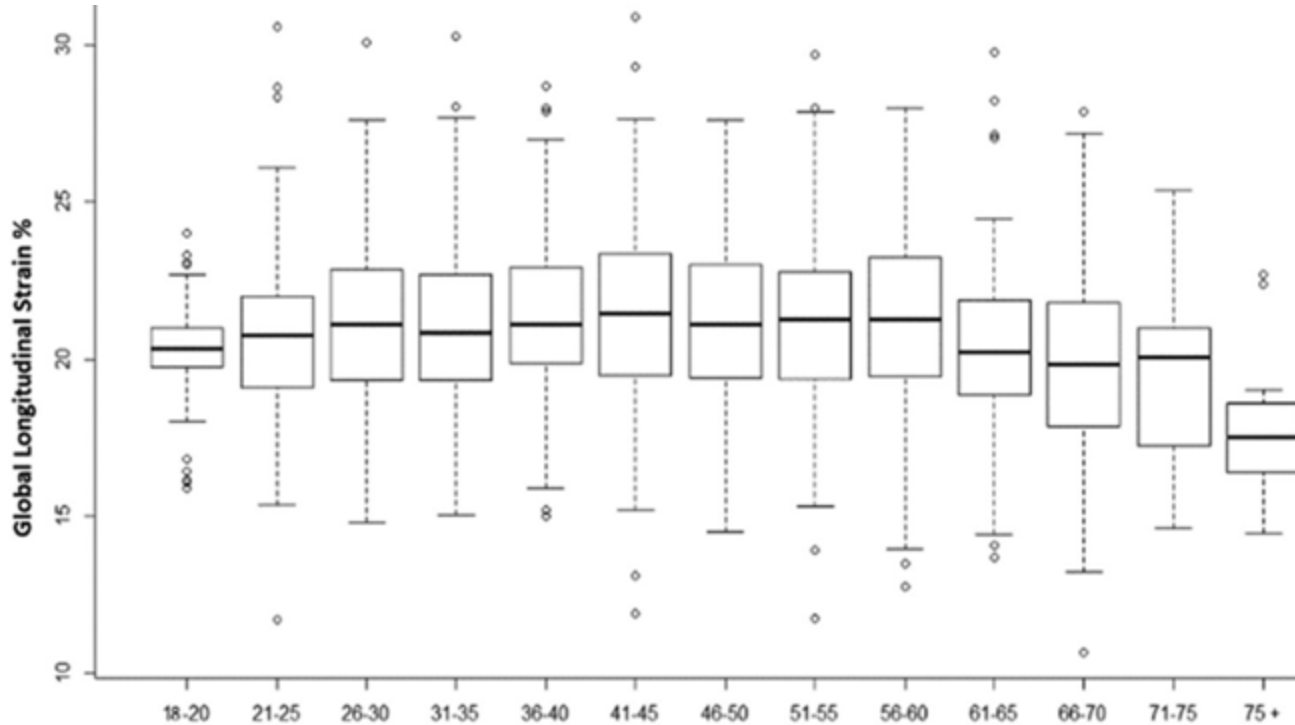
Manually trace endocardial border in end systole
 Software creates a ROI that includes entire myocardial thickness
 Regional strain curves are generated (base, mid, apical segments) and color coded
 White represents average strain



A3C GLS = -19.1
A4C GLS = -17.6
A2C GLS = -18.0

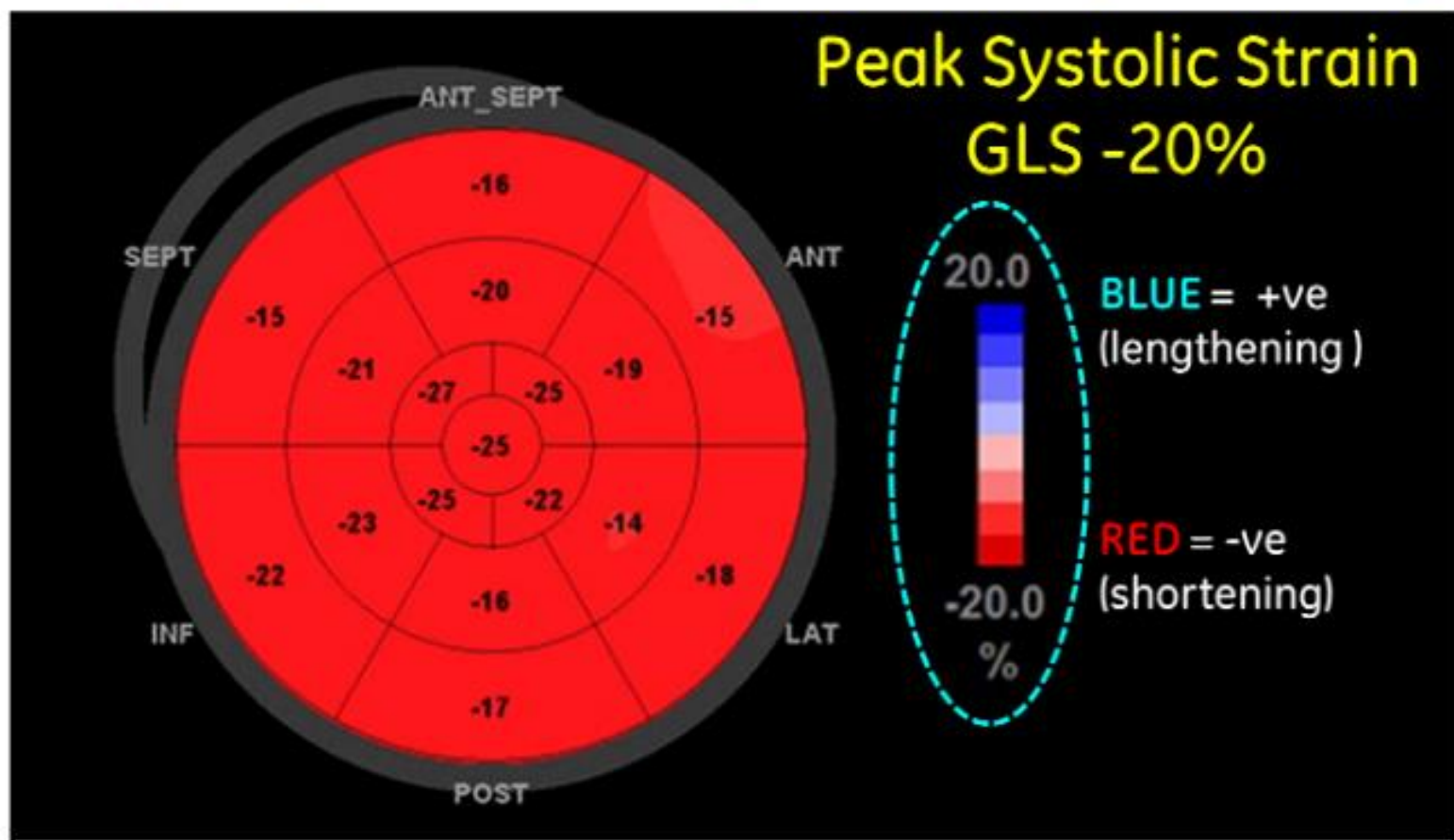
Average GLS = -18.23

GLS VALUES

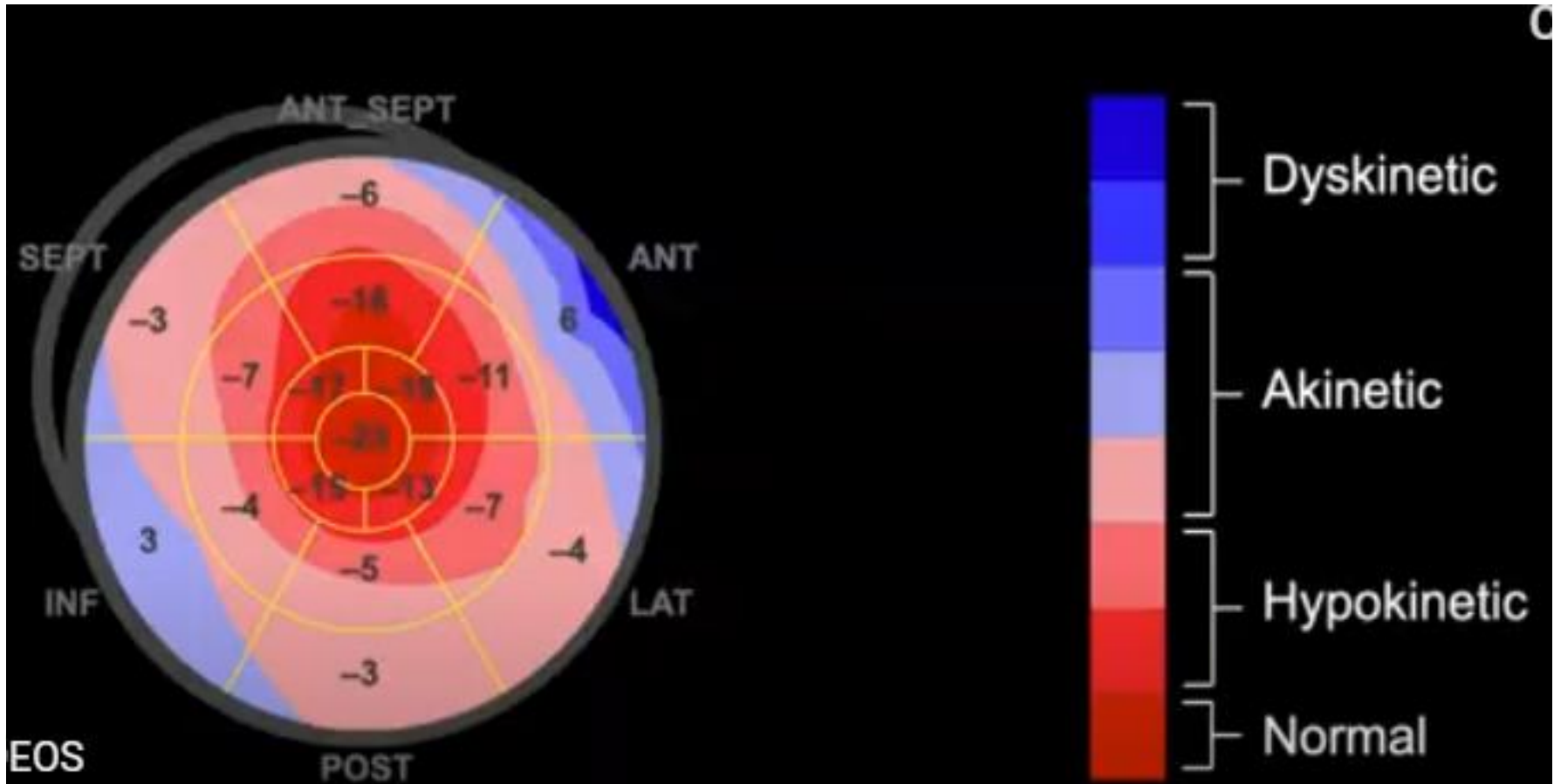


Normal: < -18 , borderline 16-18
Abnormal > -16

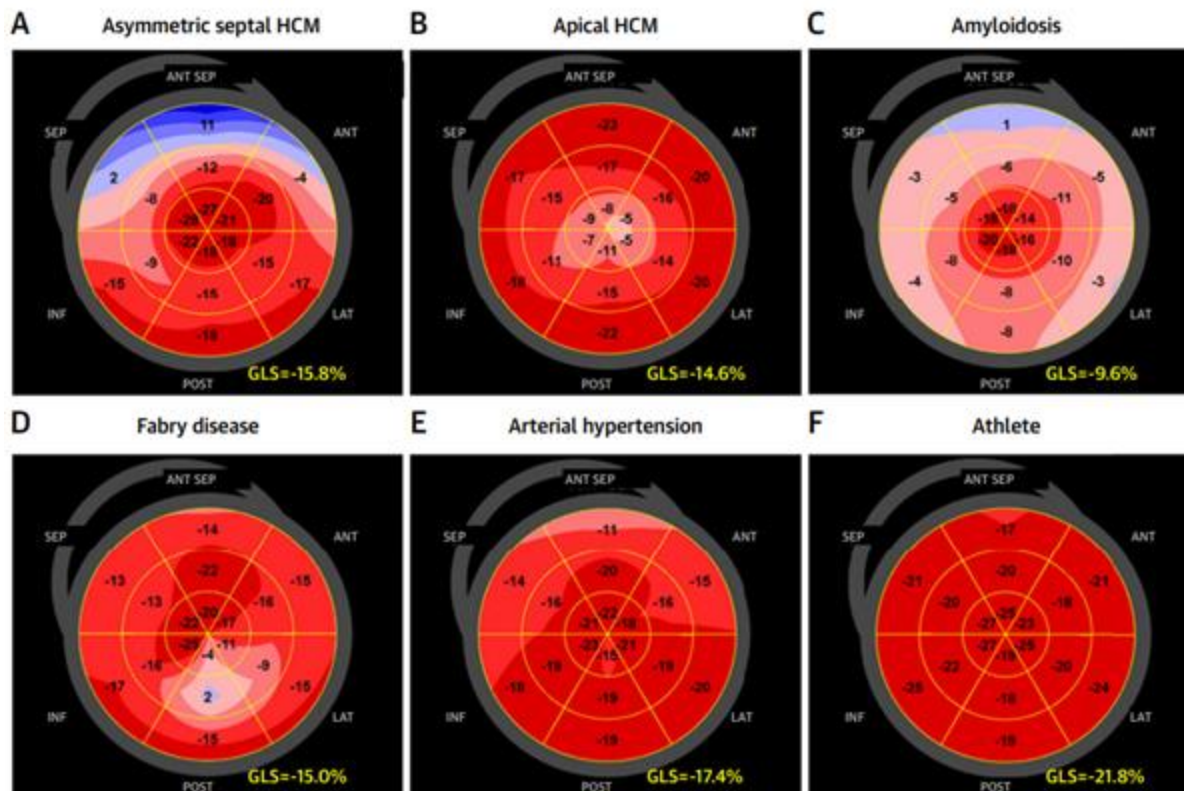
Display of GLS (Bull's Eye Plot)



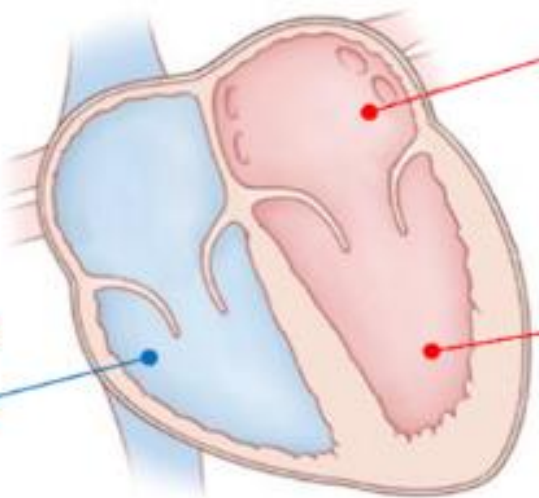
INTERPRETATION



LVH DIAGNOSIS



CLINICAL APPLICATIONS



RV strain

- PHTn
- CHD
- ARVD

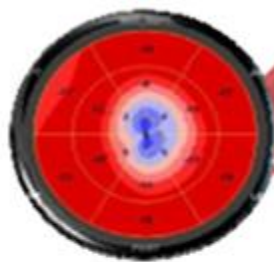
LA strain

- Diastolic function
- Atrial function
- AF risk
- Embolic risk in PAF

LV strain

- HF
- CTRCD
- Valve disease
- LV "hypertrophy"
- IHD/CAD
- CRT
- Diastolic function

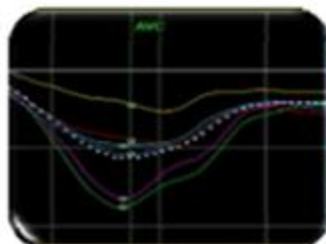
"Simplified" Clinical Applications



Pattern Recognition



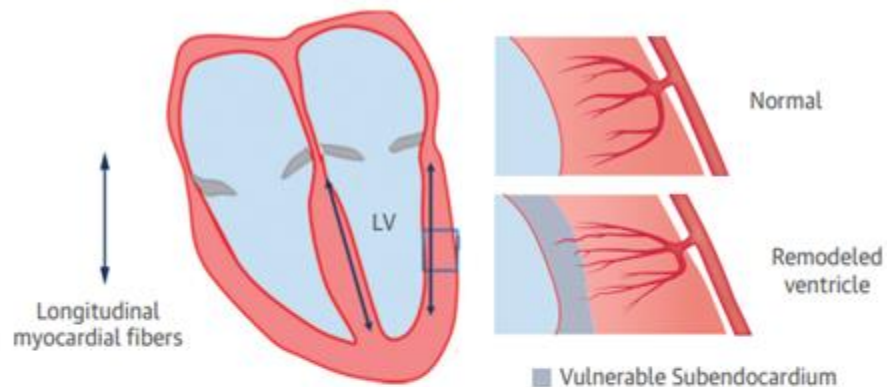
Subclinical Dysfunction



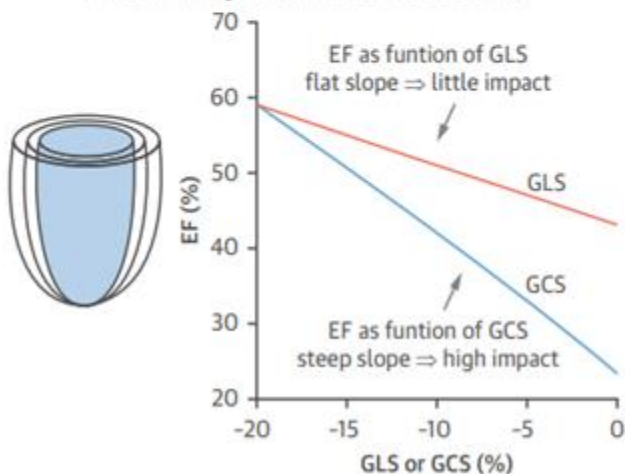
Regional variation

A

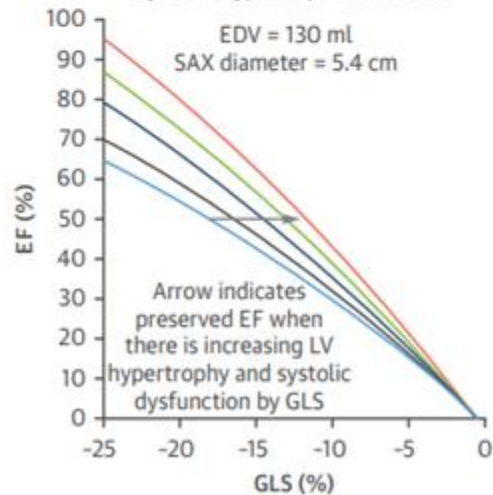
Because Longitudinal Myocardial Fibers Dominate in The Vulnerable Subendocardium,
Reduction of GLS is an Early Sign of LV Dysfunction

**B**

Due to The Elliptical LV Geometry, EF Reflects
Predominantly Circumferential Contractions

**C**

Pseudo-Normal Systolic Function
by EF in Hypertrophic Ventricles



ASYMPTOMATIC CTRCD

Mild	<ul style="list-style-type: none">• LV-EF $\geq 50\%$• AND: GLS reduction $> 15\%$• AND/OR: Rise in cardiac biomarkers (cTNI/cTNT $> 99^{\text{th}}$ percentile; BNP ≥ 35 pg/ml; NT-proBNP ≥ 125 pg/ml)
Moderate	<ul style="list-style-type: none">• LV-EF reduction ≥ 10 percentage points (LV-EF 40-49%)• LV-EF reduction < 10 percentage points (LV-EF 40-49%) AND GLS reduction $> 15\%$ OR rise in cardiac biomarkers (cTNI/cTNT $> 99^{\text{th}}$ percentile; BNP ≥ 35 pg/ml; NT-proBNP ≥ 125 pg/ml)
Severe	<ul style="list-style-type: none">• New LV-EF reduction to $< 40\%$

(a)

EF (Biplane)

58%

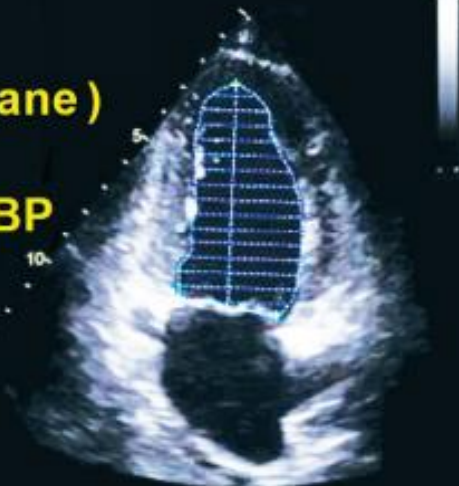
LV EDV BP

112 ml

LV ESV

BP

47 ml



(b)

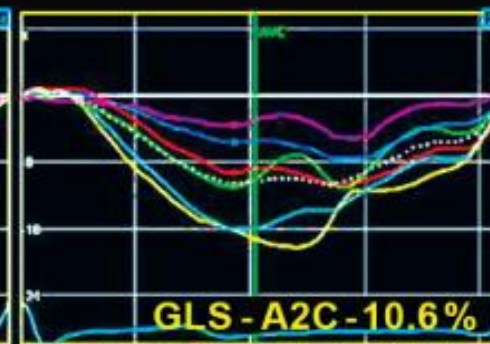
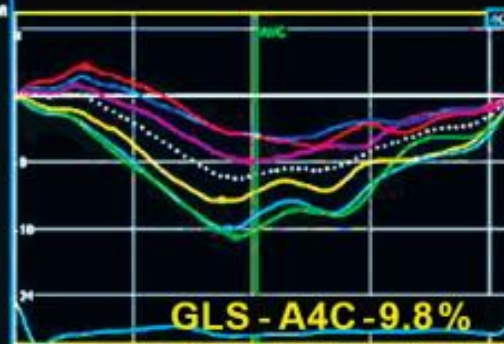
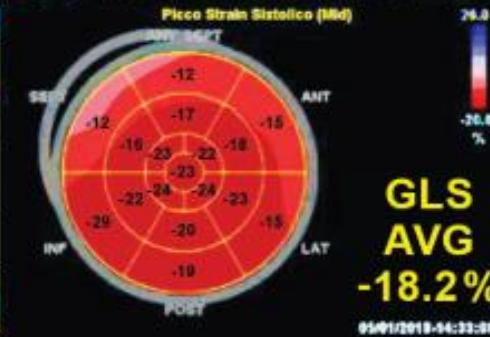
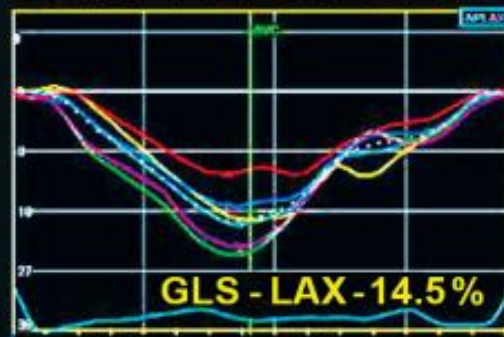
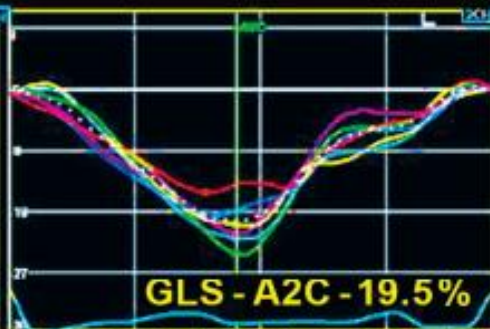
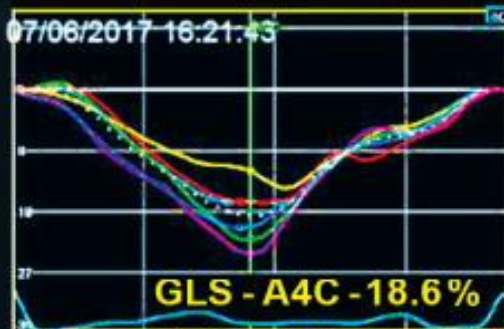
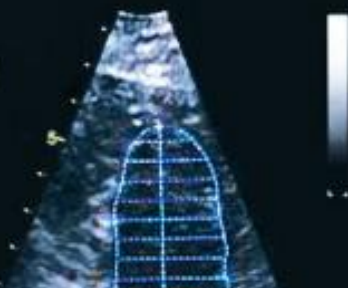
EF (Biplane)

51%

LV EDV BP

113 ml

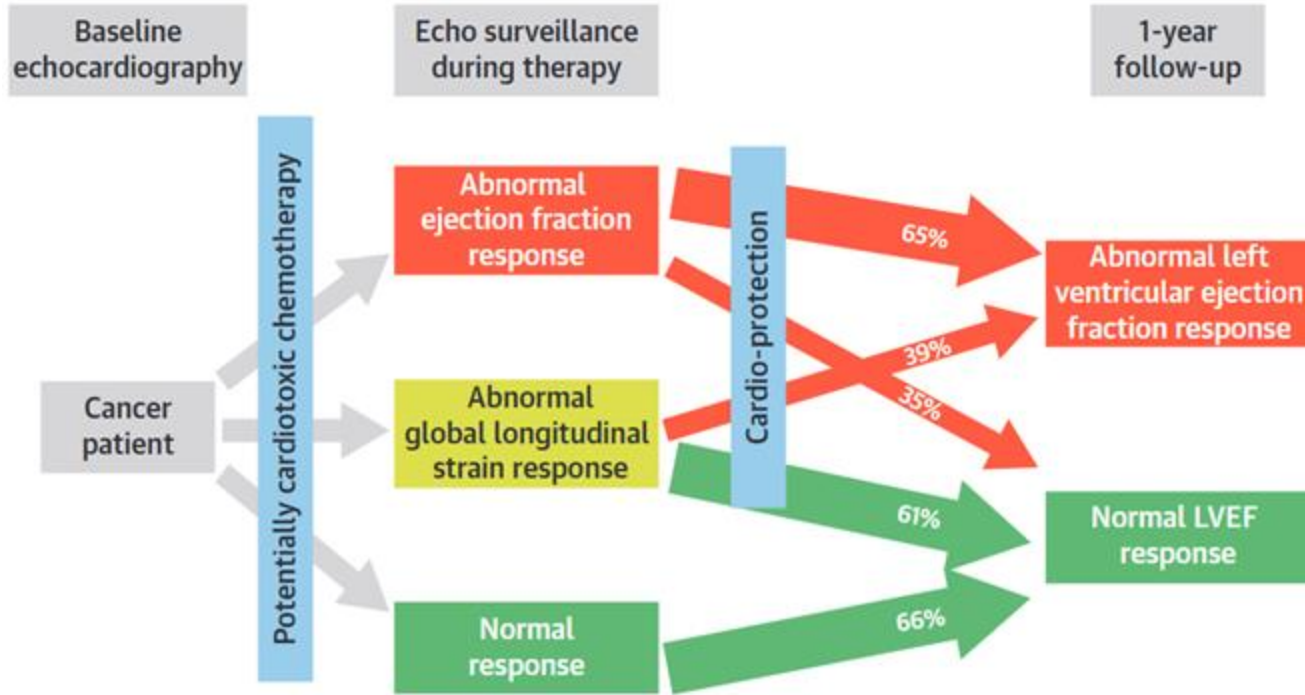
LV ESV BP



GLS PREDICTORS OF CTRCD

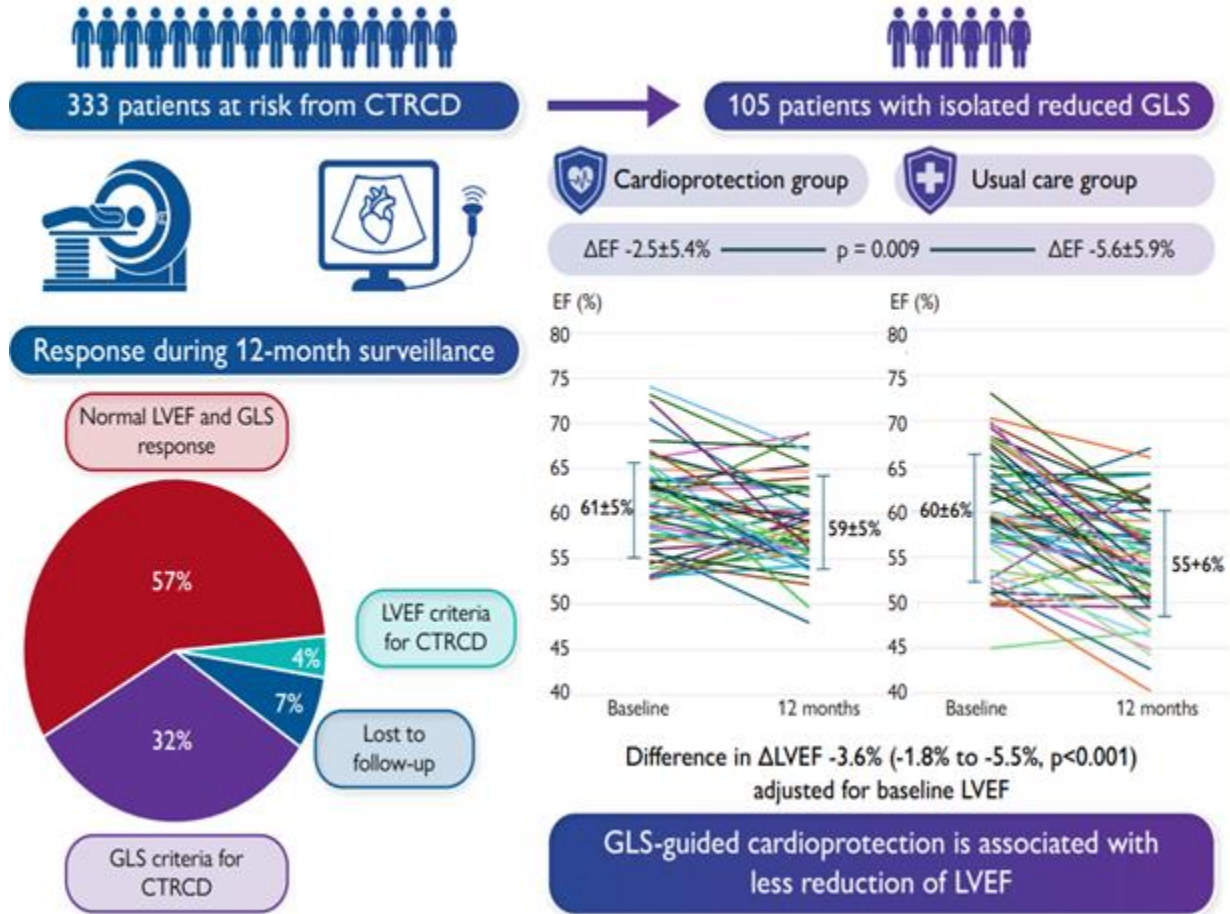
- ❖ Abnormal GLS during treatment and > 15% decrease in GLS during treatment are the best predictors
- ❖ Abnormal GLS at baseline

SUCCOUR



Primary endpoint: no difference in EF (3DE)
CTRCD 5.8% (GLS) vs 13.7% (EF)
RRR 57, NNT 13

SUCCOUR MRI

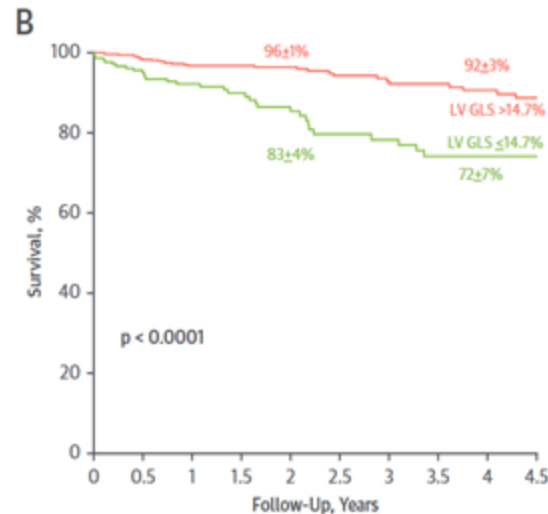
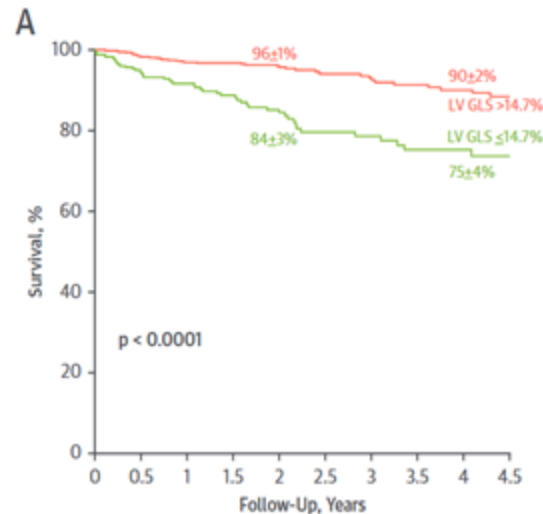


AORTIC STENOSIS

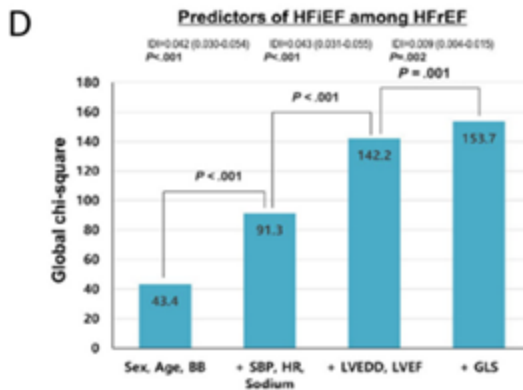
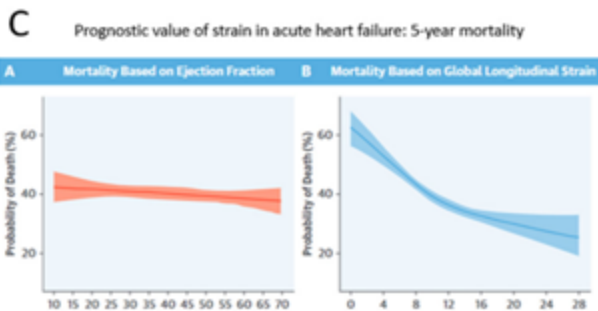
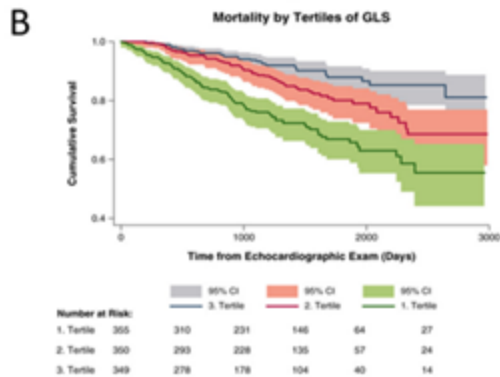
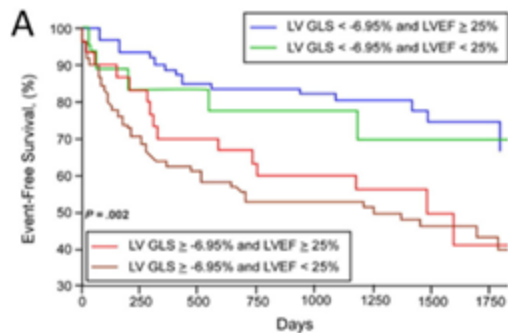
Asymptomatic severe AS EF > 50%

10 studies 1067 patients

2.5X mortality with GLS < -14.7

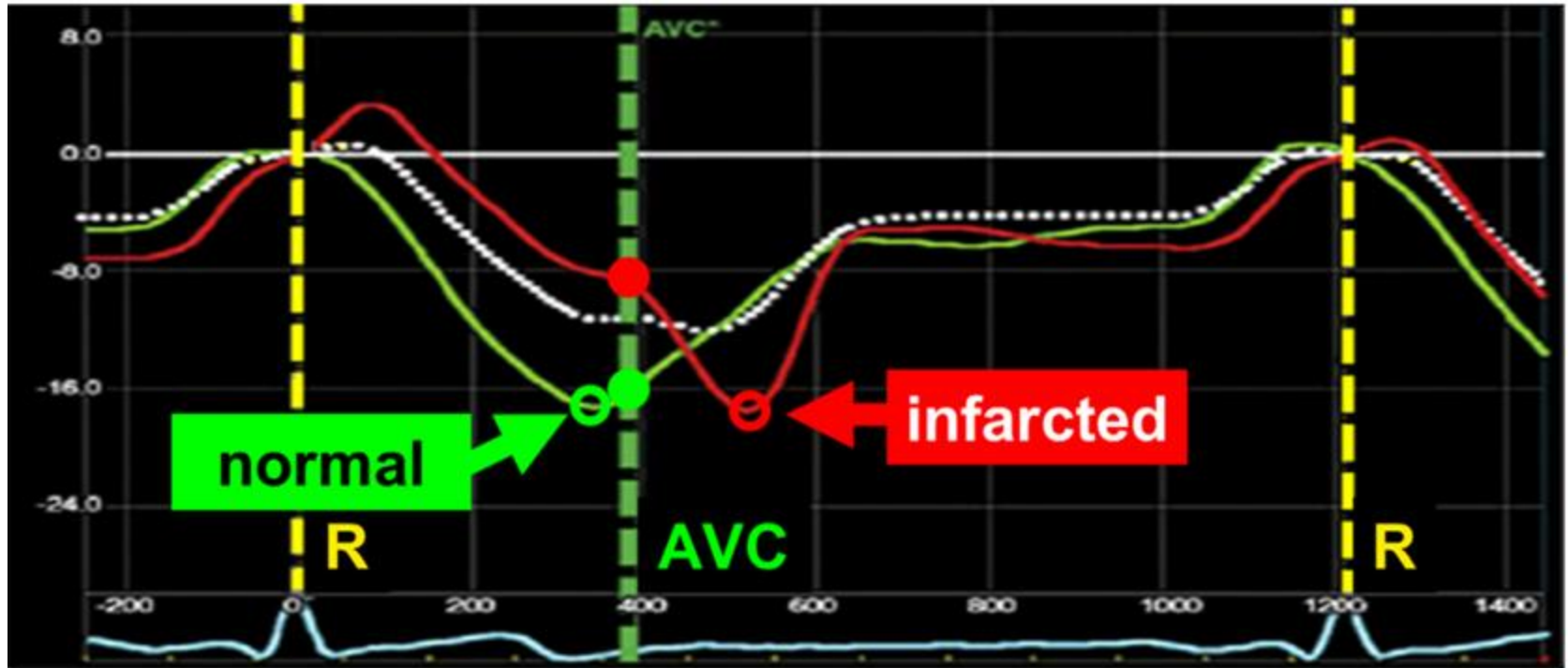


HFrEF



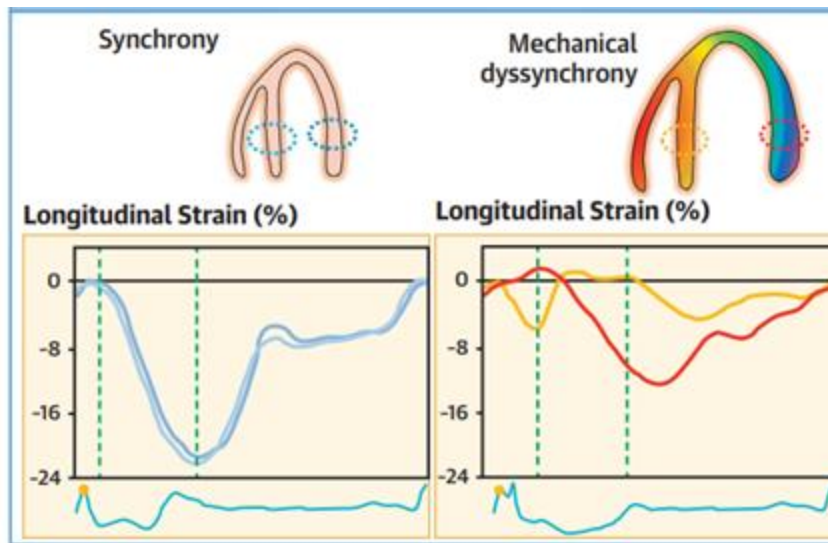
Each 1% absolute decrease in GLS increases all cause mortality 15%

ISCHEMIC HEART DISEASE

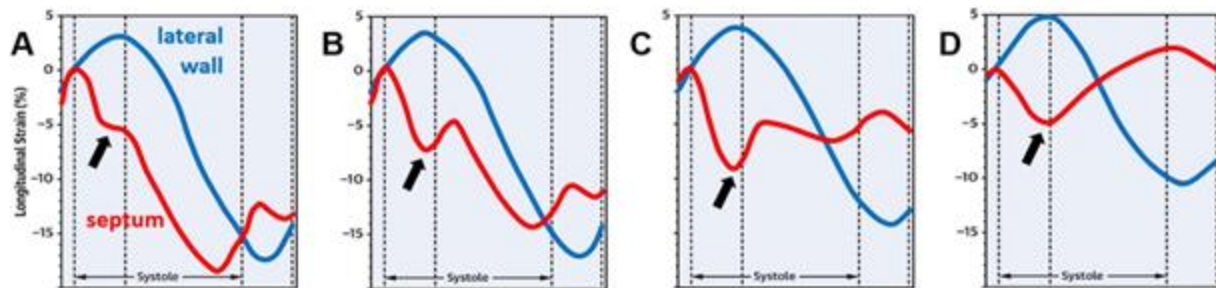


- 1 Early systolic stretching
- 2 Reduced end systolic strain
- 3 Enhanced post systolic strain

DYSSYNCHRONY: RESPONSE TO CRT

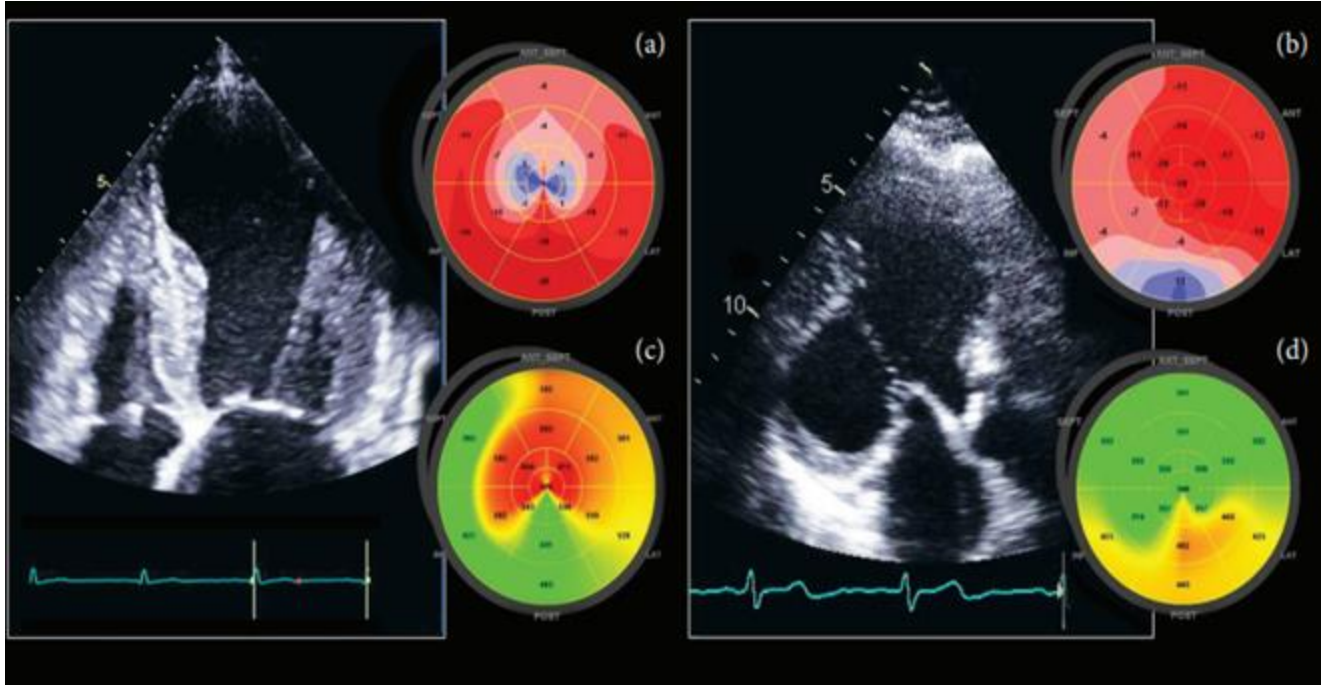


Septal flash and apical rocking



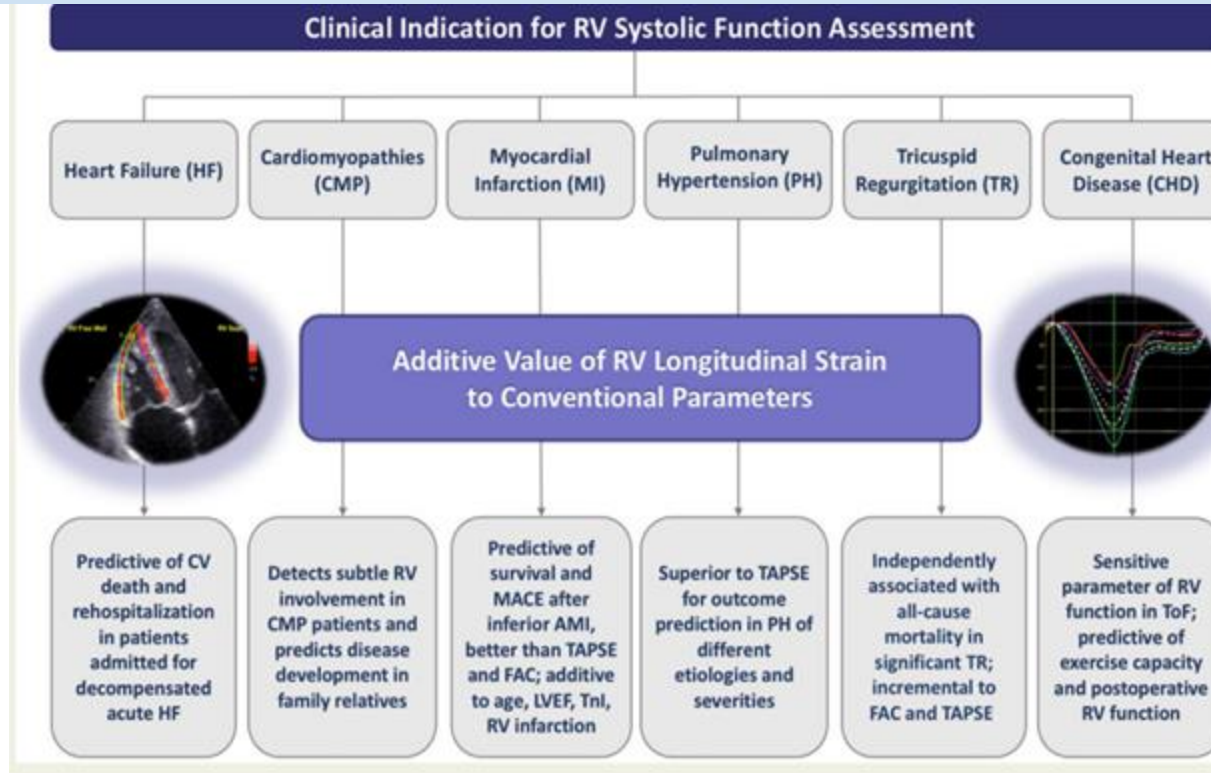
ASYMPTOMATIC CTRCD

MECHANICAL DISPERSION



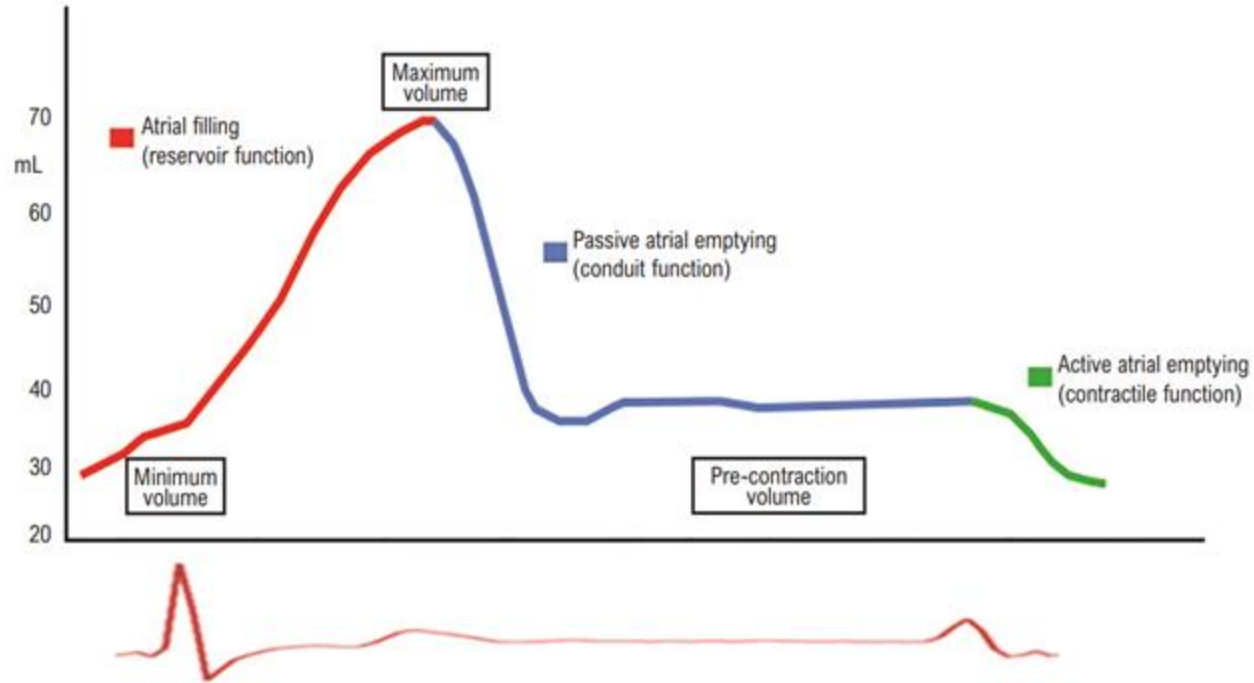
Predicts risk of cardiac arrhythmias

RV STRAIN

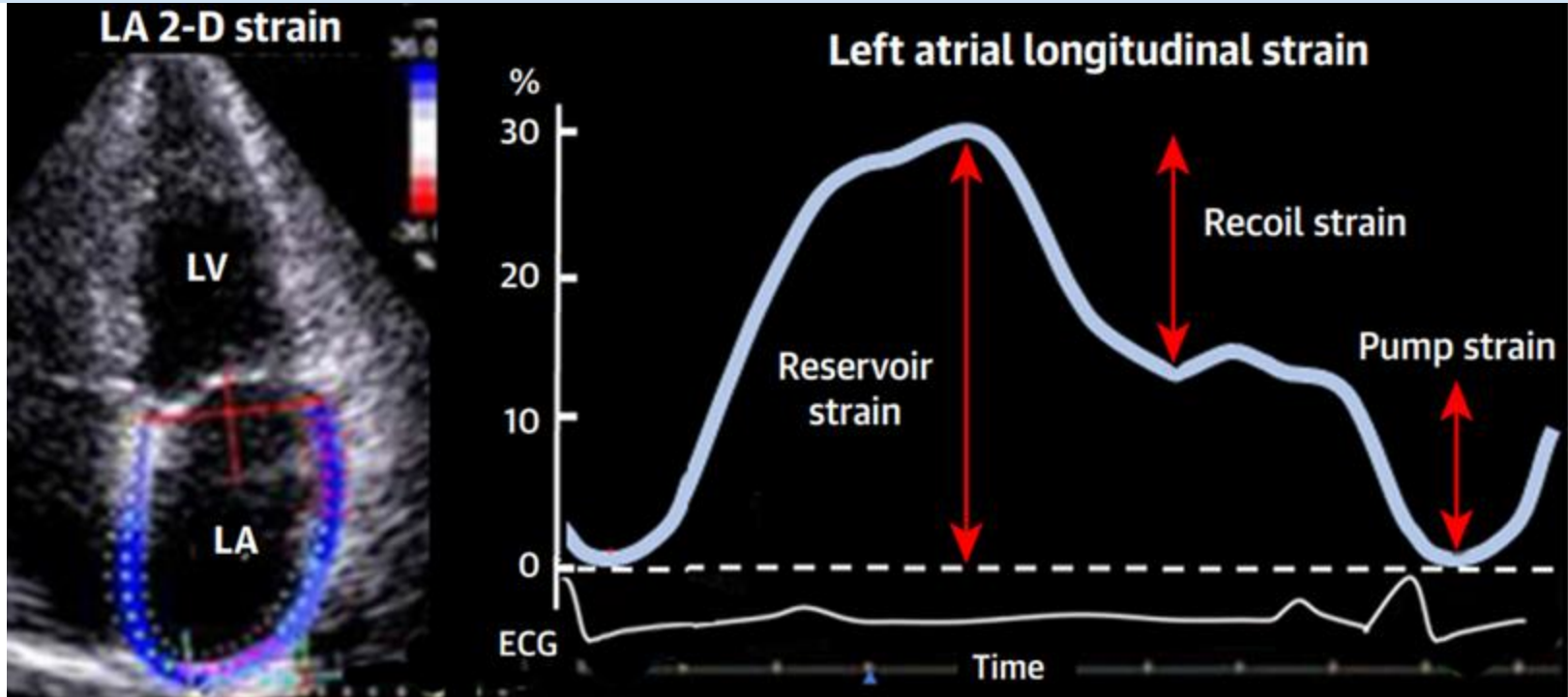


Normal < -15 - 20

LA FUNCTIONS



LA STRAIN

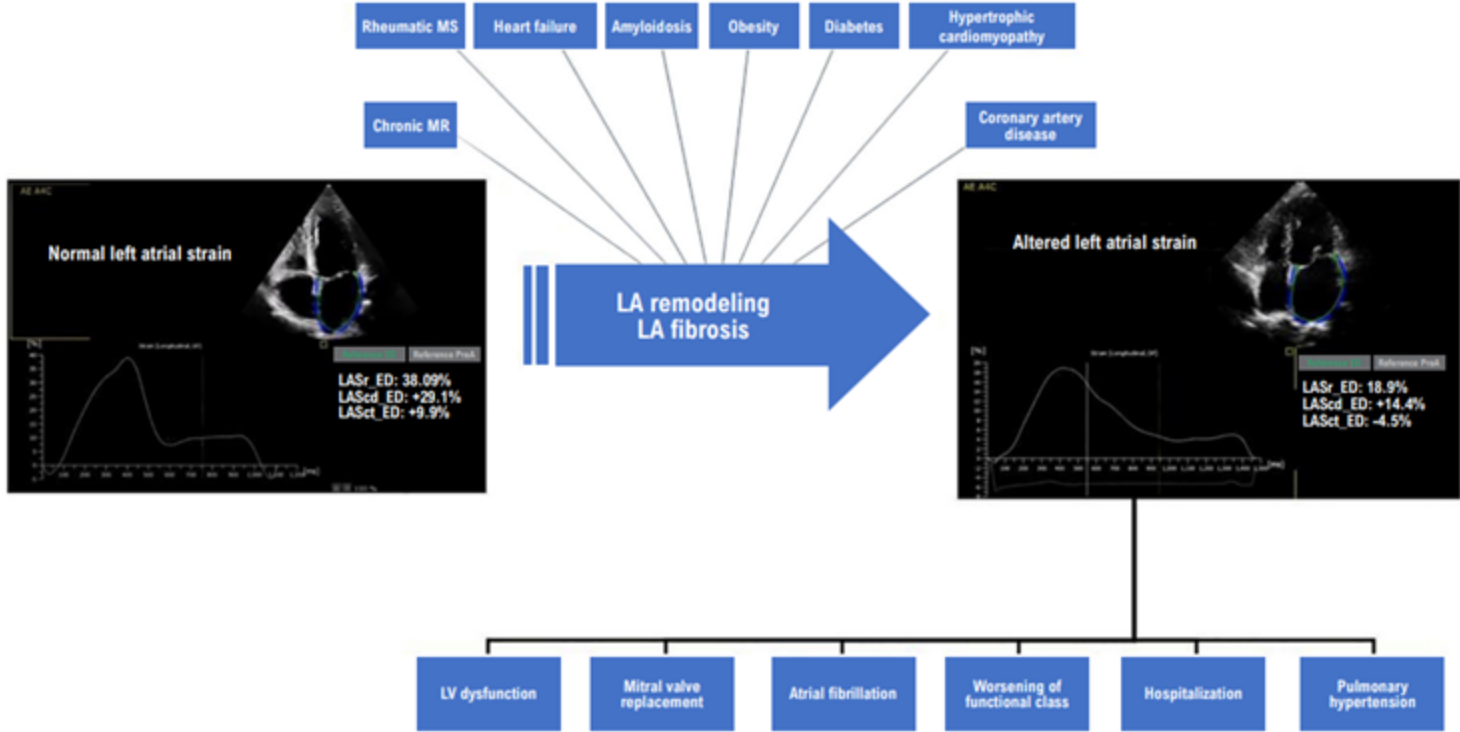


Reservoir: LA filling from PV in systole

Recoil (conduit): LV filling early diastole

Pump: LV filling late diastole atrial contraction

LA STRAIN



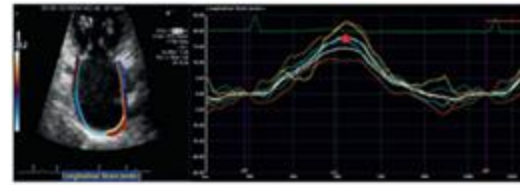
Predicts risk of AF, HFpEF, CVA

DIASTOLIC FUNCTION 2016 GUIDELINES

Conventional diastolic parameters and algorithm as per ASE/EACVI recommendations
Mitral annular velocity (e'), mitral inflow (algorithm B), E/e', TR velocity

Left atrial assessment

Functional assessment in place of structural assessment
• left atrial reservoir strain <24%



Normal diastolic function
• Increase in proportion of normal cases
• No increase in HF risk

Indeterminate diastolic function
• Reduction in indeterminate cases by 75%
• Prognosis similar to normal diastolic function

Grade 1 DD
• Minor increase in proportion of grade 1 DD

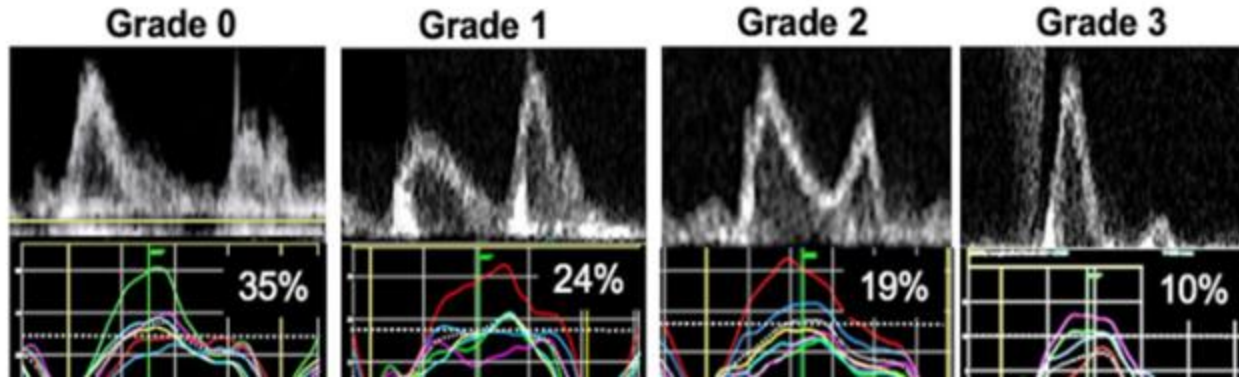
Grade 2+ DD
• Reduction in proportion of grade 2+ DD

Improved diagnostic and prognostic clarity

Potter, E.L. et al. J Am Coll Cardiol Img. 2020;13(11):2316-26.

LA STRAIN: GRADING DIASTOLIC FUNCTION

A. Grading LV diastolic function

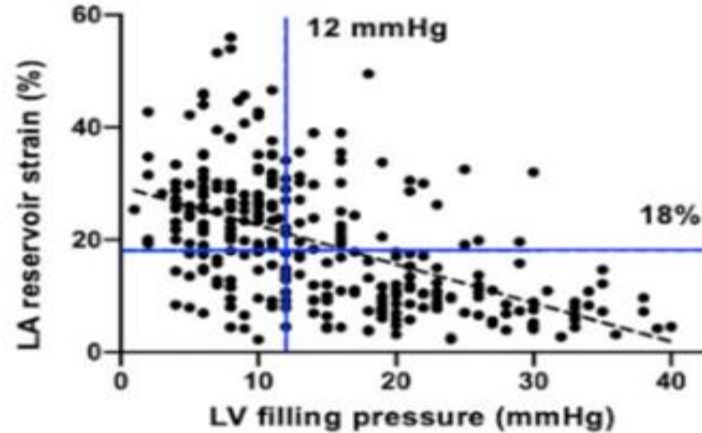


Normal 21-60: median 42

Low sensitivity and specificity

ESTIMATION OF FILLING PRESSURES

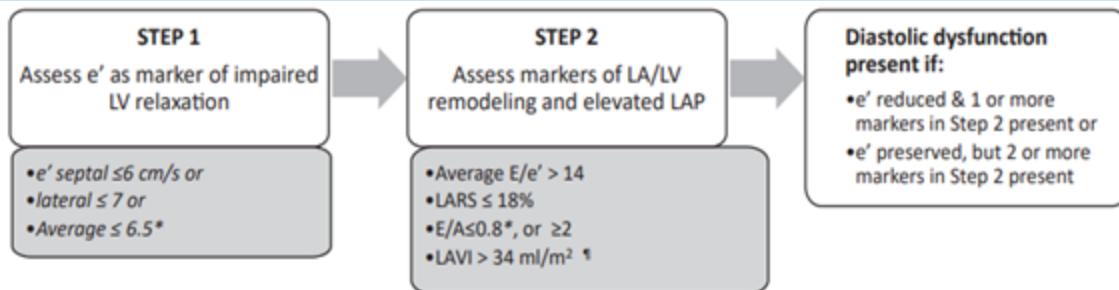
B. Estimating LV filling pressure



Better with HFrEF than HFpEF

Wide variation values 15-38

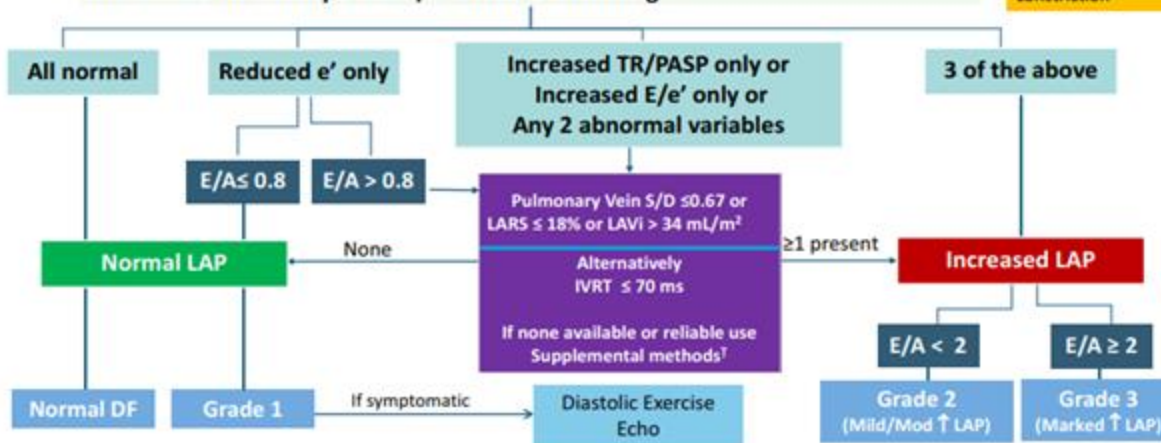
2025 GUIDELINES DIASTOLIC FUNCTION



LV Diastolic Function Grading & LAP Estimation

1. Reduced e' velocity: septal ≤ 6 or lateral ≤ 7 or average ≤ 6.5 cm/s *
2. Increased E/e' : septal ≥ 15 or lateral ≥ 13 or average ≥ 14
3. Increased TR velocity ≥ 2.8 m/s or PASP ≥ 35 mm Hg

Except in
MAC, MR, MS[§]
Atrial Fibrillation
LVAD
Non-cardiac PH
HTX
Pericardial
constriction



FUTURE DIRECTIONS

- ❖ AI: faster, more reliable, more consistent results
- ❖ Higher frame rates: use of 3D STE and strain rate analysis
- ❖ Better assessment of diastolic function: myocardial work, twist, torsion, untwist

STRAIN REAL LIFE APPLICATIONS



Thank You



The use of Intracoronary Imaging and Plaque Modification to Optimize Percutaneous Coronary Revascularization (PCI)

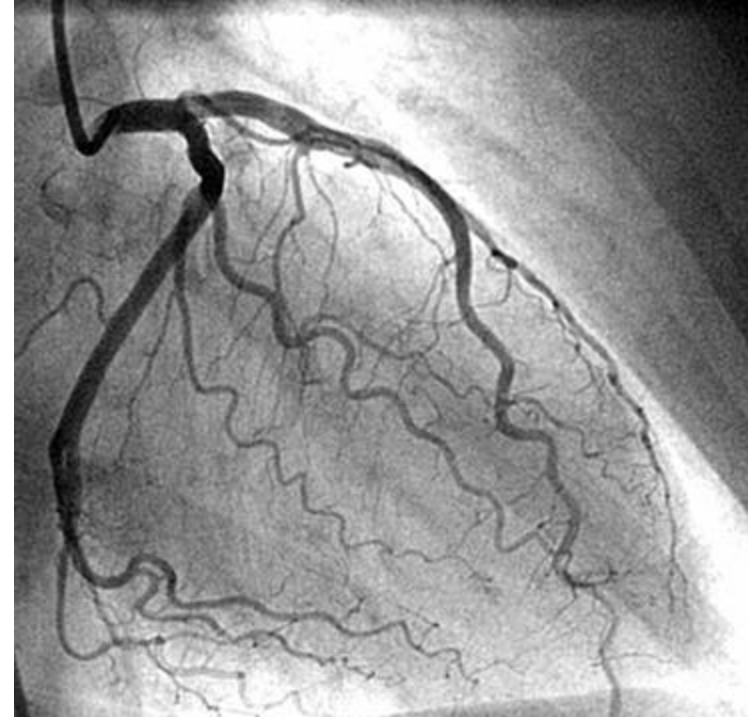
Allen Rassa, MD, FACC

Disclosures

❖ NO RELEVANT DISCLOSURES

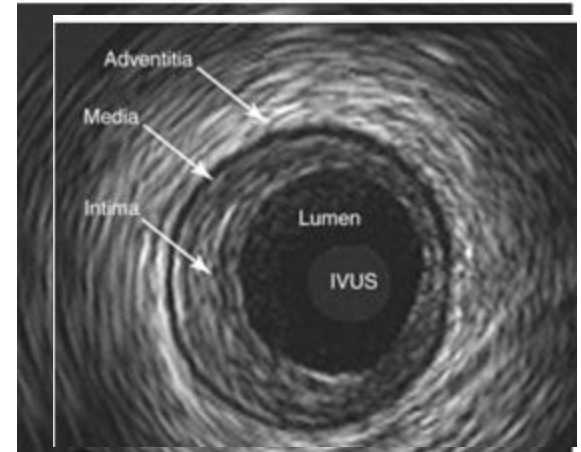
Intracoronary imaging for PCI

- ❖ Angiography with X-ray is considered the gold standard for diagnosis of coronary disease
- ❖ Primary modality to guide PCI
- ❖ Angiography has several limitations
 - 2D representation of a 3D structure
 - Only visualize the internal lumen
 - Plaque composition
- ❖ Intracoronary imaging helps fill these gaps



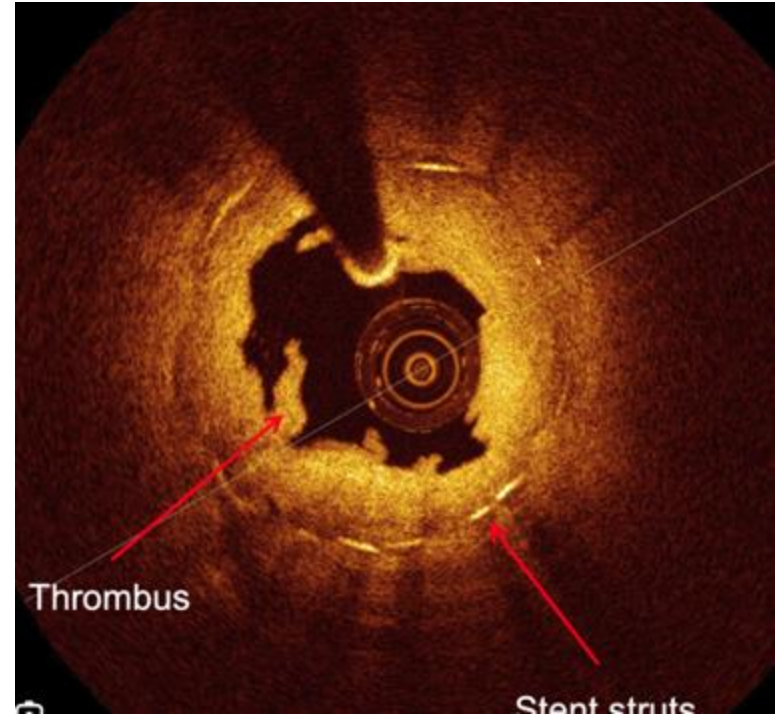
Intravascular Ultrasound (IVUS)

- ❖ First clinical use in 1998
- ❖ Sound based system using piezoelectric crystalline transducers
- ❖ US waves reflected differently across varied tissues
- ❖ Generated into grayscale cross sectional images
- ❖ Information provided
 - Vessel size and architecture
 - Plaque morphology

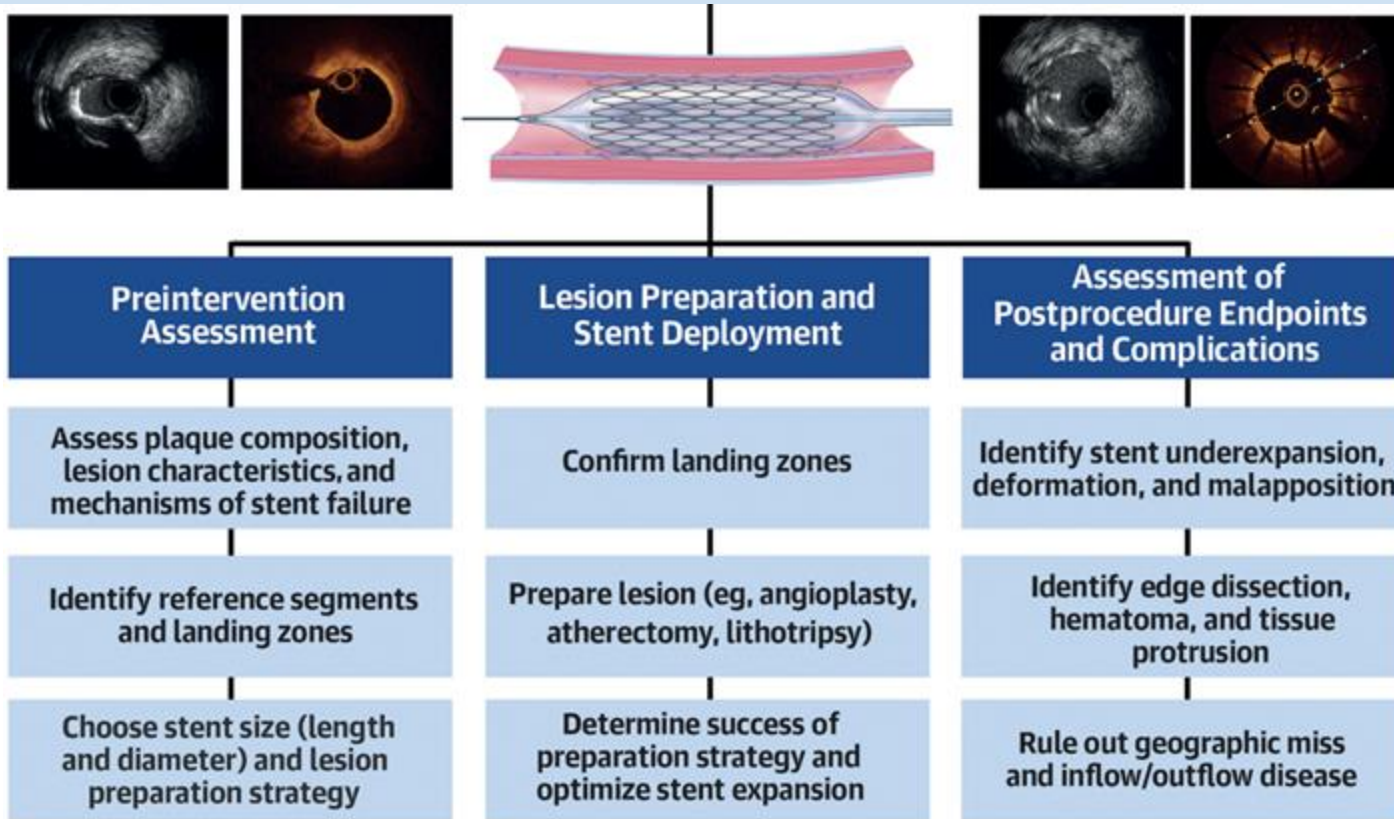


Optical Coherence Tomography (OCT)

- ❖ Emits and receives near infrared light waves
- ❖ Creates very high resolution images
- ❖ Comes at expense of penetration
- ❖ Requires contrast opacification to create a “bloodless” imaging field
- ❖ Not as useful for large vessels



Clinical use of intracoronary imaging



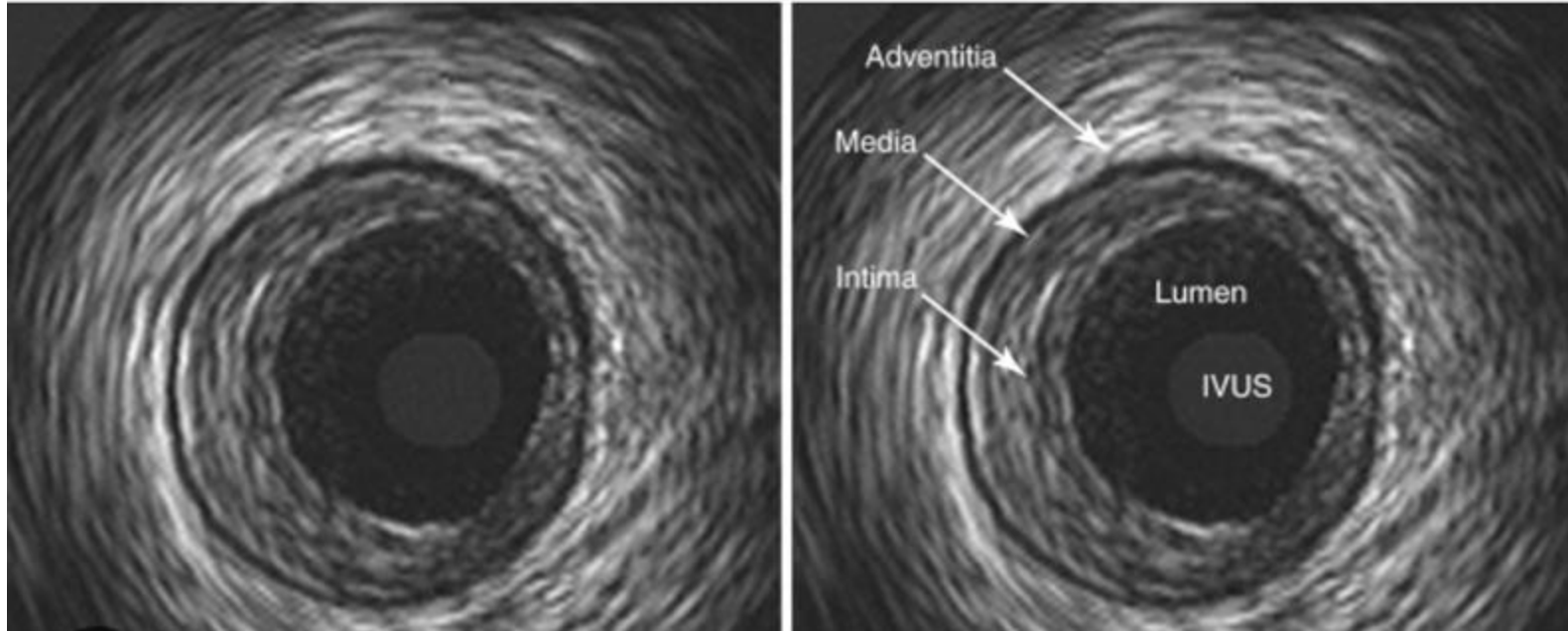
Clinical advantages of IVI

- ❖ Accurate sizing of the blood vessel
- ❖ Assessment of lesion length
- ❖ Choosing the right tools for plaque modification
 - Atherectomy, cutting balloon, POBA
- ❖ Assess for plaque modification after treatment
- ❖ Ensure stent is well placed
- ❖ Avoid/diagnose complications
- ❖ Not many downsides beyond slight increase in procedural time and X-ray dose, more contrast for OCT.

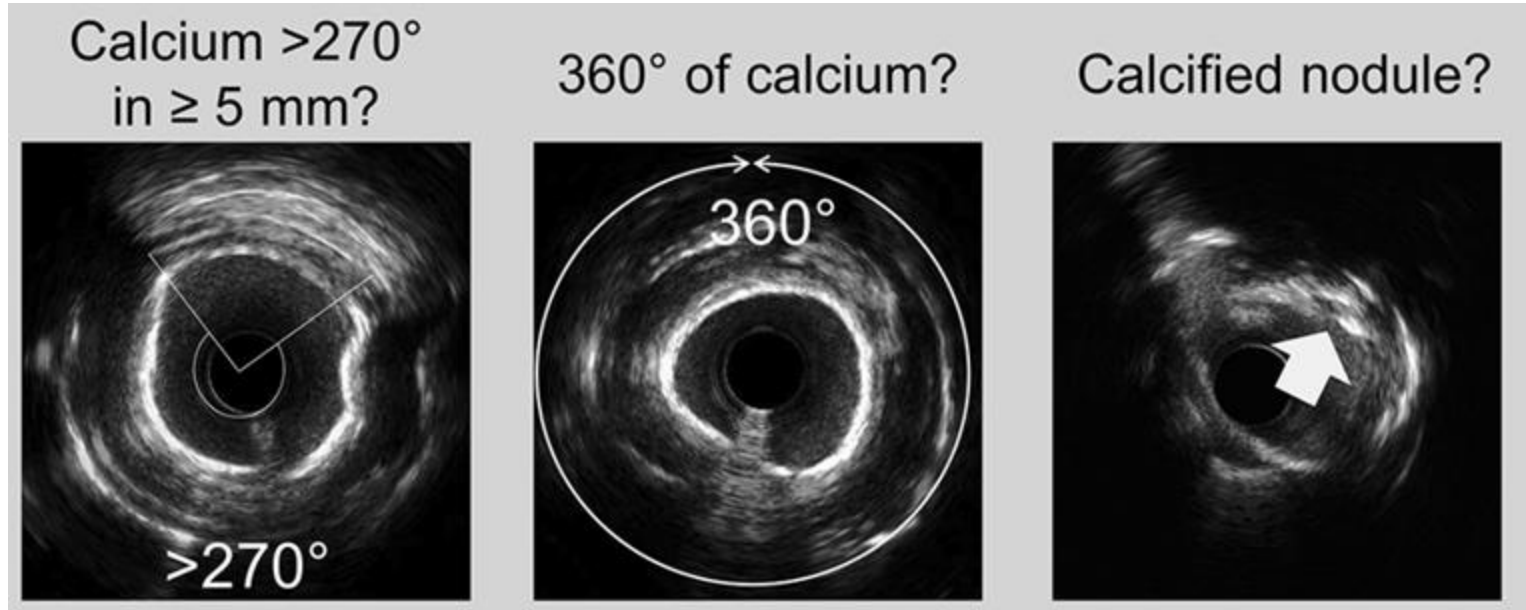
IVUS Properties

- ❖ After crossing lesion with a wire, an IVUS catheter is directed across coronary lesion and turned on to visualize the lumen
 - Solid state transducers use phased array transducers arranged in a circular manner and active sequentially
 - Mechanical transducers rotate a single transducer at high speed to create a uniform circular image
- ❖ Imaging resolution has improved with newer technology
- ❖ Tissue penetration by US is inversely related to frequency

Example of normal artery on IVUS

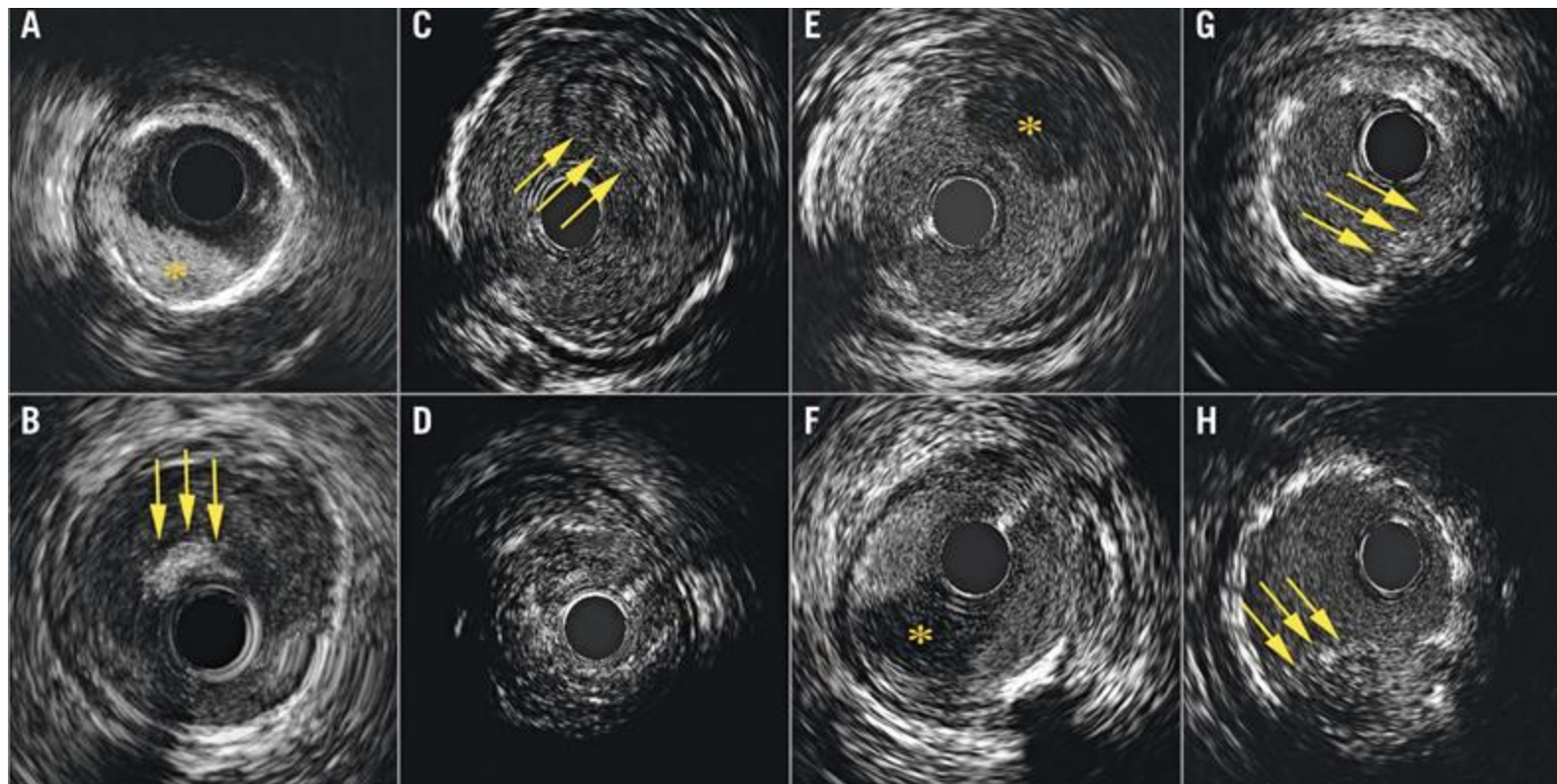


Example of calcified coronary disease

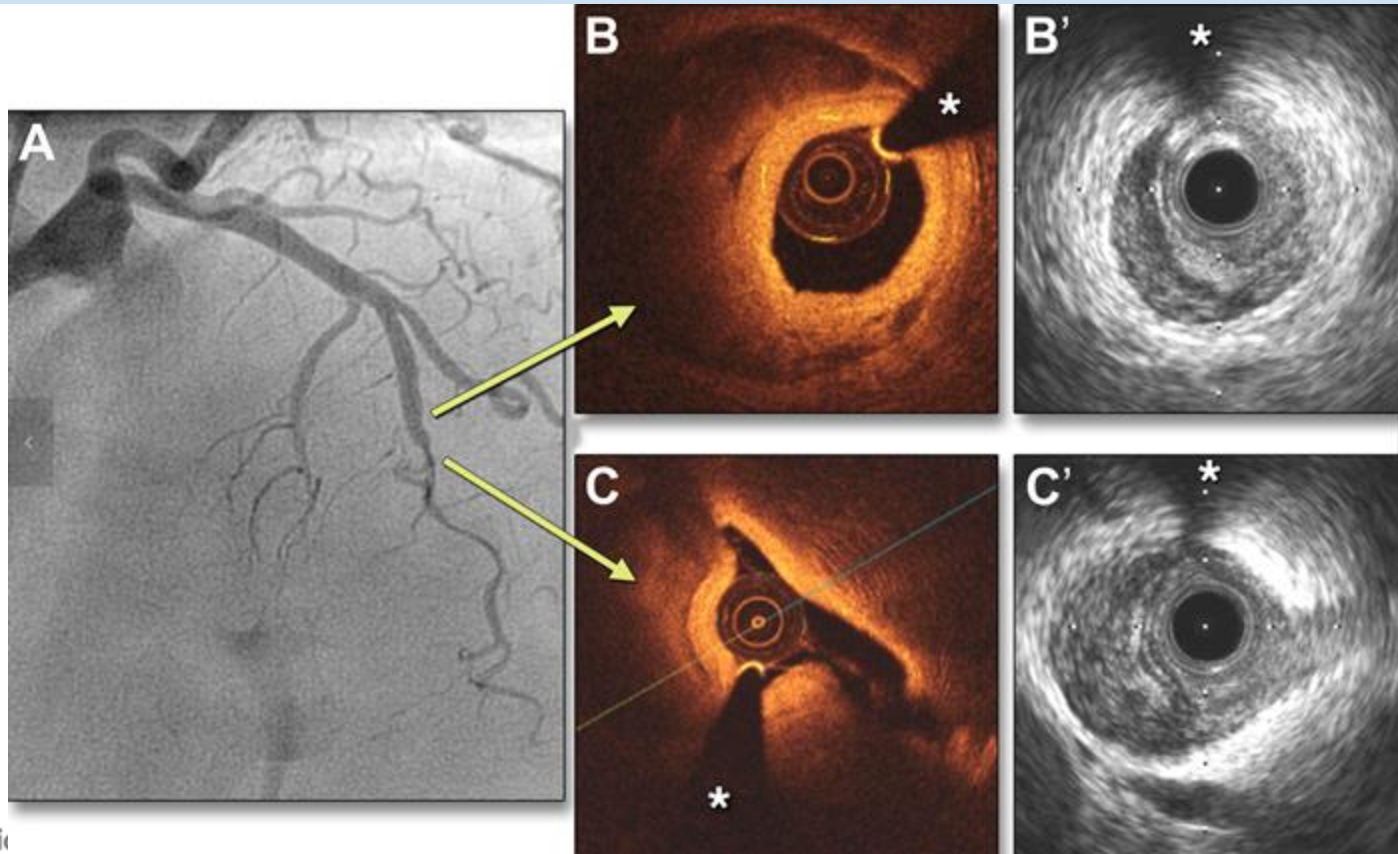


Techniques to modify calcium these lesions (atherectomy or intravascular lithotripsy) will result in better stent delivery and expansion

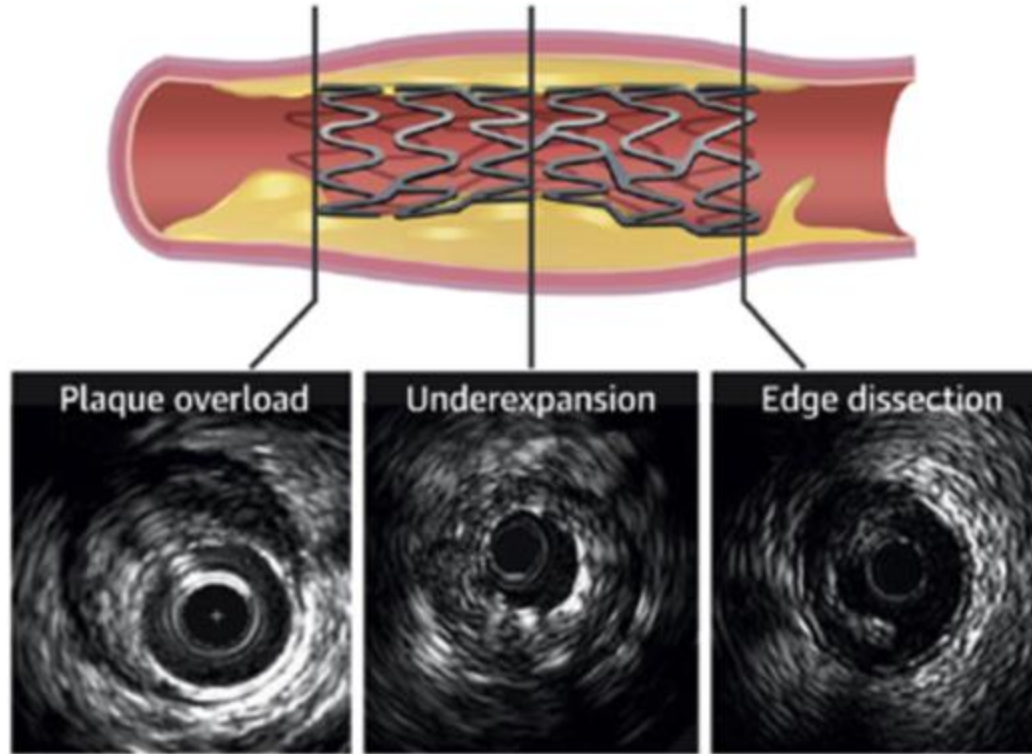
Examples of acute thrombotic lesions



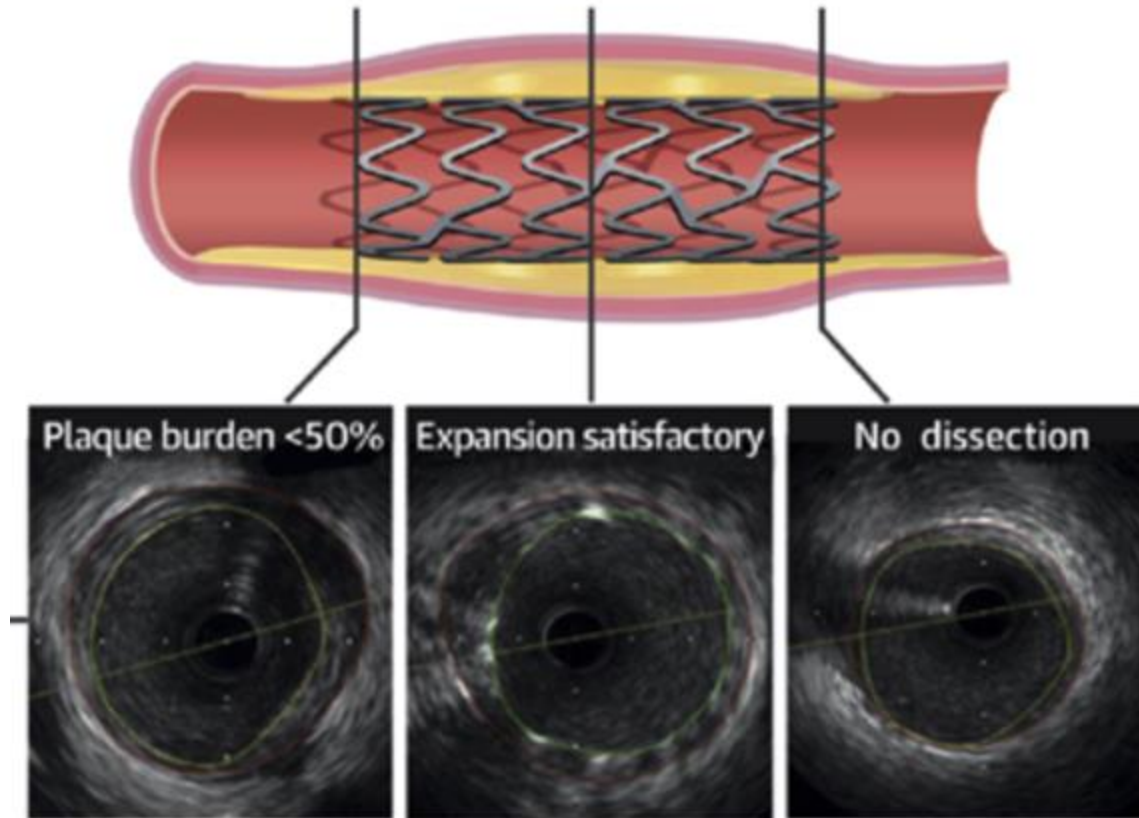
Example of coronary dissections



Stent problem identification



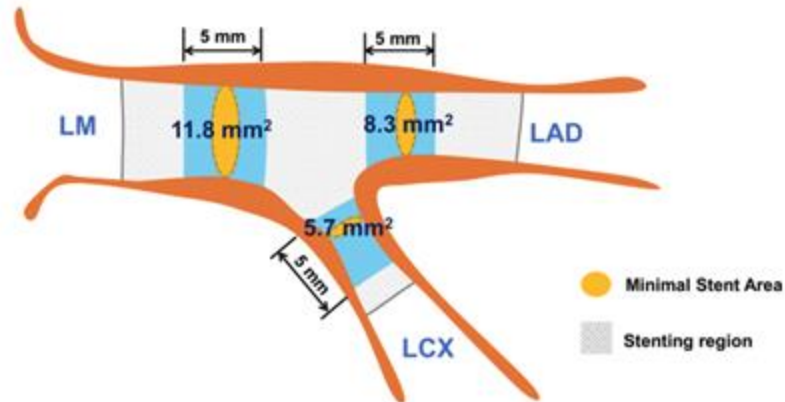
Stent optimization with IVUS



Minimal Stent Area (MSA) on IVUS

- ❖ Refers to the smallest cross-sectional area of a coronary artery after a stent has been placed
- ❖ A higher MSA indicates better stent expansion
- ❖ A low MSA is a powerful predictor of future events, including restenosis, stent thrombosis, and target lesion revascularization

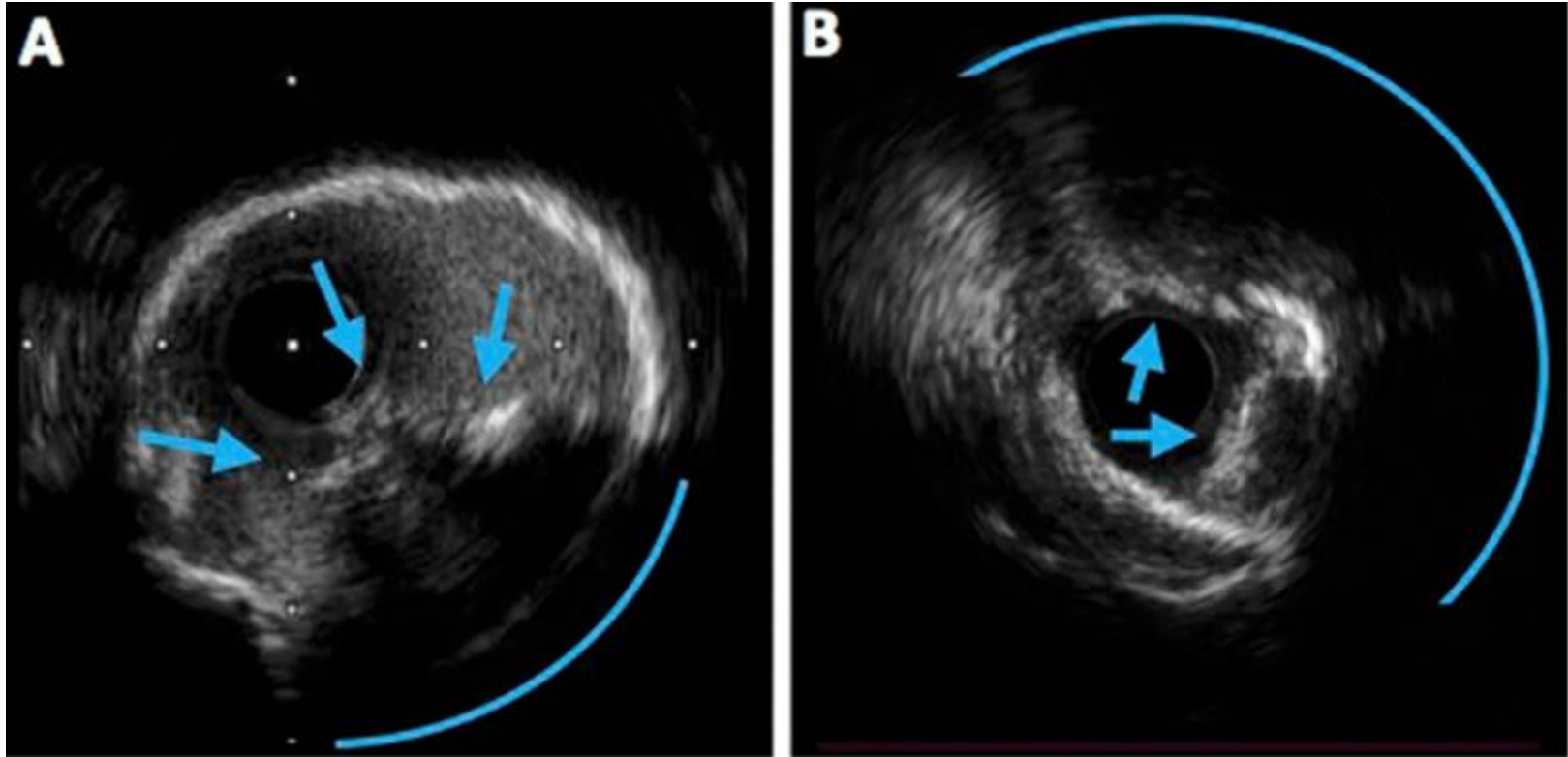
The Optimal Minimal Stent Area within Each Left Main Segment



IVUS criteria for “Stent Success”

1. MSA > 5.0 mm² or > 90% MLA at distal reference point
1. Plaque burden < 50% at stent edge
1. No dissection > 3 mm

Example of plaque modification



Data supporting the use of IVL

- ❖ In era of bare metal stents, the use of IVUS was shown to have lower rates of restenosis and target lesion revascularization (TLR) (Schiele *et al.* 1998, Frey *et al.*, 2000)
- ❖ Other trials have demonstrated similar results for drug eluting stents (DES)
- ❖ Challenging to demonstrate benefit since event rates are so low with modern DES
 - Often surrogate endpoints are used for clinical trials

Clinical trials on IVUS- vs angio only-PCI

- ❖ **IVUS-XPL (2015)** IVUS guided PCI vs angio only
 - Lower rate of composite endpoint (MAACE, TLR-MI, ischemia driven revascularization at one year)
- ❖ **ULTIMATE (2018)**
 - Lower target-vessel failure (TVF) at 12 months
 - IVUS-defined optimal criteria had to be met to count as successful.
- ❖ **Amin, Amit. Presented at: CRT 2024**
 - PCI procedures incorporating IVUS were associated with reduced mortality at both 1-year and ten-year intervals.

Clinical trials on IVUS in left main (LM) PCI

❖ Wang et al., 2018

- Meta analysis of 1 prospective RCT and 6 observational studies
- IVUS-guided DES implantation was associated with better clinical outcomes including death, myocardial infarction, and stent thrombosis.

❖ de la Torre et al., 2014

- Observational study of LM stenting
- IVUS-guided revascularization was identified as an independent predictor for major adverse events in the overall population

Clinical trials for CTO-PCO

❖ CTO-IVUS (2015)

- major adverse cardiac event rates were significantly lower in the IVUS-guided group than that in the angiography-guided group

❖ Kwon, et al., 2021

- post-stent IVUS evaluation was associated with a lower risk of TLR/reocclusion. The final MSA was independently associated with TLR/reocclusion

❖ Panuccio et al., 2023

- IVUS did not significantly improve clinical outcomes, except for reducing stent thrombosis.

IVUS Utilization by WA state hospitals

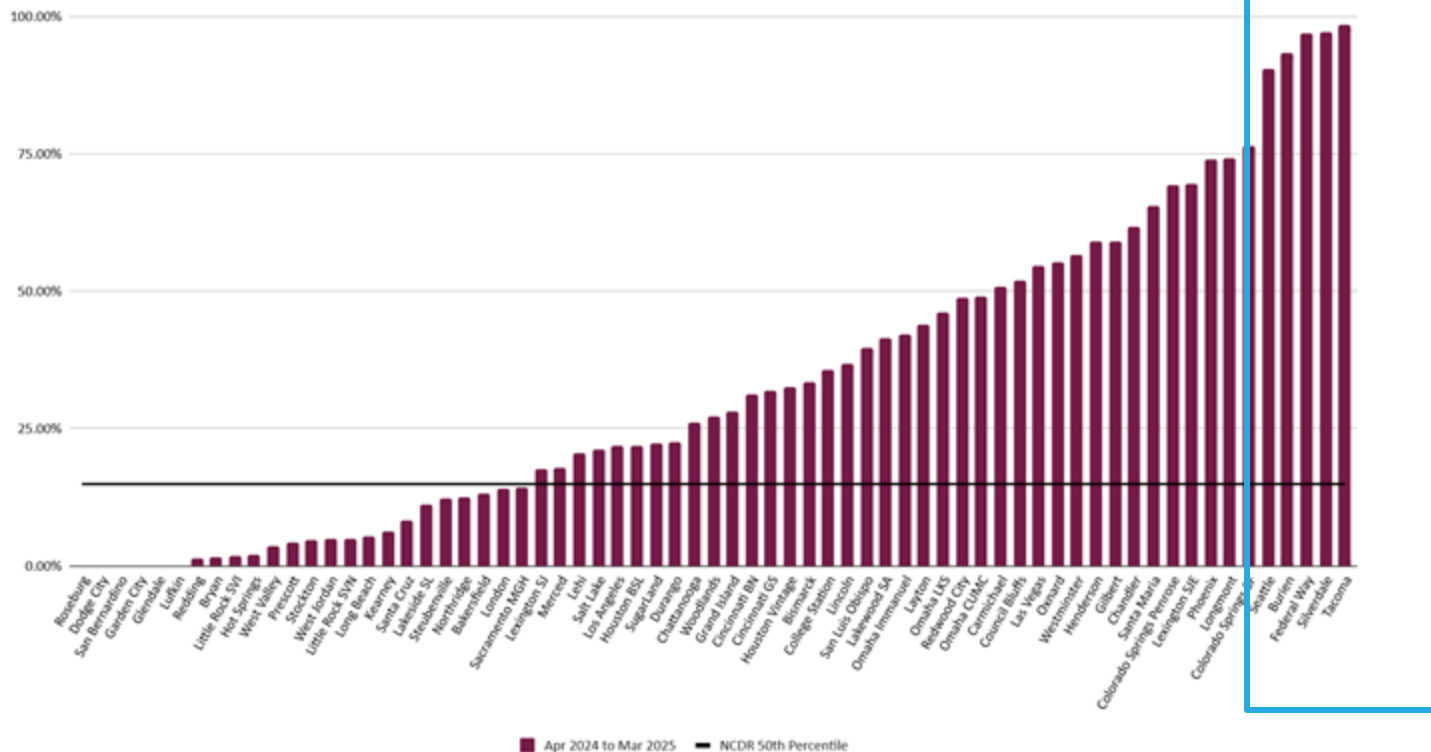
COAP Regional Summary Report: Q1 2024-Q4 2024

ALL PCI, Level I & II Metrics

	All PCI Vol.	Emergency CABG	Acute Kidney Injury - Risk Adjusted	Intra- or Post-Procedure Stroke	Median Cumulative Air Kerma in mGy	Intracoronary Imaging
Central WA	328	0.00%	6.3%	0.00%	1385.0	29.3%
Evergreen	471	0.00%	3.8%	0.68%	1361.5	69.2%
Harbor Regional Health	75	0.00%	5.2%	0.00%	1337.0	2.7%
MHS Auburn	218	0.00%	7.1%	0.00%	566.0	70.6%
MHS Capital	192	0.00%	3.6%	0.00%	1068.0	2.1%
MHS Deaconess	692	0.00%	5.0%	0.00%	650.0	66.3%
MHS Good Samaritan	376	0.00%	3.6%	0.58%	1344.5	71.0%
MHS Tacoma General	532	0.00%	4.4%	0.20%	1115.0	79.9%
MHS Yakima Memorial	436	0.00%	6.5%	0.00%	832.0	83.0%
Overlake	501	0.00%	7.0%	0.21%	808.5	88.6%
PH Sacred Heart	776	0.13%	3.7%	0.60%	602.5	79.8%
PH Southwest	619	0.34%	4.9%	0.36%	485.0	74.0%
PH St. John	277	0.00%	5.3%	0.37%	1358.0	68.6%
PH St. Joseph	767	0.00%	4.8%	0.41%	892.0	67.3%
Prov Everett	1135	0.00%	7.9%	0.48%	800.0	68.5%
Prov Kadlec	757	0.14%	5.5%	0.69%	994.0	56.1%
Prov Sacred Heart	826	0.00%	5.7%	0.13%	799.0	89.7%
Prov St. Mary	301	0.00%	4.0%	1.06%	1581.5	30.2%
Prov St. Peter	1208	0.00%	7.7%	0.44%	692.5	63.6%
Prov Swedish CH	1067	0.10%	6.1%	0.51%	1298.0	78.0%
Prov Swedish Ed	336	0.00%	4.1%	0.65%	1468.0	90.2%
Prov Swedish Iss	150	0.00%	10.2%	2.16%	1628.0	84.7%
Skagit Valley	257	0.00%	5.8%	0.00%	1191.5	26.5%
UWMC Montlake	1001	0.00%	11.2%	0.22%	516.0	71.9%
UWMC Northwest	268	0.00%	9.0%	0.39%	845.0	15.3%
UWM Harborview	130	0.00%	8.4%	2.44%	737.5	90.8%
UWM Valley	357	0.00%	6.7%	0.00%	758.0	98.0%
VMFH St. Anne	49	0.00%	7.2%	0.00%	574.0	91.8%
VMFH St. Francis	261	0.00%	2.0%	0.45%	487.0	95.0%
VMFH St. Joseph	579	0.00%	4.8%	0.00%	444.0	96.9%
VMFH St. Michael	998	0.00%	7.7%	0.21%	420.5	96.4%
VMFH Virginia Mason	380	0.27%	6.1%	0.28%	774.0	88.7%
All COAP	16320	0.04%	6.2%	0.37%	785.0	72.5%
Benchmark		0.00%	3.5%	0.00%	444.9	
2021	15374	0.07%	7.1%	0.46%	950.0	
2022	15066	0.08%	7.2%	0.42%	899.0	
2023	15613	0.07%	6.6%	0.44%	834.0	

IVUS Utilization by Commonspirit hospitals

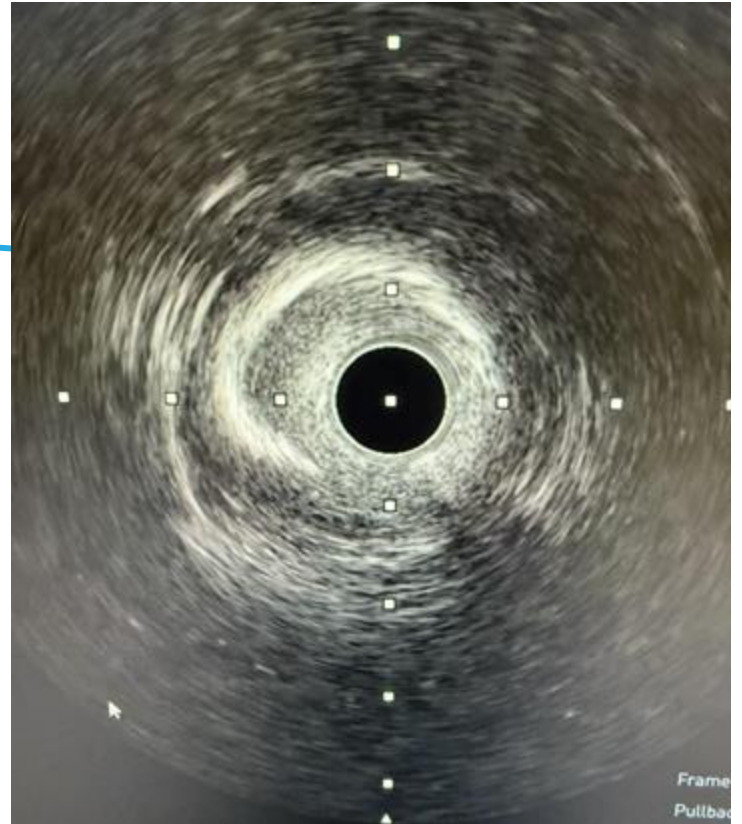
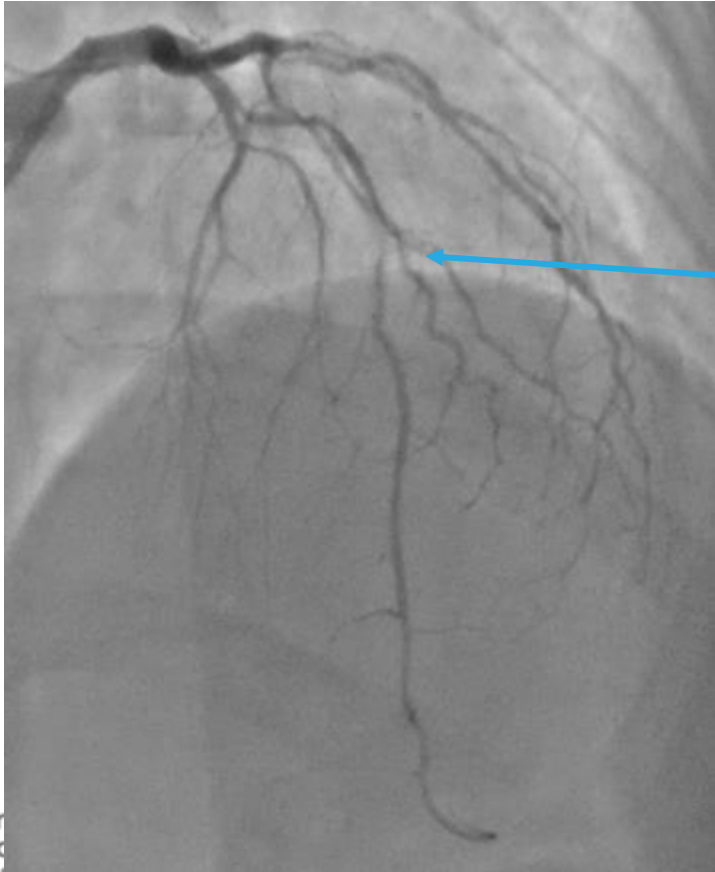
Intravascular Ultrasound (IVUS) - DL 15785



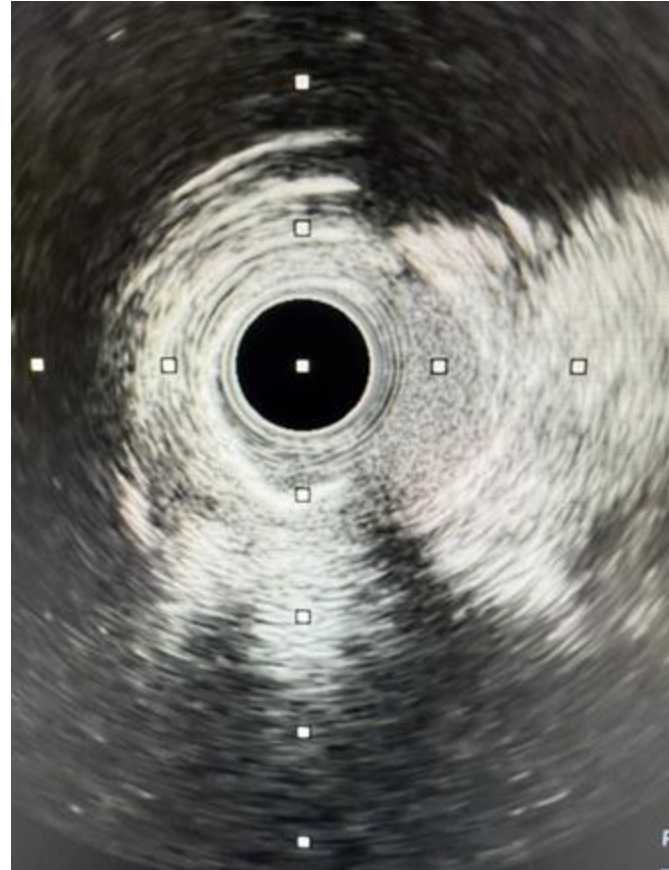
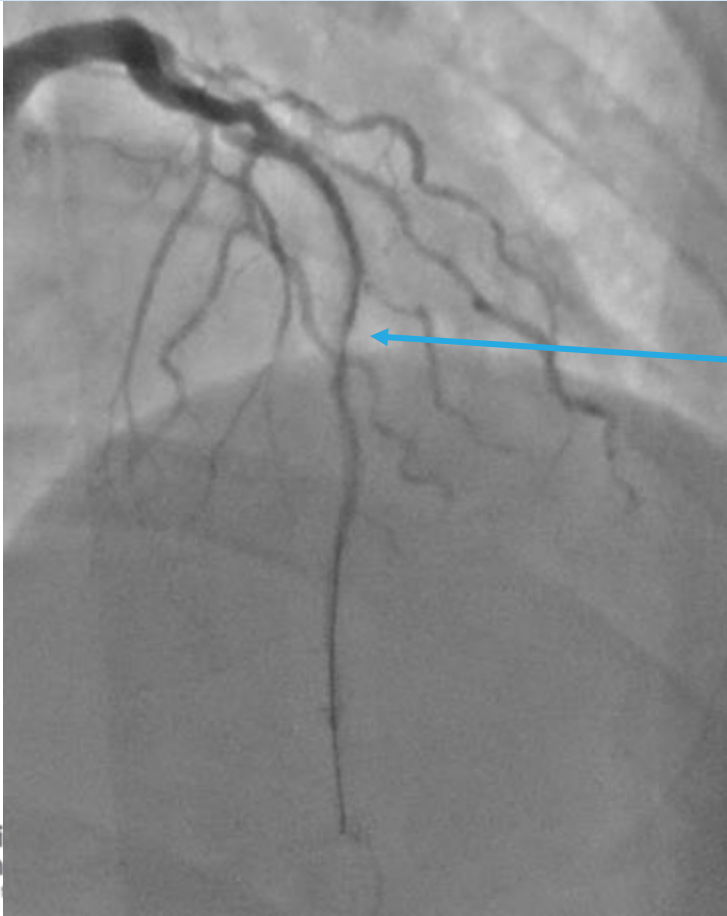
Rates of IVUS use

- ❖ IWI/IVUS use is low nationally (~15% of all PCIs)
 - Use is increasing
- ❖ In late 2010s use was as low as 6-7%
- ❖ Other countries (Japan, Korea) have higher utilization rates up to 75-80%

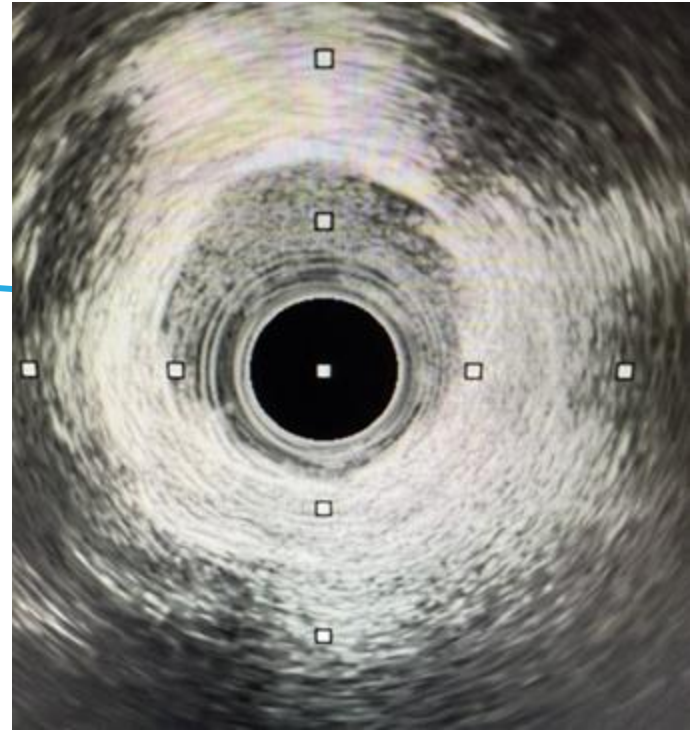
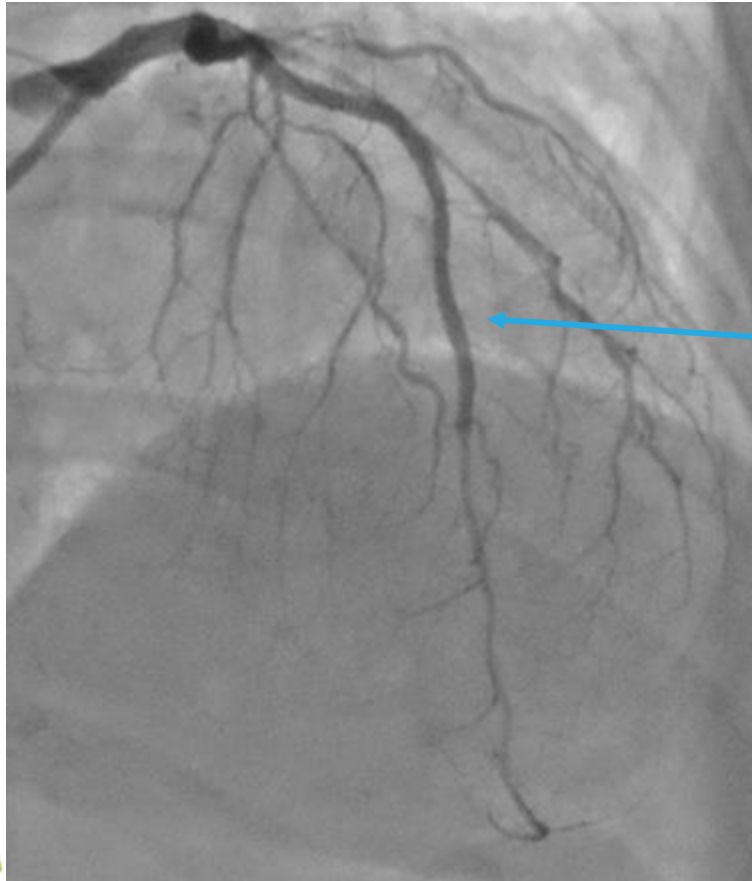
Case example, severe LAD disease



Vessel after rotational atherectomy



Vessel after stent placed



Take home points

- ❖ Use of Intravascular imaging/IVUS is associated with better clinical outcomes and is an indispensable tool in contemporary PCI
- ❖ Optimize stent placement and long term durability
- ❖ Helps avoid/diagnose complications such as coronary dissection
- ❖ Can aid in individualized recommendations regarding DAPT duration
- ❖ IVUS is underutilized nationally
- ❖ IVUS use is strong in the VMFH system

Thank You



Coronary CT Angiography and FFR-CT

Justin Penn, MD FACC

Introduction

Coronary CT Angiography and FFR-CT

- ❖ 62 year old with new onset angina
- ❖ Referred for stress test
- ❖ Abnormal
- ❖ Referred to Cardiology
- ❖ Sent for invasive angiography



Coronary CT Angiography and FFR-CT

- ❖ Her angiogram is shows only luminal irregularities
- ❖ No stent is indicated
- ❖ Risk of ICA: 0.082%
- ❖ Is there a better way?



Absolutely

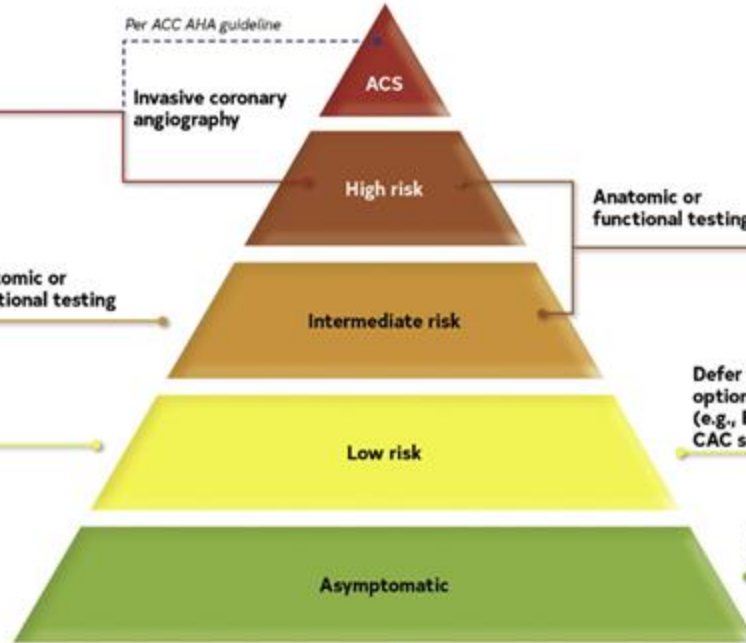


Guidelines

Acute Chest Pain Evaluation ED evaluation



Risk of Major CAD Events



Stable Chest Pain Evaluation Outpatient evaluation





Guidelines

Pretest likelihood of CAD	Low	→	No testing necessary	→	Option for CAC for ASCVD risk stratification
	Intermediate-high	→	Younger patient (<65 y of age)	OR	Less obstructive CAD suspected → CCTA favored
	Intermediate-high	→	Older patient (≥65 y of age)	OR	More obstructive CAD suspected → Stress testing favored

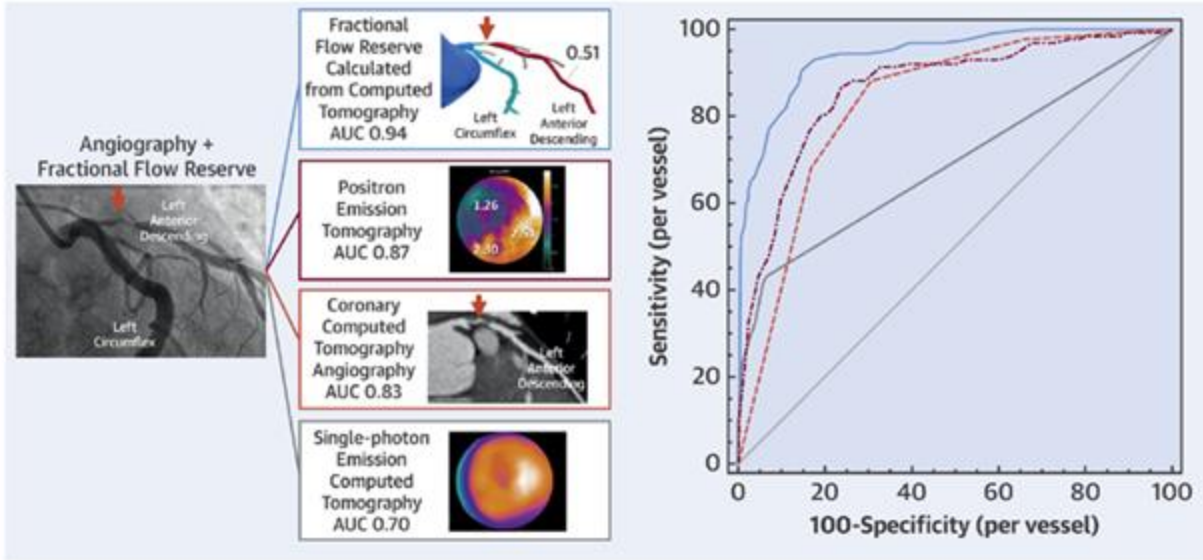
	Favors use of CCTA	Favors use of stress imaging
Goal	<ul style="list-style-type: none"> • Rule out obstructive CAD • Detect nonobstructive CAD 	<ul style="list-style-type: none"> • Ischemia-guided management
Availability and expertise	<ul style="list-style-type: none"> • High-quality imaging and expert interpretation routinely available 	<ul style="list-style-type: none"> • High-quality imaging and expert interpretation routinely available
Likelihood of obstructive CAD	<ul style="list-style-type: none"> • Age <65 y 	<ul style="list-style-type: none"> • Age ≥65 y
Prior test results	<ul style="list-style-type: none"> • Prior functional study inconclusive 	<ul style="list-style-type: none"> • Prior CCTA inconclusive
Other compelling indications	<ul style="list-style-type: none"> • Anomalous coronary arteries • Require evaluation of aorta or pulmonary arteries 	<ul style="list-style-type: none"> • Suspect scar (especially if PET or stress CMR available) • Suspect coronary microvascular dysfunction (when PET or CMR available)



Guidelines

Test	Stress electrocardiogram
Requirements and considerations	Exercise stress test Requires electrocardiogram (ECG) (left bundle branch block or major ST-segment changes)
Sensitivity	0.58 (95% CI 0.48-0.68)
Specificity	0.62 (95% CI 0.52-0.72)
Findings indicating high risk	>2-mm ST-segment depression ST-segment depression with ventricular tachycardia or ventricular fibrillation

CENTRAL ILLUSTRATION: Discriminative Ability of Imaging Modalities for the Detection of Per-Vessel Fractional Flow Reserve-Defined Ischemia



Driessen, R.S. et al. J Am Coll Cardiol. 2019;73(2):161-73.

invasive coronary angiography

invasive procedure
bleeding risks
higher with radial vs
femoral approach)

use with caution for
patients with kidney
dysfunction

multiple coronary
arteries with $\geq 70\%$
stenosis
main stenosis $\geq 50\%$



Guideline Recommendations

❖ 1) Initial Chest Pain Evaluation

- For intermediate-high risk patients with stable chest pain and no known CAD, CCTA is effective for diagnosis of CAD, for risk stratification, and for guiding treatment decisions.

❖ 2A) FFR-CT for 40-90% stenosis to defer ICA

- FFR-CT can be useful for diagnosis of vessel-specific ischemia and to guide decision-making regarding the use of revascularization for intermediate-high risk patients with stable symptoms with 40% to 90% in a proximal or middle coronary segment on CCTA.



Guideline Recommendations

❖ 2A) Abnormal Stress Tests

- For patients with an inconclusive or abnormal exercise ECG or stress imaging study, CCTA is reasonable.

❖ 2B) Normal Stress Tests with high clinical suspicion

- For patients with negative stress test but with high clinical suspicion of CAD, CCTA or ICA may be reasonable.



Guideline Recommendations

❖ 1) CABG Graft Assessment

- Post CABG patients with suspected coronary ischemia, it is reasonable to perform stress imaging or CCTA to evaluate for myocardial ischemia or **graft** stenosis or occlusion.

❖ 2A) Reassessment of non-obstructive disease

- For patients with known non-obstructive CAD with stable chest pain, CCTA is reasonable for determining plaque burden and progression to obstructive CAD and to guide therapeutic decision-making.

When not CCTA?

- ❖ Previous coronary stent
- ❖ Previous bypass surgery - when looking for changes in native vessel - okay to use when addressing graft patency
- ❖ Known high calcium score
- ❖ Recent CCTA with known moderate or greater stenoses without change in symptoms
- ❖ Known elevated calcium score - to assess soft plaque volume

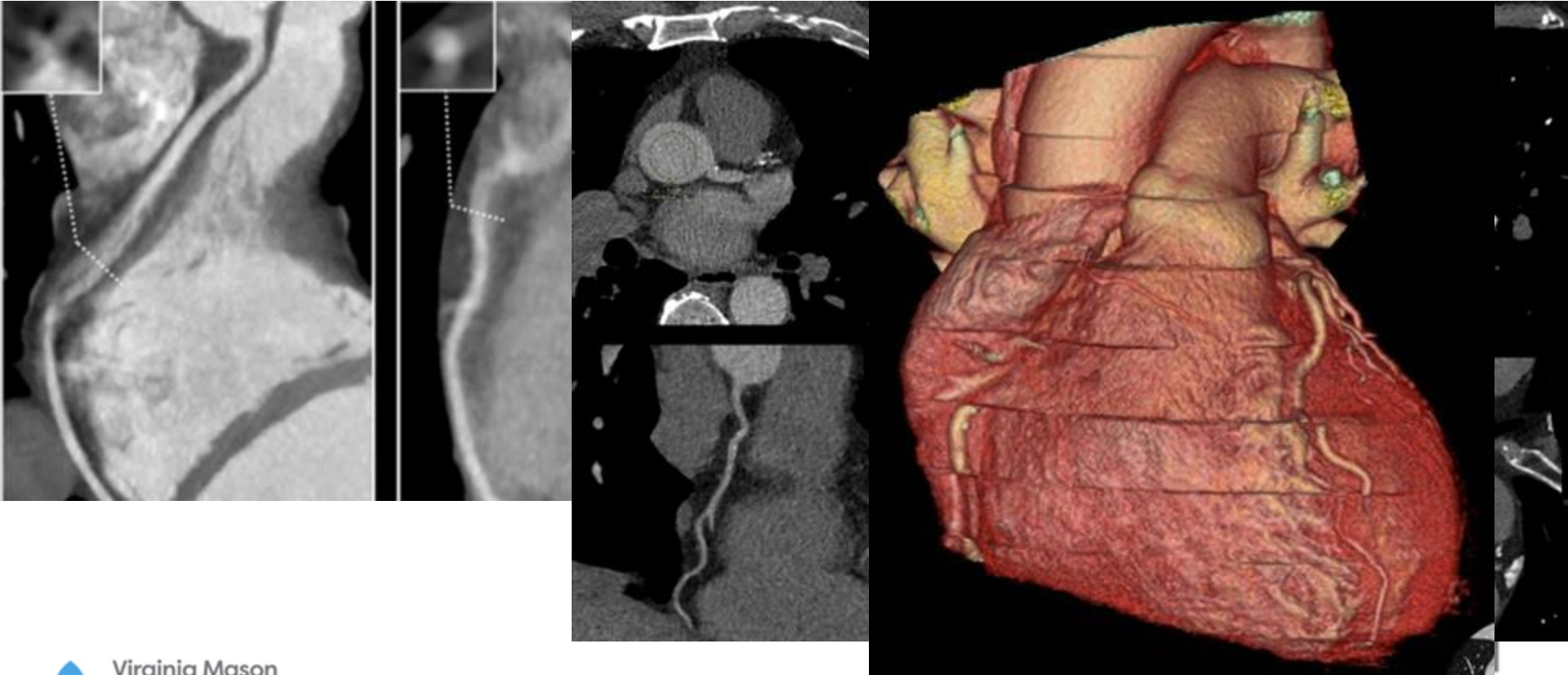
How?

□ CT Angiography Performed

- ❖ Heart rate slowed
- ❖ Images timed to the ECG
- ❖ Non-con CT - Calcium Score
- ❖ NTG administered
- ❖ IV Con with Saline bolus
- ❖ Images acquired
- ❖ Radiation is 3-5 mSv



Image Quality

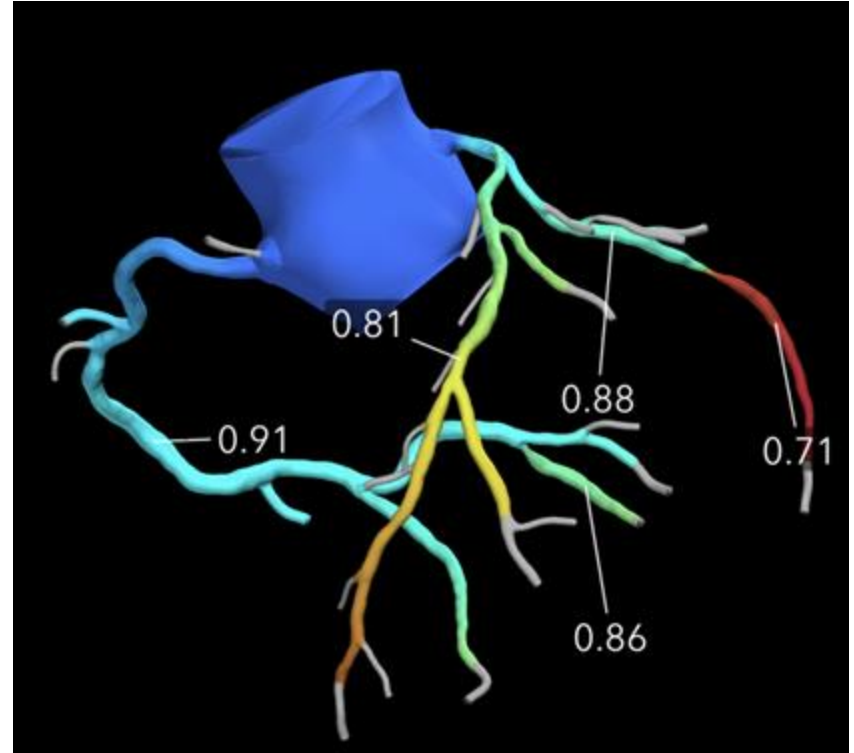


Relative & Absolute Contraindications

- ❖ Inability to lower heart rate
- ❖ Inability to follow commands and hold breath
- ❖ Irregular heart rate (atrial fibrillation, frequent PVC's)
- ❖ Obesity BMI > 35-40
- ❖ Contrast allergy
- ❖ Renal insufficiency (typical contrast: 70-120 mL)
- ❖ Presence of coronary stents
- ❖ High calcium burden

What is FFR-CT?

- ❖ Angiographic stenosis \neq ischemia
- ❖ Fractional Flow Reserve developed in the cath lab
- ❖ Changes in pressure = Flow / resistance
- ❖ FFR-CT estimates invasive FFR via computer modeling of fluid dynamics
- ❖ Ratio of pressure distal/proximal



What is FFR-CT?

- ❖ $FFR \leq 0.75$ - Abnormal, correlates with ischemia, may benefit from revasc
- ❖ $FFR > 0.8$ - Normal, unlikely to cause ischemia, may defer revasc
- ❖ $FFR 0.76-0.8$ - Grey-zone, depends on symptoms, lesion location, and degree of pressure loss (i.e. if FFR value 1-2 cm prox to lesion drops by > 0.12 at 1-2 cm distal to lesion), may want to perform ICA if clinically appropriate
- ❖ Distal or Terminal $FFR < 0.75$ - Defer ICA

Understanding a CCTA Report

Category	Degree of maximal coronary stenosis	Interpretation	Further Cardiac Investigation	Management considerations
CAD-RADS 0	0% (No plaque or stenosis)	Absence of CAD ^a	None	- Reassurance. Consider non-atherosclerotic causes of symptoms
CAD-RADS 1	1–24% (Minimal stenosis or plaque with no stenosis ^b)	Minimal non-obstructive CAD ^b	None	- Consider non-atherosclerotic causes of symptoms - P1: Consider risk factor modification and preventive pharmacotherapy - P2: Risk factor modification and preventive pharmacotherapy - P3 or P4: Aggressive risk factor modification and preventive pharmacotherapy
CAD-RADS 2	25–49% (Mild stenosis)	Mild non-obstructive CAD	None	- Consider non-atherosclerotic causes of symptoms - P1 or P2: Risk factor modification and preventive pharmacotherapy - P3 or P4: Aggressive risk factor modification and preventive pharmacotherapy
CAD-RADS 3	50–69% (Moderate stenosis)	Moderate stenosis	Consider functional assessment ^c	- P1, P2, P3 or P4: Aggressive risk factor modification and preventive pharmacotherapy - Other treatments (including anti-anginal therapy) should be considered per guideline directed care ^d - When modifier I+, consider ICA, especially if frequent symptoms persist after guideline-directed medical therapy
CAD-RADS 4	A - 70–99% stenosis or B - Left main \geq 50% or 3- vessel obstructive (\geq 70%) disease	Severe stenosis	A: Consider ICA ^e or functional assessment B: ICA is recommended	P1, P2, P3 or P4: Aggressive risk factor modification and preventive pharmacotherapy. - Other treatments (including anti-anginal therapy and options of revascularization) should be considered per guideline directed care ^d
CAD-RADS 5	100% (total occlusion)	Total coronary occlusion or sub-total occlusion	Consider ICA, functional and/or viability assessment	P1, P2, P3 or P4: Aggressive risk factor modification and preventive pharmacotherapy. - Other treatments (including anti-anginal therapy and options of revascularization) should be considered per guideline directed care ^d
CAD-RADS N	Non-diagnostic study	Obstructive CAD cannot be excluded	Additional/alternative evaluation may be needed	

Understanding a CCTA Report

TABLE 3 Risk of Death or Myocardial Infarction by CAD-RADS

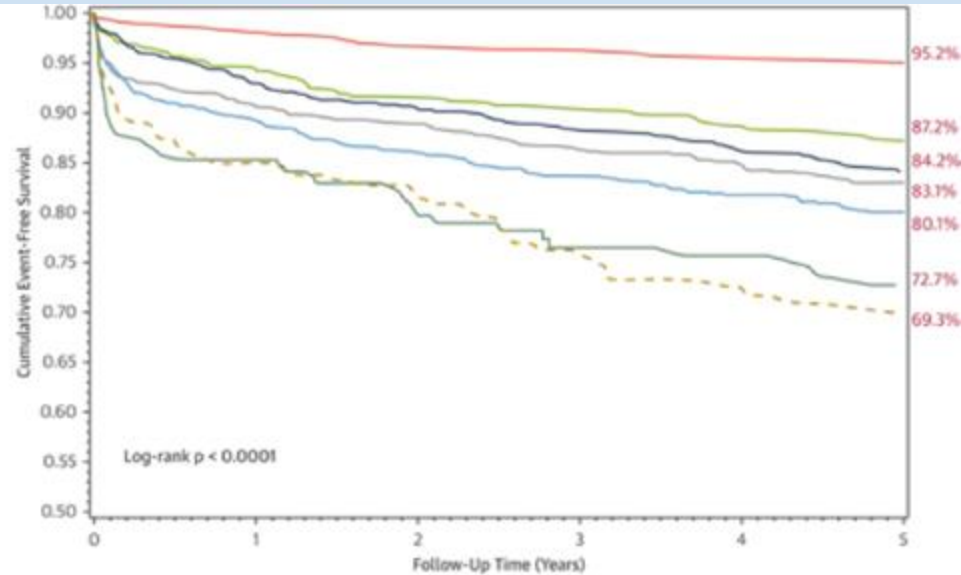
	Composite Outcome				All-Cause Mortality			
	Univariable HR (95% CI)	p Value	Multivariable* HR (95% CI)	p Value	Univariable HR (95% CI)	p Value	Multivariable* HR (95% CI)	p Value
CAD-RADS 0	1.00	Reference	1.00	Reference	1.00	Reference	1.00	Reference
CAD-RADS 1	2.45 (1.82-3.29)	<0.0001	2.46 (1.82-3.31)	<0.0001	2.04 (1.37-3.02)	<0.0001	1.81 (1.21-2.69)	0.0036
CAD-RADS 2	3.28 (2.48-4.34)	<0.0001	3.19 (2.40-4.24)	<0.0001	2.82 (1.95-4.06)	<0.0001	2.22 (1.52-3.23)	<0.0001
CAD-RADS 3	3.67 (2.81-4.80)	<0.0001	3.42 (2.59-4.51)	<0.0001	2.27 (1.55-3.33)	<0.0001	1.67 (1.12-2.49)	0.0107
CAD-RADS 4A	4.23 (3.30-5.43)	<0.0001	3.73 (2.87-4.86)	<0.0001	2.18 (1.51-3.14)	<0.0001	1.55 (1.05-2.28)	0.0264
CAD-RADS 4B	6.31 (4.46-8.93)	<0.0001	5.39 (3.76-7.73)	<0.0001	4.31 (2.59-7.17)	<0.0001	2.78 (1.64-4.71)	0.0001
CAD-RADS 5	7.11 (5.14-9.83)	<0.0001	6.09 (4.34-8.54)	<0.0001	4.71 (2.97-7.48)	<0.0001	3.09 (1.87-4.92)	<0.0001

TABLE 3 Continued

	Nonfatal MI			
	Univariable HR (95% CI)	p Value	Multivariable* HR (95% CI)	p Value
CAD-RADS 0	1.00	Reference	1.00	Reference
CAD-RADS 1	2.98 (1.89-4.71)	<0.0001	3.25 (2.15-4.91)	<0.0001
CAD-RADS 2	3.93 (2.55-6.05)	<0.0001	3.75 (2.50-5.64)	<0.0001
CAD-RADS 3	5.78 (3.89-8.58)	<0.0001	6.03 (4.18-8.70)	<0.0001
CAD-RADS 4A	7.19 (4.96-10.45)	<0.0001	6.87 (4.85-9.75)	<0.0001
CAD-RADS 4B	9.15 (5.58-15.01)	<0.0001	9.24 (5.87-14.55)	<0.0001
CAD-RADS 5	9.97 (6.23-15.94)	<0.0001	9.07 (5.79-14.20)	<0.0001

*Multivariable models were adjusted for patient age, sex, hypertension, diabetes, hyperlipidemia, smoking, and chest pain characteristics.
CAD-RADS = Coronary Artery Disease-Reporting and Data System; CI = confidence interval; HR = hazard ratio; MI = myocardial infarction.

CAD-RADS Predicts Outcomes



Number at Risk

CAD-RADS 0	1679	1646	1614	1602	1589	1581
CAD-RADS 1	592	559	537	529	516	505
CAD-RADS 2	616	571	534	516	500	483
CAD-RADS 3	712	636	576	521	487	461
CAD-RADS 4A	963	838	672	562	502	465
CAD-RADS 4B	190	161	120	87	80	74
CAD-RADS 5	206	168	135	107	91	82

CAD-RADS 0 — CAD-RADS 1 — CAD-RADS 2 — CAD-RADS 3 —
 CAD-RADS 4A — CAD-RADS 4B — CAD-RADS 5 - - -



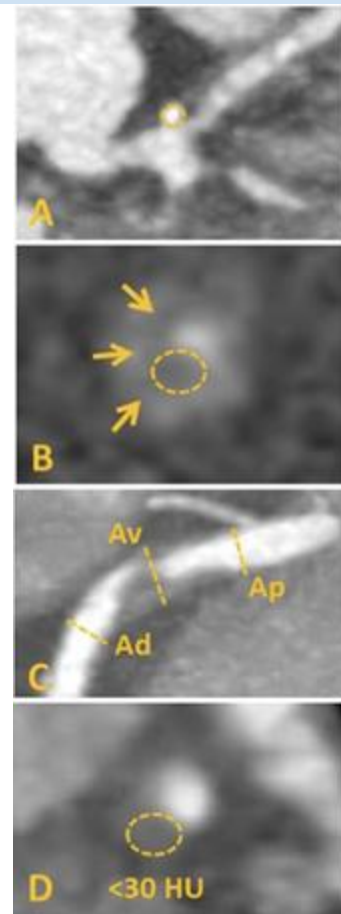
The Vulnerable Plaque

- ❖ What is the vulnerable plaque?
 - Spotty calcifications
 - Napkin ring sign
 - Positive remodeling
 - Low attenuation < 30 Hu
- ❖ Consider more aggressive prevention

TABLE 3 Univariable and Multivariable Analysis for Coronary Heart Disease Death or Nonfatal Myocardial Infarction Compared With Patients With Normal Coronary Arteries

	Univariable Analysis	p Value	Multivariate Analysis*	p Value
Nonobstructive disease without adverse plaque†	4.95 (1.34-18.29)	0.016	2.79 (0.64-12.18)	0.172
Nonobstructive disease with adverse plaque†	5.81 (1.50-22.46)	0.011	2.67 (0.53-13.43)	0.234
Obstructive disease without adverse plaque†	7.73 (1.73-34.54)	0.007	3.20 (0.52-19.61)	0.208
Obstructive disease with adverse plaque†	11.50 (3.39-39.04)	<0.001	4.10 (0.76-22.0)	0.100
Coronary artery calcium score‡	1.23 (1.13-1.35)	<0.001	1.12 (0.98-1.28)	0.107
Cardiovascular risk score§	1.65 (1.13-2.41)	0.01	1.10 (0.71-1.70)	0.673

Values are hazard ratio (95% confidence interval). Values in **bold** indicate statistical significance. *Log rank statistic 27.29, $p < 0.001$; Harrell's C-statistic 0.728 (standard error = 0.046). †Adverse plaque defined as the presence of positive remodeling or low-attenuation plaque. ‡Per doubling of coronary artery calcium score. §ASSIGN score, per doubling of cardiovascular risk score.



Now what?

How to manage abnormal CAC/CCTA

- ❖ Anti-atherosclerosis therapy
 - Antiplatelets
 - Lipid lowering
 - Optimize risk factors (blood pressure, blood sugar)
 - Anti inflammatory therapy
- ❖ Anti-ischemic therapy
- ❖ Revascularization (PCI/CABG)

Coronary CT Angiography and 5-Year Risk of Myocardial Infarction

The SCOT-HEART Investigators*

ABSTRACT

BACKGROUND

Although coronary computed tomographic angiography (CTA) improves diagnostic certainty in the assessment of patients with stable chest pain, its effect on 5-year clinical outcomes is unknown.

METHODS

In an open-label, multicenter, parallel-group trial, we randomly assigned 4146 patients with stable chest pain who had been referred to a cardiology clinic for evaluation to standard care plus CTA (2073 patients) or to standard care alone (2073 patients). Investigations, treatments, and clinical outcomes were assessed over 3 to 7 years of follow-up. The primary end point was death from coronary heart disease or nonfatal myocardial infarction at 5 years.

RESULTS

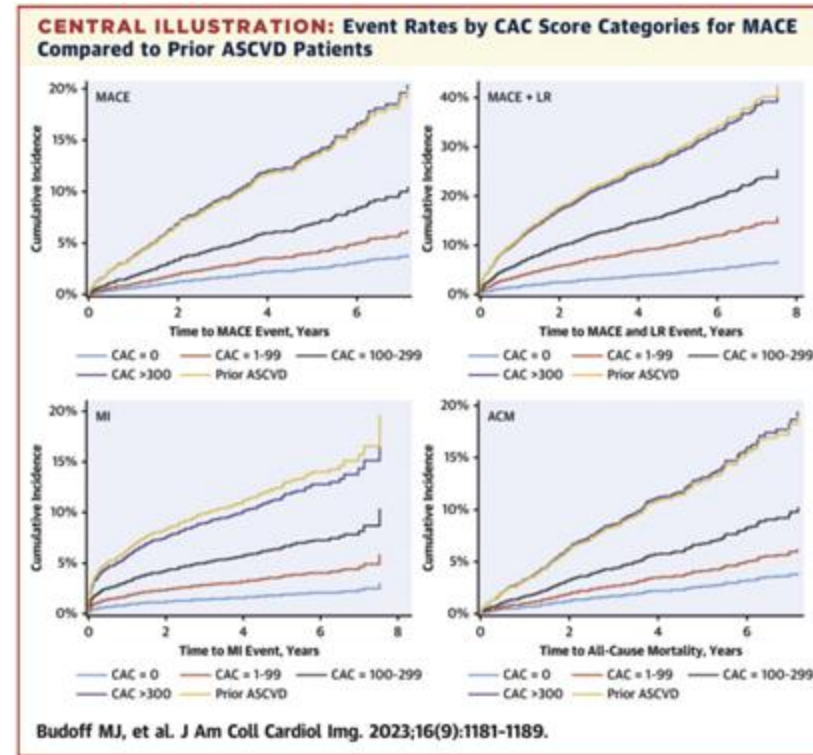
The median duration of follow-up was 4.8 years, which yielded 20,254 patient-years of follow-up. The 5-year rate of the primary end point was lower in the CTA group than in the standard-care group (2.3% [48 patients] vs. 3.9% [81 patients]; hazard ratio, 0.59; 95% confidence interval [CI], 0.41 to 0.84; $P=0.004$). Although the rates of invasive coronary angiography and coronary revascularization were higher in the CTA group than in the standard-care group in the first few months of follow-up, overall rates were similar at 5 years: invasive coronary angiography was performed in 491 patients in the CTA group and in 502 patients in the standard-care group (hazard ratio, 1.00; 95% CI, 0.88 to 1.13), and coronary revascularization was performed in 279 patients in the CTA group and in 267 in the standard-care group (hazard ratio, 1.07; 95% CI, 0.91 to 1.27). However, more preventive therapies were initiated in patients in the CTA group (odds ratio, 1.40; 95% CI, 1.19 to 1.65), as were more antianginal therapies (odds ratio, 1.27; 95% CI, 1.05 to 1.54). There were no significant between-group differences in the rates of cardiovascular or noncardiovascular deaths or deaths from any cause.

CONCLUSIONS

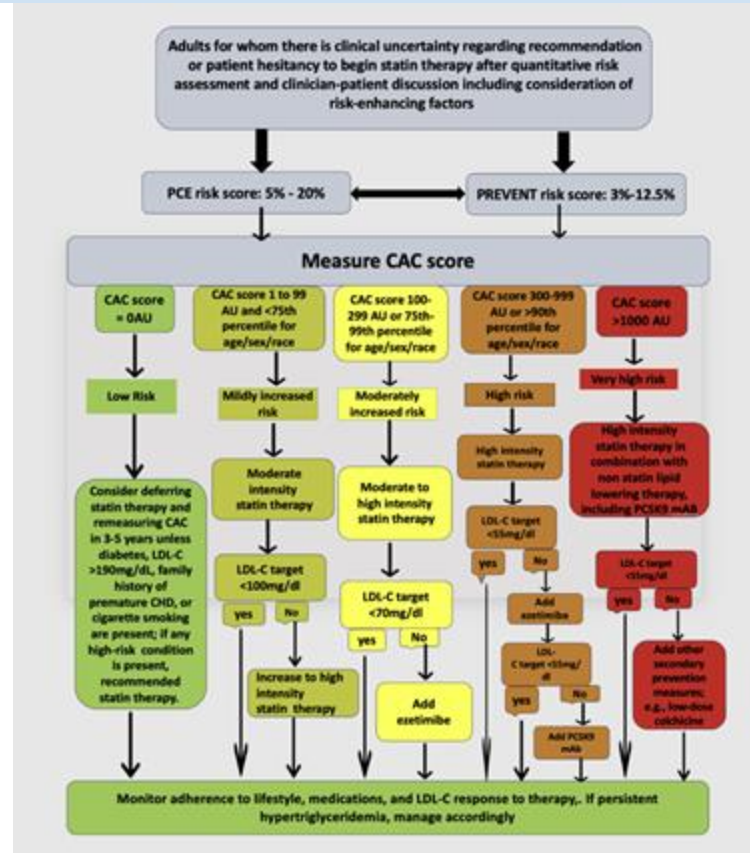
In this trial, the use of CTA in addition to standard care in patients with stable chest pain resulted in a significantly lower rate of death from coronary heart disease or nonfatal myocardial infarction at 5 years than standard care alone, without resulting in a significantly higher rate of coronary angiography or coronary revascularization. (Funded by the Scottish Government Chief Scientist Office and others; SCOT-HEART ClinicalTrials.gov number, NCT01149590.)

How to manage abnormal CAC/CCTA

- ❖ Calcium score of ≥ 300 is ASCVD
- ❖ CAD-RADS ≥ 3 is ASCVD



How to manage abnormal CAC/CCTA

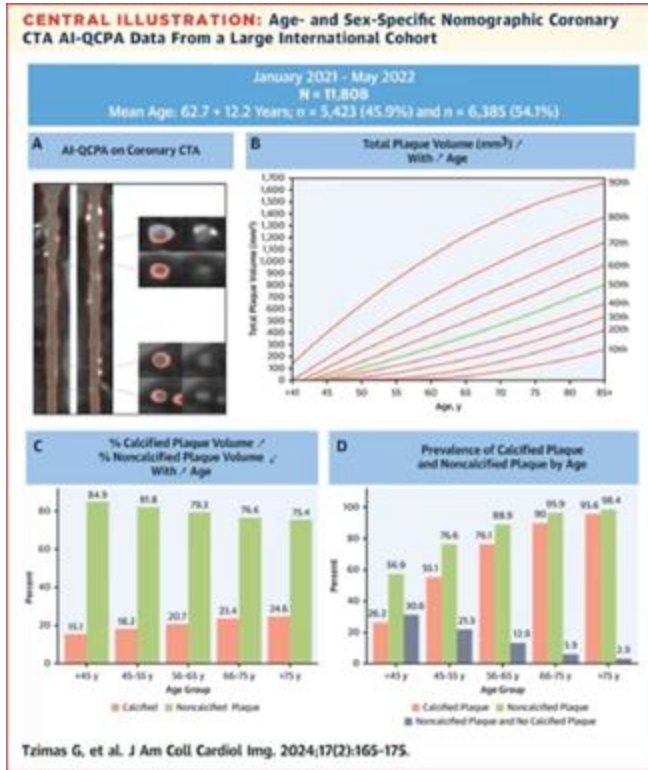


What's Next in CT?

What's Next?

- ❖ AI-QCT - AI guided analysis of CT for ischemia
- ❖ Plaque analysis
 - Provides quantification of soft and calcified plaque
 - Unclear role in management of chronic atherosclerosis

Plaque Analysis



Key Question

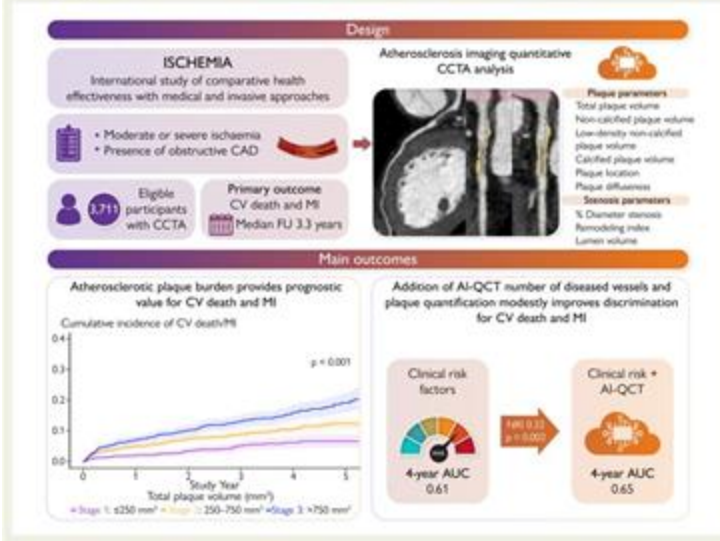
What is the prognostic value of coronary computed tomography angiography (CCTA)-derived atherosclerotic plaque analysis in ISCHEMIA?

Key Finding

In a population with advanced coronary artery disease with moderate to severe ischaemia, atherosclerotic plaque quantification modestly improved prognostication of a composite outcome of cardiovascular death or myocardial infarction beyond clinical risk factors alone.

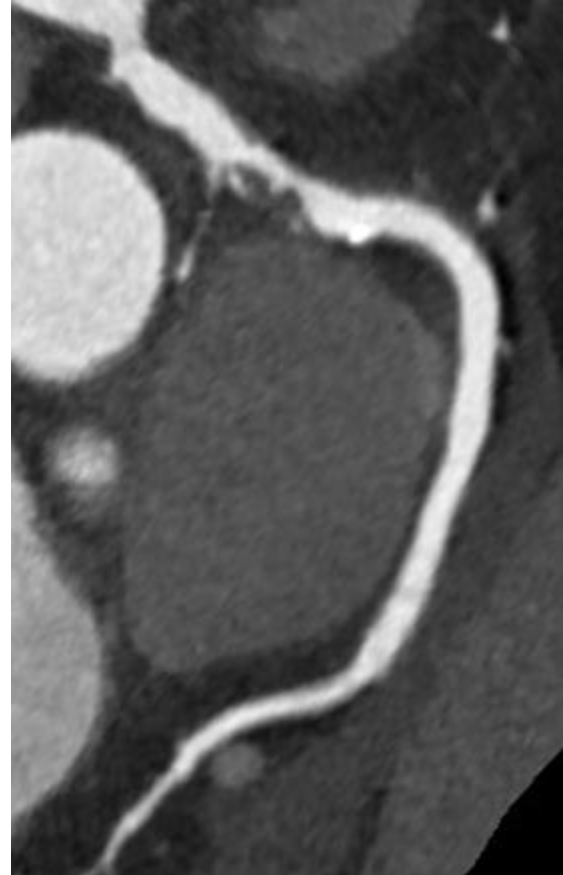
Take Home Message

Even in a highly-diseased population, quantitative CCTA evaluation of stenosis severity and atherosclerotic burden can enhance prediction of major adverse cardiovascular events, albeit modestly. These findings support the use of CCTA in patients with advanced coronary artery disease.



Conclusion

- ❖ CCTA with FFR is the most accurate non-invasive test for coronary disease
- ❖ Class 1A guideline recommendation for the evaluation of chest pain
- ❖ “Seeing is believing” you have the opportunity to initiate preventive therapies to reduce myocardial infarctions



Thank You



Improving Cardiac Care Through the Incorporation of Remote Cardiac Monitoring Devices

Alicia Porter, RN, CCDS

Disclosures

❖ NO RELEVANT DISCLOSURES

What is Remote Monitoring?

- ❖ Today, almost every patient with a cardiac implantable electronic device (CIED) has a remote monitor to use at home.
- ❖ Remote monitors transmit data from the CIED to the managing device clinic for review, showing us the same info we see during in-office checks.
 - Transmits on a schedule, as well as unscheduled “alert” transmissions.
- ❖ Historically, patients had quarterly in-office CIED checks.
 - With remote monitoring, annual in-office checks with quarterly scheduled transmissions is the current standard of care. Monthly transmissions for loop recorders.
- ❖ Allows for early detection of arrhythmias, device, and/or lead problems.
- ❖ Reduces the number of in-office device checks and provider visits.

CIEDs: Therapy Devices

- ❖ Therapy devices are implanted to treat a specific diagnosis.
- ❖ Pacemakers:
 - Symptomatic bradycardia (e.g SSS, HB)
- ❖ Implantable Cardioverter Defibrillator (ICD):
 - Treat life-threatening arrhythmias
 - Known h/o VT/VF
 - HF with reduced EF (increased risk for VT/VF)
- ❖ Cardiac Resynchronization Therapy (CRT) devices (pacemaker or ICD):
 - HF with reduced EF and LBBB

CIEDs: Diagnostic Devices

❖ Implantable Loop Recorders (ILRs):

- Indications: Cryptogenic stroke, syncope, palpitations, AF management
- ILRs are long-term cardiac monitoring when temporary monitors don't catch anything but there is still strong suspicion for arrhythmias.
- Can detect tachycardia, bradycardia, pauses, AT/AF, symptoms (patient-triggered), and PVC burden.

❖ Scheduled monthly transmissions.

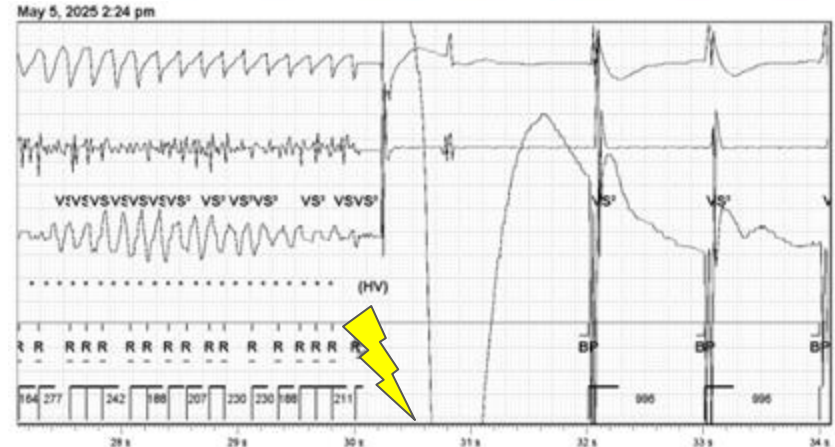
- No need for in-office checks.

❖ Alerts tailored to the indication.

	Current	Lifetime	Parameters
Symptom	0	5	Off
Tachy	0	0	>176 bpm, >=16 beats
Pause	0	1	>5 seconds
Brady	0	0	<30 bpm, >=12 beats
AT	0	0	Off
AF	0	0	All Episodes
Time in AT/AF	0.0%	---	
PVCs (% beats)	0.1%	---	On

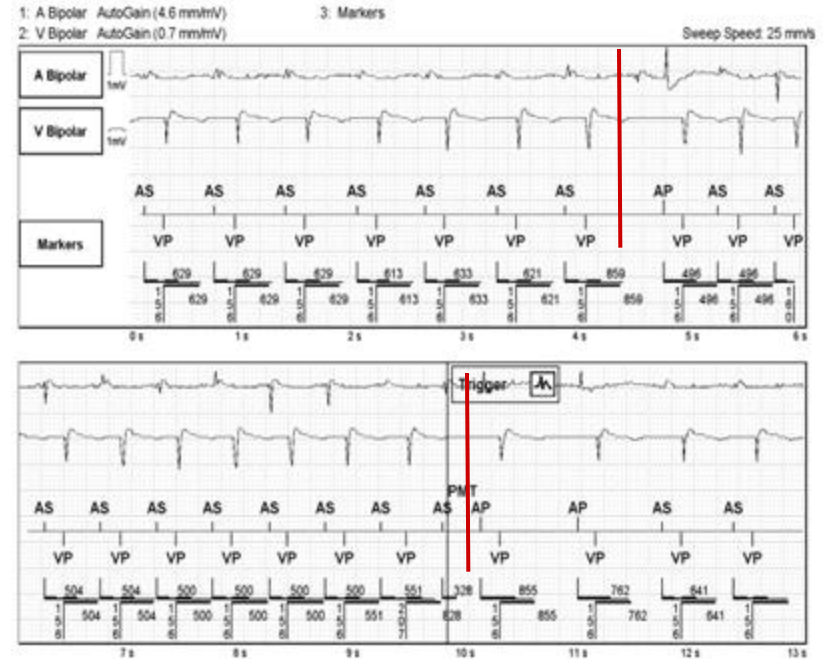
Impact on Patient Care

- ❖ Quarterly in-office checks delayed care:
 - New onset AF >12 hours → remote alert → start anticoagulation
 - ICD shock delivered, patient unaware → remote alert → review with patient and provider team → med change, EP f/u



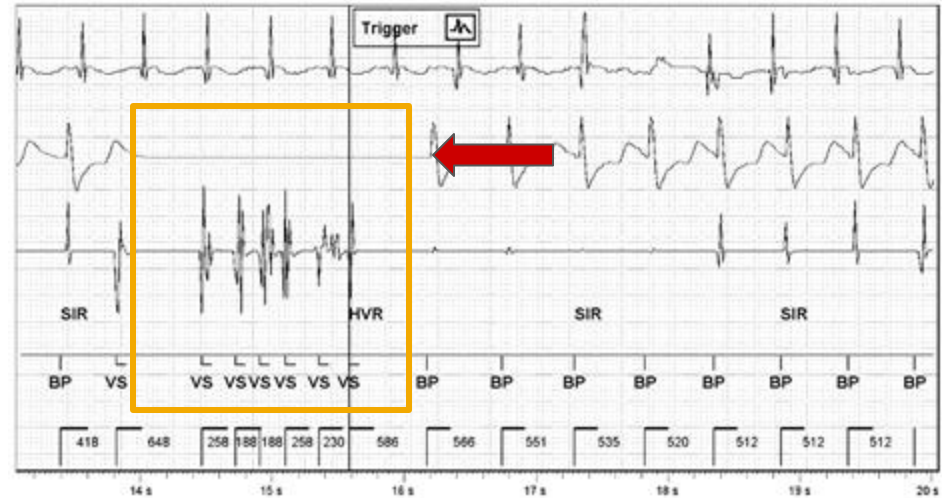
Impact on Patient Care

- ❖ Real-time assessment of arrhythmia-related symptoms:
 - Manual transmission → called office reporting palpitations → pacemaker-mediated tachycardia (PMT) found → scheduled in-office check to reprogram
 - Easy fix!



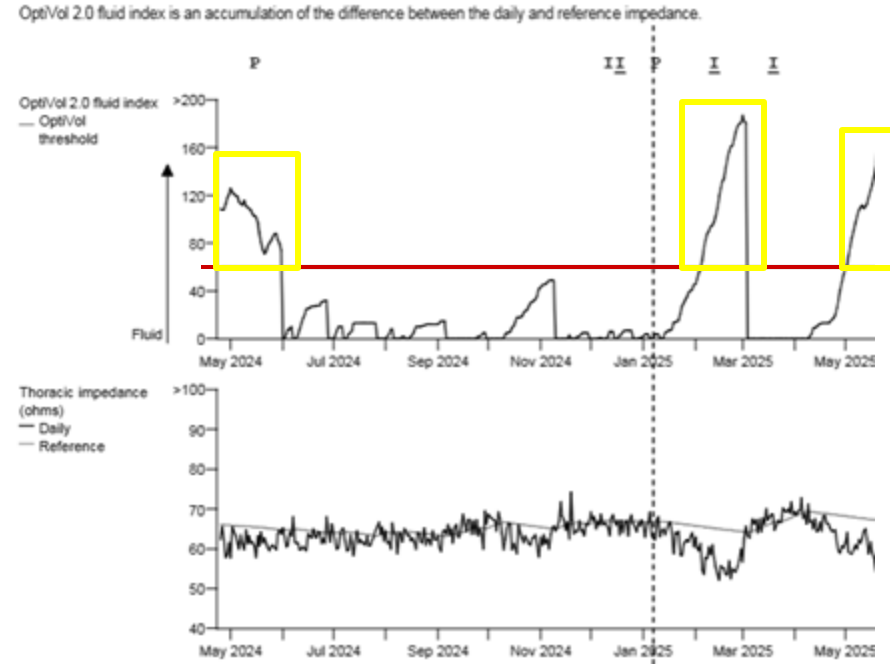
Impact on Patient Care

- ❖ Early detection of lead problems:
 - High ventricular rate event triggered → Remote alert → Clinician reviewed, noted to be RV lead noise inhibiting RV pacing in ventricularly-dependent patient → scheduled in-office check to assess/reprogram, EP f/u



Impact on Patient Care

- ❖ Signs of HF decompensation (ICDs, CRTs):
 - Changes in thoracic impedance (suggestive of increased fluid volume)
→ Remote alert → Assess for symptoms, discuss with provider, intervene prior to full decompensation.
 - HF Monitoring is designed to catch signs of a problem so we can address **before** symptoms occur.



Limitations of Remote Monitoring

- ❖ NOT continuous cardiac monitoring.
 - If it's not scheduled, and there are not any alerts, there is no updated report.
- ❖ NOT an emergency response system.
 - It is meant to be a supplement to in-office checks only.
- ❖ Cannot tell us what a patient's heart rate was at a specific time of day.
 - We can review heart rate trends, but we can't pinpoint exactly what was happening last night at 10:30 pm.
- ❖ Cannot remotely reprogram therapy devices.

Reference

- ❖ Ferrick, A. M., Raj, S. R., Deneke, T., et al. (2023). 2023 HRS/EHRA/APHRS/LAHRS expert consensus statement on practical management of the remote device clinic. *Heart Rhythm*, 20(9), E92-E144.

Thank You



Ambulatory Hemodynamic Monitoring

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Disclosures

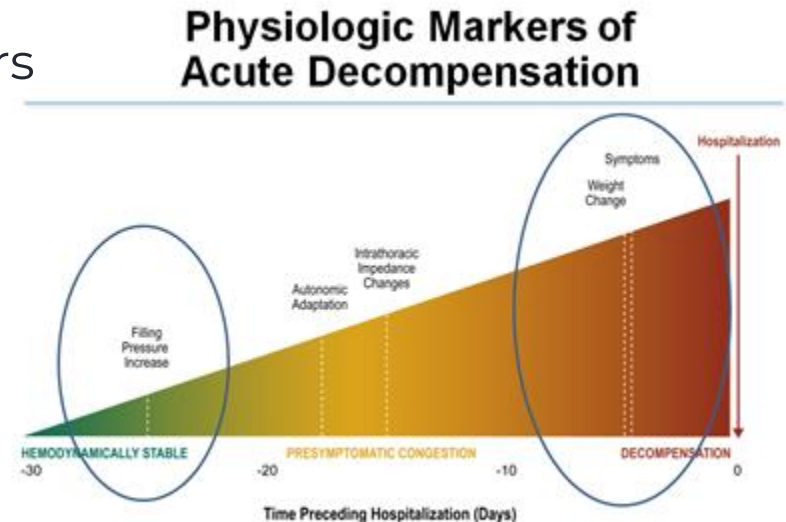
❖ NO RELEVANT DISCLOSURES

Learning Objectives

- ❖ **Highlight limitations of current heart failure management**
- ❖ **Discuss available implantable wireless hemodynamic devices and their impact on heart failure outcomes**
- ❖ **Review new devices being studied**

What makes ambulatory management of heart failure so hard?

- Difficult to identify high risk patients early enough to prevent HF hospitalization
- Historical use of physiological markers
 - Weight gain
 - Swelling
 - Shortness of breath
 - Orthopnea



Implantable Devices

CardioMEMS™



cordella™



The sensor remotely monitors changes in pulmonary artery diastolic (PAD) pressure. This is a far earlier indicator of fluid retention than physiologic signs or patient reported symptoms.

Why use PAD?

- Baseline PAD and change in PAD are independent predictors of mortality
- Change by >2 mm Hg predicted a 26.7% increase in mortality or a 14.7% decrease
- The CHAMPION-HF & GUIDE-HF trials demonstrated implantable devices were able to reduce PAD, reduce hospitalizations and improve mortality in HFpEF and HFrEF
- Patients with lower PAD are more likely to be on ARNIs, MRAs, and lower diuretic doses

Home equipment



Virginia Mason Franciscan Health Data-

Data from 114 patients, showed an average decrease of 1.92 mmHg over the first six months. This translated into :

- 72% reduction in heart failure hospitalizations
- 79% reduction in 30-day readmissions,

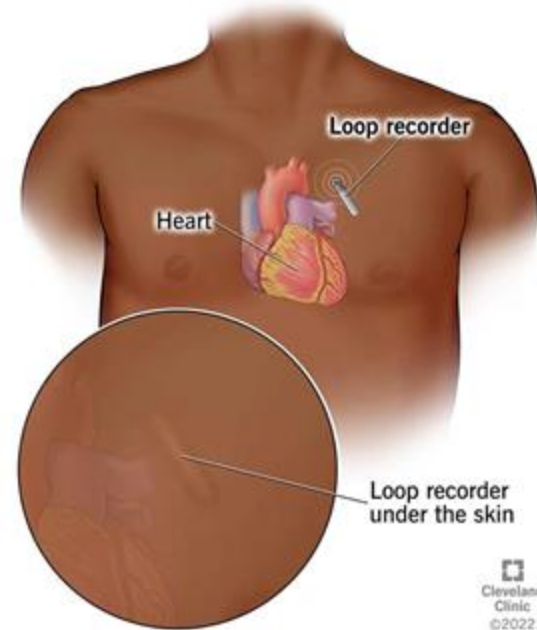
ALLEVIATE-HF TRIAL

Subcutaneous loop recorder with investigational sensors designed for early detection of heart failure

Advantages include:

- easier insertion
- does not rely on pt compliance
- no weight restriction

Loop Recorder
Insertable cardiac monitor



ALLEVIATE -HF DETAILS

In Phase 1, pt with high risk scores took an additional diuretic for 4 days, irrespective of symptoms. The data showed no safety concerns and suggested a reduction in HF hospitalizations and all cause mortality.

Phase 2 designed to validate the clinical benefit noted in Phase 1. This data is pending publication

What is coming next?

Elevate- HFpEF trial-

There is emerging evidence to suggest that prolonging diastolic filling time may lead to elevated filling pressures and adverse outcomes in HFpEF

The trial will insert a dual chamber pacemaker and randomize pts to

1. No pacing
2. Customized pacing rate

References:

Relationship Between Remote, Ambulatory Pulmonary Artery Pressures, and All-Cause Mortality in Patients With Chronic Heart Failure

Circulation: Heart Failure 2025 Jun;18(6):e012754. doi: 10.1161/CIRCHEARTFAILURE.124.012754. Epub 2025 Apr 14.

Early Reduction of Pulmonary Artery Pressures Is Associated With Improved Mortality Among Medicare Beneficiaries With Heart Failure

JACC Heart Failure 2025 Aug 13;13(10):102589. doi: 10.1016/j.jchf.2025.102589. Online ahead of print.

Pulmonary Artery Pressure-Guided Management of Patients With Heart Failure and Reduced Ejection Fraction

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Thank You

