Myocardial Work

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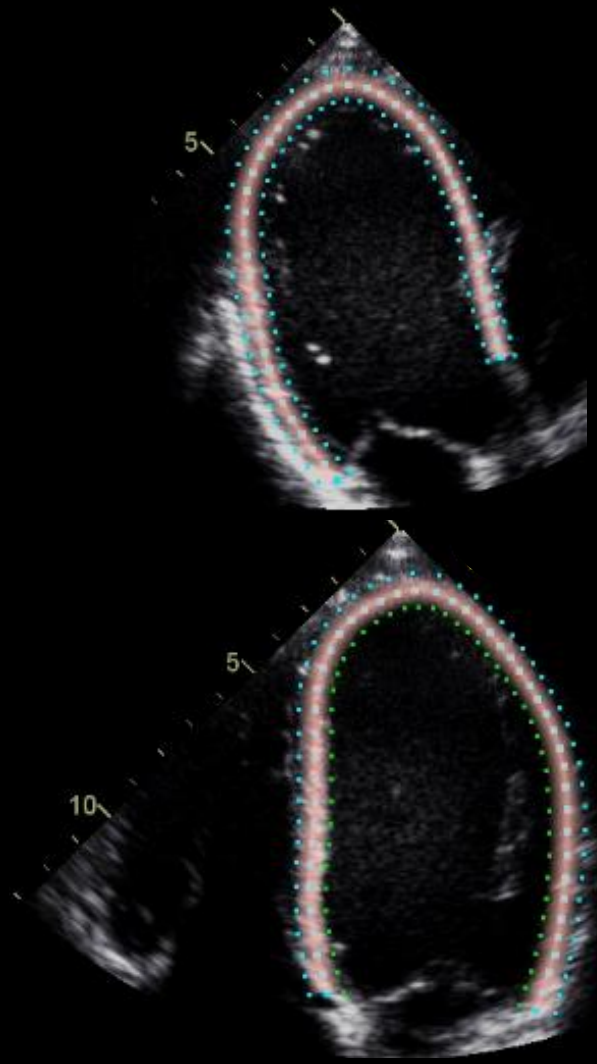
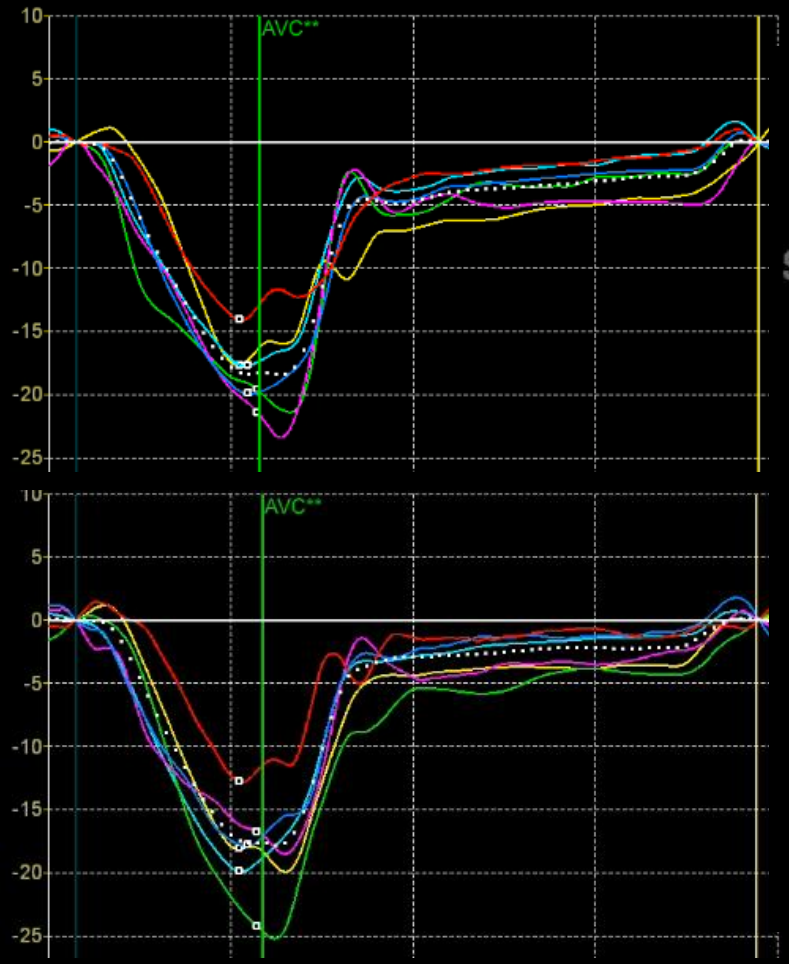
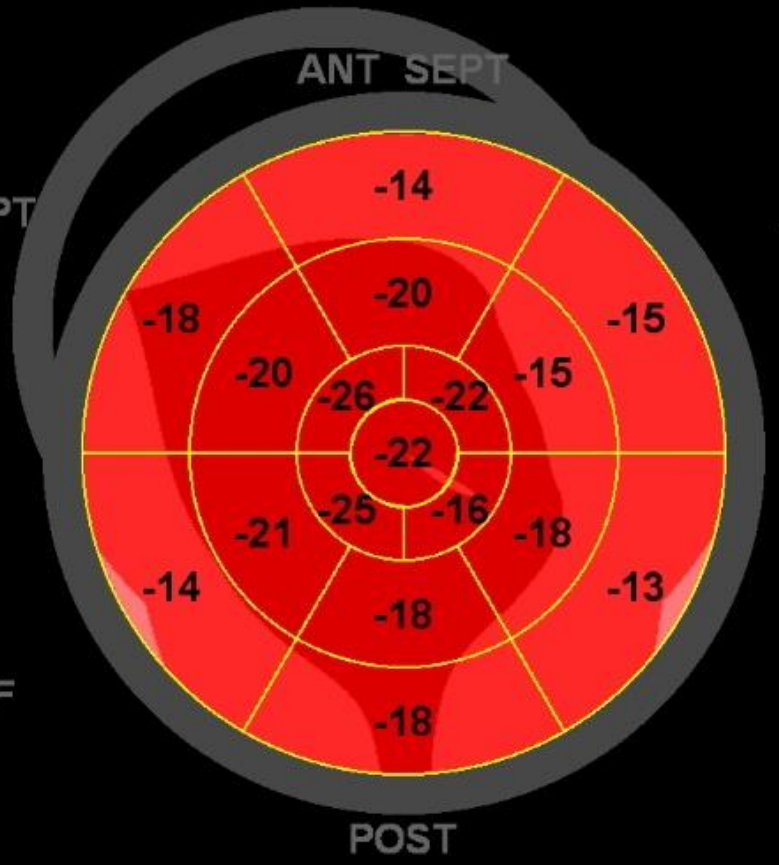
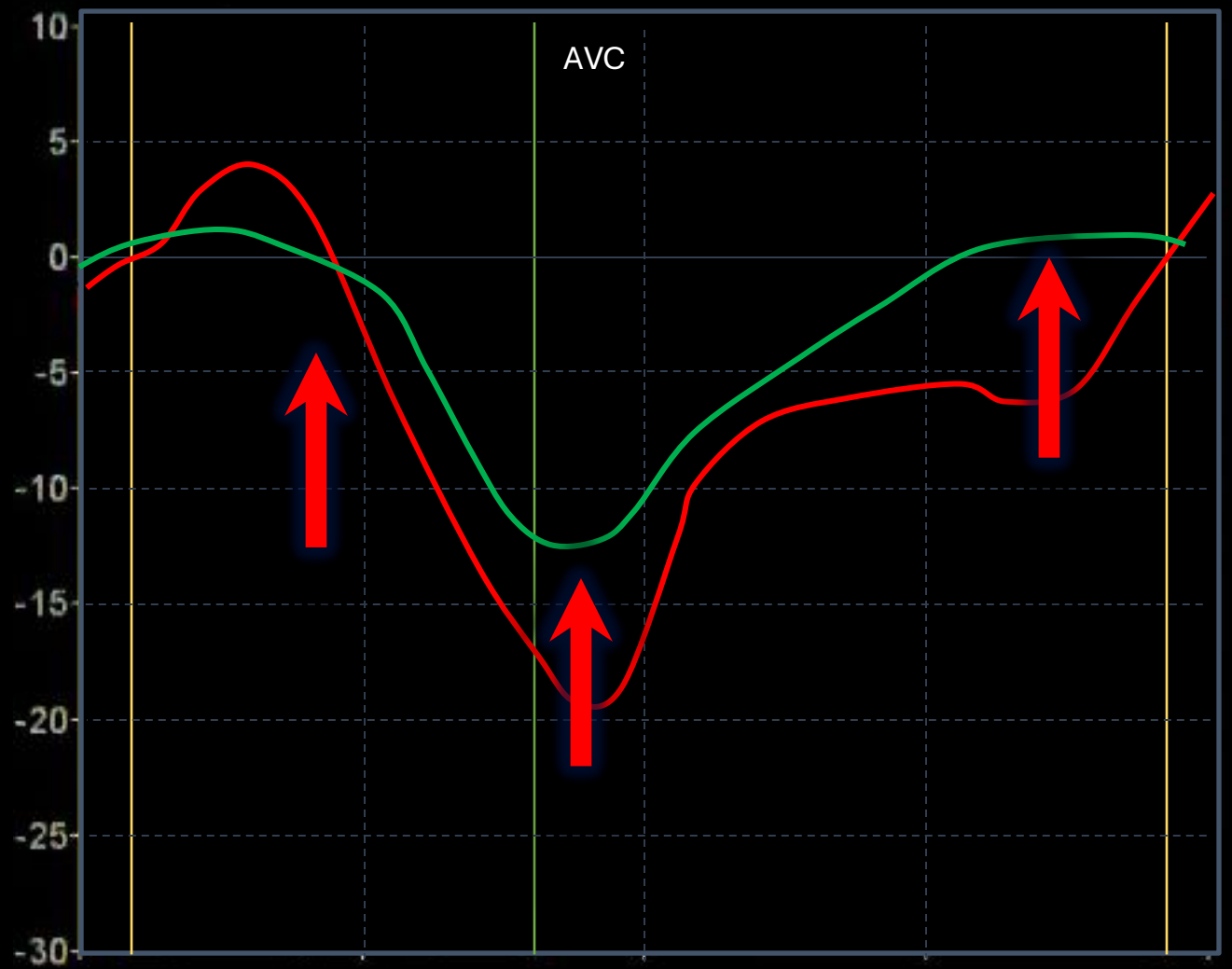
Myocardial Deformation Imaging







Myocardial Deformation Imaging



Donal et al. Eur Heart J CV Imaging 2009;10(8):911-921

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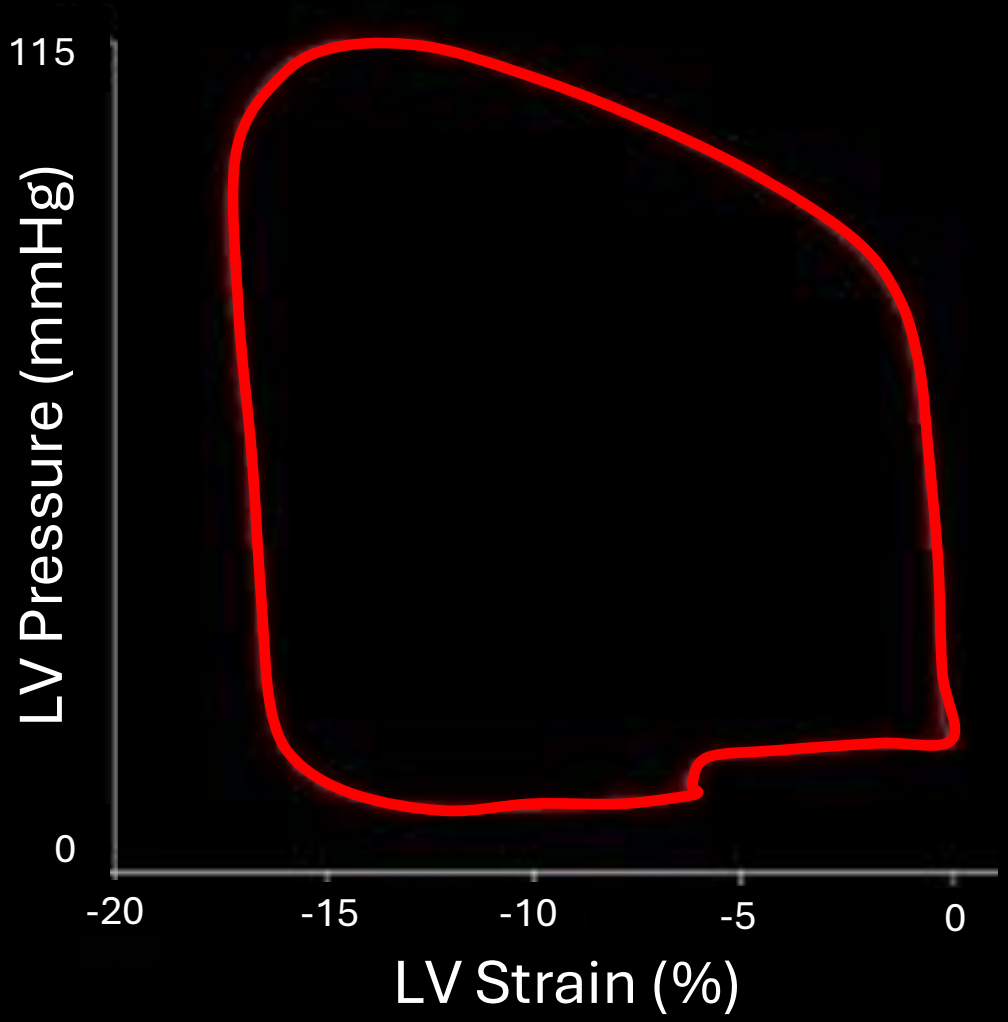
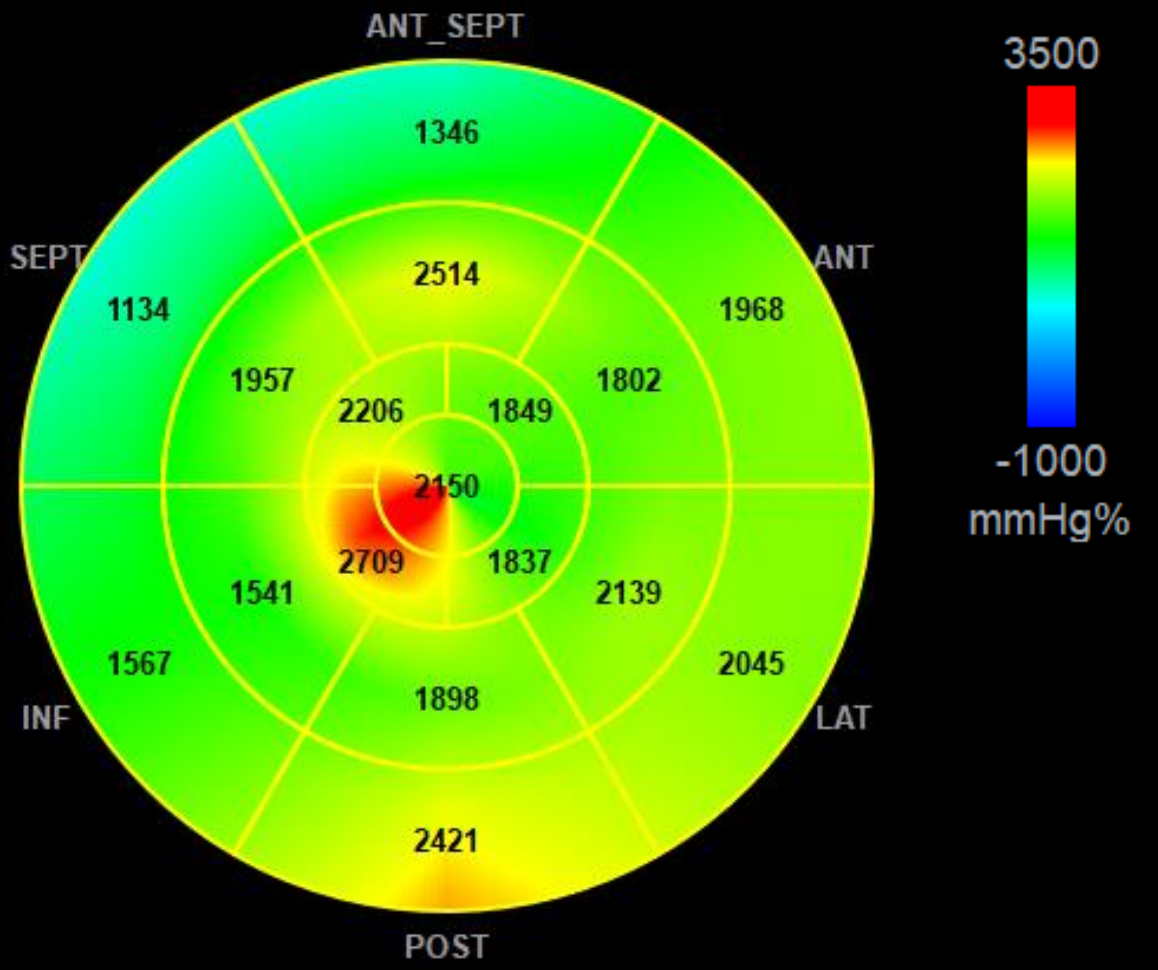
Non-Invasive Myocardial Work





Russell et al. Eur Heart J 2012;33:724-733

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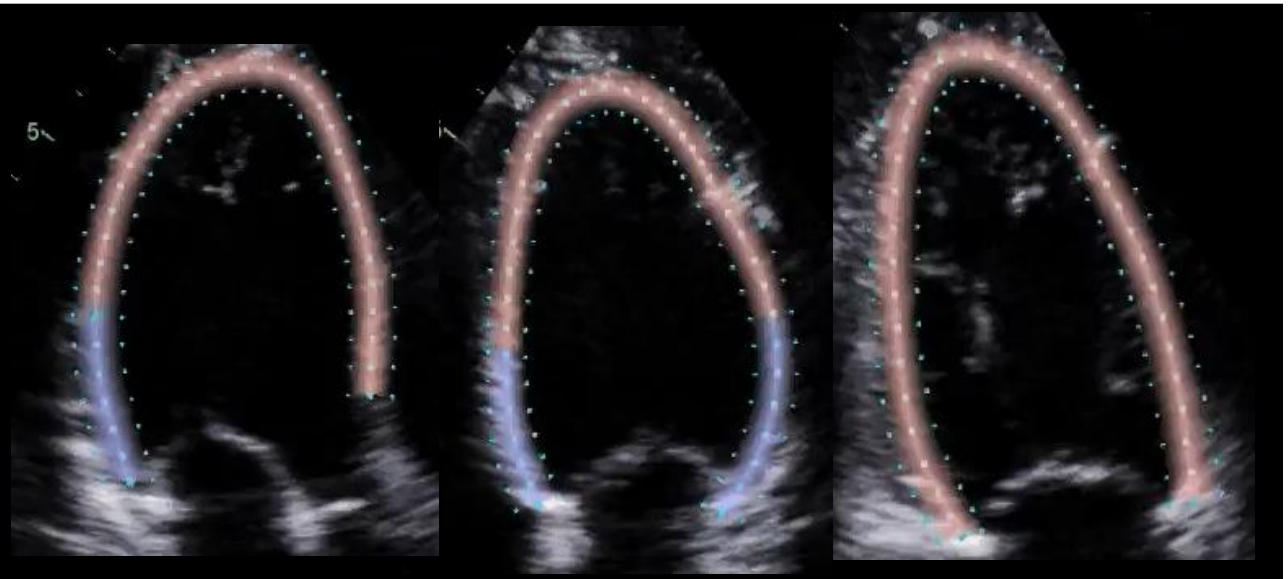
DATA ACQUISITION



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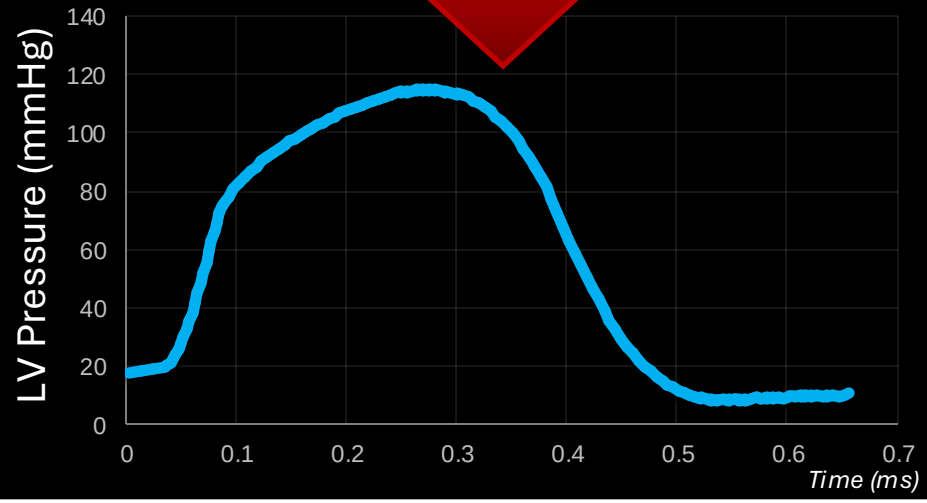

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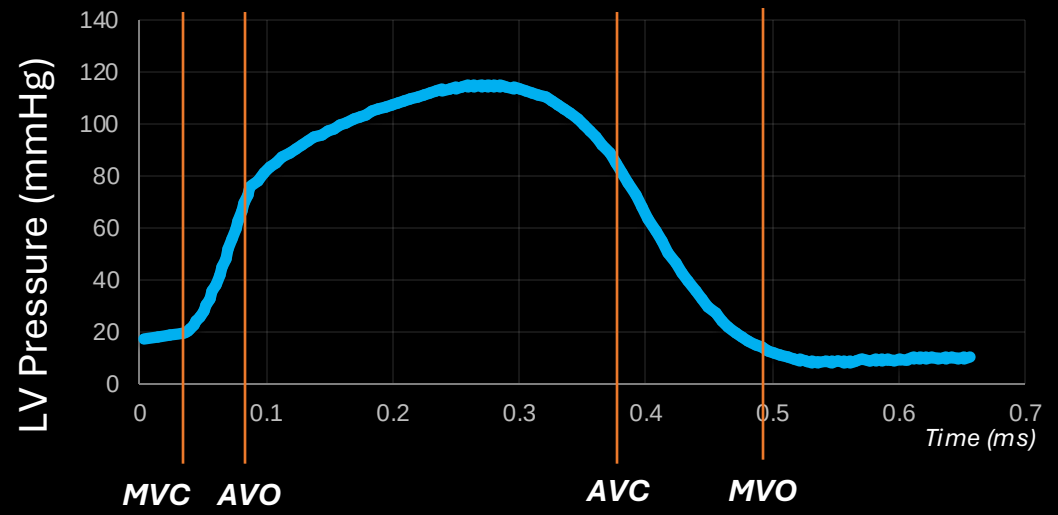
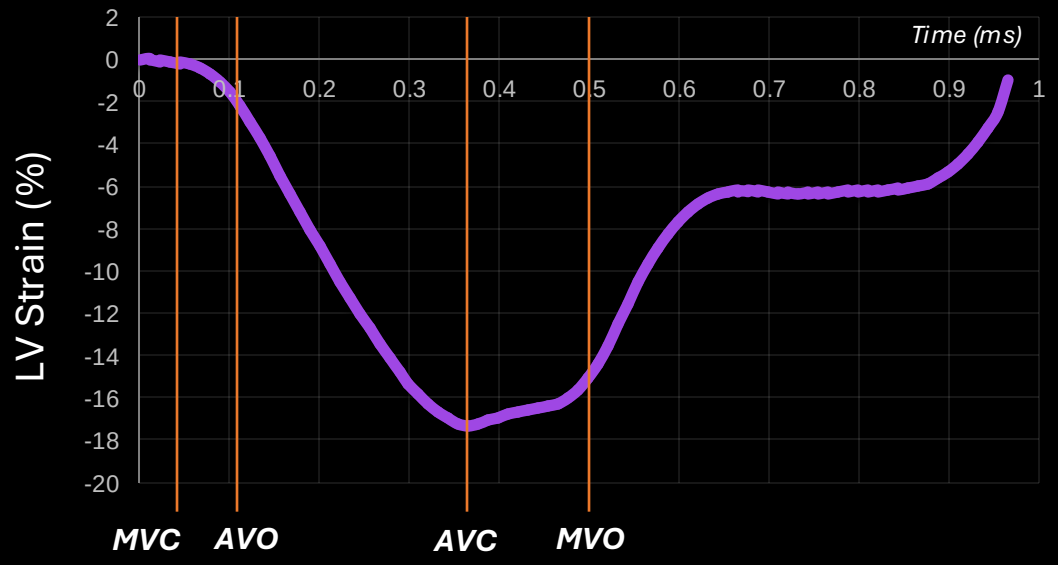
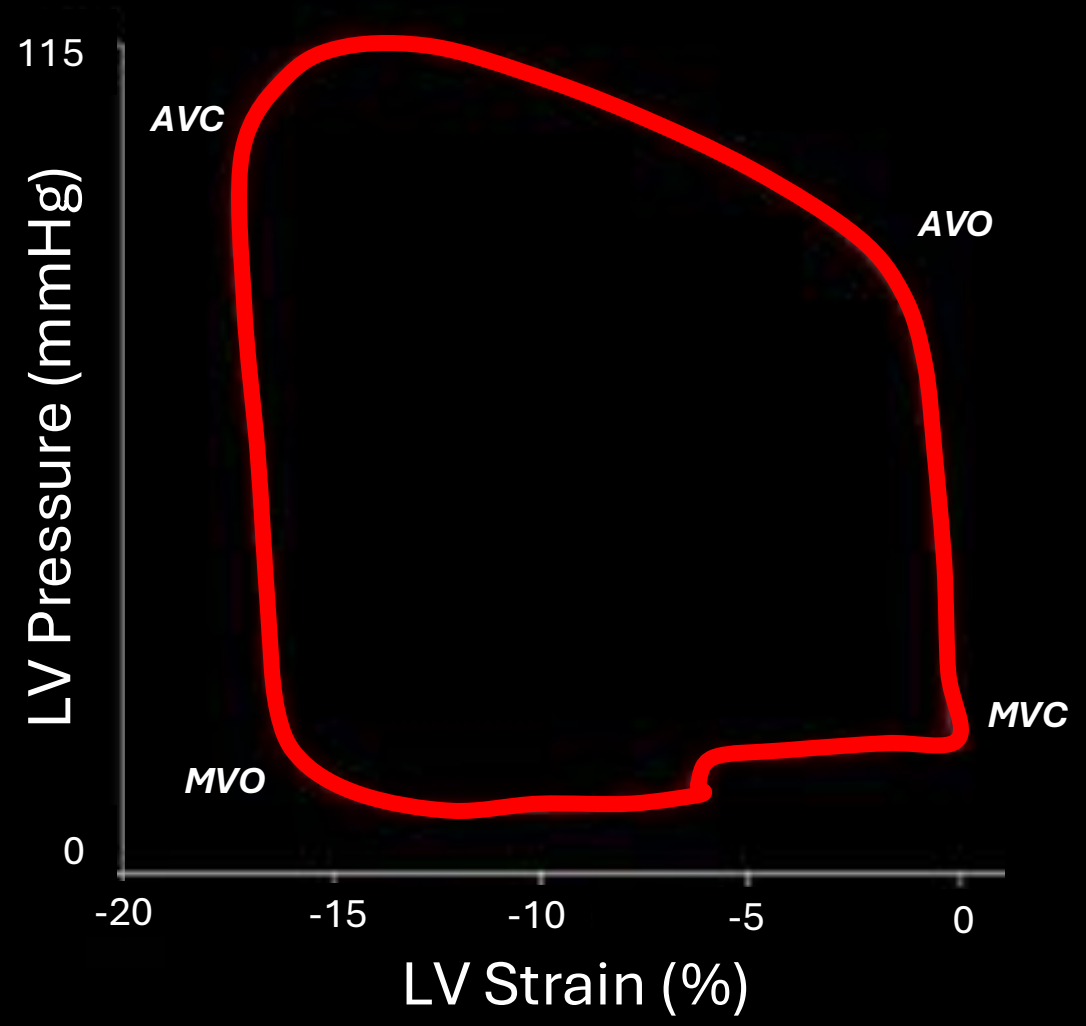
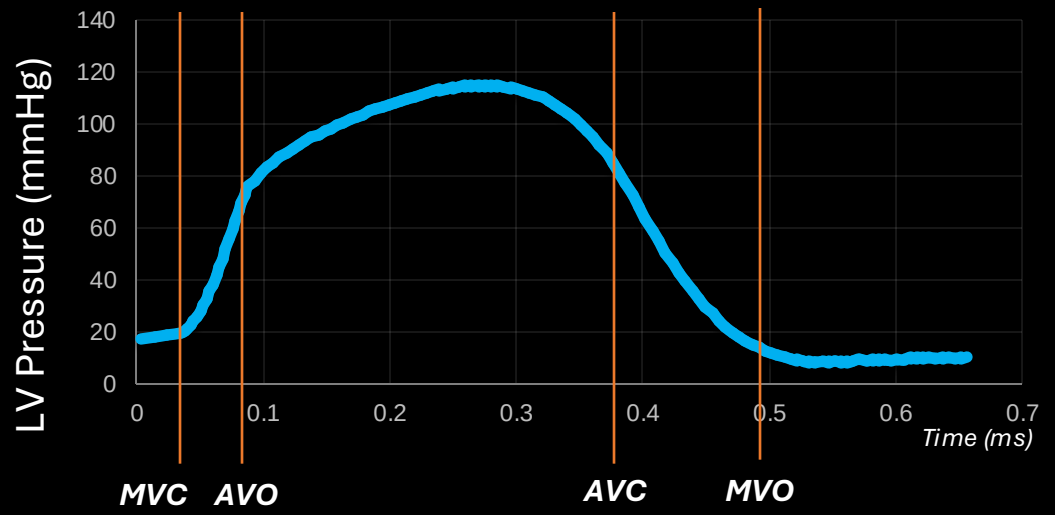
Myocardial Work Calculation

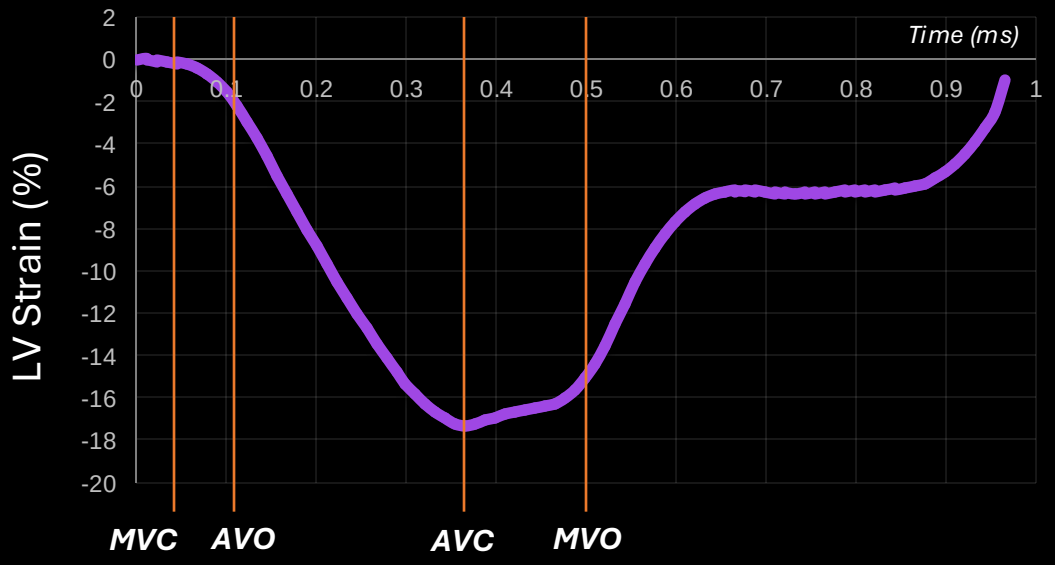




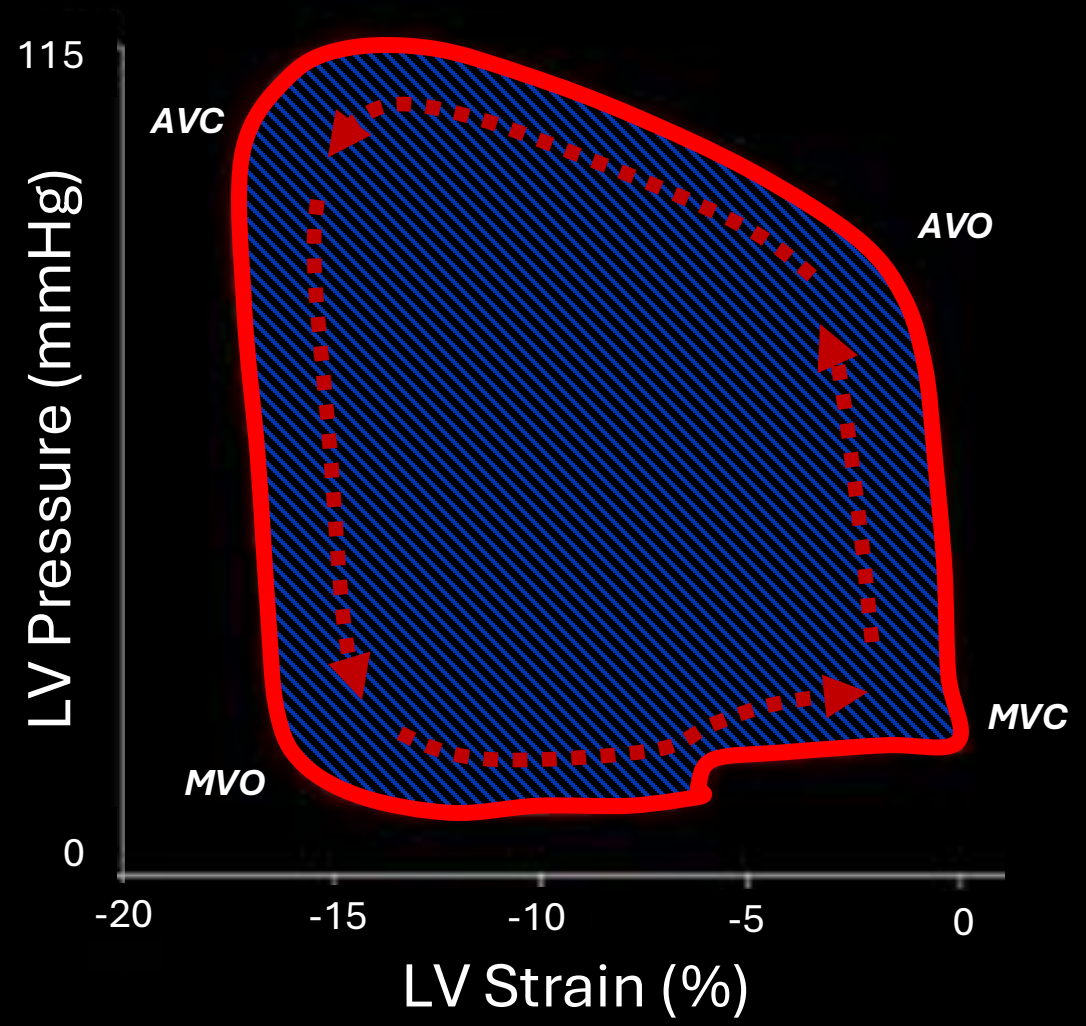


Myocardial Work Calculation





MW = Area within the loop



Units of MW = mmHg%

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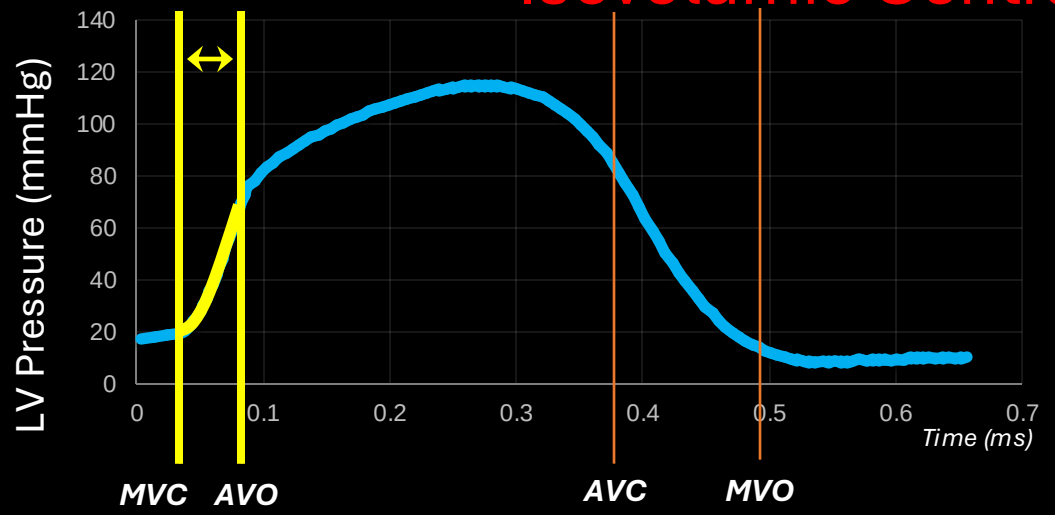
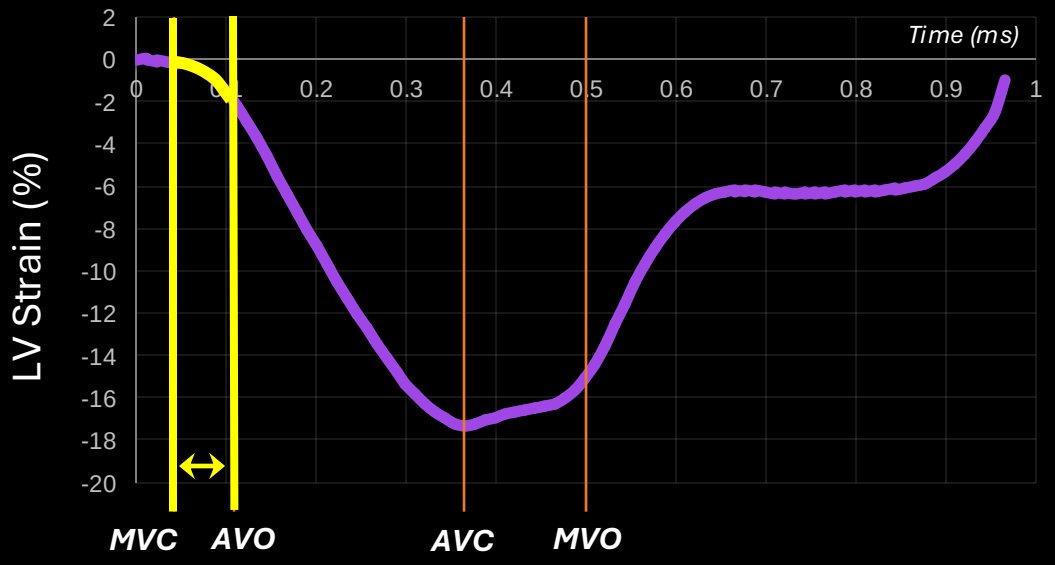
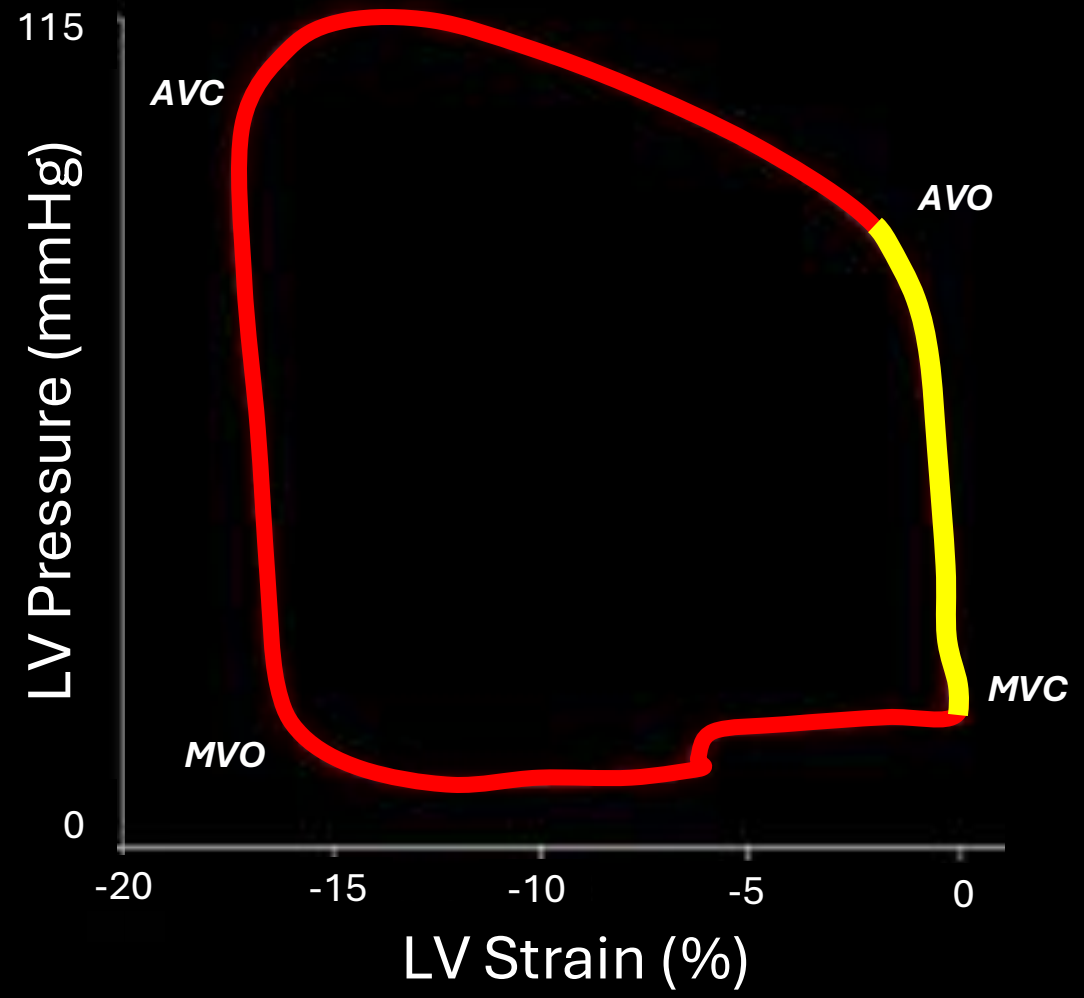
Myocardial Work Calculation

Isovolumic Contraction (MVC to AVO)







Little change in strain while LVP rises

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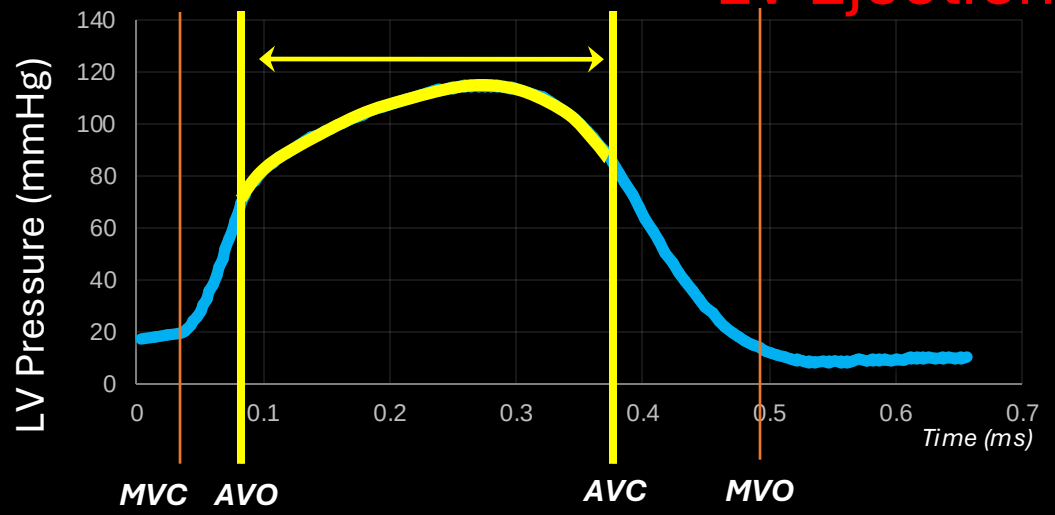
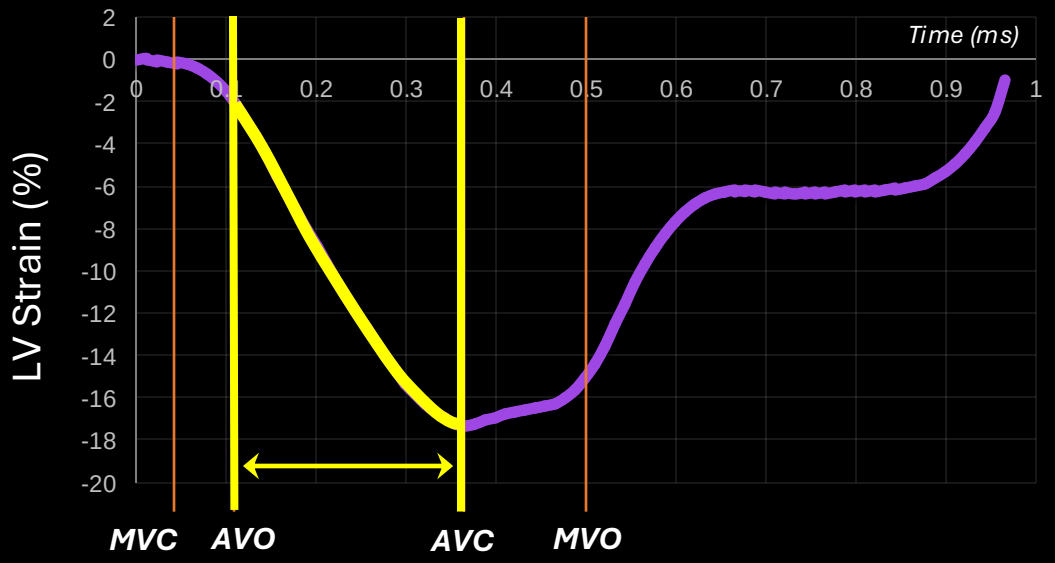
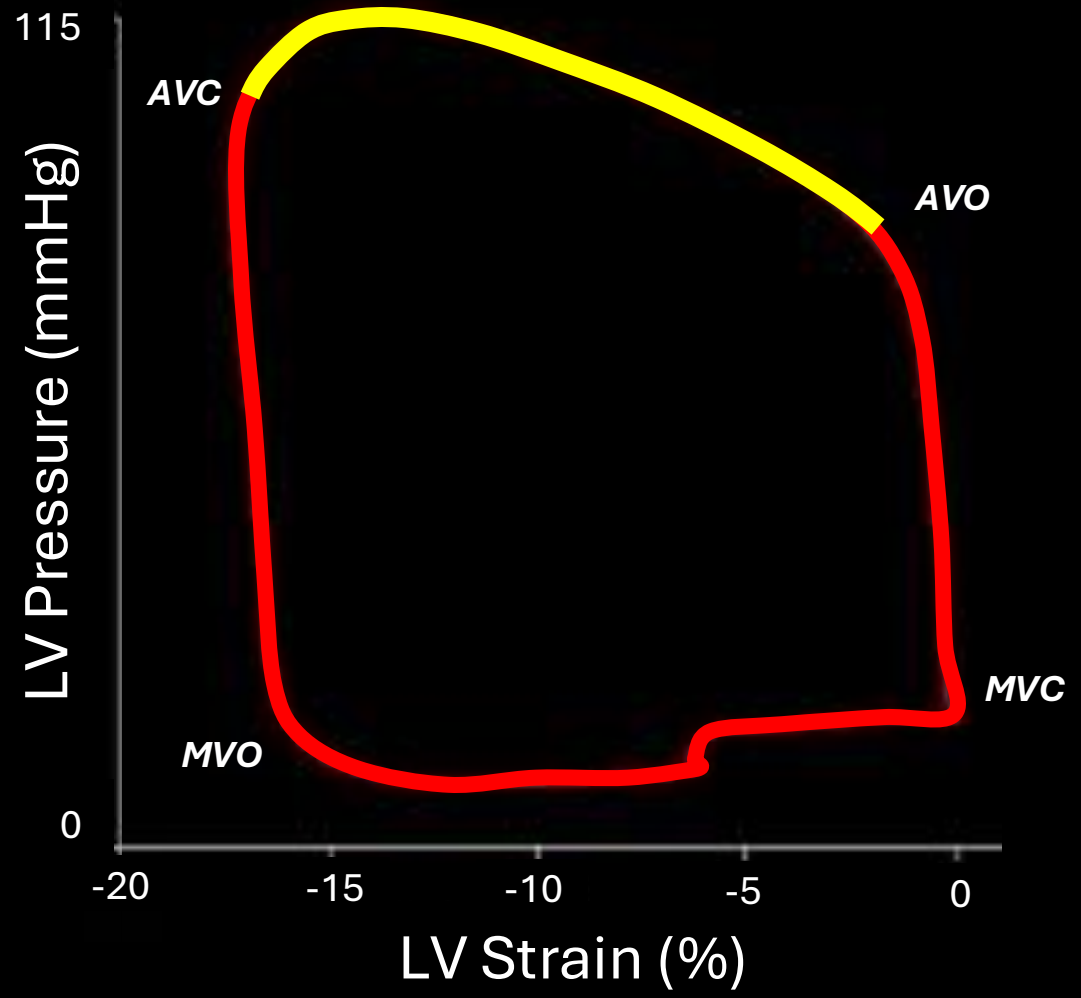
Myocardial Work Calculation

LV Ejection (AVO to AVC)







Slow rise in LVP while strain becomes more negative

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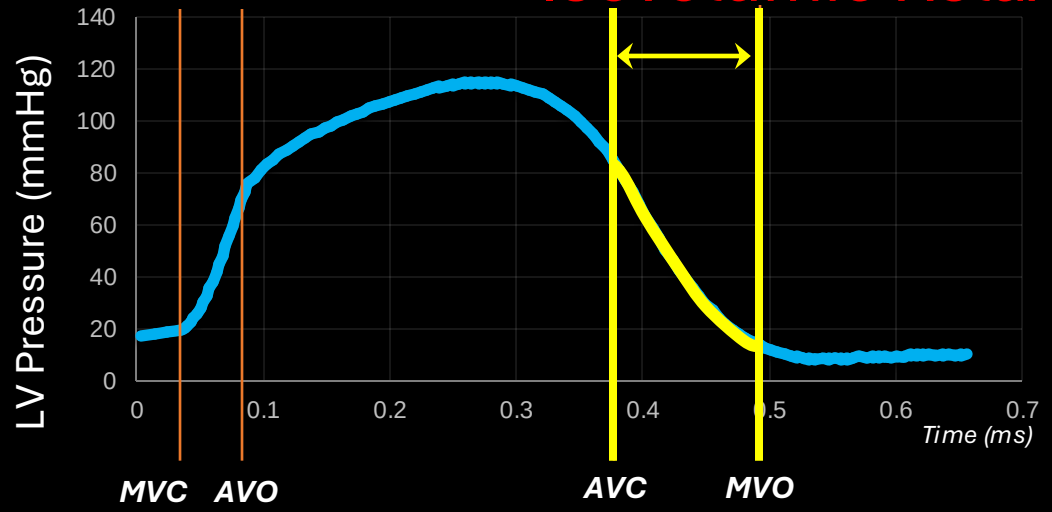
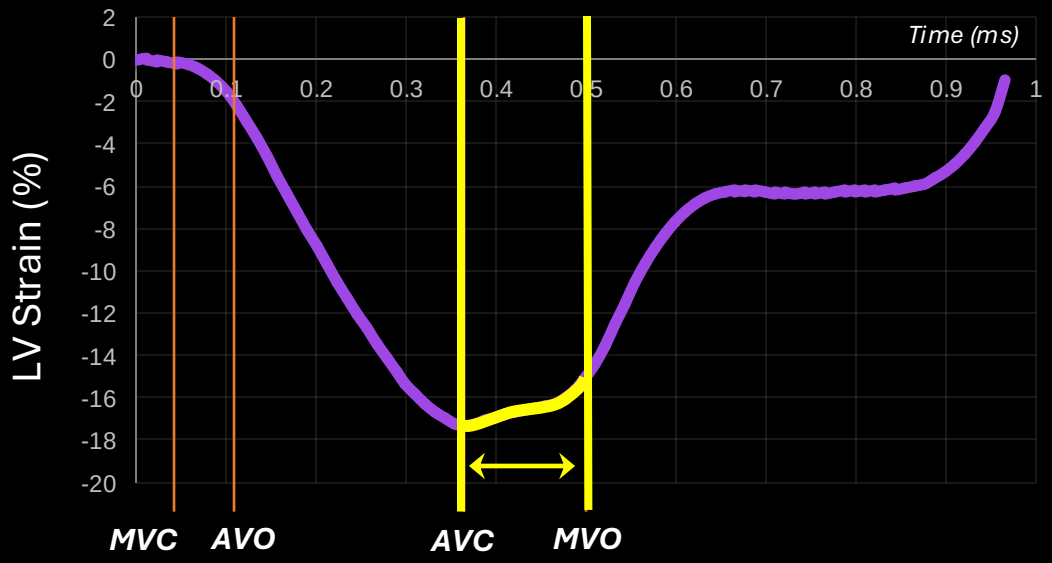
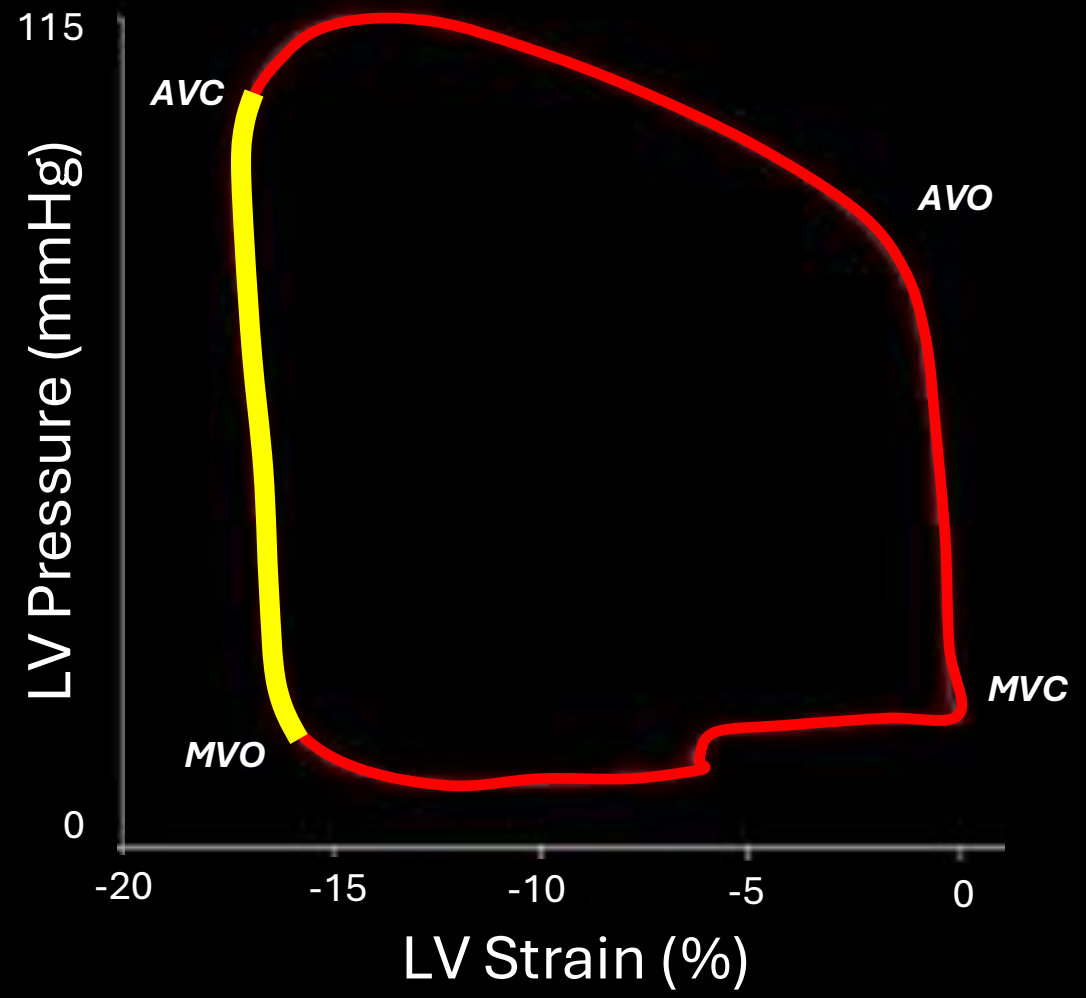
Myocardial Work Calculation

Isovolumic Relaxation (AVC to MVO)







LVP drops with little ⊿ in strain until beginning of diastole

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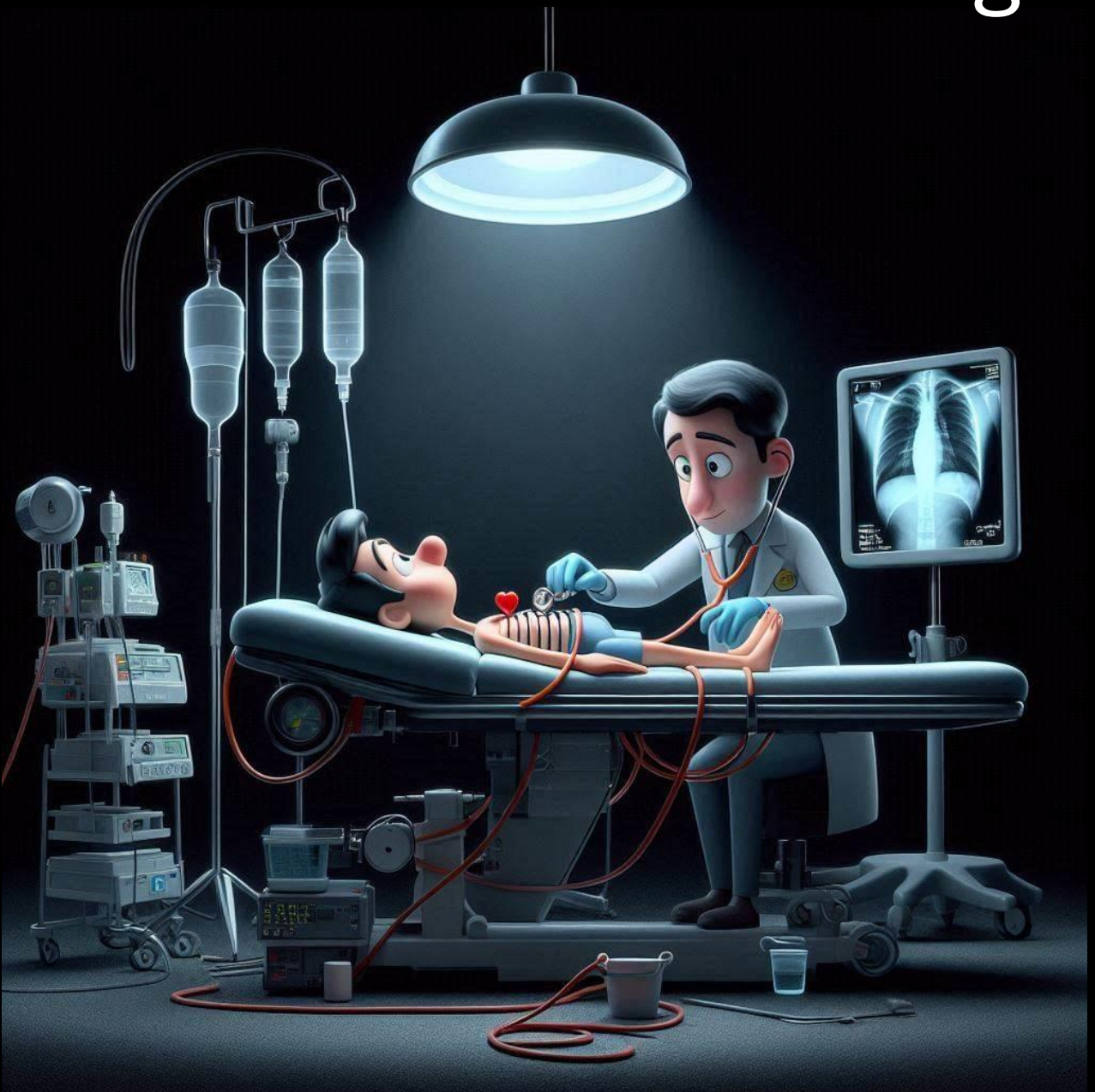
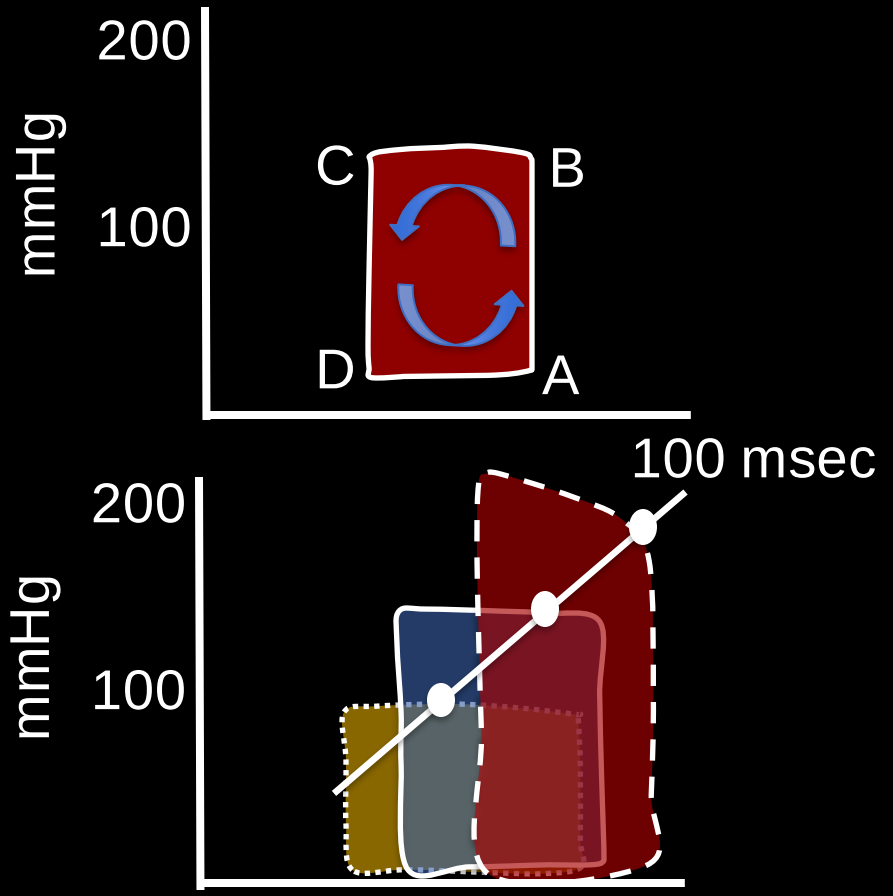
Validated PVL During Cardiac Catheterisation



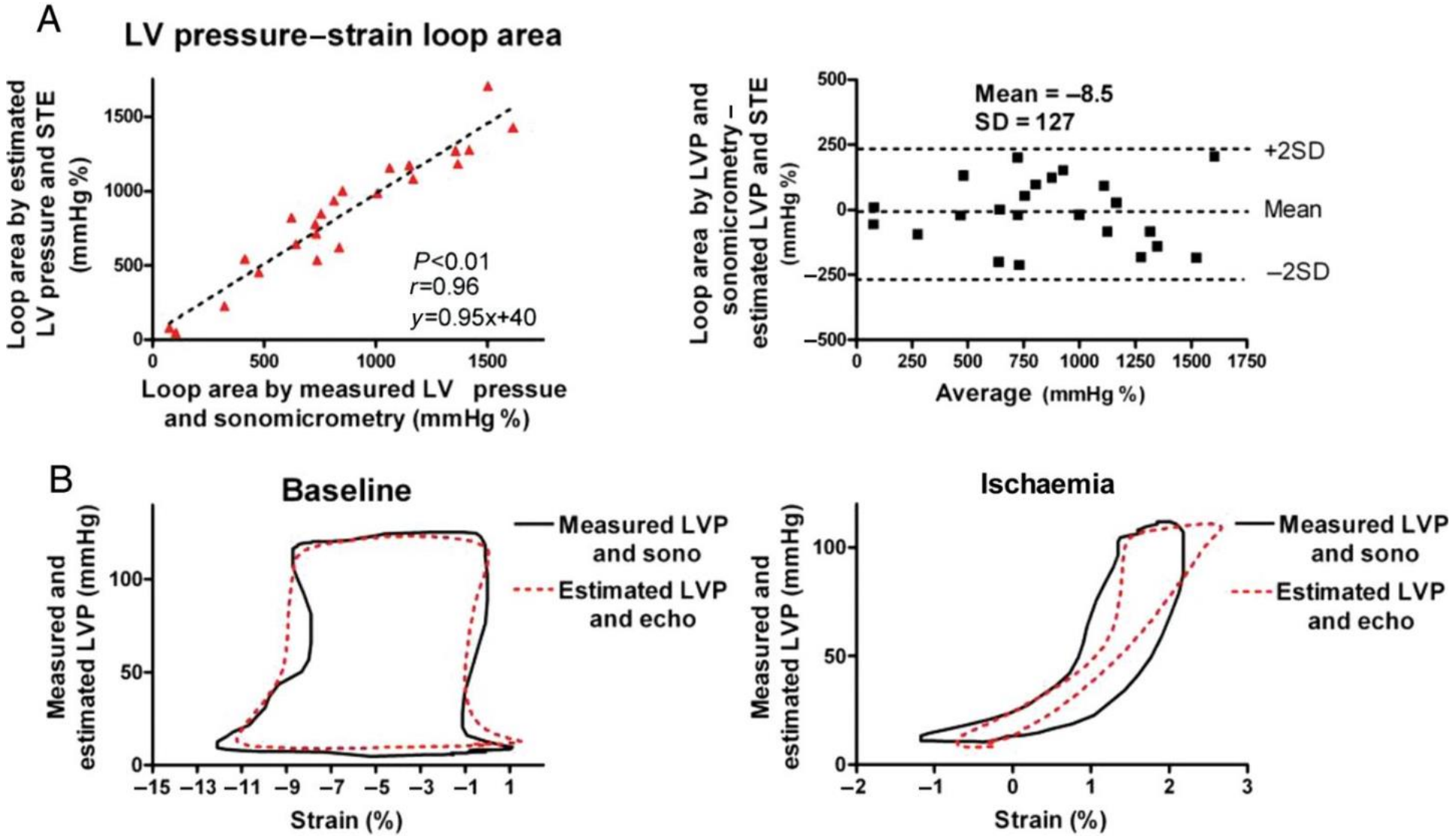


PVL – haemodynamic parameters of myocardial contractility

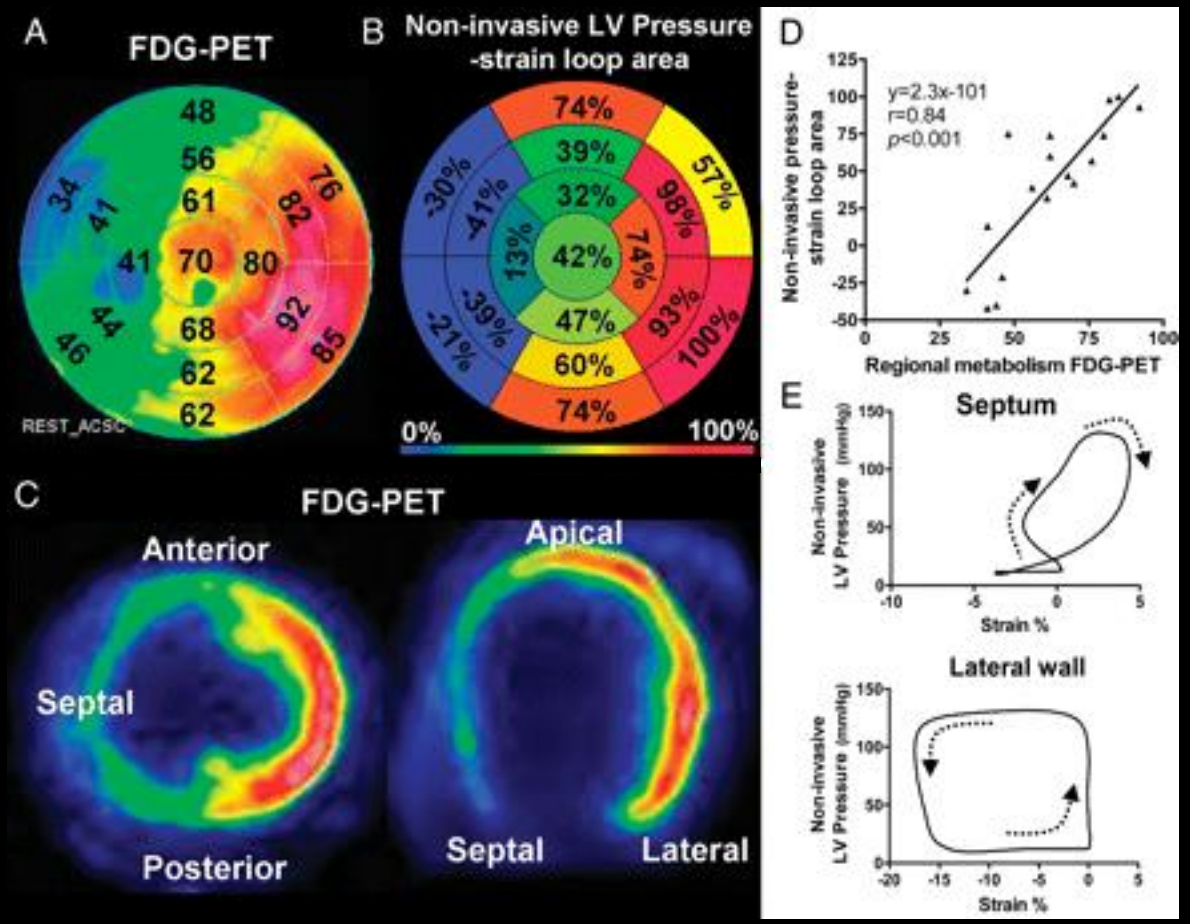
Area = Myocardial O^2 consumption

Suga et al. Am J Physiol 1979;236:H498-H505

Myocardial Work Validation



Myocardial Work Validation



- Glucose metabolism was measured with FDG PET in patients with LBBB
- Good agreement with MW
- MW bullseye plot & PET showed similar regional differences
- Highest metabolism in lateral segments
- Lowest in septal segments

Russell et al. Eur Heart J 2012;33:724-733

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Myocardial Work Parameters

Global Myocardial Work Index (GWI) (mmHg%)

- *Global representation of MW*

Constructive MW (CW) (mmHg%)

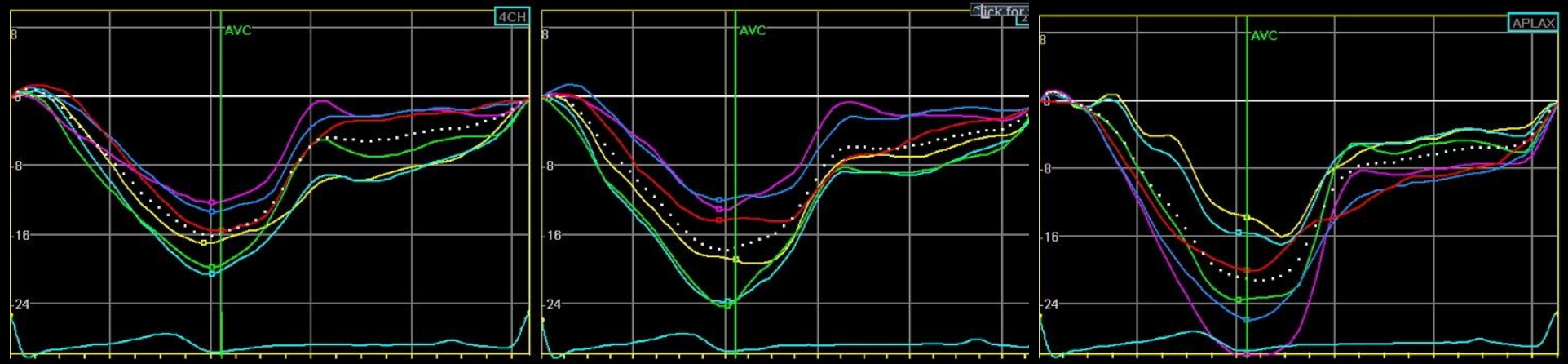
- *Positive work contributing to LV ejection*
- *Myocardial shortening during systole + lengthening during IVR*

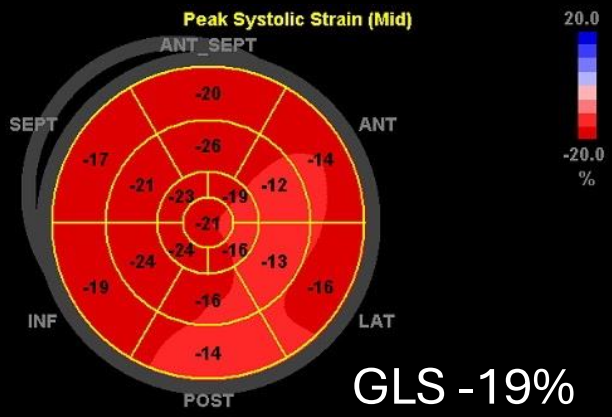
Wasted MW (WW) (mmHg%)

- *Negative work not contributing to LV ejection – energy loss*
- *Myocardial lengthening during systole + shortening during IVR*

MW Efficiency (%)

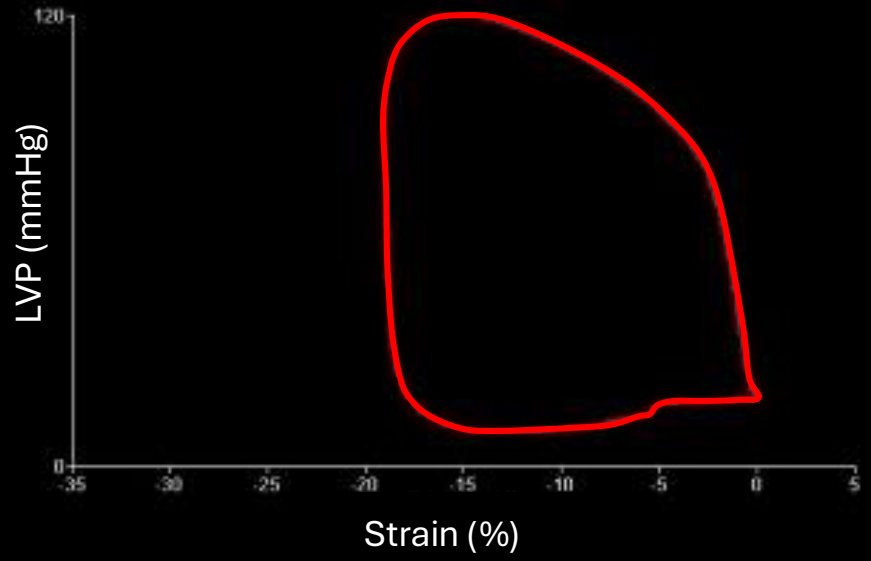
- *CW / (CW+WW)*

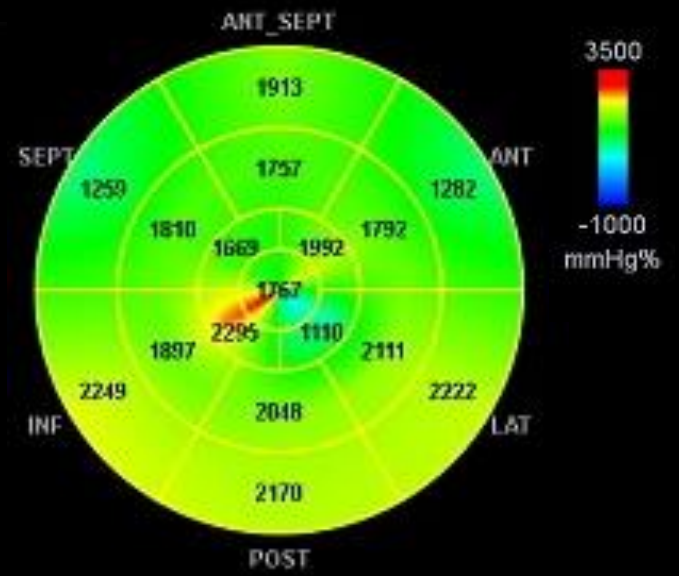




GLS -19%

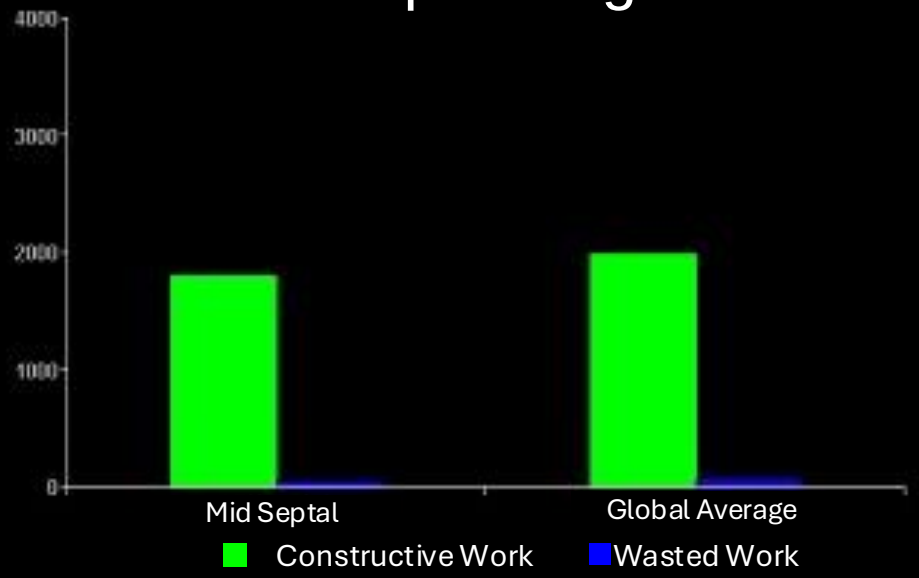
GWI 1840mmHg%

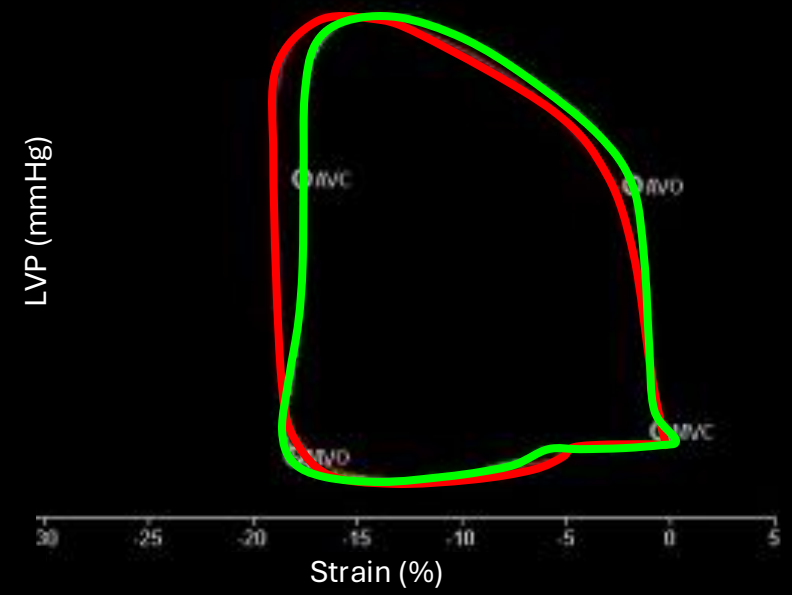


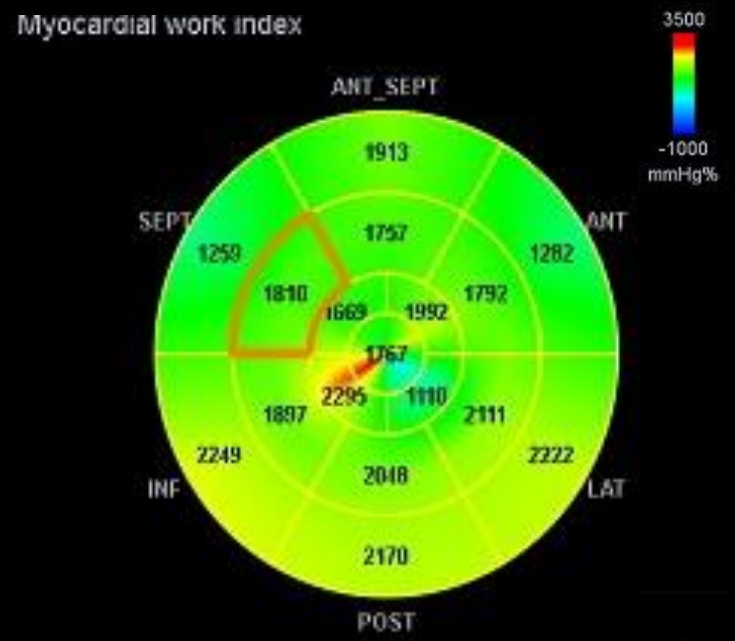


GCW 1979mmHg%
GWW 59mmHg%
GWE 96%

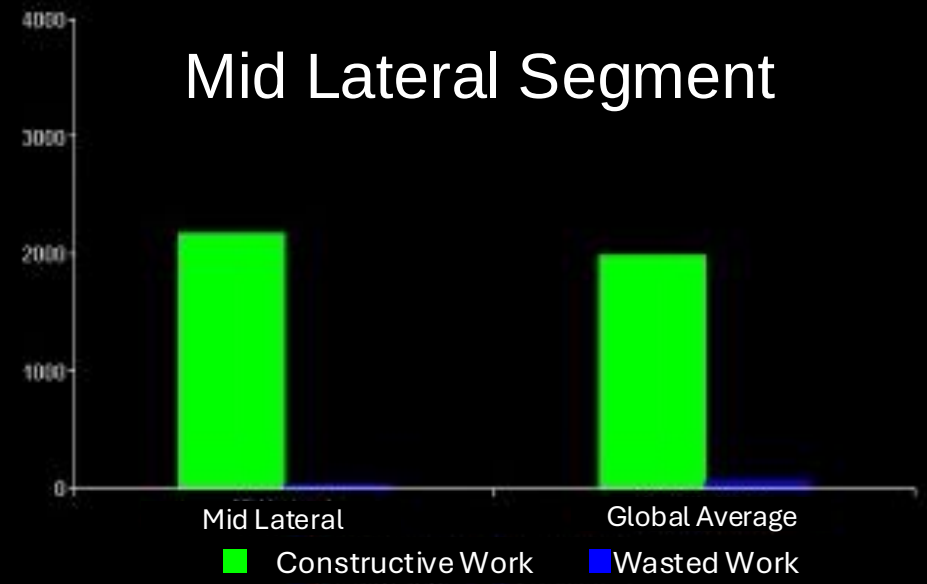
Mid Septal Segment

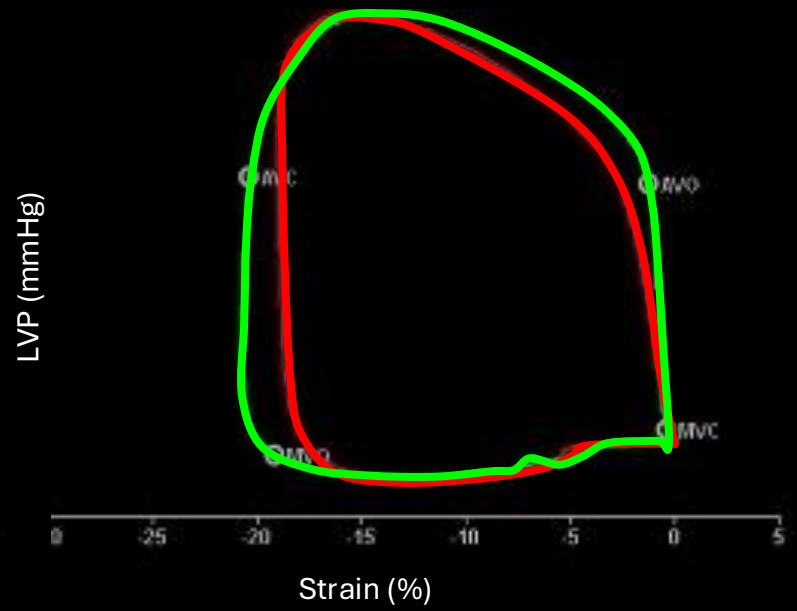


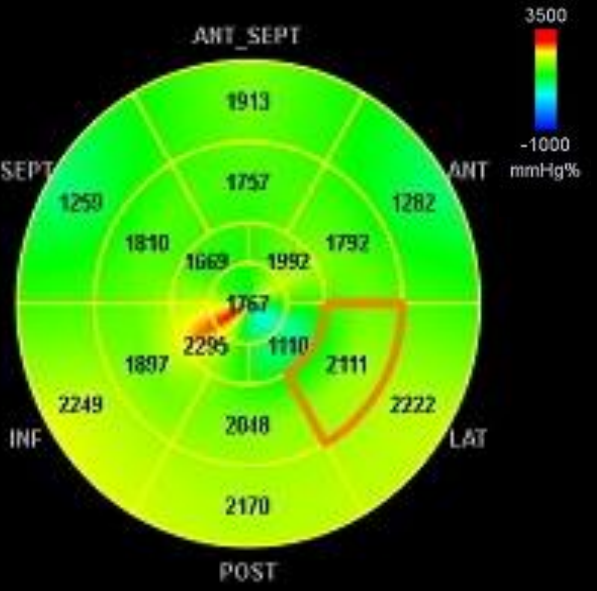


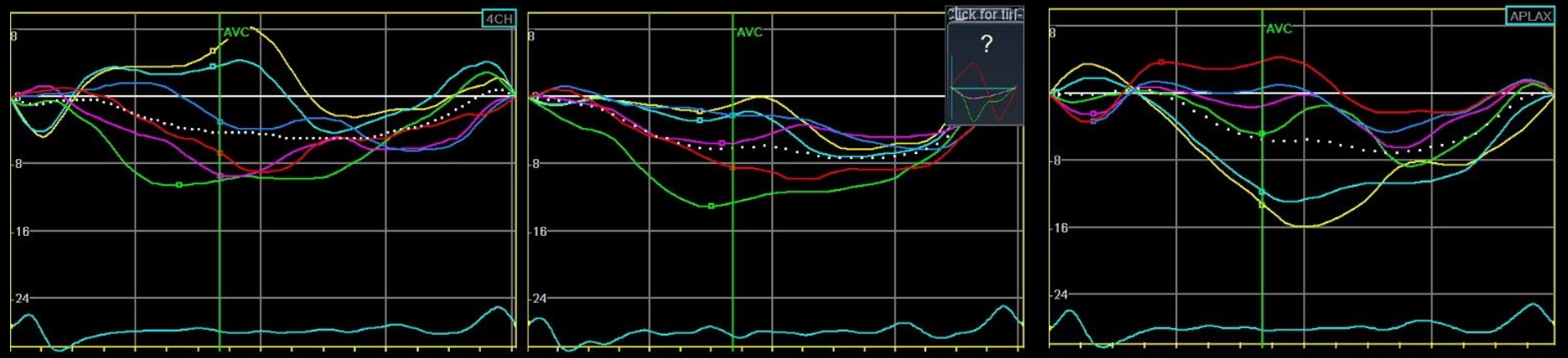


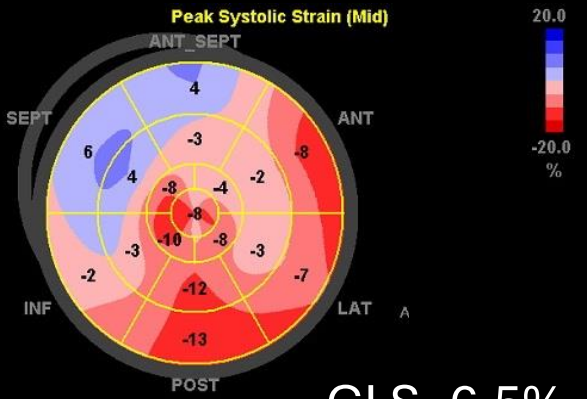
Mid Lateral Segment





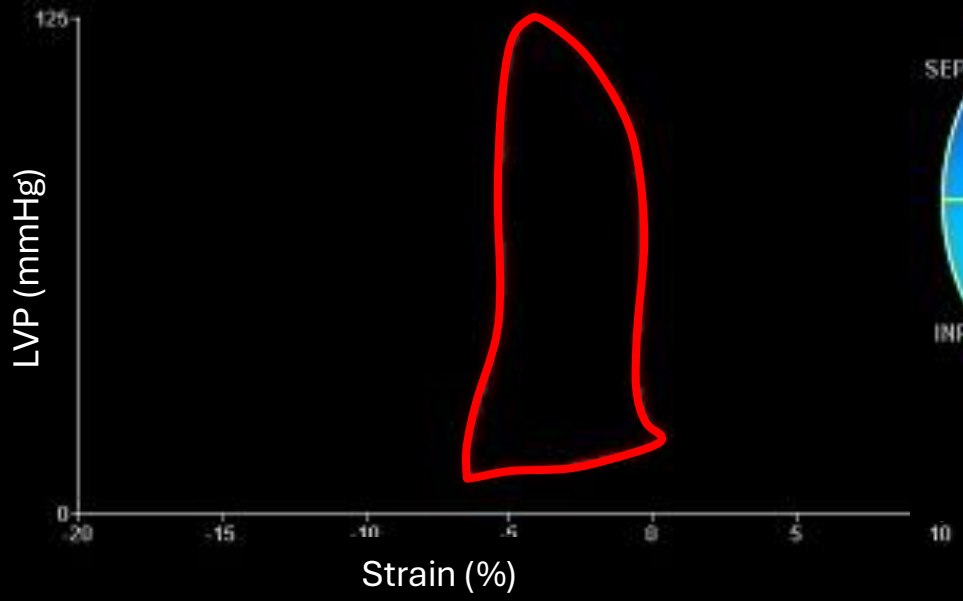


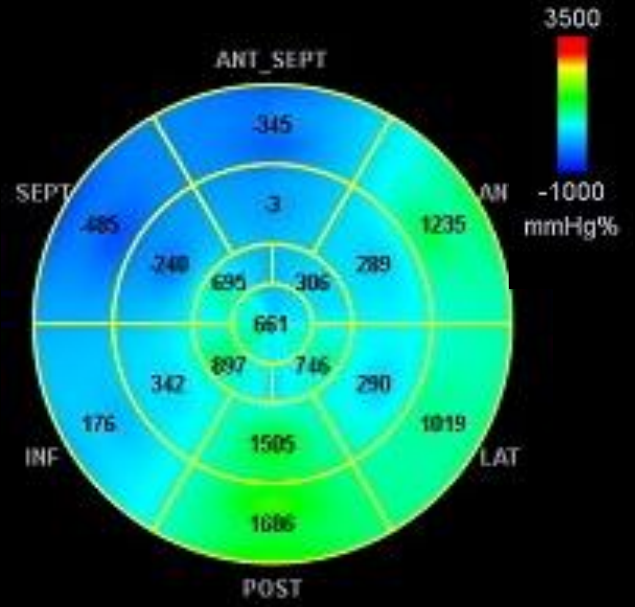




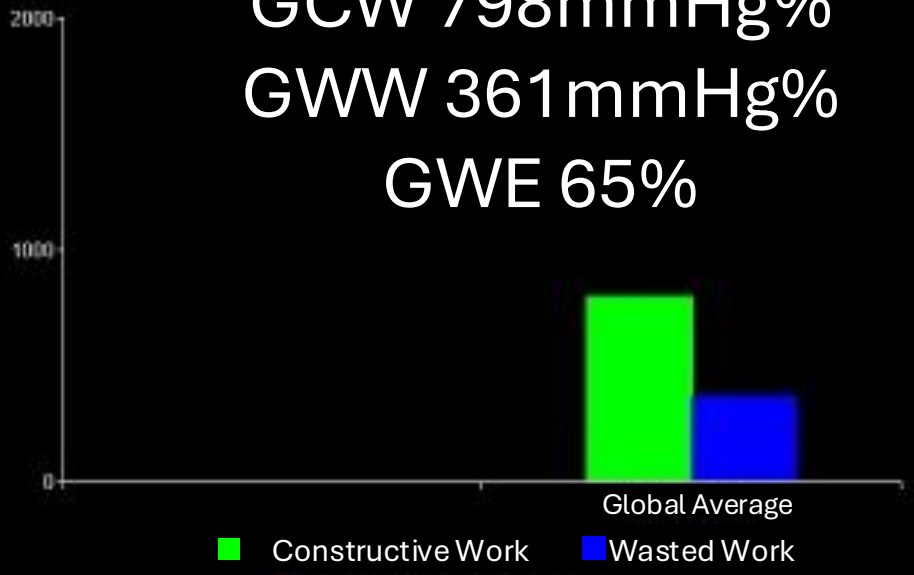
GLS -6.5%

GWI 524mmHg%

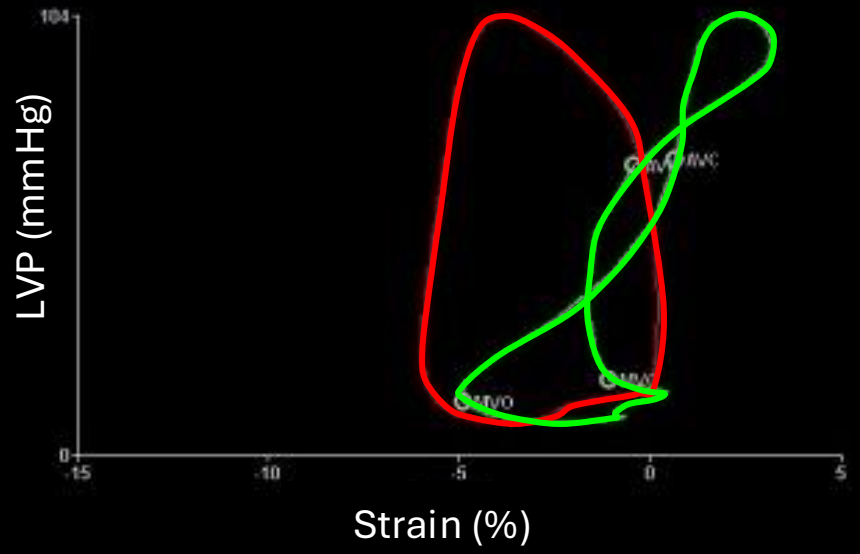


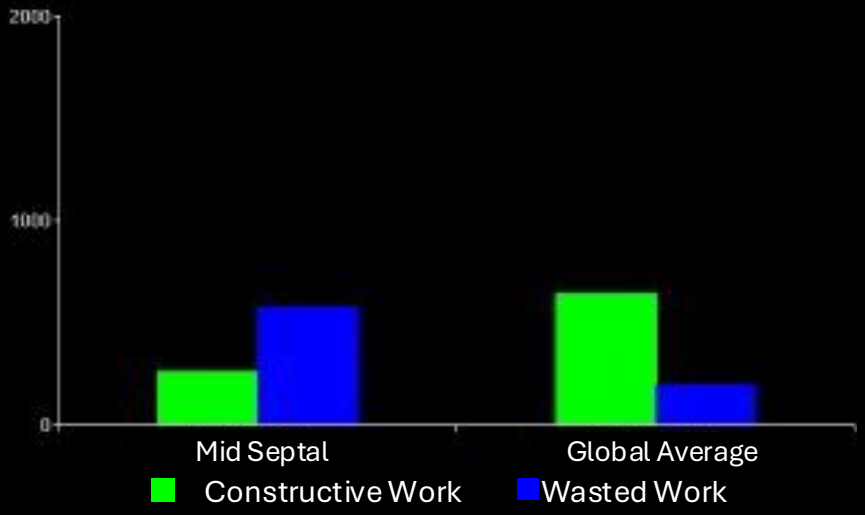


GCW 798mmHg%
GWW 361mmHg%
GWE 65%

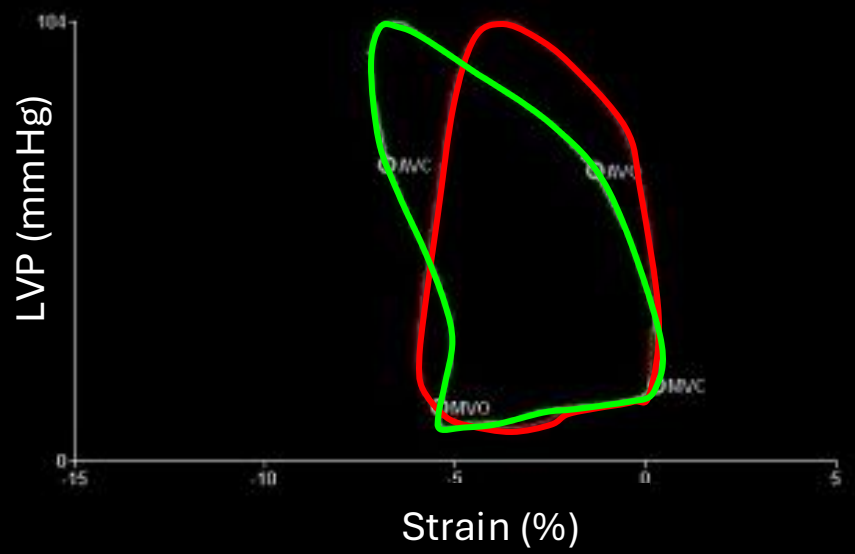


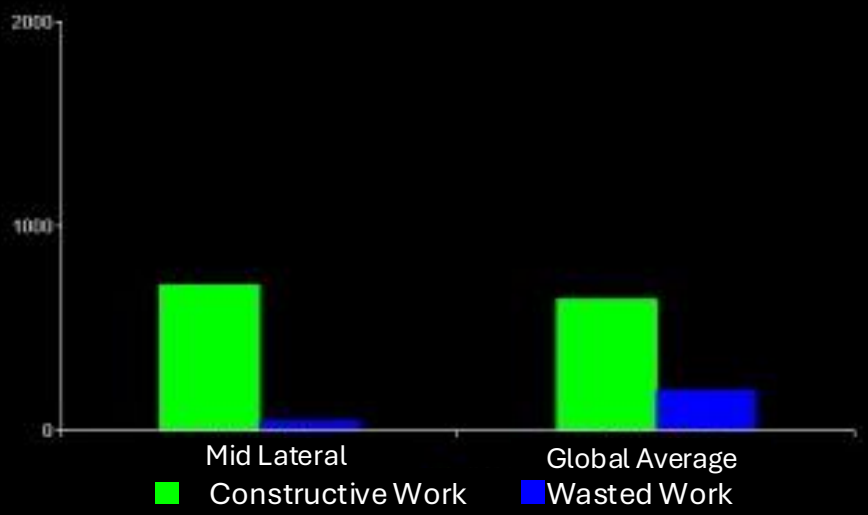
Mid Septal Segment



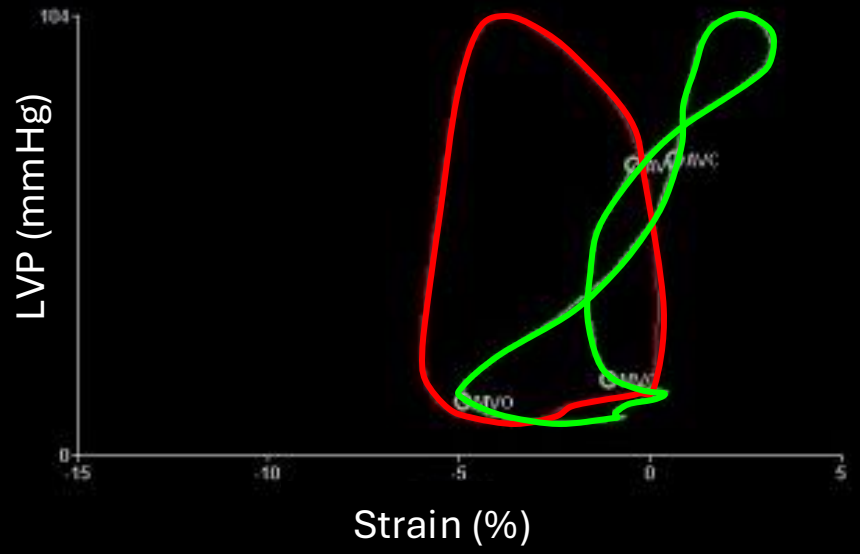


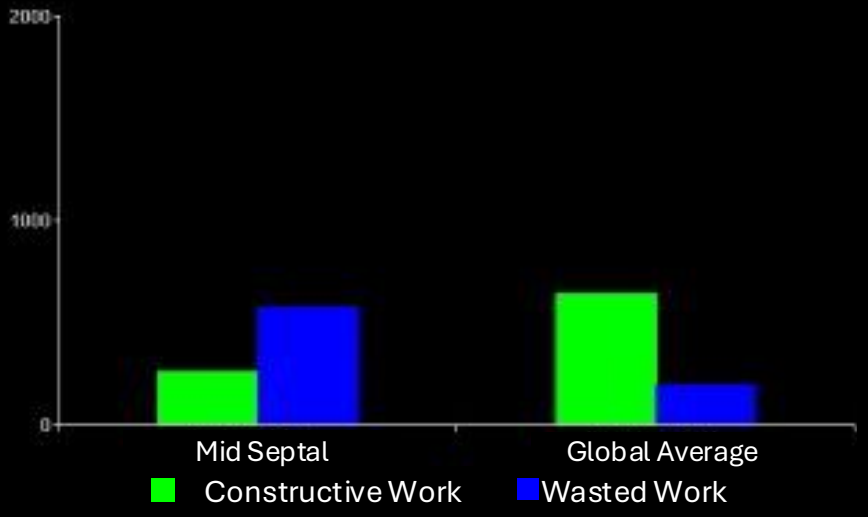
Mid Lateral Segment



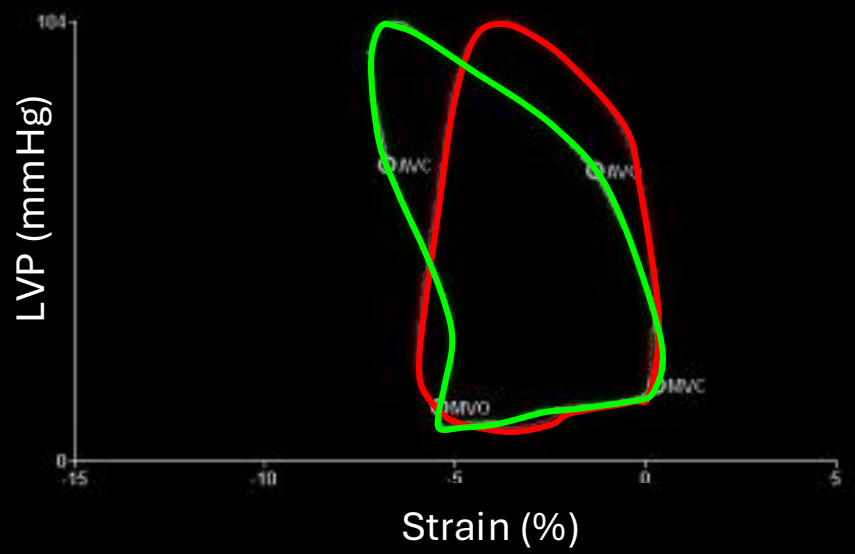


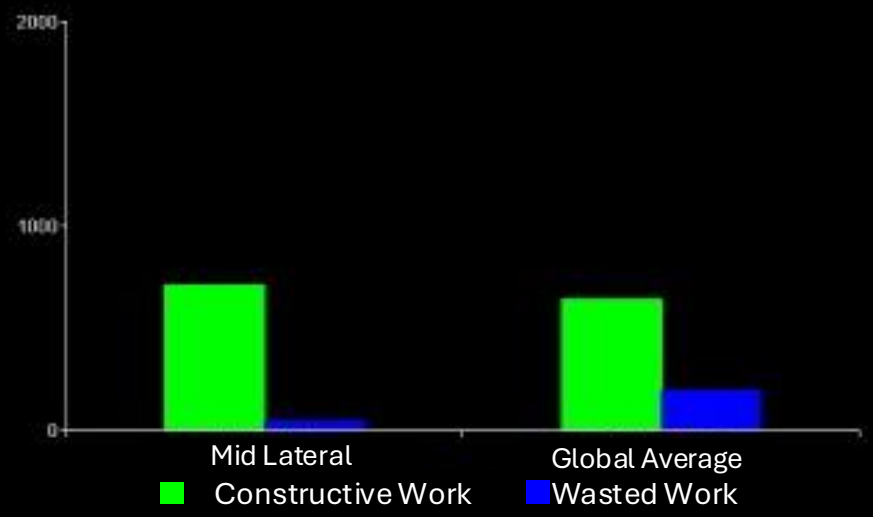
Mid Septal Segment

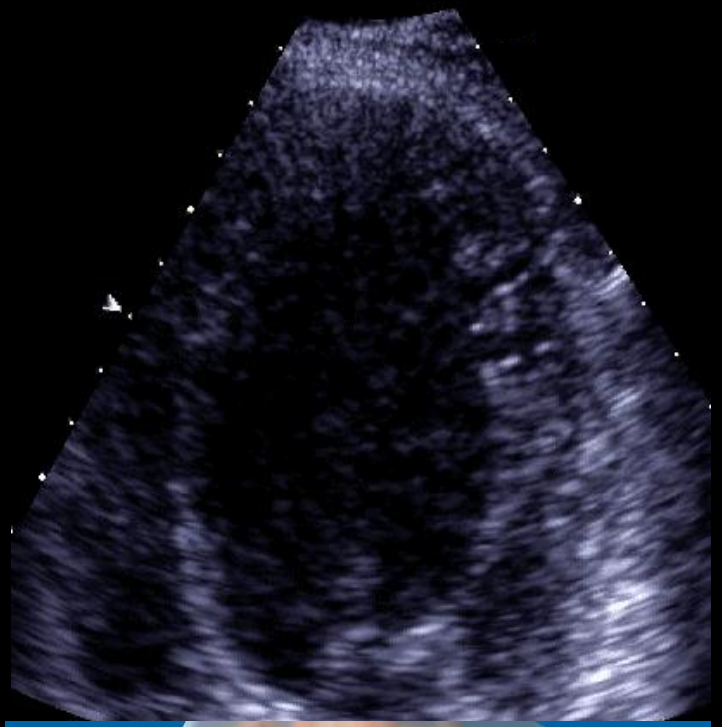


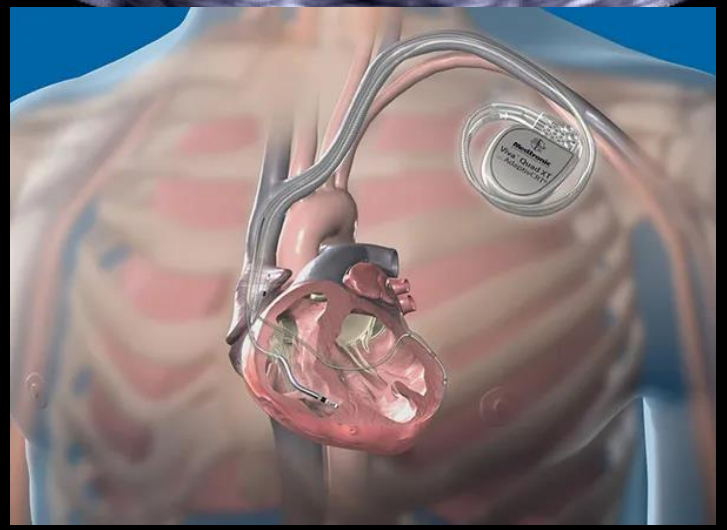


Mid Lateral Segment

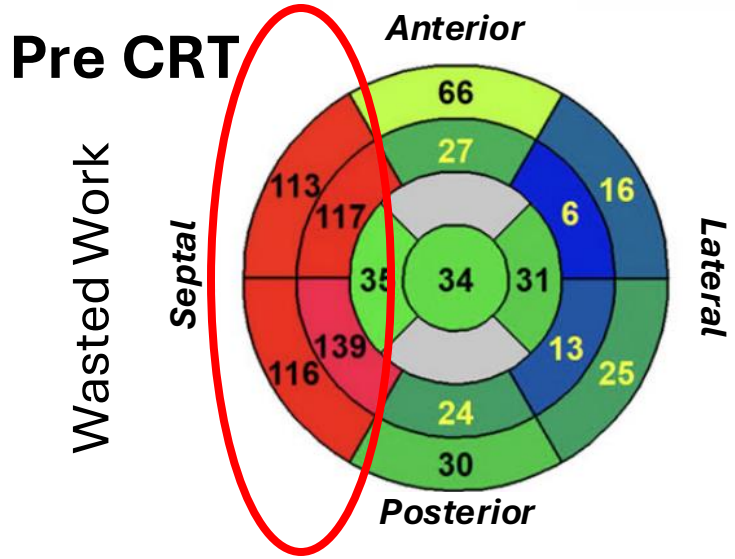


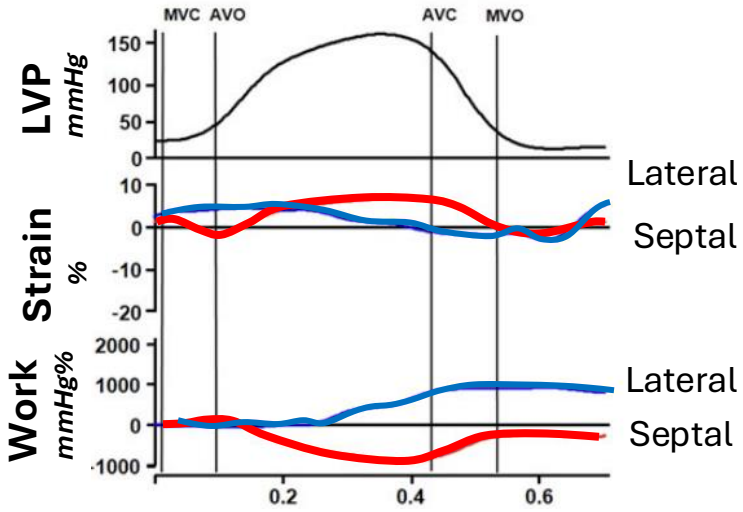






Myocardial Work – CRT Responder

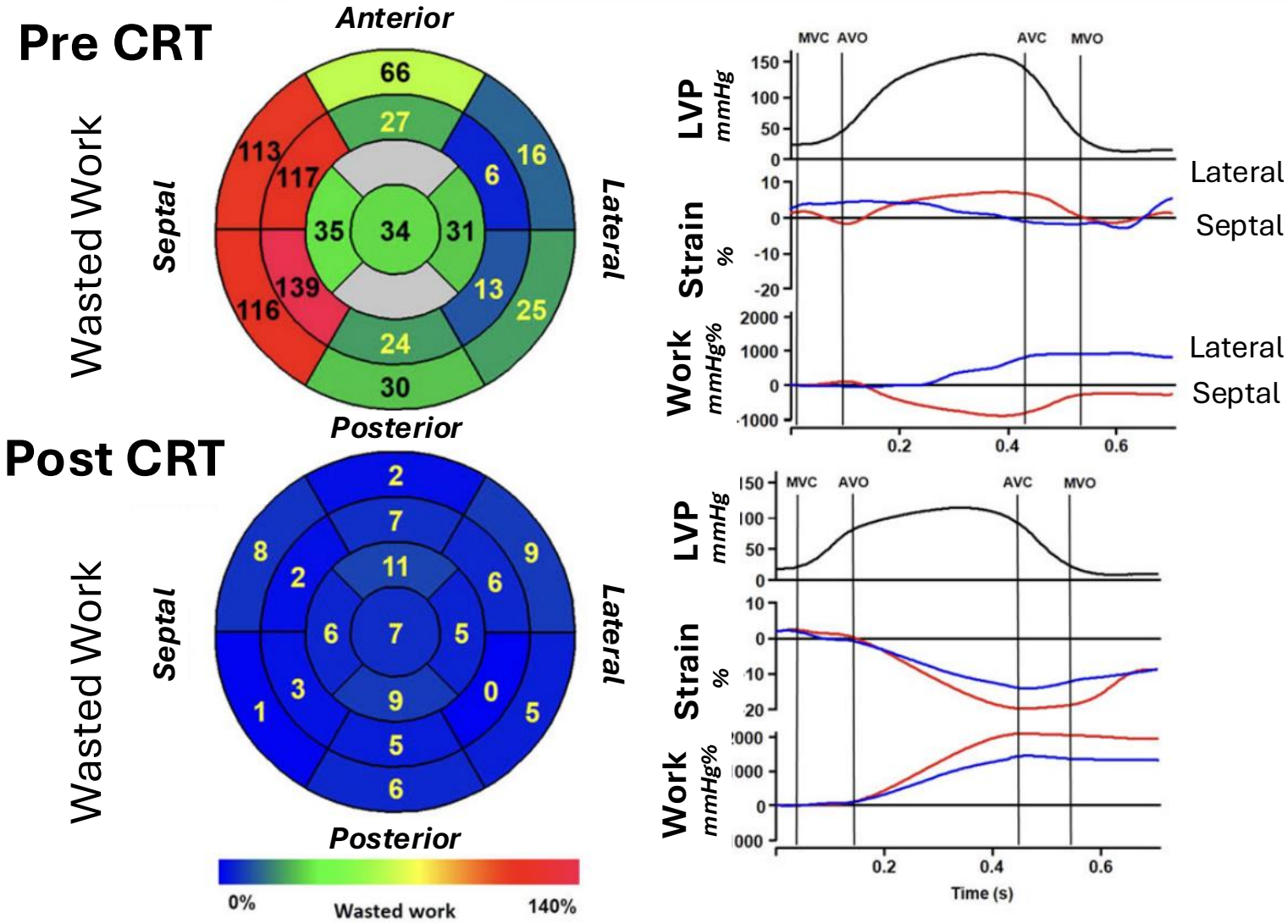




CRT Responders

- Higher global WW
- Particularly higher septal WW compared to lateral segments

Myocardial Work – CRT Responder

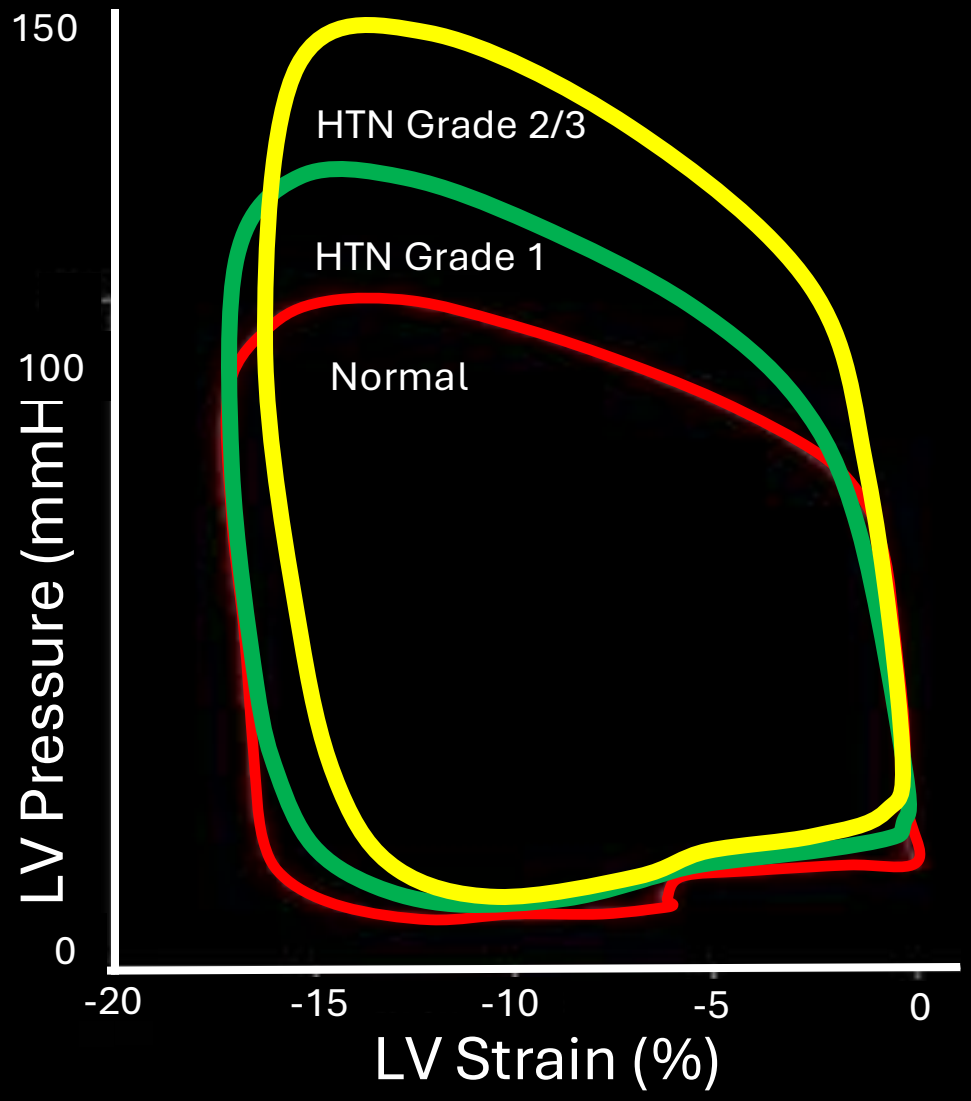


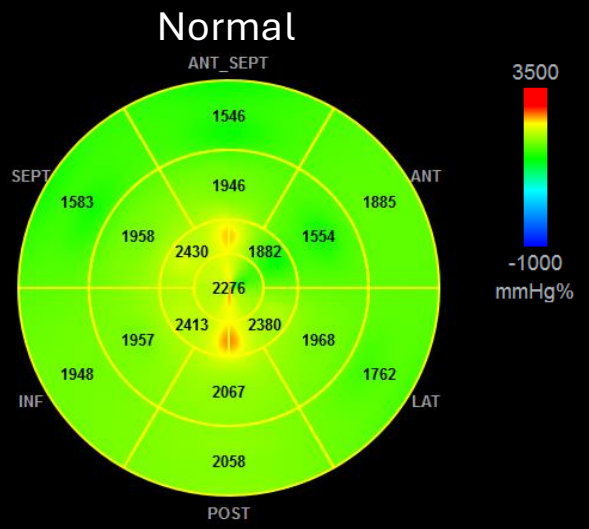
Veccera et al. Eur Heart J CV Imaging 2016;17:624-32

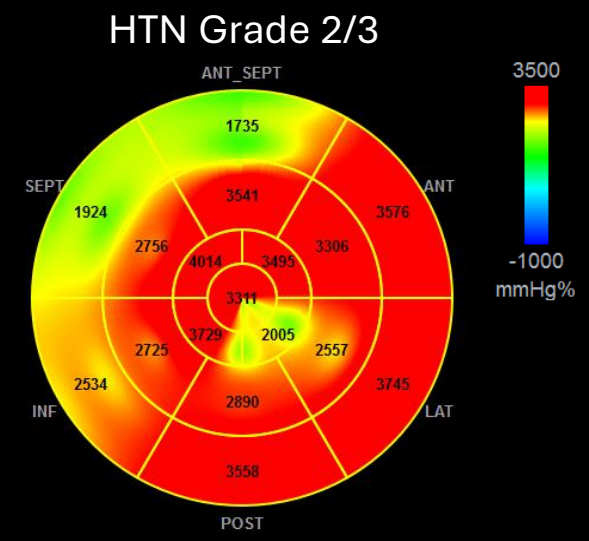
Research Applications

- Hypertensive heart disease
- Coronary artery disease
- Hypertrophic CMP
- Ischaemic CMP
- Amyloid
- Cardio-oncology
- HFrEF
- HFpEF

Hypertensive Heart Disease







Chan et al. Eur Heart J Cardiovasc Imag 2019;20:31-39

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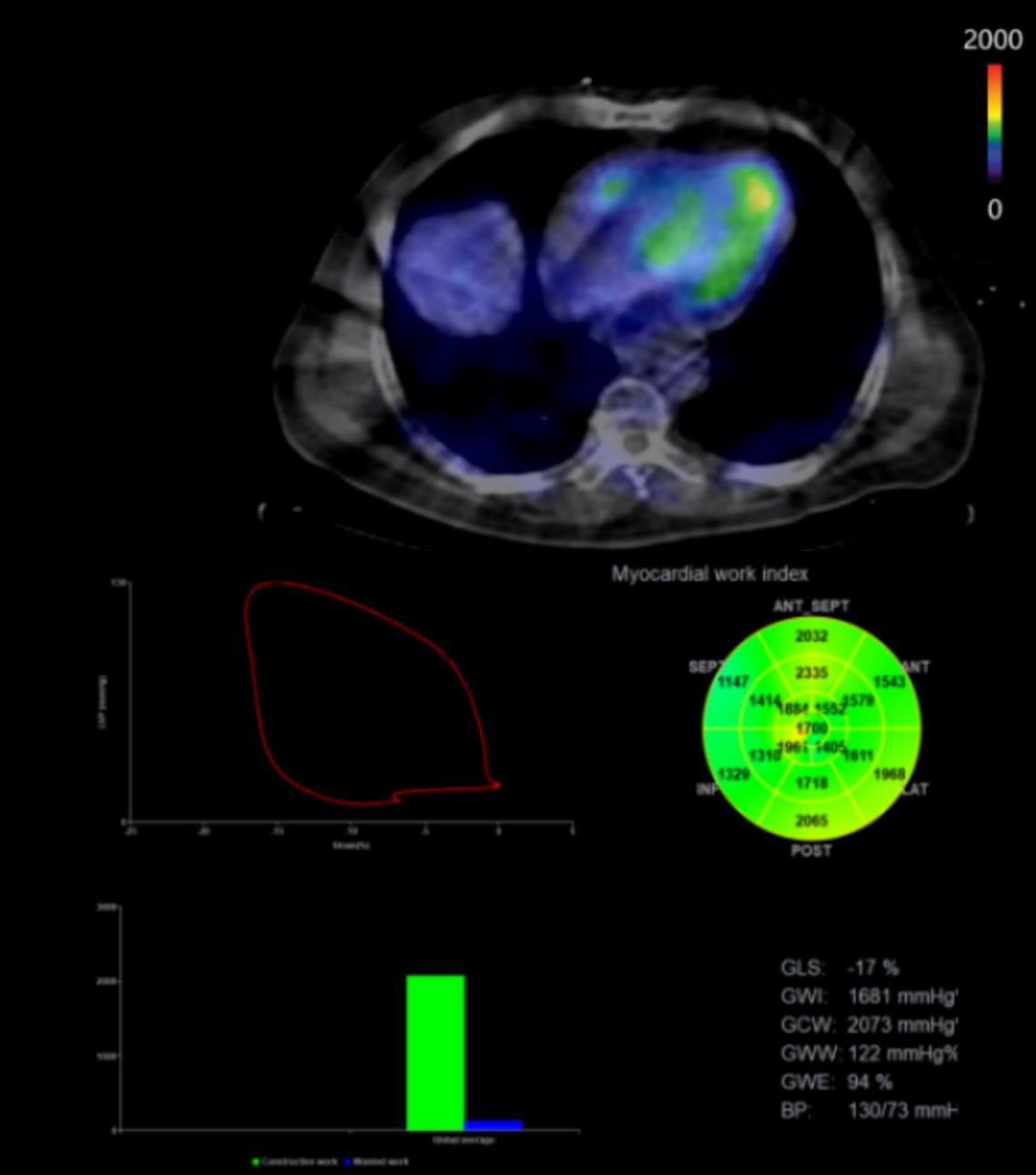

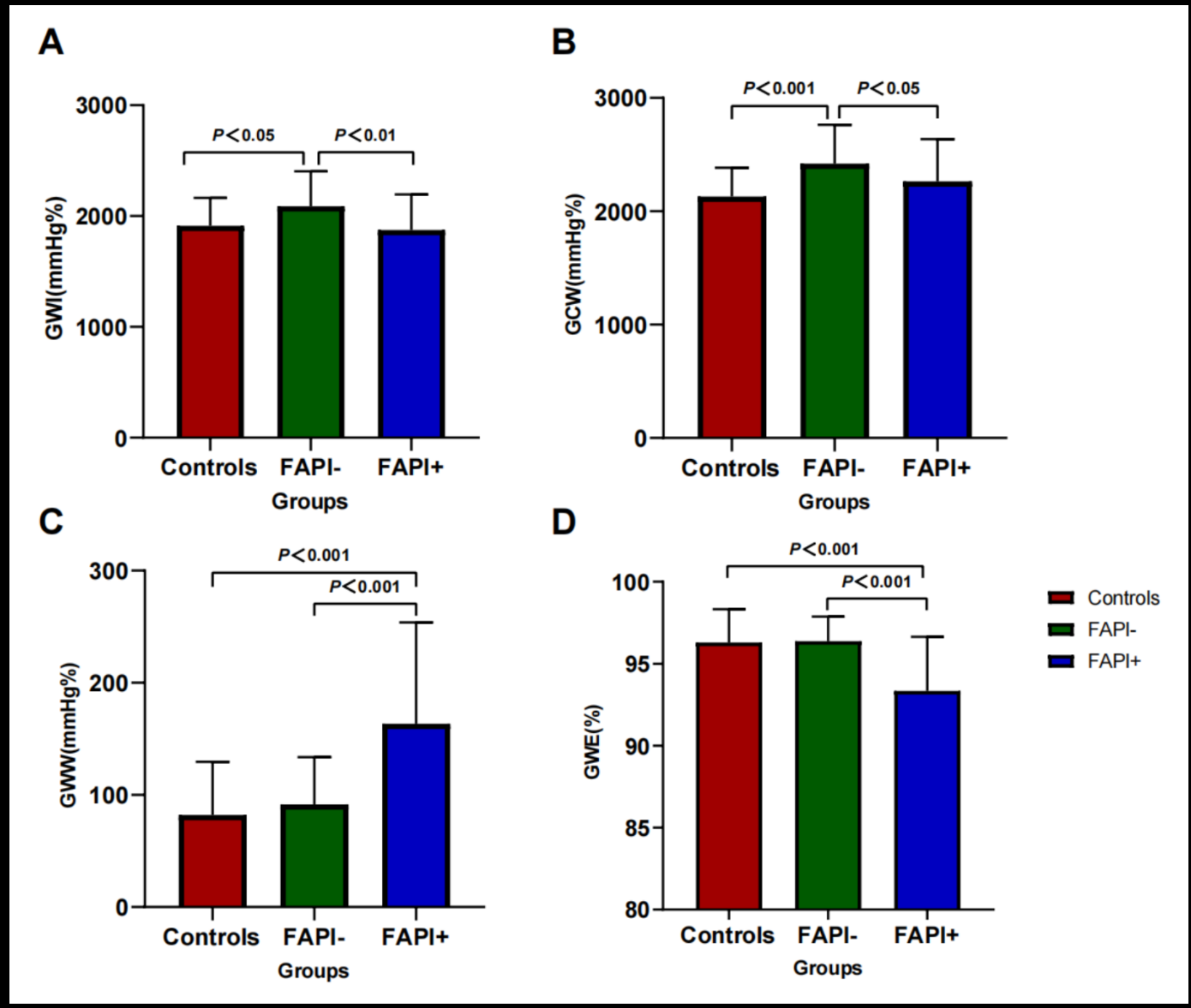

Adapted from Leng et al. Int J Cardiovasc Imag 2024; 40:1931-1939

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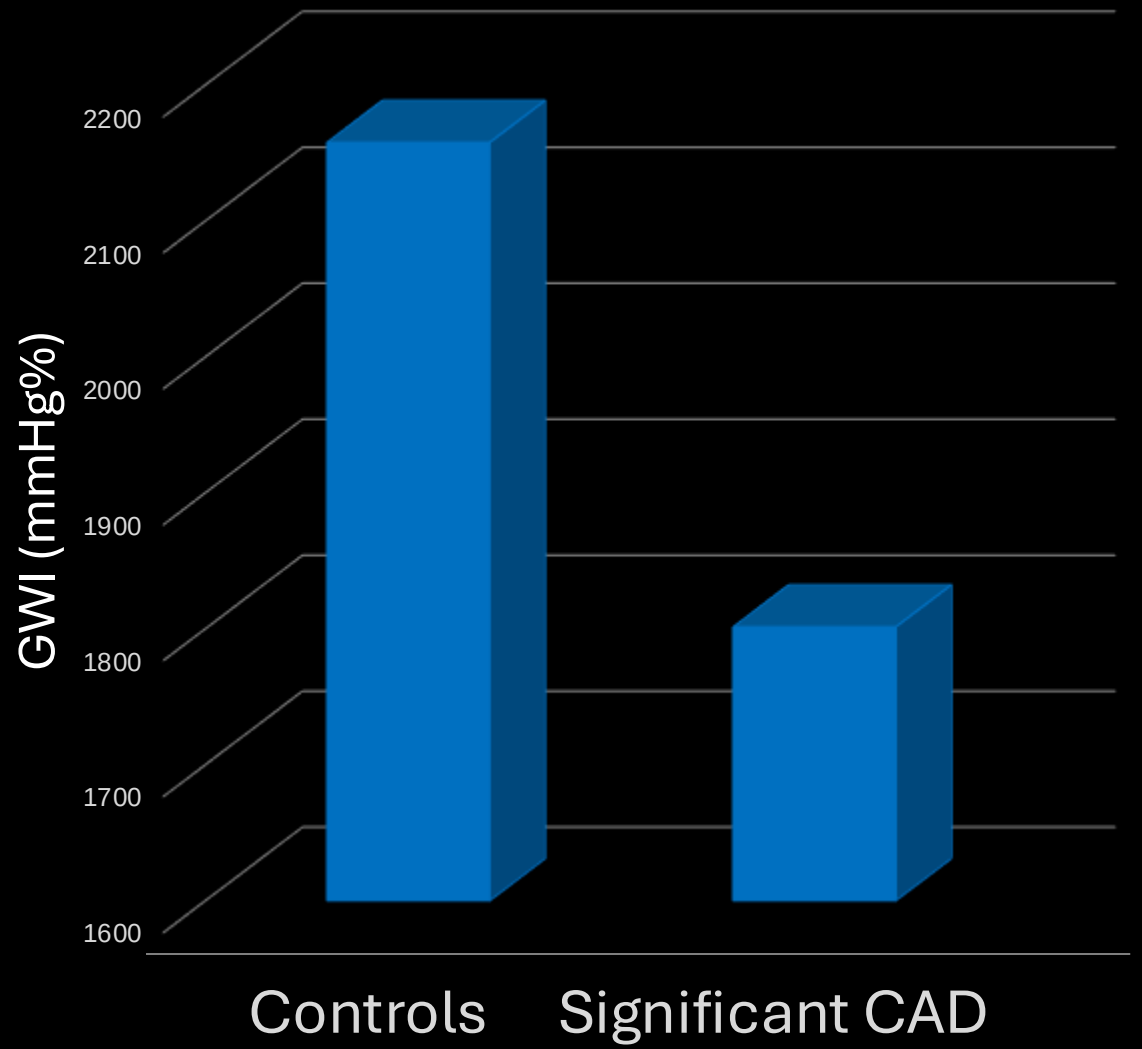
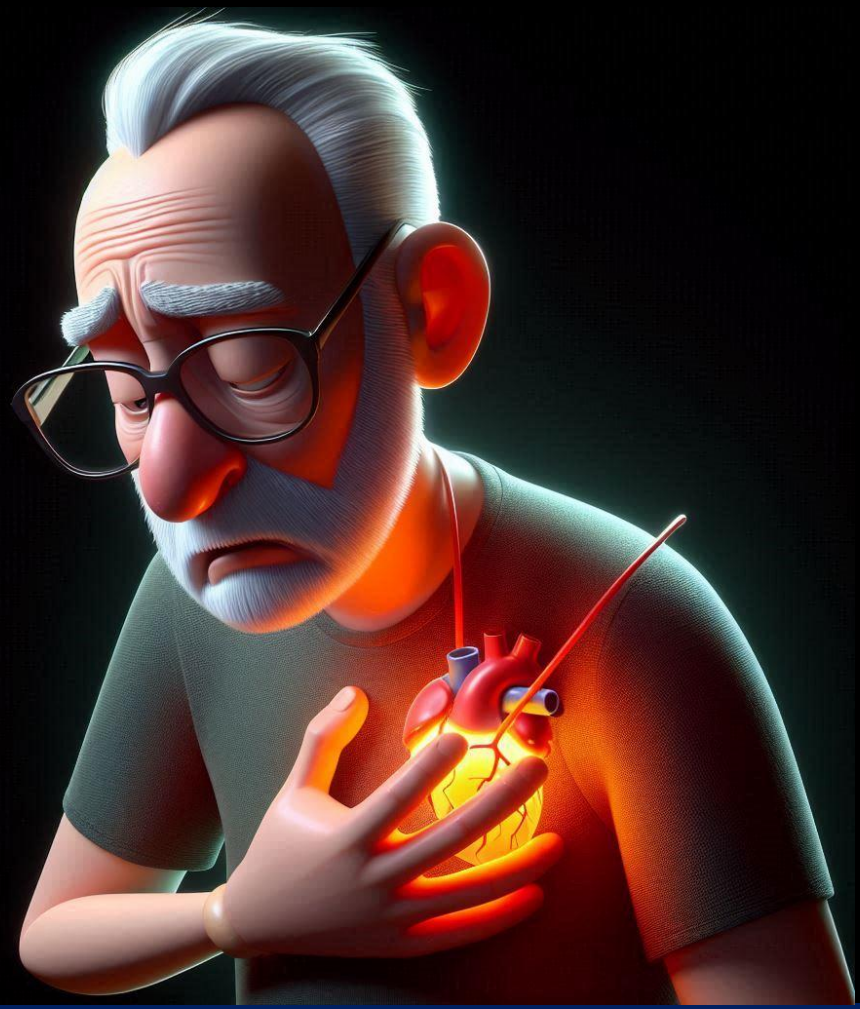
Coronary Artery Disease

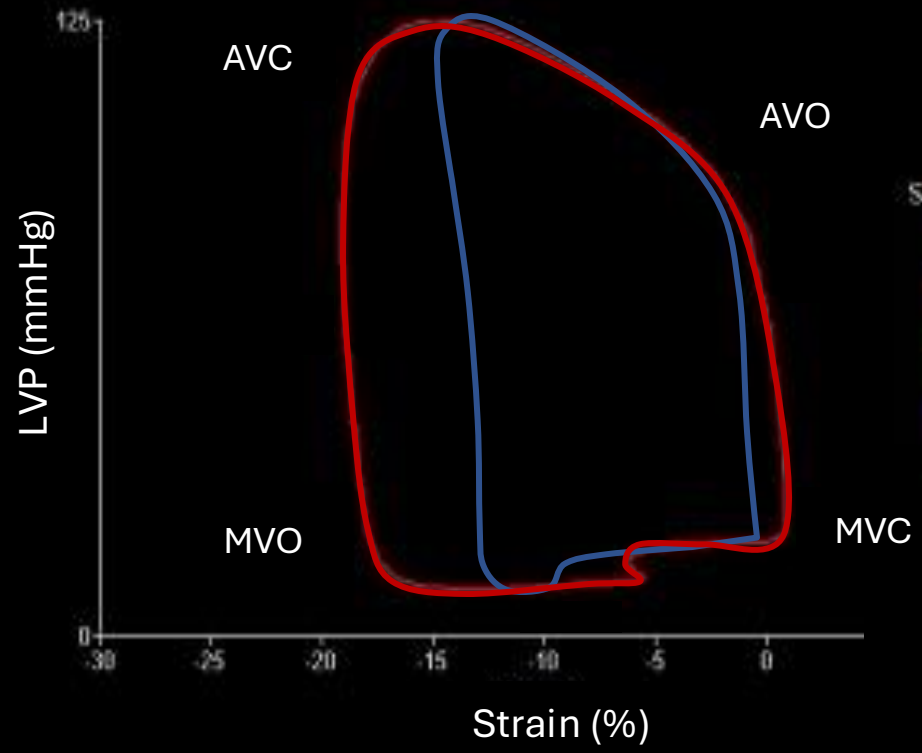




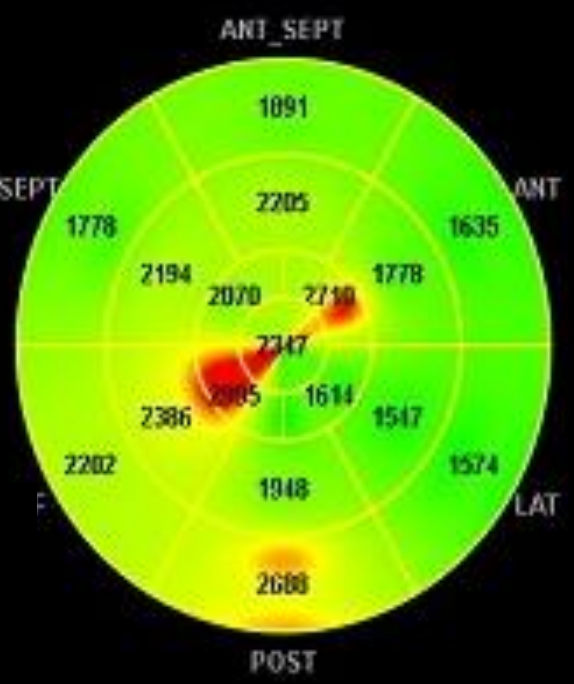
Edwards et al. J Am Soc Echocardiogr 2019;32:947-957

ECHO AUSTRALIA

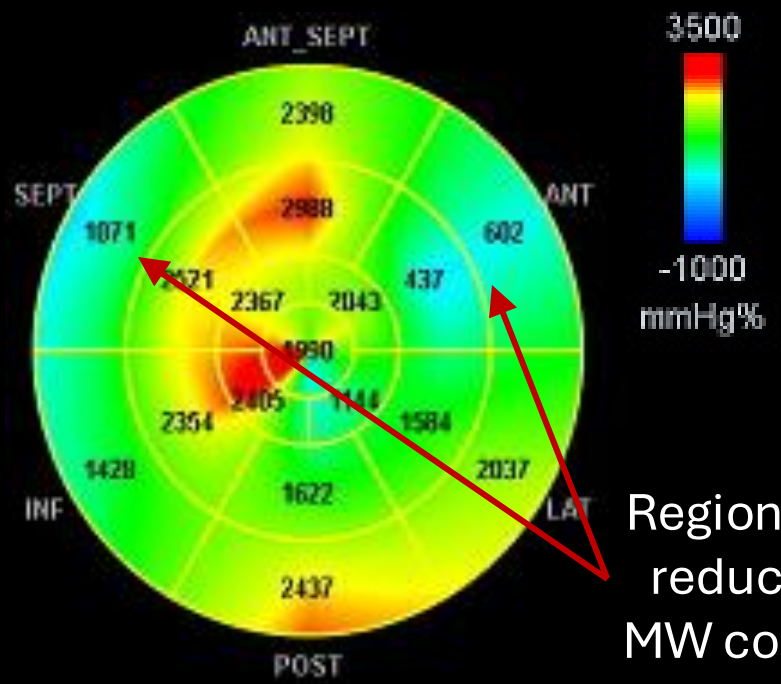
Coronary Artery Disease



Control



Multi-vessel CAD ≥70%

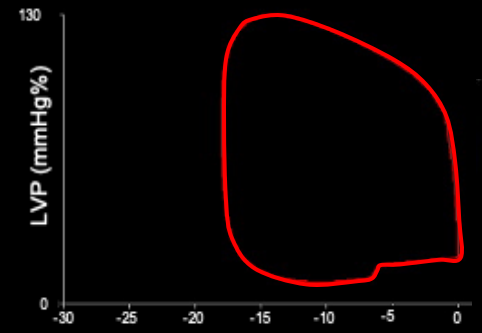


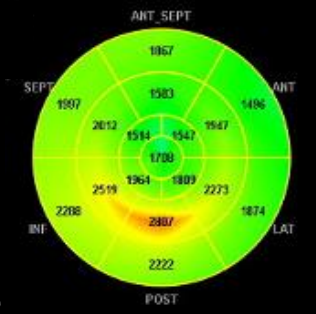
Regions of reduced MW coded in blue

Edwards et al. J Am Soc Echocardiogr 2019;32:947-957

Coronary Artery Disease

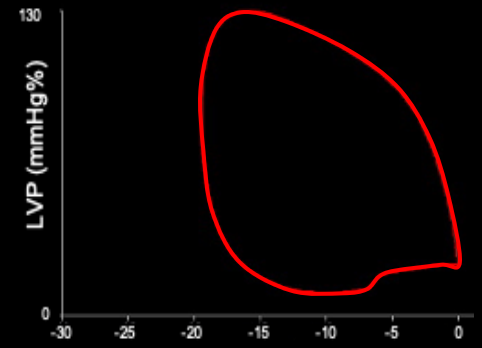
	Negative ESE (n=193)	False-Positive ESE (n=39)	True-Positive ESE (n=40)
GLS (%)	**-18.6 ± 1.8**	**-18.5 ± 2.1**	**-16.6 ± 2.5*#**
GWI (mmHg%)	**1819 ± 317**	**1857 ±344**	**1544 ± 354*#**
GWE (%)	96 ± 2	95 ± 3	94 ± 3*#
Global CW (mmHg%)	2228 ± 358	2196 ± 399	1881 ± 390*#
Global WW (mmHg%)	73 ± 40	93±63	113±87*#





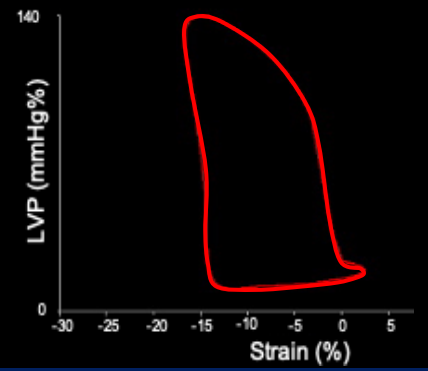
Negative ESE

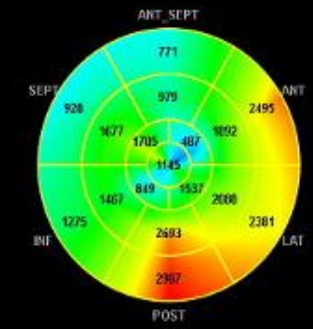
BP 130/80mmHg
GLS -17%
GWI 1952mmHg%



False Positive

BP 130/80mmHg
GLS -19%
GWI 1925mmHg%





True Positive

BP 140/80mmHg
GLS -17%
GWI 1578mmHg%

Edwards et al. Int J Cardiovasc Imaging 2021;37:2409-2417

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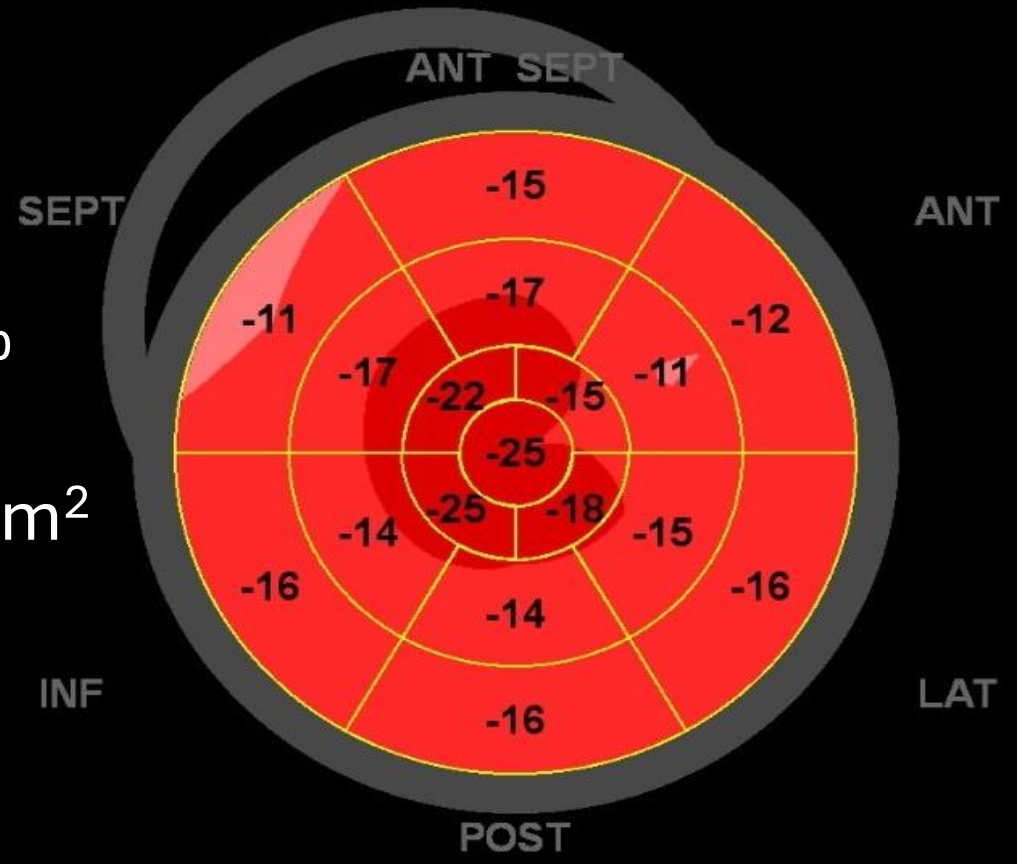
Cardio-Oncology

GLS -15.7%

EF 45%

LVEDVi 71ml/m^2

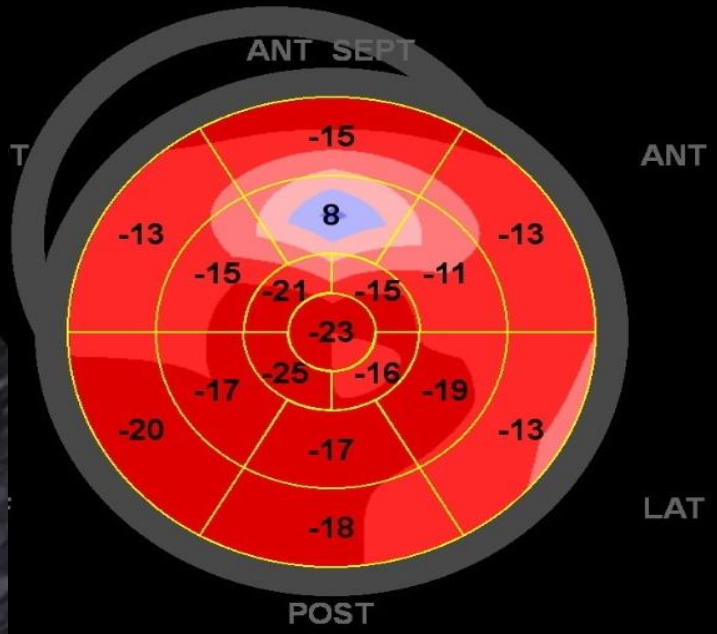


BP 127/80 mmHg

Cardio-Oncology

BP 160/100 mmHg

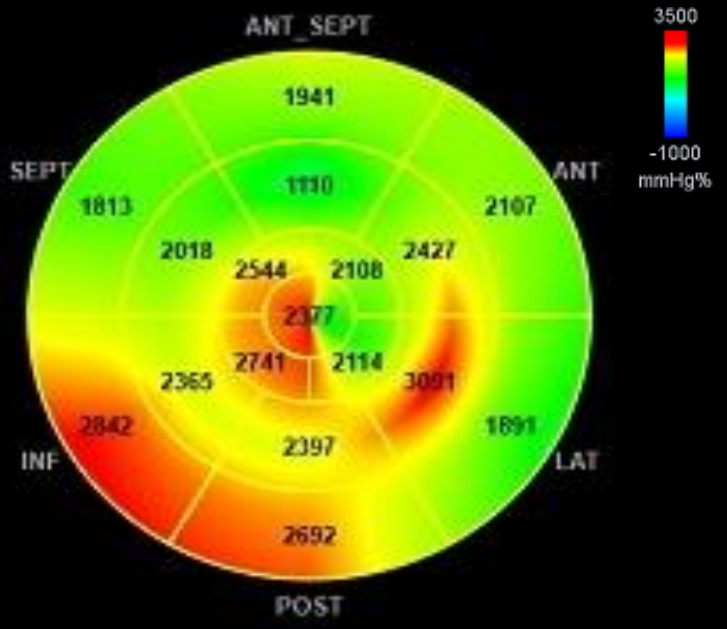
SBP Increase of 33mmHg



GLS -16.1%

EF 58%

LVEDVi 62ml/m^2



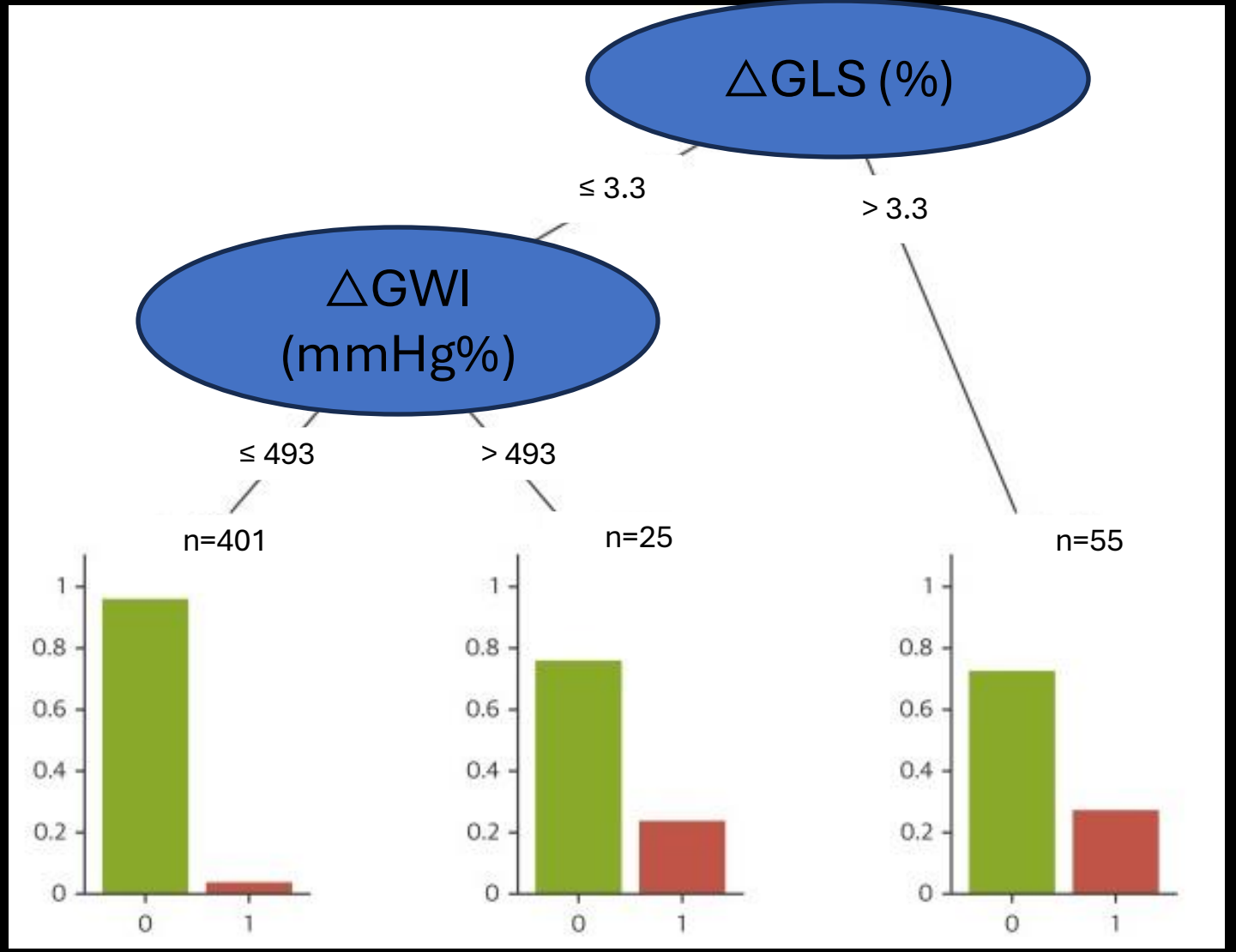
GWI 2275 mmHg%

GCW 2490 mmHg%

GWW 259 mmHg%

GWE 90%

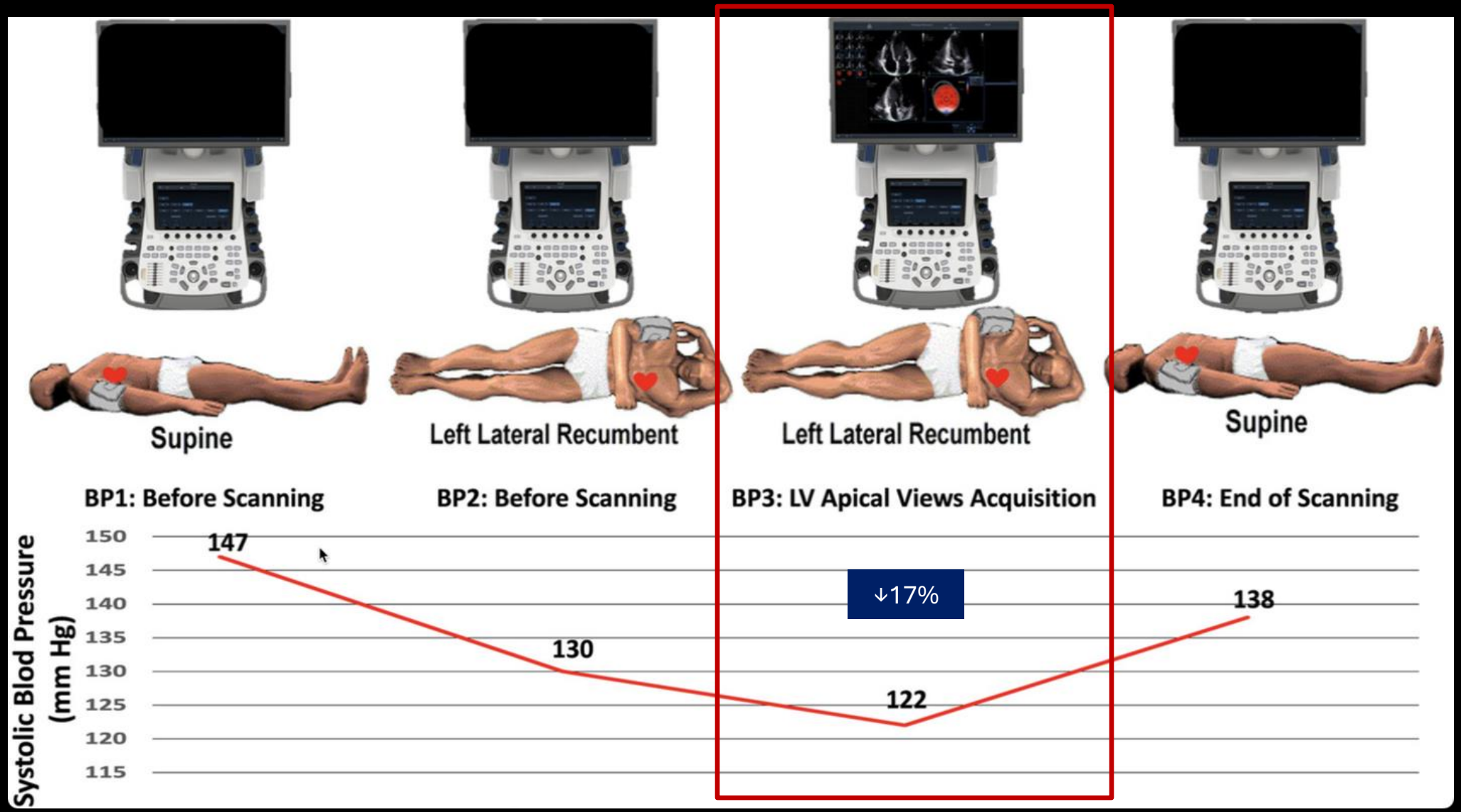
- Normal GLS & lower GWI
  - *Higher probability of concurrent or subsequent CTRCD*
- Reduced GLS & higher GWI
  - Reduced probably of concurrent CTRCD
  - *(in context of ~22mmHg higher SBP)*
  - *Reduced GLS is a result of increased afterload*
- Patients with higher GLS & GWI
  - *0% probably of concurrent or subsequent CTRCD*



Timing of Blood Pressure Matters!

1. Patient's emotional state at beginning of echo ↑BP

2. Position of sphygmomanometer relative to heart



Fisicaro et al. J Am Soc Echocardiogr 2024; Apr 7:S0894-7317(24)00166-4.

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Myocardial Work – Normal Ranges

	Mean	95% CI
GWI (mmHg%)	2010 mmHg%	1907 – 2113 mmHg%
GWE (%)	96%	96 -96 %
GCW (mmHg%)	2278 mmHg%	2186 – 2369 mmHg%
GWW (mmHg%)	80 mmHg%	73 – 87 mmHg%

Truong et al. J Am Soc Echocardiogr 2022;35:36

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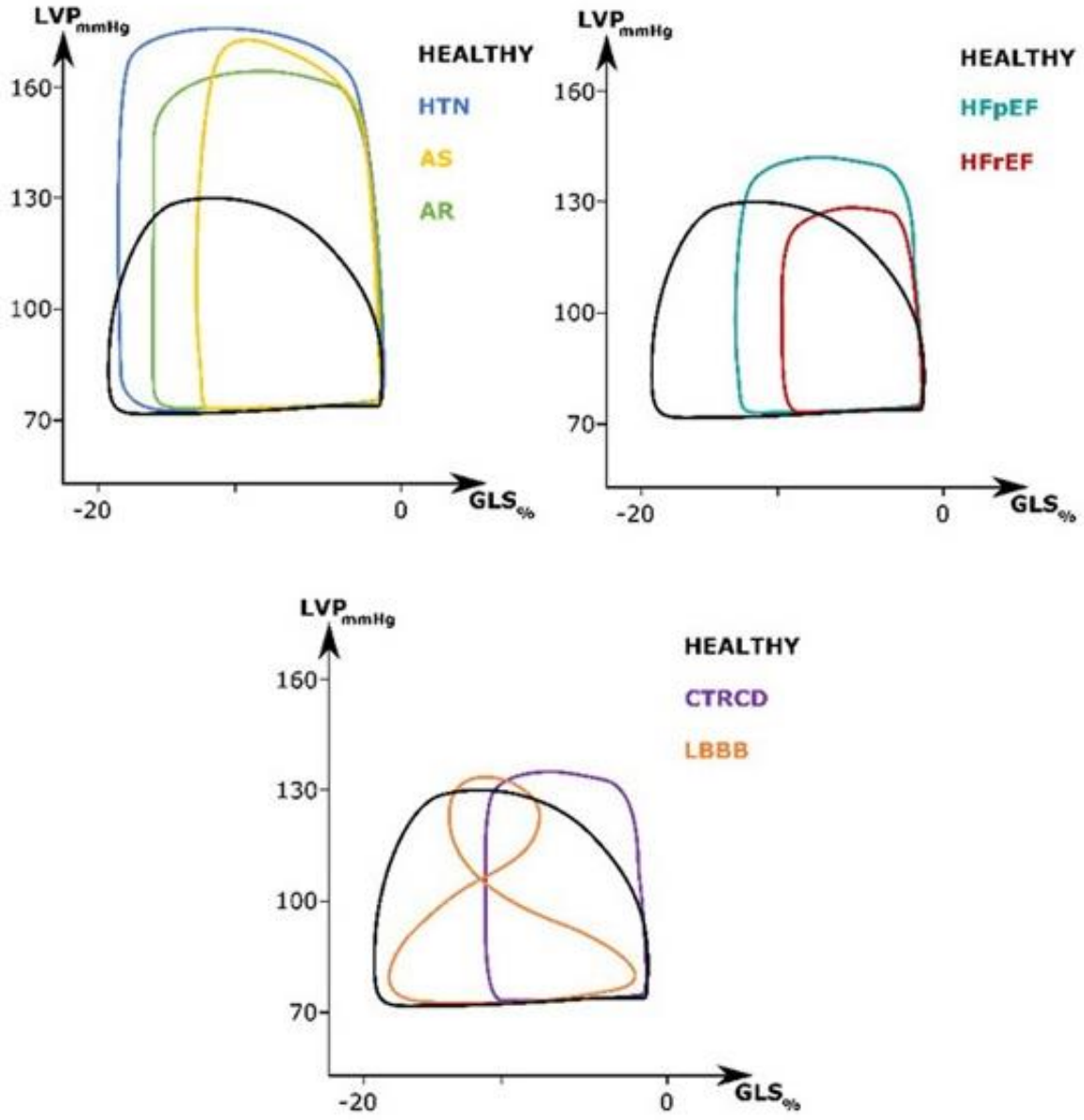

Cardiac condition	**Peak LVP** *afterload*	**LVEDV** *preload*	**Peak GLS** *myoc. shortening*	**MWI** *myoc. energetics*	**Reference**
Healthy	± 120mmHg	± 120mL	± -20%	± 1800mmHg%	EACVI-NORRE study
HTN	↑	≈	≈/↓	↑	Chan et al. 2019 Li et al. 2021 Sahiti et al. 2021
AS	↑	↓/≈	↓	↑	Fortuni et al. 2020 Jain et al 2021 De Rosa et al. 2022
AR	↑	↑	≈/↓	↑	Meucci et al. 2022 Jain et al. 2022
HFpEF	↑	↓	↓	≈/↓	Tomoaia et al. 2020 D'Andrea et al 2021 Lin et al. 2022
HFrEF	≈	↑	↓	↓	Chan et al. 2019 Hedwig et al. 2021 Wang et al. 2021
LBBB	↓/↑	≈	↓	GWW↑ ; GWE ↓	Russel et al. 2013 Aalen et al. 2019 Calle et al. 2021
CTRCD	≈/↑	≈	↓	↓	Guan et al. 2021 Zhan et al. 2022 Calvillo-Argüelles et al. 2022

Adapted from Moya et al. J Am Soc Echocardiogr 2023;36:1027-1042

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Myocardial Work – Limitations

- Arrhythmias
- Image quality
- Peak SBP assumed to be equal to arterial SBP
  - *Only true in absence of AS, LVOT obstruction*
  - *Studies – adding cuff pressure to mean Doppler AS gradient = invasive SBP*
- Multicentre studies required to determine validity of technique

Take Home Points

- MW provides a non-invasive method for LV function evaluation in relation to pressure dynamics
- MW may be valuable for serial LV quantification with respect to variable afterload conditions
- Timing of blood pressure matters!