Tetralogy of Fallot and Pulmonary Hypertension

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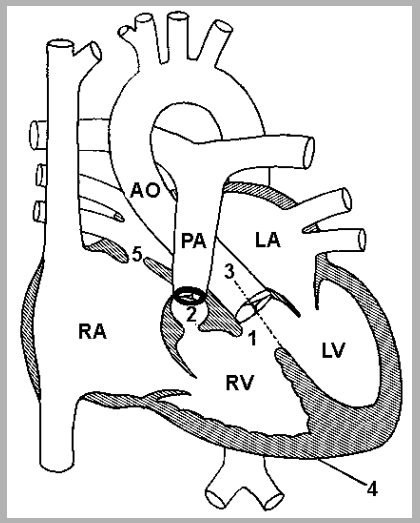
- Female 52y
- Tetralogy of Fallot
- Secundum atrial septal defect
- Interventions

Right BT shunt at age 3

Surgical correction TOF at age 6

Tetralogy of Fallot
Most common cyanotic congenital heart disease

- Valvular and subvalvular pulmonary stenosis
- Ventricular septal defect
- Aorta overriding the septum
- Right ventricular hypertrophy

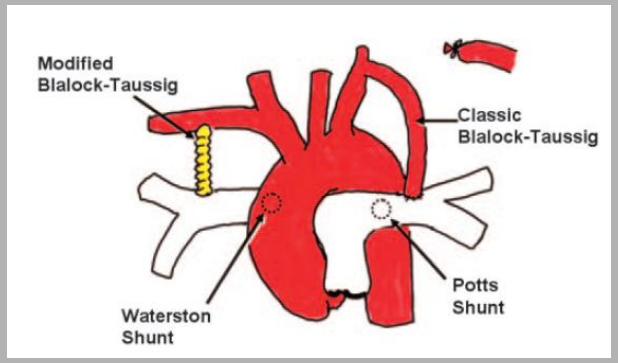


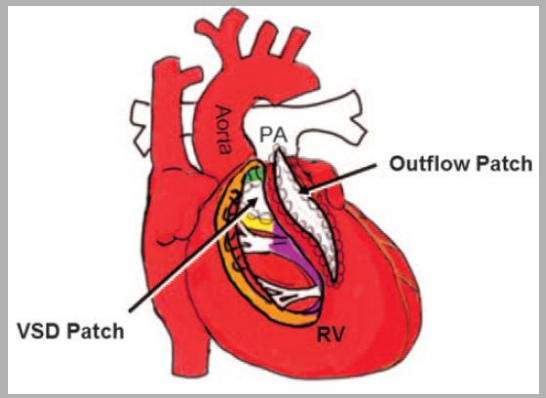
Anterior malalignment of the septum

Surgical Treatment

- 1944: Blalock Taussig shunt
- 1948: Brock procedure (resection of the stenosed infudibulum with a punch)
- 1954: First total repair by

  C Walton Lillehei





Bashore Circulation 2006

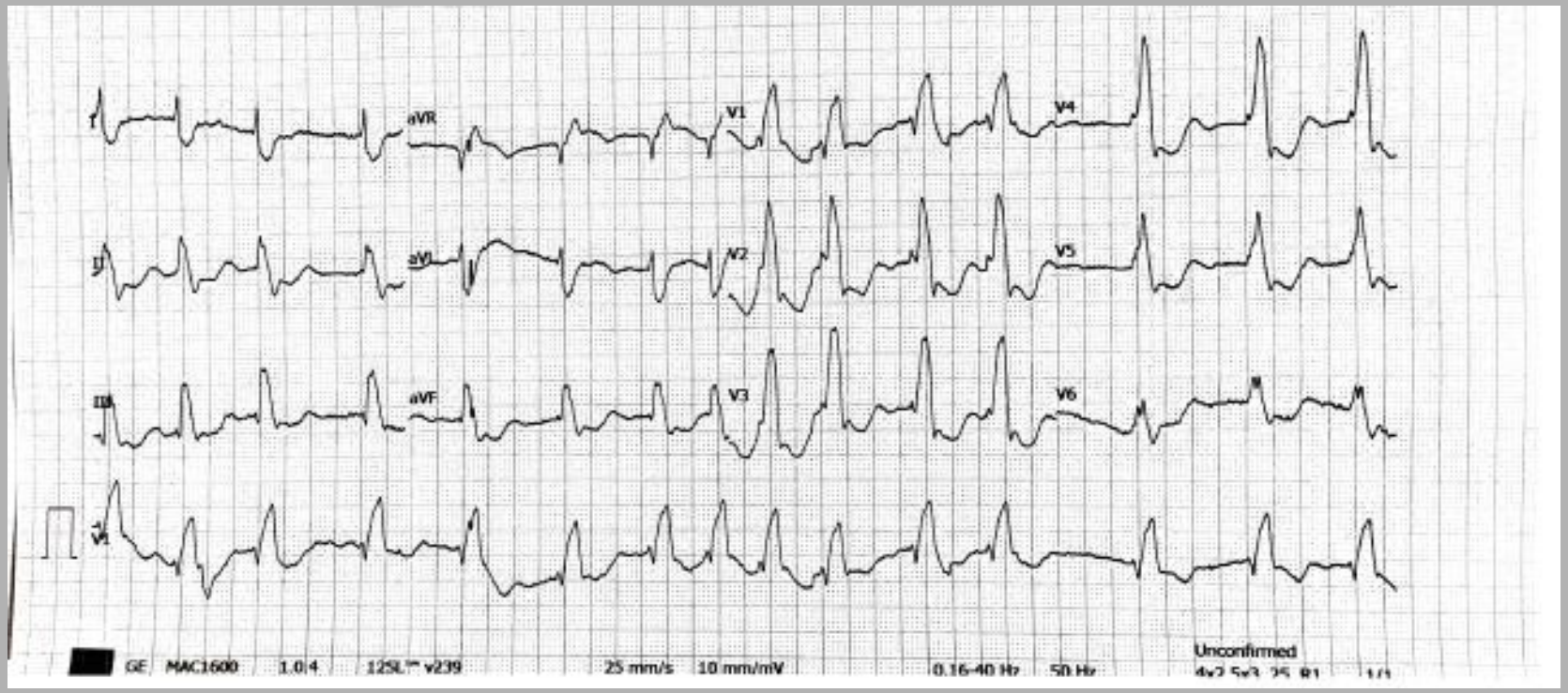
Clinical

- Atrial fibrillation
- History of hemoptysis 1/2019
- NYHA III

On examination

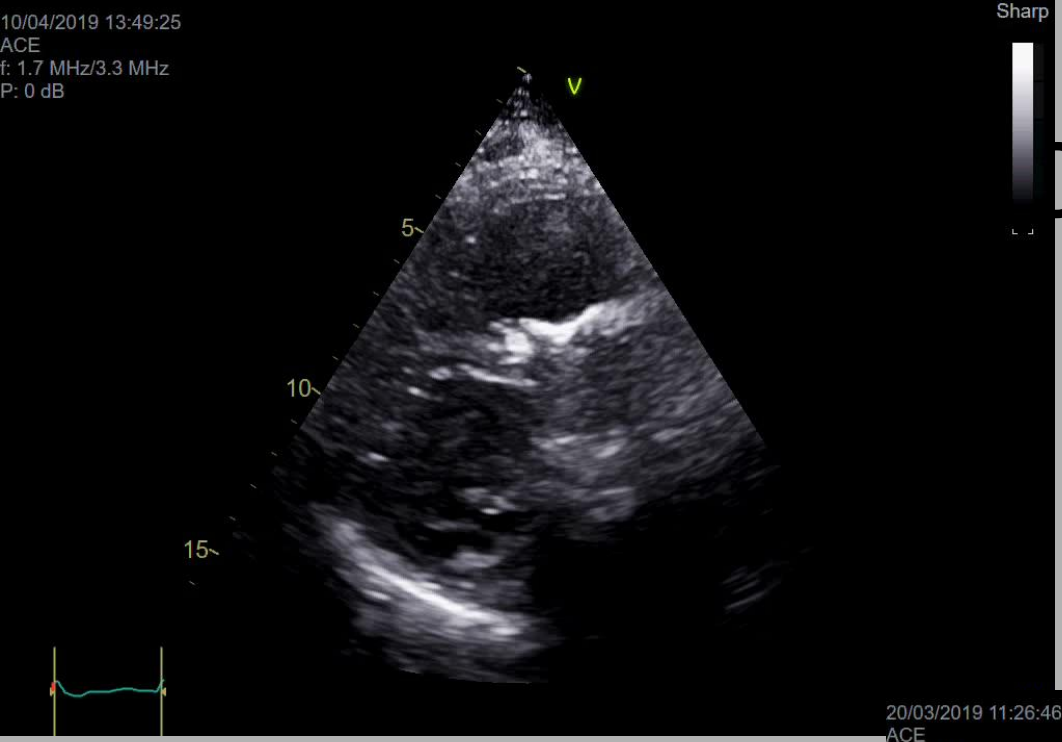
- Cyanotic SAT 75%
- BP 110/60mmHg, HR 100/min
- Diastolic murmur left parasternal edge
- Mild peripheral oedema

ECG


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
GE MAC1600 1.0/4 12SL™ v239
25 mm/s 10 mm/mV
0.16-40 Hz 50 Hz
Unconfirmed

Hematology-Biochemistry

- Ht 47% MCV 66
- Bilirubin 2.3 mg/dl (direct 0.5mg/dl)>1.7 mg/dl
- NTproBNP 6131pg/ml
- Normal kidney function
- TSH 5.03μUI/ml
- Slightly elevated AST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ACE
f: 1.7 MHz/3.3 MHz
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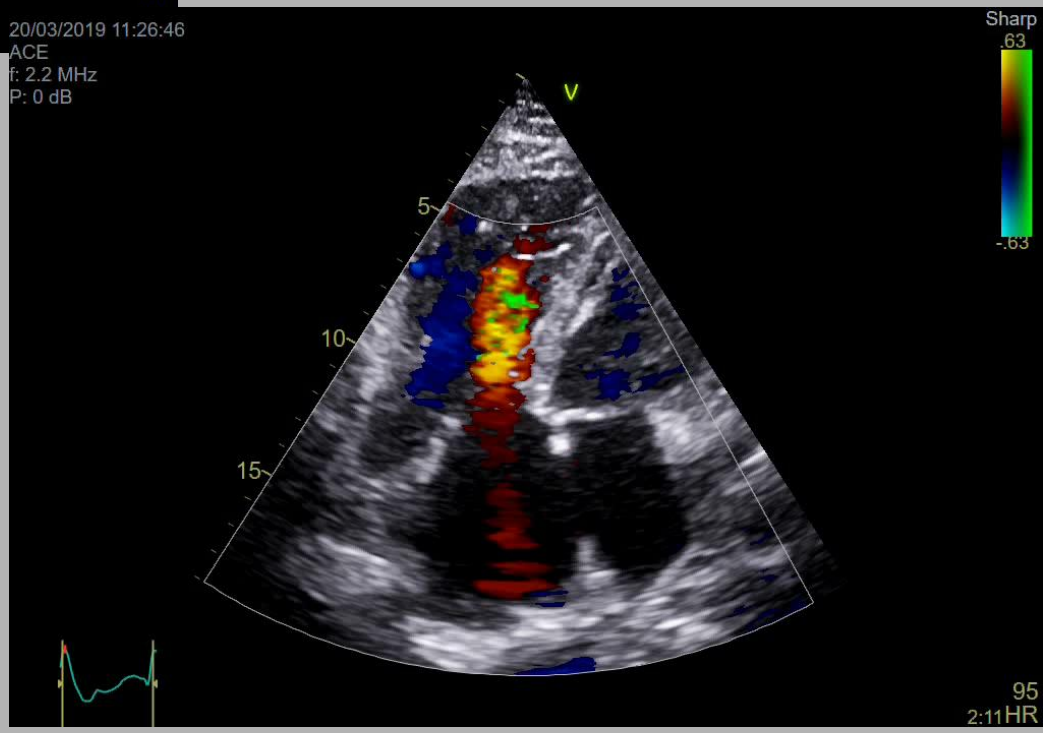
V
5
10
15


20/03/2019 11:26:46
ACE
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Sharp
.63
-.63
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10
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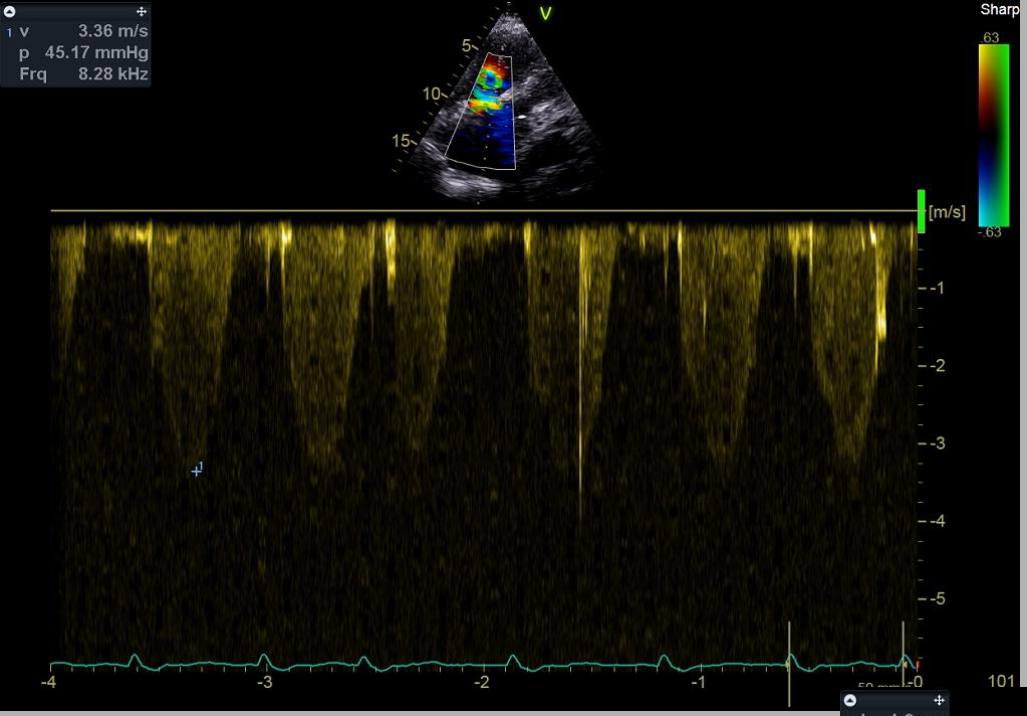
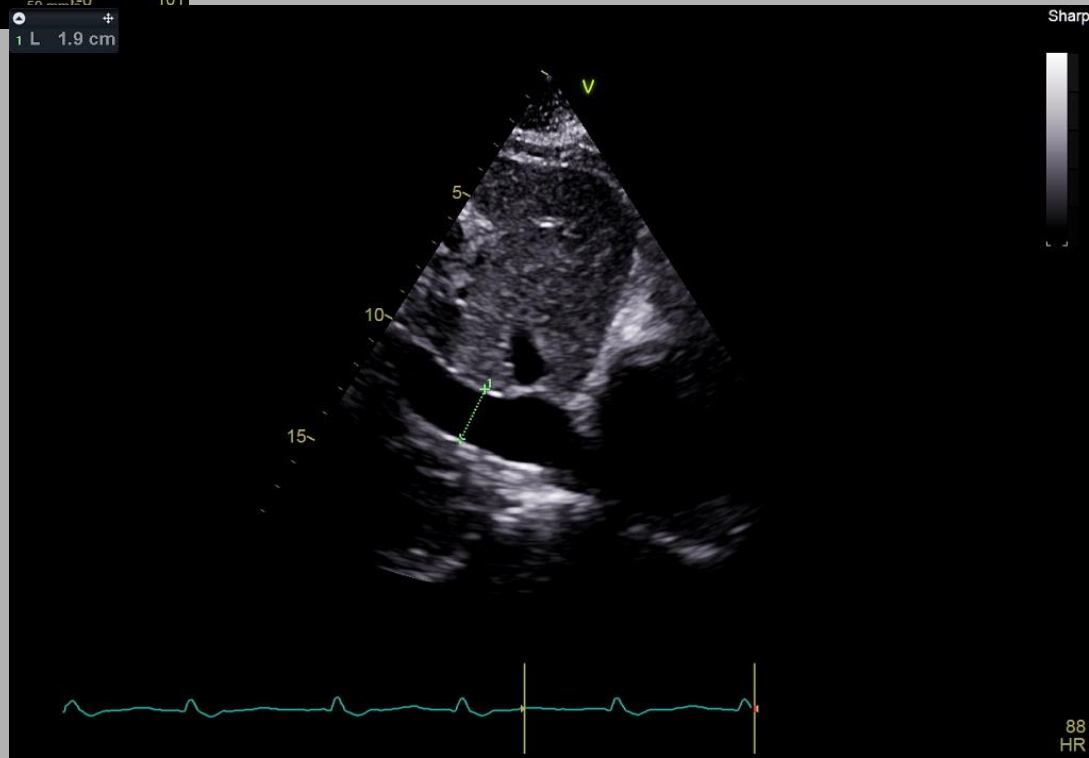
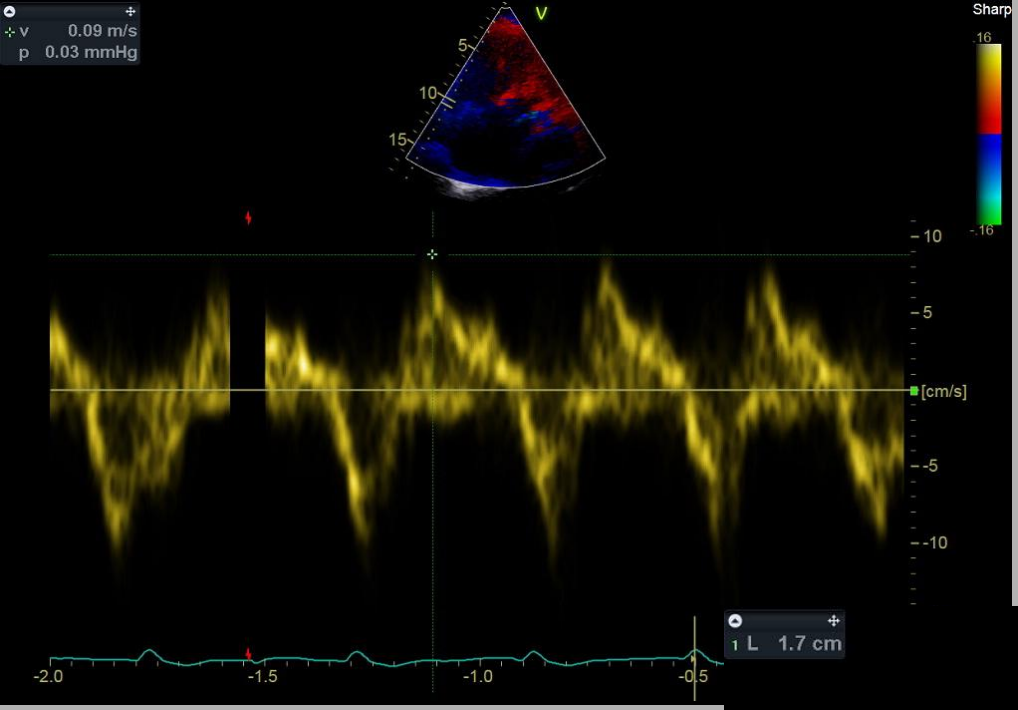
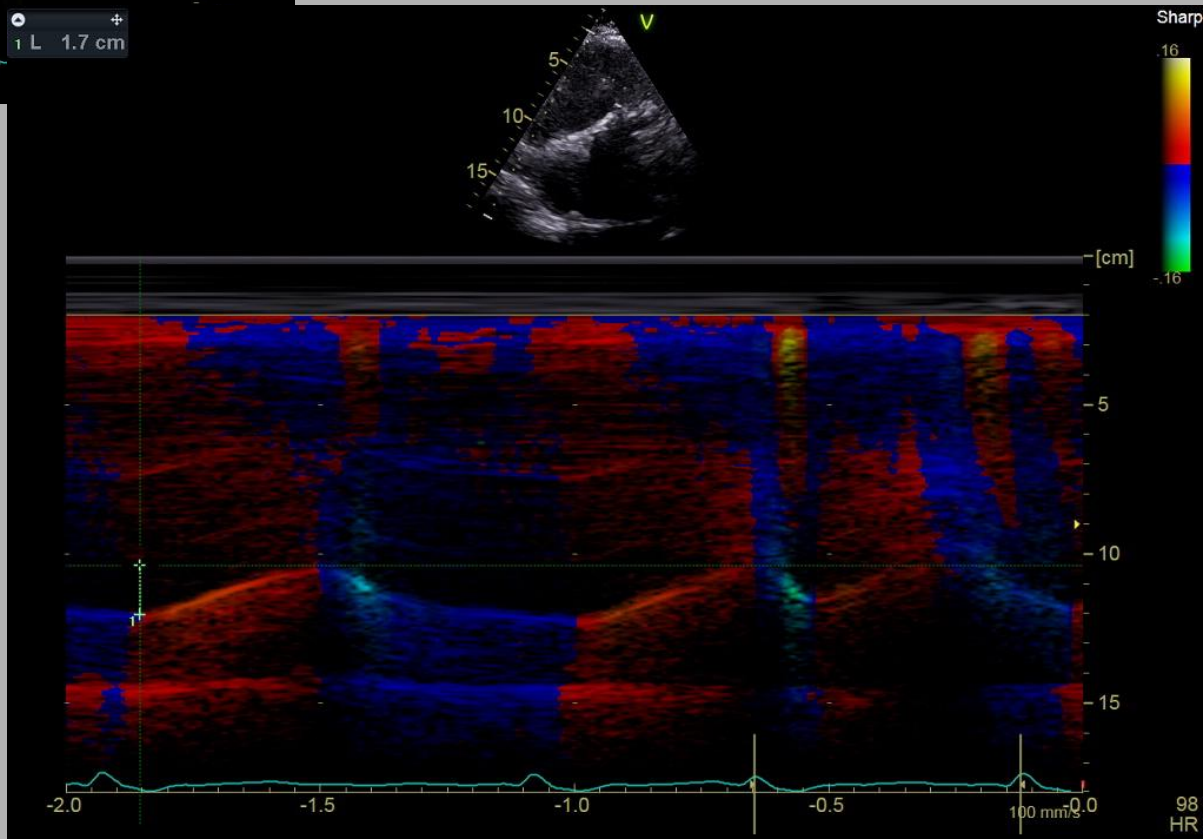
95
2:11 HR

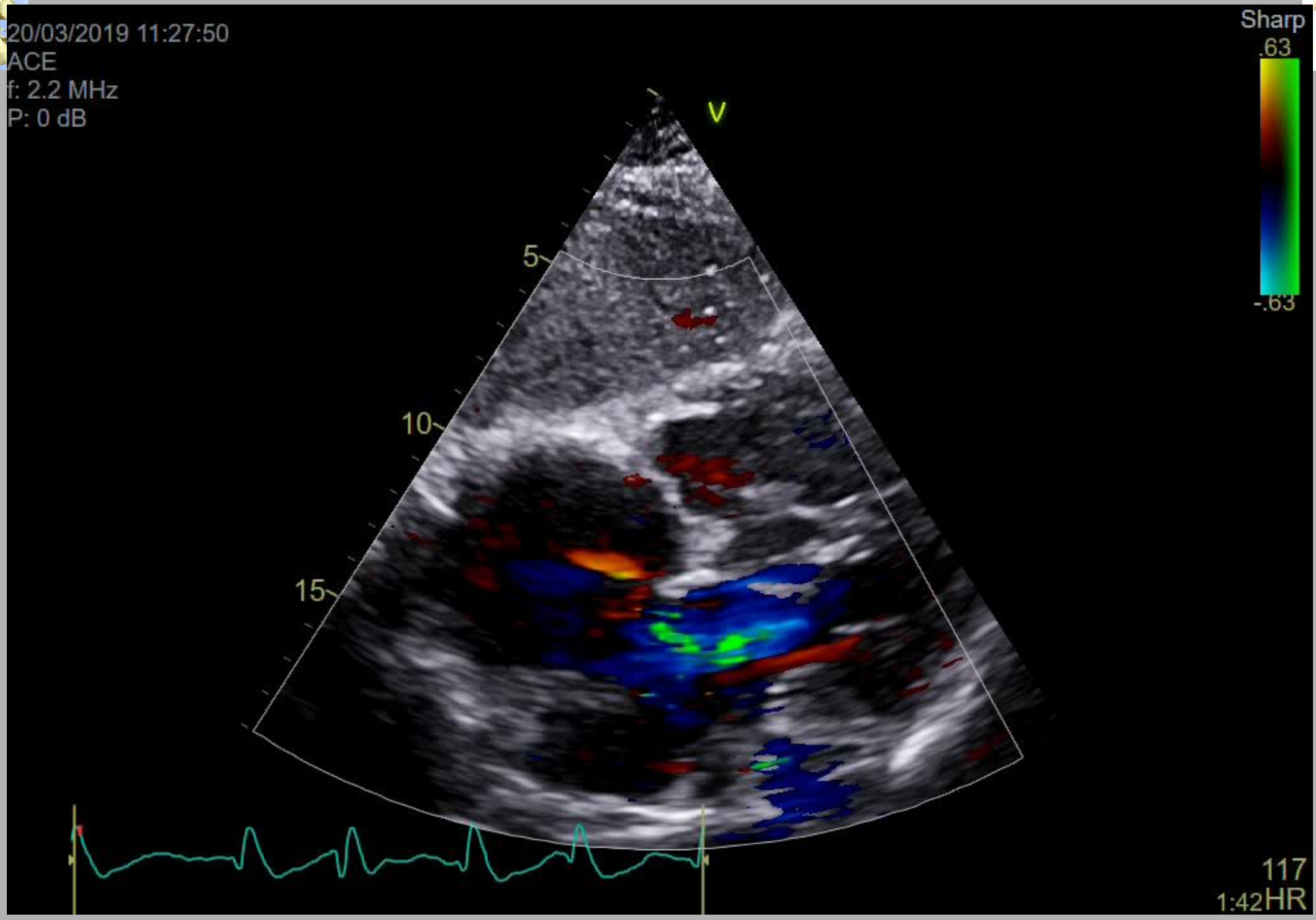


RV SP 55-60mmHg




v 0.09 m/s
p 0.03 mmHg
V
5
10
15
Sharp
16
-16
10
5
[cm/s]
-5
-10
1 L 1.7 cm
-2.0
-1.5
-1.0
-0.5


V
5
10
15
Sharp
16
-16
[cm]
5
10
15
-2.0
-1.5
-1.0
-0.5
0.0
100 mm/s
98
HR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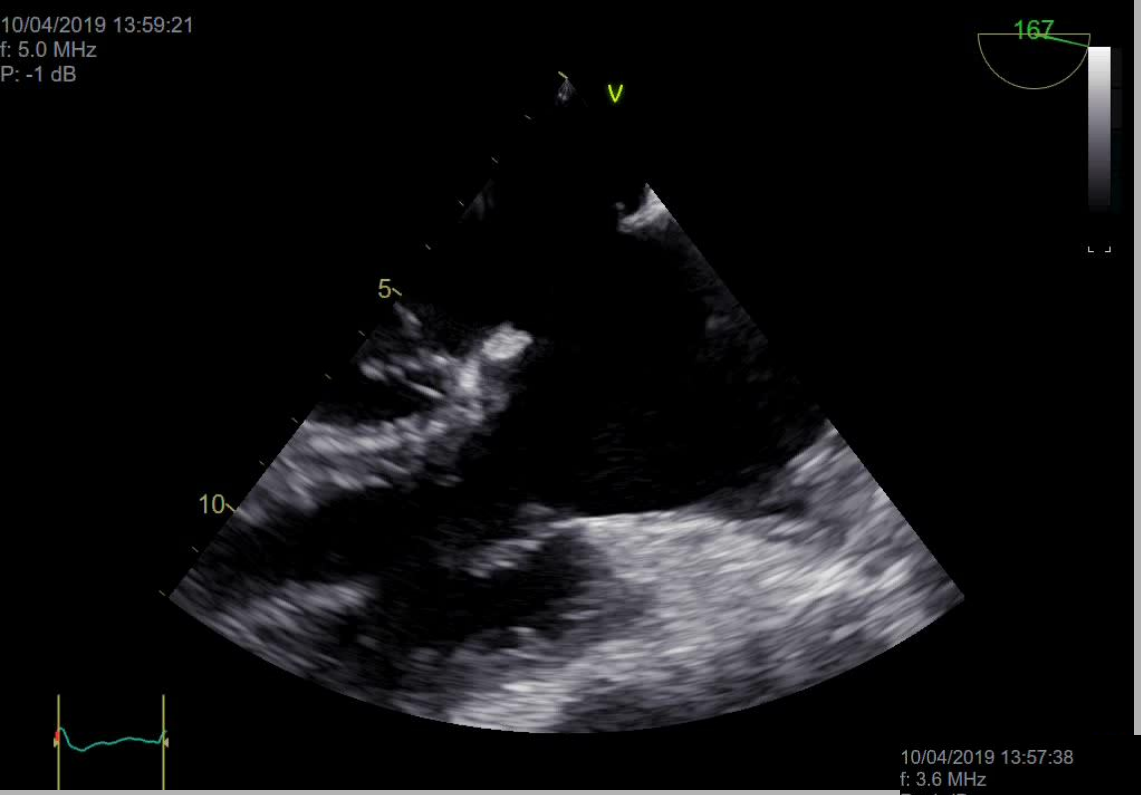
ACE
f: 2.2 MHz
P: 0 dB
V
5
10
15
Sharp
.63
-.63
117
1:42HR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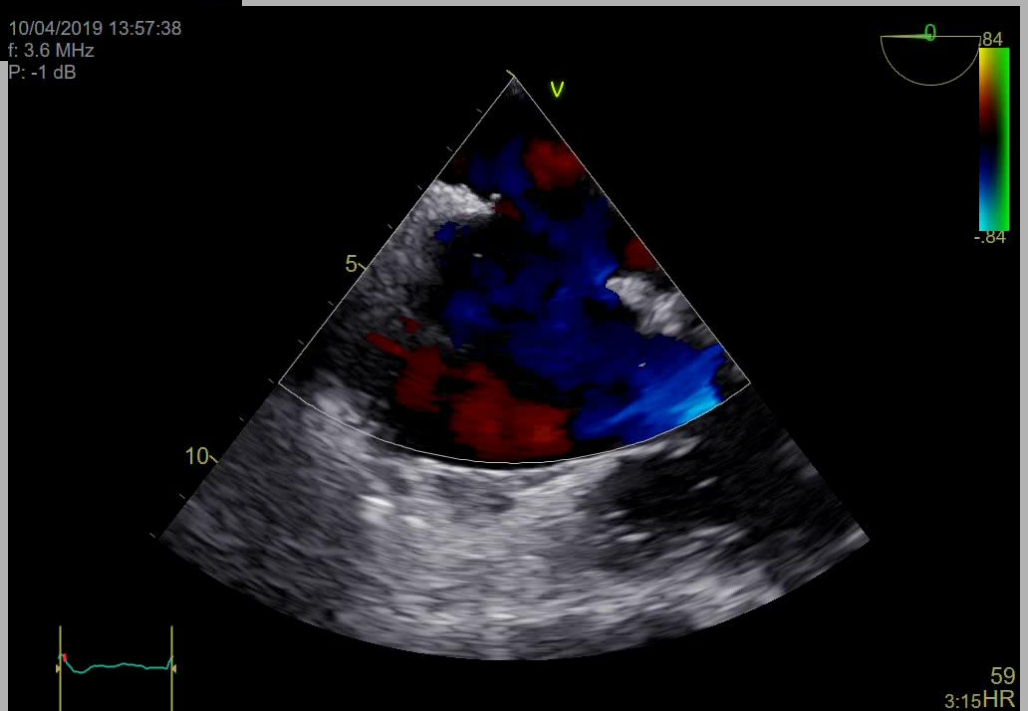
P: -1 dB
167
V
5
10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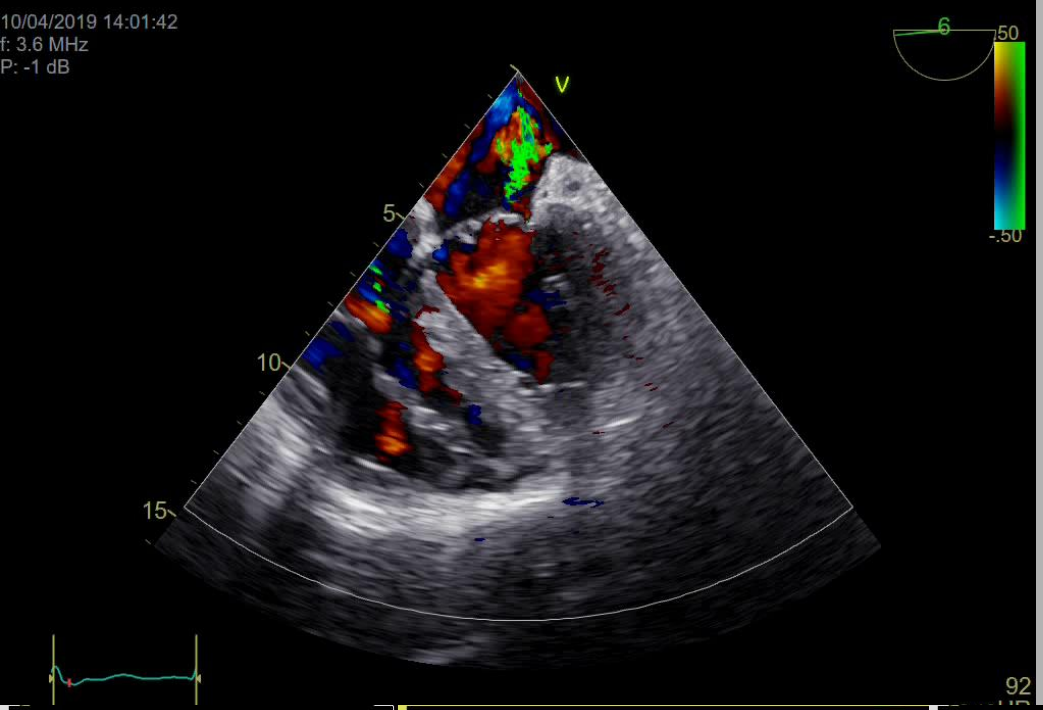
0
84
-.84
V
5
10
59
3:15HR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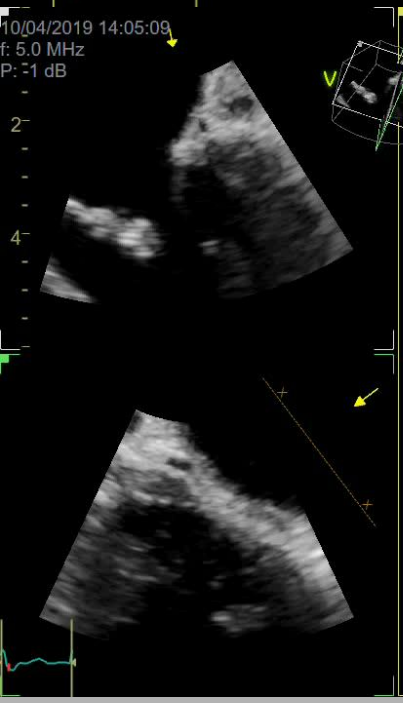
P: -1 dB
6
50
-.50
V
5
10
15
92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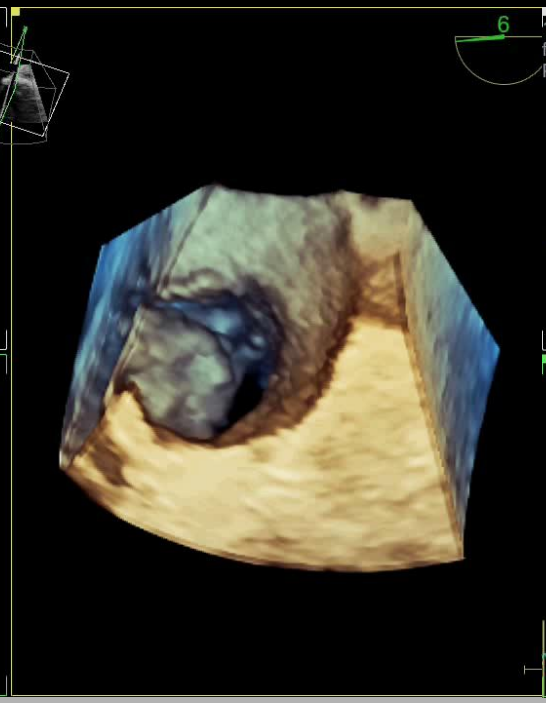
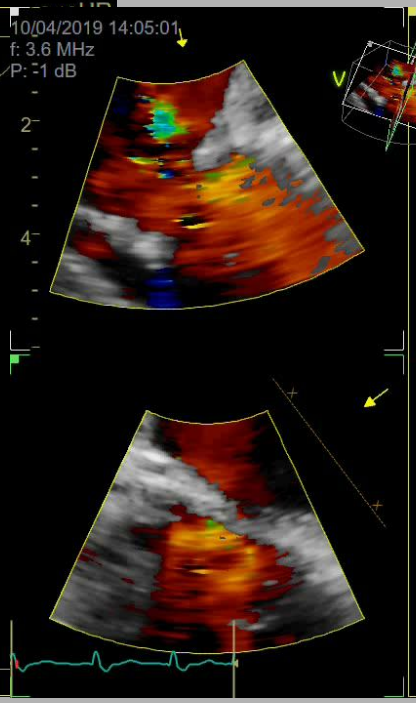
f: 5.0 MHz
P: -1 dB
V
2
4


6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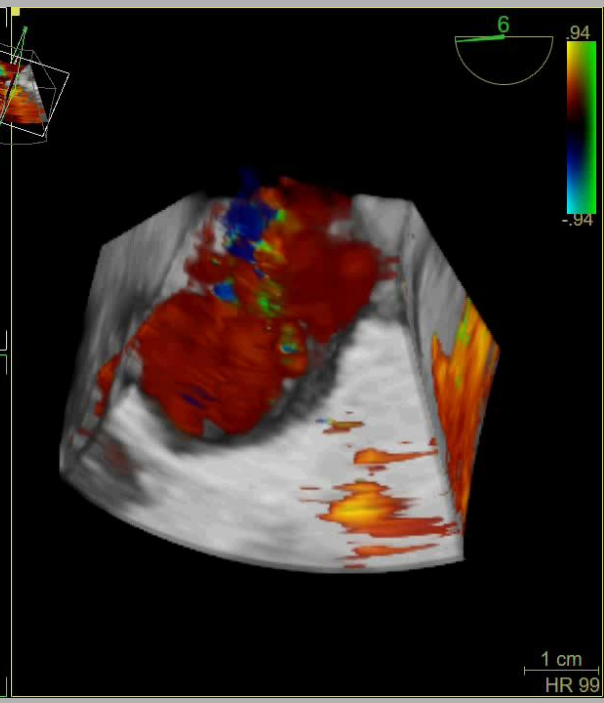
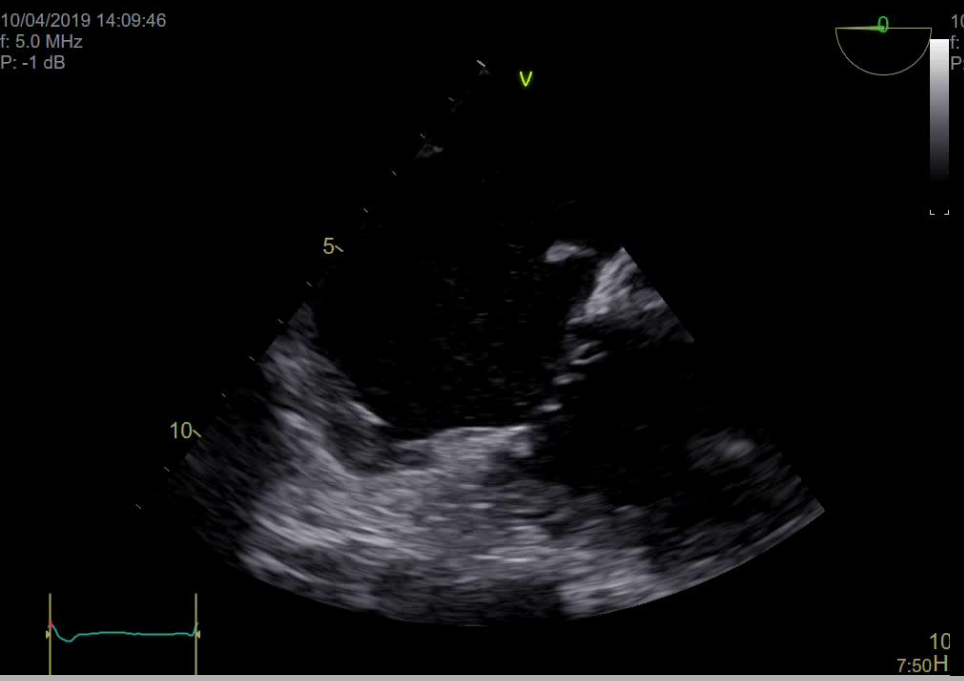
f: 3.6 MHz
P: -1 dB
6
V
2
4


6
.94
-.94
1 cm
HR 99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P: -1 dB
V
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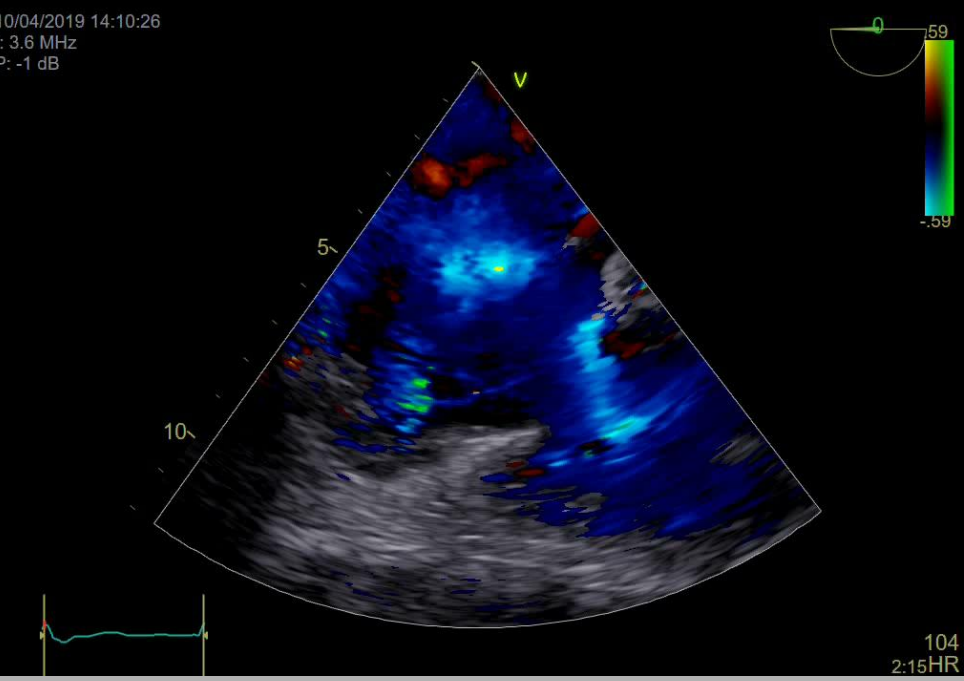
7:50H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P: -1 dB
59
-.59
V
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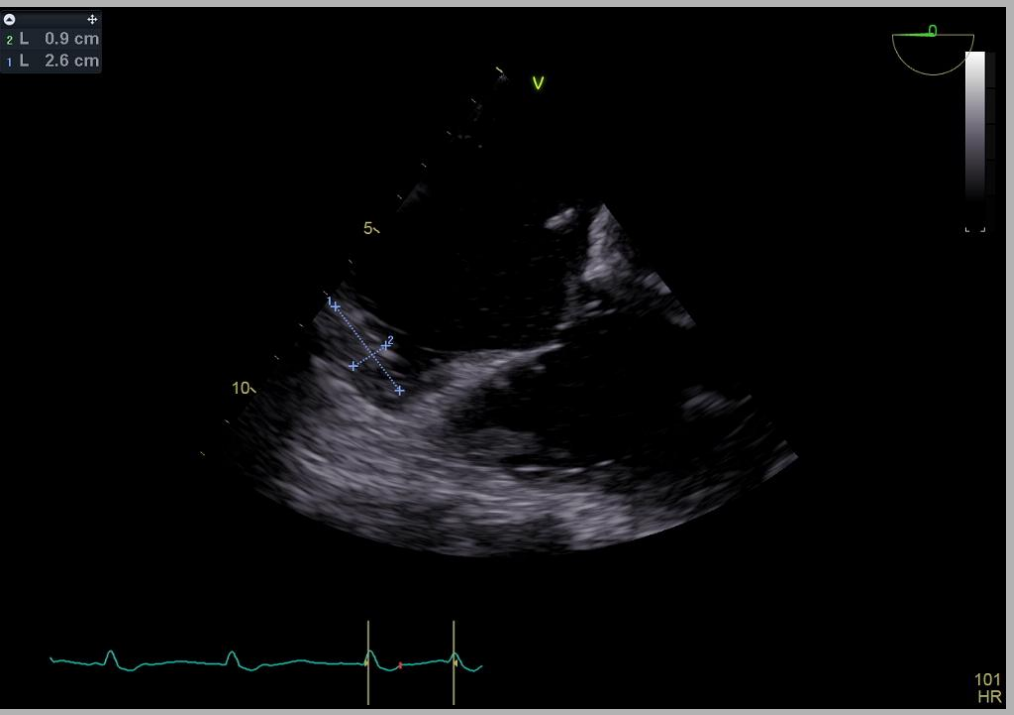
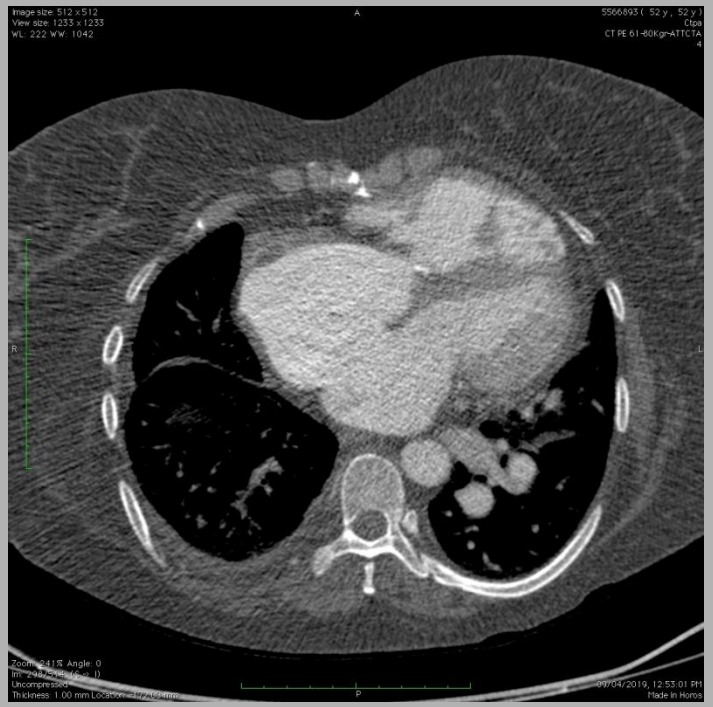
104
2:15HR


2 L 0.9 cm
1 L 2.6 cm
V
5
10
101
HR

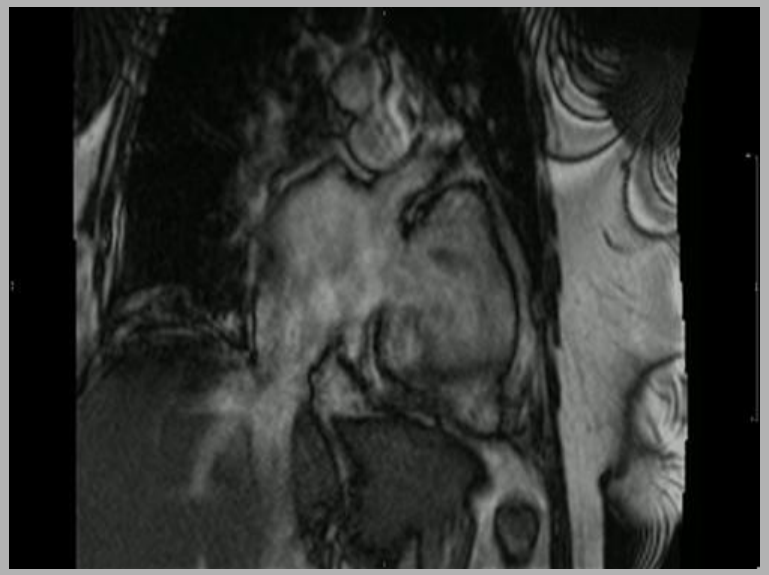
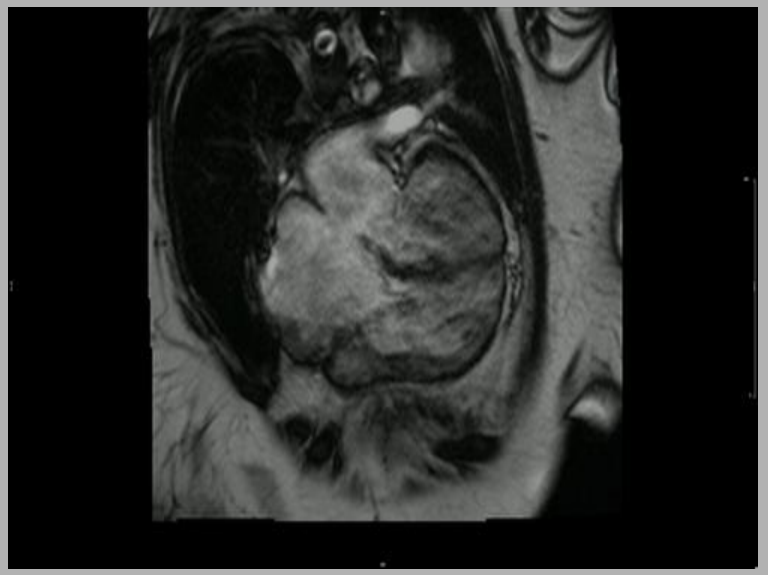
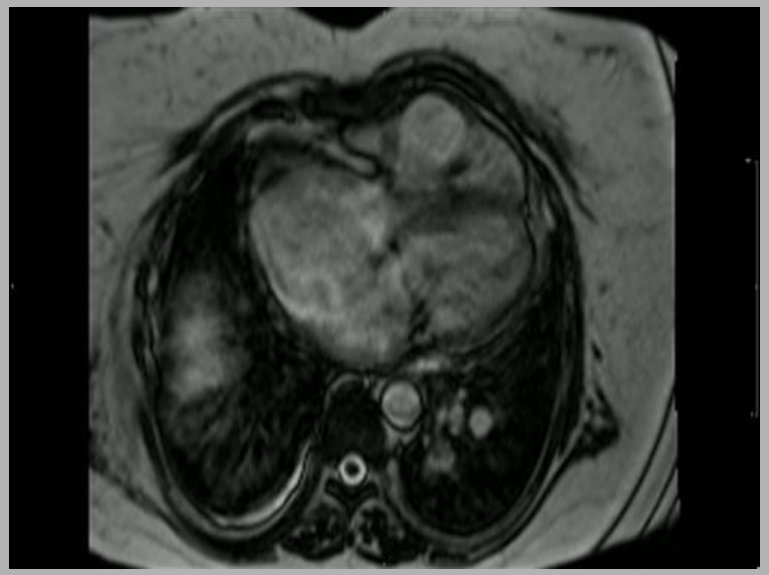
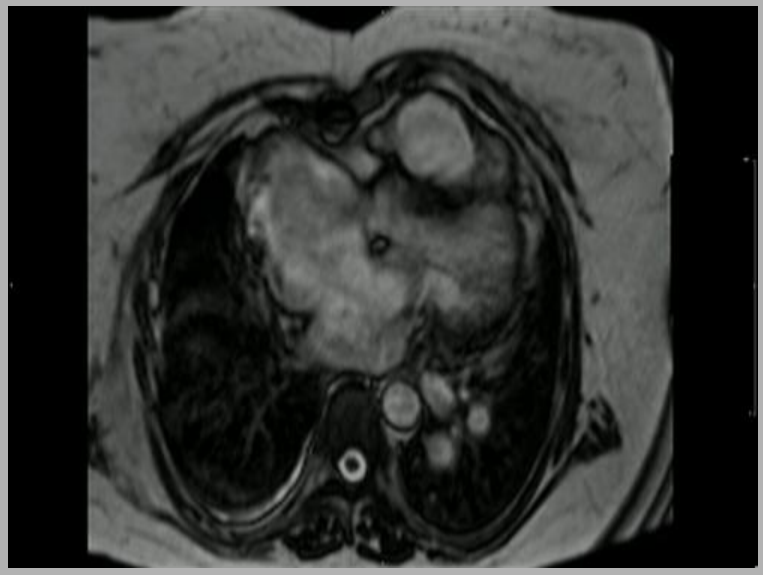
CTPA

- No signs of pulmonary embolism
- Main and left PA dilation up to 4cm
- Small right PA
- Small pleural effusion

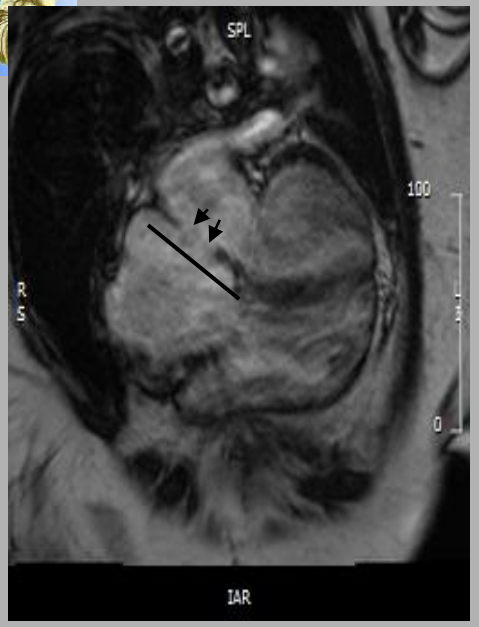


MRI

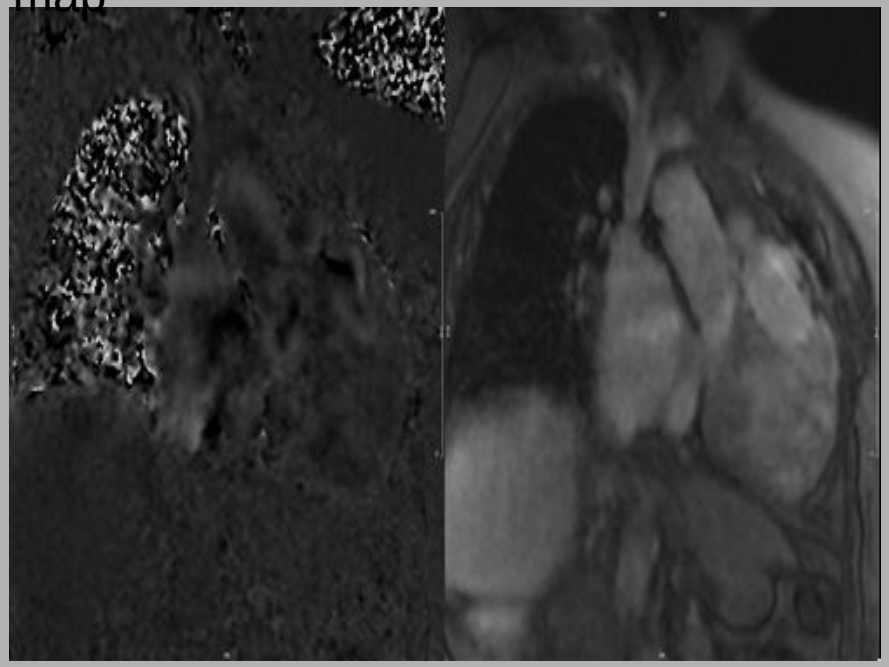
- LV EF 45%
- RV EF 25%
- Severe pulmonary regurgitation (RF 40%)
- Dilated main and left PA
- Small right PA (RPA: LPA 23%:77%)
- Small RA thrombus

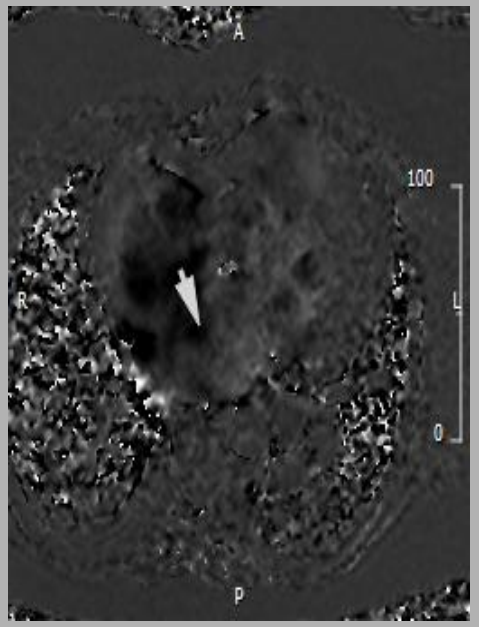





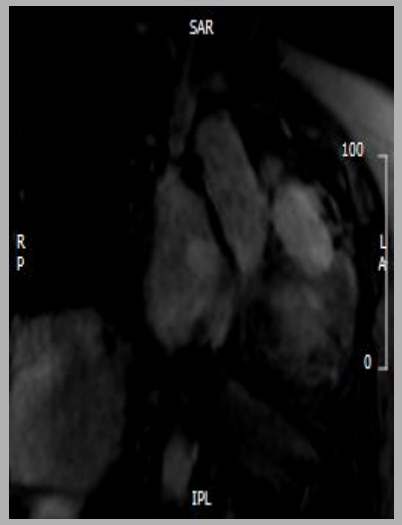
En face flow map

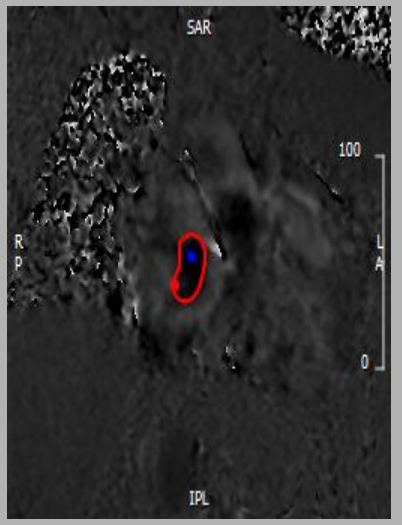


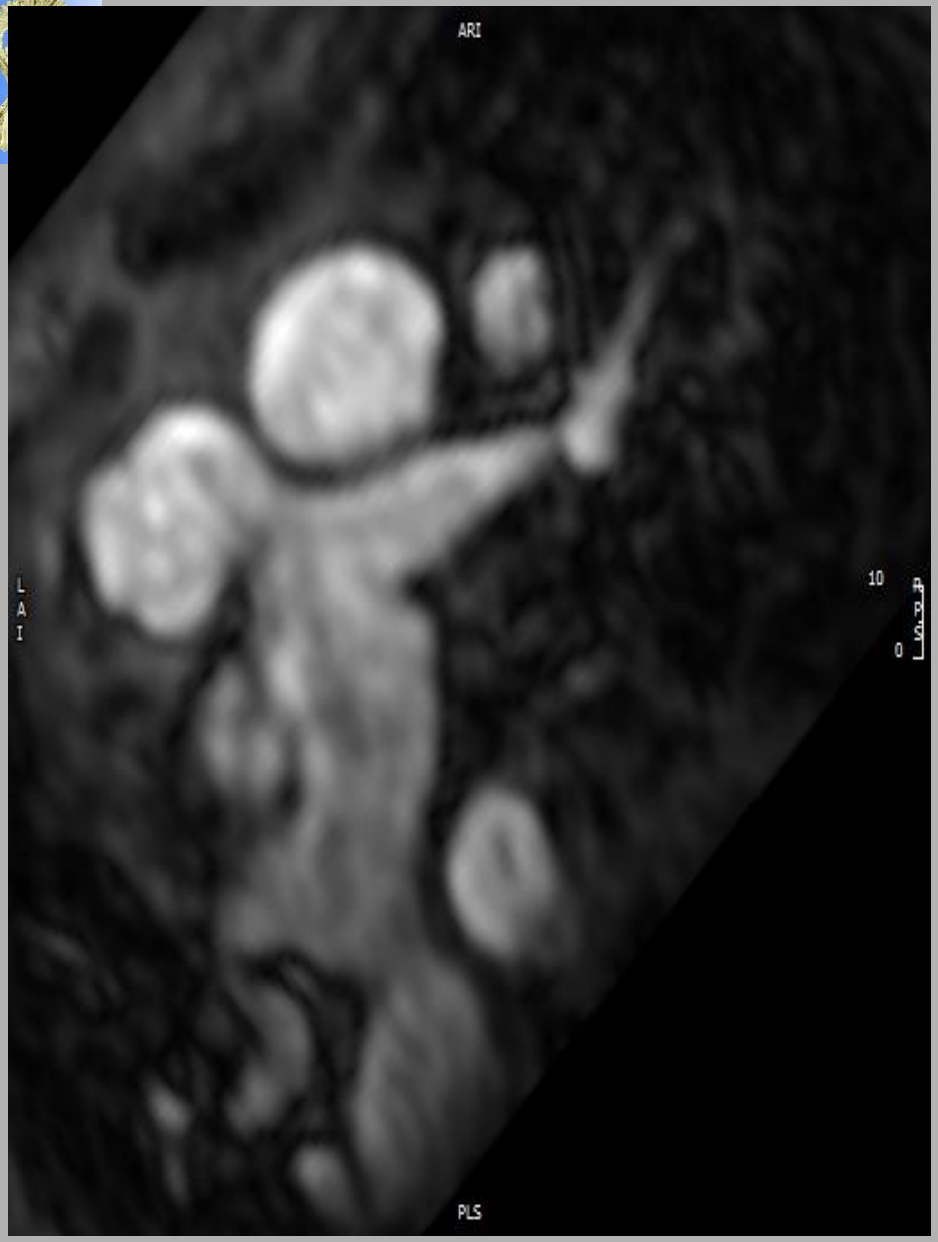
Large ASD
Bidirectional flow










ARI
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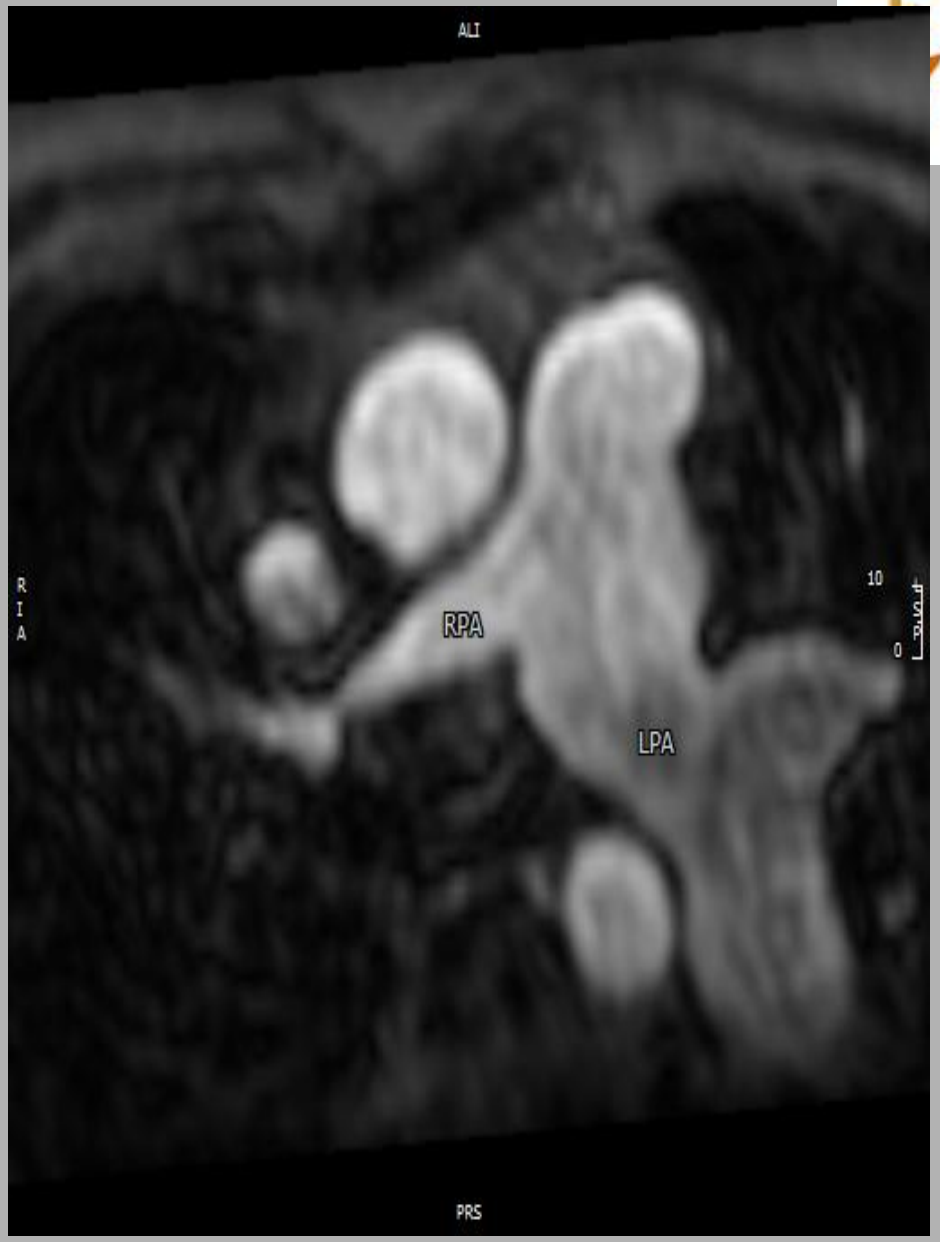
PLS


ALI
R
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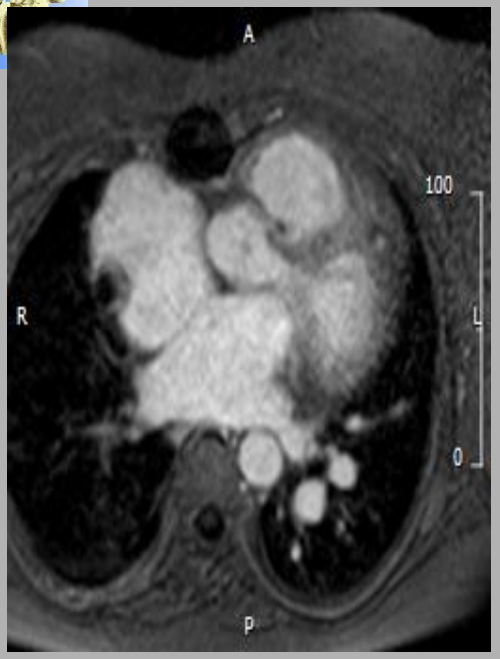
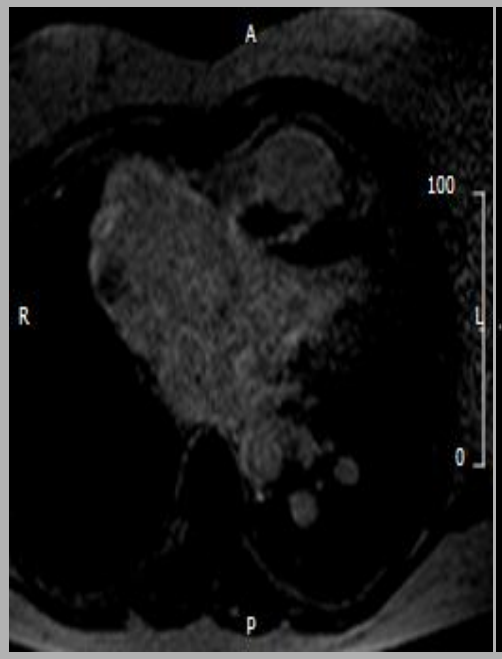
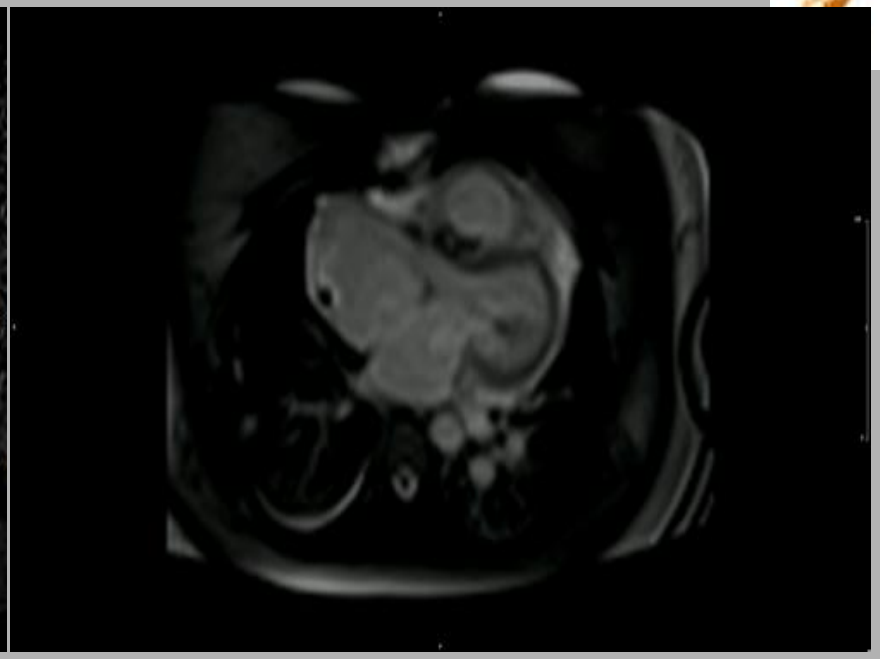
RPA
LPA
10
P
S
0
PRS

Early Gd

Late Gd







Work-up

- Abdomen U/S
- Connective tissue diseases work-up
- 24 hour Holter monitoring

Treatment

- Iron intravenously
- Digoxin
- B Blocker
- Eplerenone
- Furosemide
- Coumadin

What is the cause of pulmonary hypertension?

- Segmental pulmonary hypertension?
- Atrial septal defect?
- Post capillary pulmonary hypertension?

Management?

- Reduce the RV volume overload
- Targeted PAH therapy
- Medical treatment

Haemodynamic definitions and updated clinical classification of pulmonary hypertension

Gérald Simonneau[1,2], David Montani[1,2], David S. Celermajer[3], Christopher P. Denton[4], Michael A. Gatzoulis[5], Michael Krowka[6], Paul G. Williams[7] and Rogerio Souza[8]

Number 4 in the series
"Proceedings of the 6th World Symposium on Pulmonary Hypertension"
Edited by N. Galiè, V.V. McLaughlin, L.J. Rubin and G. Simonneau

TABLE 1 Haemodynamic definitions of pulmonary hypertension (PH)

Definitions	Characteristics	Clinical groups#
Pre-capillary PH	mPAP >20 mmHg PAWP ⩽15 mmHg PVR ⩾3 WU	1, 3, 4 and 5
Isolated post-capillary PH (IpcPH)	mPAP >20 mmHg PAWP >15 mmHg PVR <3 WU	2 and 5
Combined pre- and post-capillary PH (CpcPH)	mPAP >20 mmHg PAWP >15 mmHg PVR ⩾3 WU	2 and 5

Eur Respir J Jan 2019

Pulmonary Hypertension associated with Congenital Heart Disease

1. Eisenmenger's syndrome Includes all large intra- and extra-cardiac defects which begin as systemic-to-pulmonary shunts and progress with time to severe elevation of PVR and to reversal (pulmonary-to-systemic) or bidirectional shunting; cyanosis, secondary erythrocytosis, and multiple organ involvement are usually present.
2. PAH associated with prevalent systemic-to-pulmonary shunts • Correctable[a] • Non-correctable Includes moderate to large defects; PVR is mildly to moderately increased, systemic-to-pulmonary shunting is still prevalent, whereas cyanosis at rest is not a feature.
3. PAH with small/coincidental defects[b] Marked elevation in PVR in the presence of small cardiac defects (usually ventricular septal defects <1 cm and atrial septal defects <2 cm of effective diameter assessed by echo), which themselves do not account for the development of elevated PVR; the clinical picture is very similar to idiopathic PAH. Closing the defects is contra-indicated.
4. PAH after defect correction Congenital heart disease is repaired, but PAH either persists immediately after correction or recurs/develops months or years after correction in the absence of significant postoperative haemodynamic lesions.

PAH Guidelines 2015

GROUP 5

TABLE 7 Pulmonary hypertension with unclear and/or multifactorial mechanisms

5.1 Haematological disorders	Chronic haemolytic anaemia Myeloproliferative disorders
5.2 Systemic and metabolic disorders	Pulmonary Langerhans cell histiocytosis Gaucher disease Glycogen storage disease Neurofibromatosis Sarcoidosis
5.3 Others	Chronic renal failure with or without haemodialysis Fibrosing mediastinitis
5.4 Complex congenital heart disease	See the Task Force article by ROSENZWEIG *et al.* [31] in this issue of the *European Respiratory Journal*

Galie et al Eur J Respir 2019

TABLE 5 Complex congenital heart disease (group 5.4)

Segmental pulmonary hypertension
- Isolated pulmonary artery of ductal origin
- Absent pulmonary artery
- Pulmonary atresia with ventricular septal defect and major aorto-pulmonary collateral arteries
- Hemitruncus
- Other

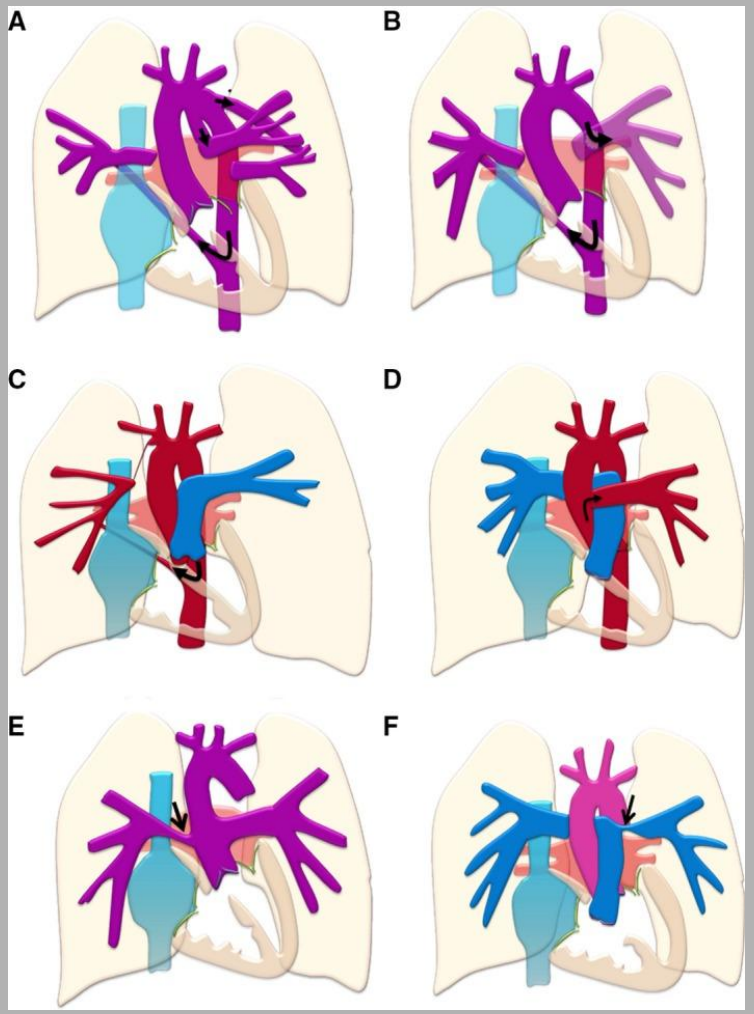
Single ventricle
- Unoperated
- Operated

Scimitar syndrome

Rosenweig et al EurJ Respir 2019

Definition and Management of Segmental Pulmonary Hypertension

Konstantinos Dimopoulos, MD, MSc, PhD, FESC; Gerhard-Paul Diller, MD, PhD, FESC; Alexander R. Opotowsky, MD, MPH, MMSc; Michele D'Alto, MD, PhD, FESC; Hong Gu, MD, PhD; George Giannakoulas, MD, PhD; Werner Budts, MD, PhD, FESC; Craig S. Broberg, MD; Gruschen Veldtman, FRCP, MBChB; Lorna Swan, MBChB, FRCP, MD; Maurice Beghetti, MD, FESC; Michael A. Gatzoulis, MA, MD, PhD, FESC, FACC



In patients with complex pulmonary atresia or truncus arteriosus, the **RV does not eject blood into the pulmonary circulation**, and hence it is not directly affected by changes in pulmonary pressure and resistances

Separate detailed assessment of PA pressures and calculation of pulmonary vascular resistance (PVR) in each lung segment is required to fully understand lung pathophysiology and the severity of PH in these patients.This often, however, proves difficult even in expert hands.

Targeted therapy may be beneficial

JAMA 2018

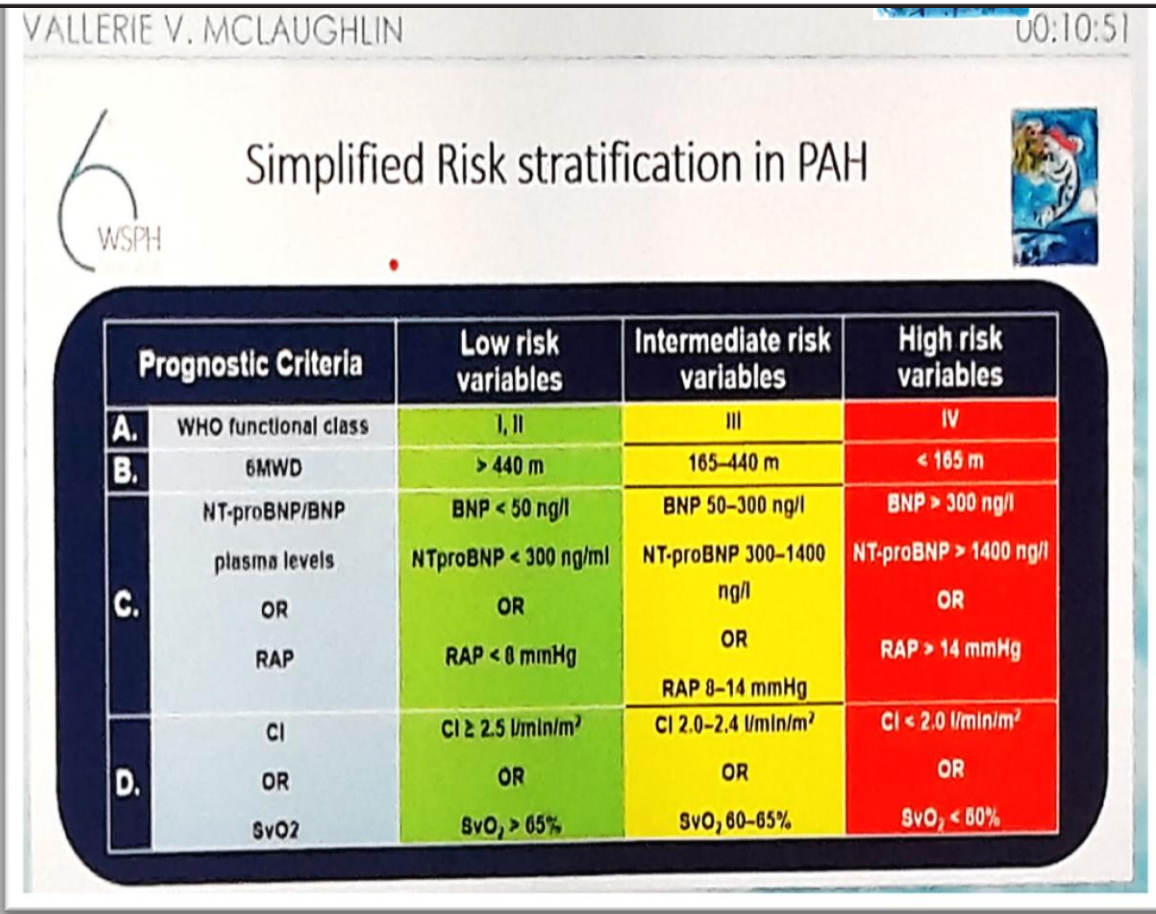
TABLE 1 Summary of four registries assessing risk scores

	REVEAL [17–19]	Swedish PAH Register [6]	COMPERA [7]	French Pulmonary Hypertension Network [8
Required variables n	12–14	8	8	4
Patients at baseline n	2716	530	1588	1017
Patients at follow-up n	2529	383	1094	1017
Associated PAH included	Yes	Yes	Yes	No
Definition of low risk	⩽6 REVEAL score	<1.5 average score	<1.5 average score	3–4 out of 4 low-risk crite
1-year mortality by risk group (low/intermediate/high) %	⩽2.6/7.0/⩾10.7	1.0/7.0/26.0	2.8/9.9/21.2	1.0/NA/13.0–30.0

- Interestingly, the variables with the highest yield in the registries analyses are similar, i.e. FC, 6MWD, NT-proBNP or BNP plasma levels, cardiac index, RAP and SvO2

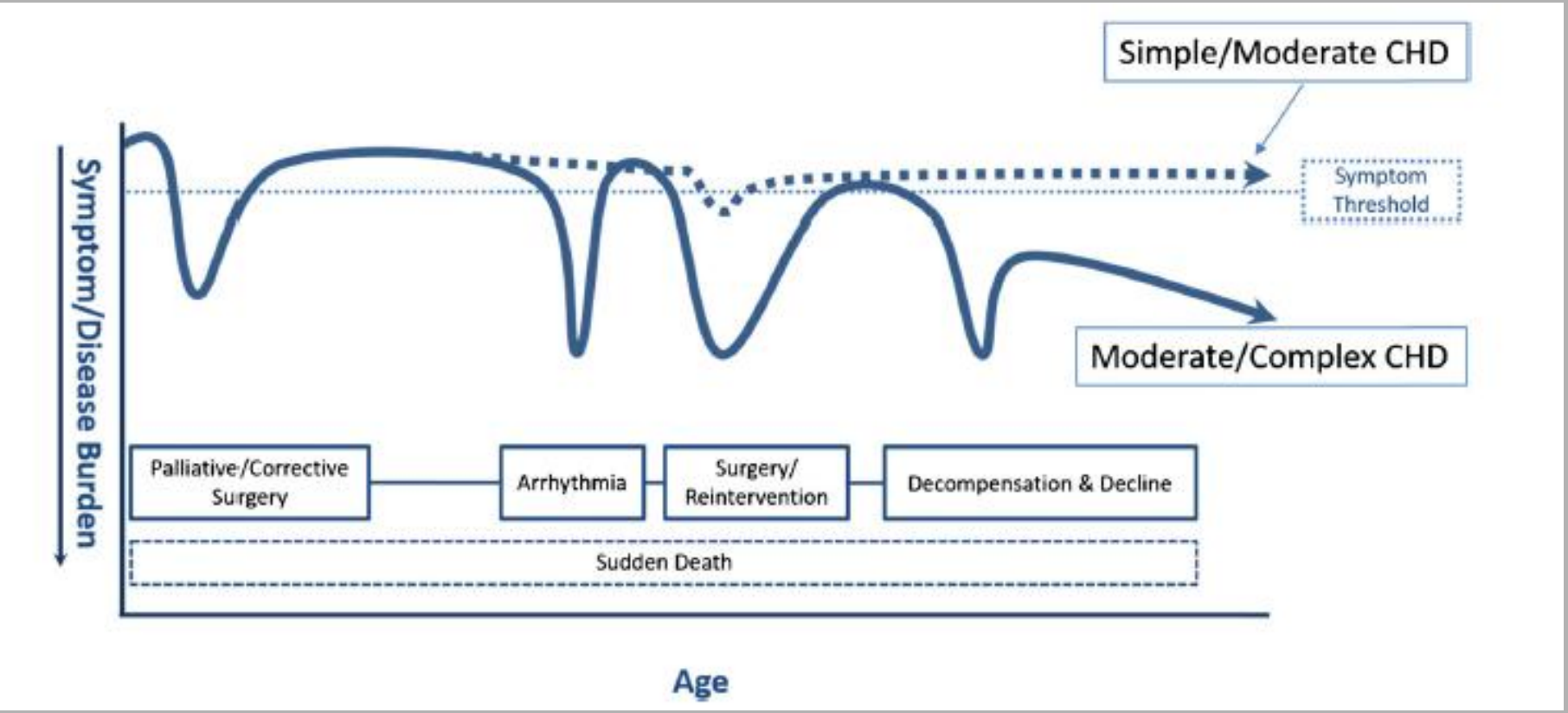
Galie et al Eur J Respir 2019

Dardi wt al ESC 2018



Prognostic Criteria		Low risk variables	Intermediate risk variables	High risk variables
A.	WHO functional class	I, II	III	IV
B.	6MWD	> 440 m	165–440 m	< 165 m
C.	NT-proBNP/BNP plasma levels OR RAP	BNP < 50 ng/l NTproBNP < 300 ng/ml OR RAP < 8 mmHg	BNP 50–300 ng/l NT-proBNP 300–1400 ng/l OR RAP 8–14 mmHg	BNP > 300 ng/l NT-proBNP > 1400 ng/l OR RAP > 14 mmHg
D.	CI OR SvO2	CI ≥ 2.5 l/min/m² OR SvO_2 > 65%	CI 2.0–2.4 l/min/m² OR SvO_2 60–65%	CI < 2.0 l/min/m² OR SvO_2 < 60%

Burden of Heart Failure in Adults with Congenital Heart Disease



Alshawabkeh and Opotowsky Curr Heart Fail Rep Aug 2016

Growing Adult Congenital Heart Disease Population

Treatment of heart failure in adult congenital heart disease: a position paper of the Working Group of Grown-Up Congenital Heart Disease and the Heart Failure Association of the European Society of Cardiology

Werner Budts[1]*, Jolien Roos-Hesselink[2], Tanja Rädle-Hurst[3], Andreas Eicken[4], Theresa A. McDonagh[5], Ekaterini Lambrinou[6], Maria G. Crespo-Leiro[7], Fiona Walker[8], and Alexandra A. Frogoudaki[9]

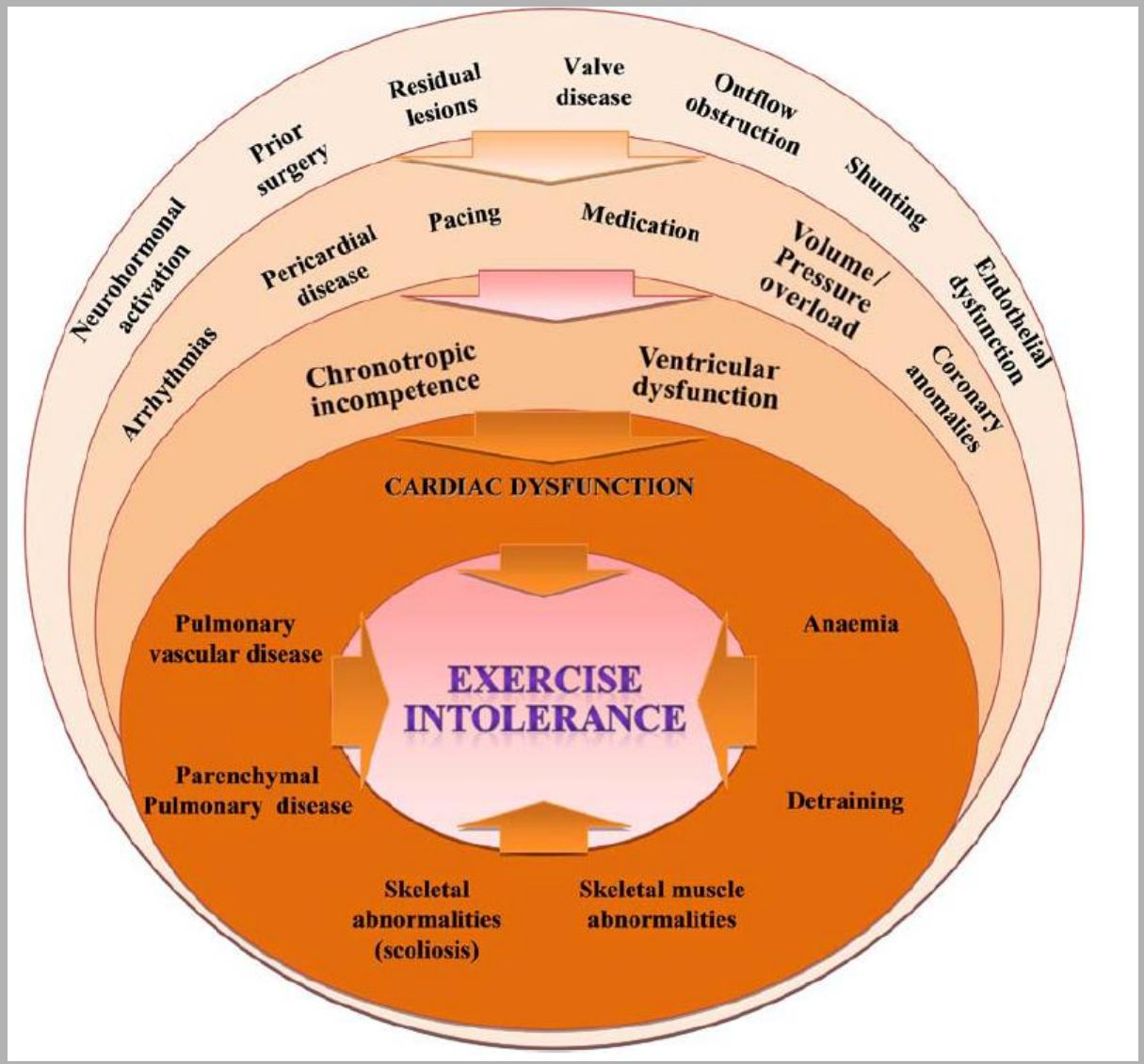
Eur Heart J Jan 2016

Causes and Mechanisms

Causes	Mechanisms
Genetics	Sarcomere structure
CHD-related hemodynamic sequelae	Pressure and/or pressure-volume overload of systemic and/or subpulmonary ventricle, reduced cardiac output
Fibrosis	Hypertrophy, increased filling pressures, surgical scars
Cyanosis	Hypoxia
Impaired myocardial perfusion—ischemia	Congenital coronary artery abnormalities, postsurgical coronary artery abnormalities, demand-supply oxygen mismatch
Arrhythmias	Tachycardia-induced cardiomyopathy, dyssynchrony
Acquired heart disease	Coronary artery disease, diabetes mellitus, arterial hypertension

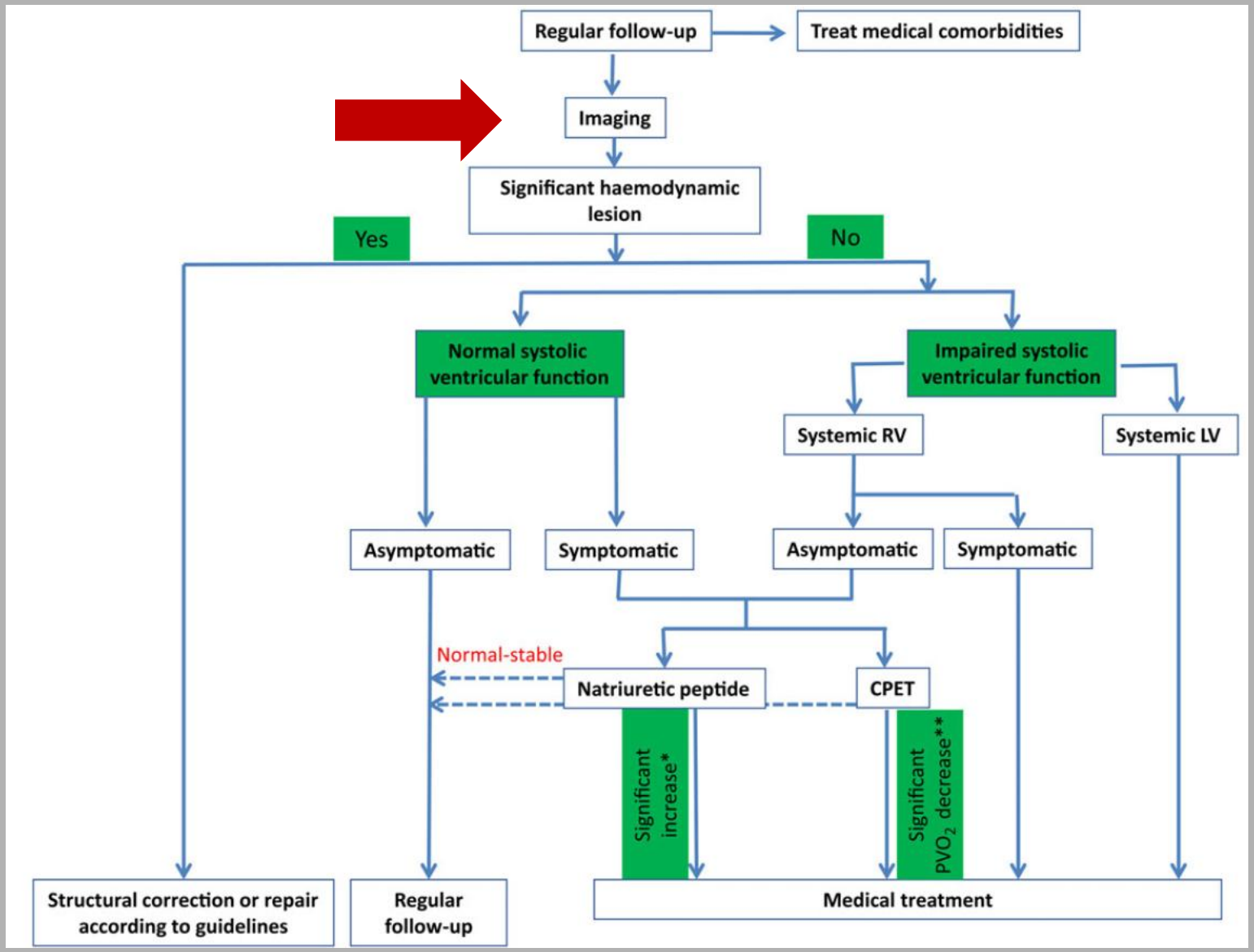
Heart Failure in Congenital Heart Disease. Swan and Frogoudaki, Springer 2018

Exercise Intolerance

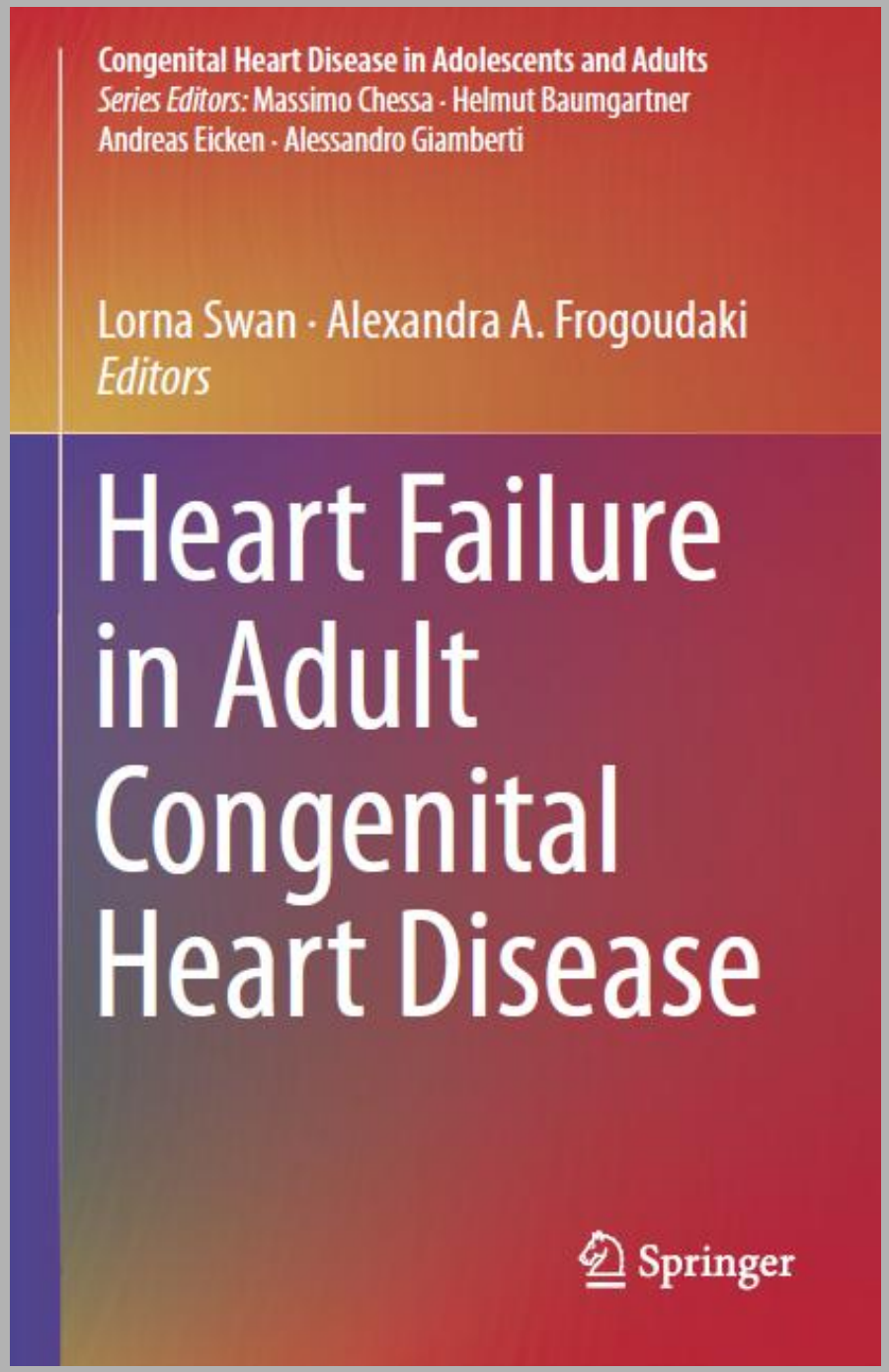


Stout et al Circulation Feb 2016

Management



Budts et al Eur Heart J Jan 2016


Congenital Heart Disease in Adolescents and Adults
Series Editors: Massimo Chessa · Helmut Baumgartner
Andreas Eicken · Alessandro Giamberti
Lorna Swan · Alexandra A. Frogoudaki
Editors
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