NewYork-Presbyterian

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Bedside echocardiography in the evaluation of right heart dysfunction in acute pulmonary embolus

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Case information

36 year old G2P1 at 9 weeks of pregnancy and without any other significant PMH. At home and syncopized after standing from using toilet. Awoke and was talking to her husband when she stopped responding. EMS was called and found her awake, hypoxic, and complaining of blurry vison and chest pain. She was taken by ambulance to Stamford Hospital…

Case information

- En route ?seizure with unclear treatment
- Once in ED brady -> PEA -> ACLS
- Intubated, epi x 1 -> VF -> shock -> Afib with RVR
- CT-PE with L and R main PA thrombi
- Heparin drip started and then transferred to NYP-WC

Case information

WBC 11, Hb 10, Plt 219

Na 140, K 5.4, HCO3 17, BUN 12, Cr 0.69

ABG 7.26/43/239

Troponin 2.8

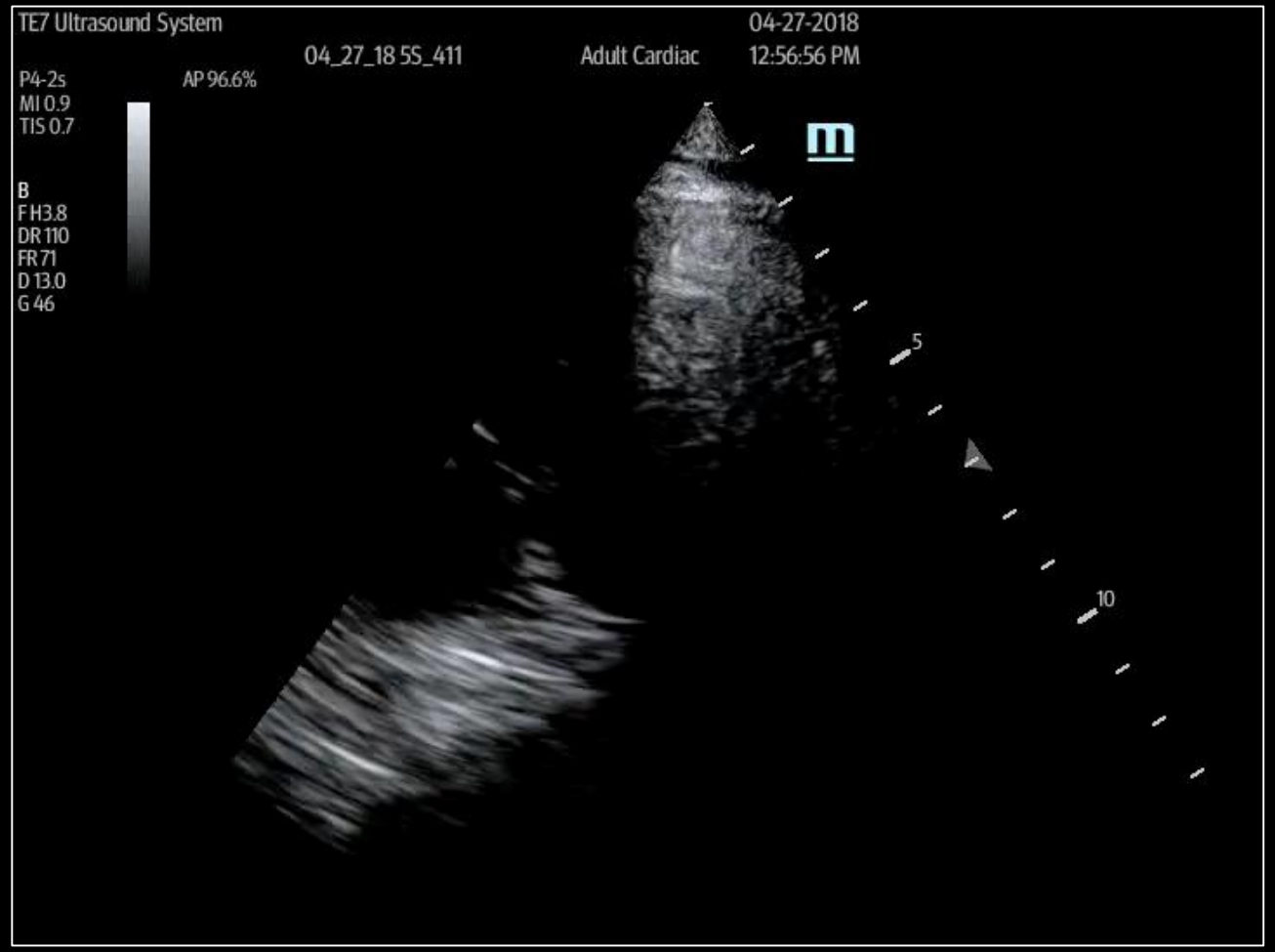
BNP 7

AST 566, ALT 529, AP 98, Tbili 0.2

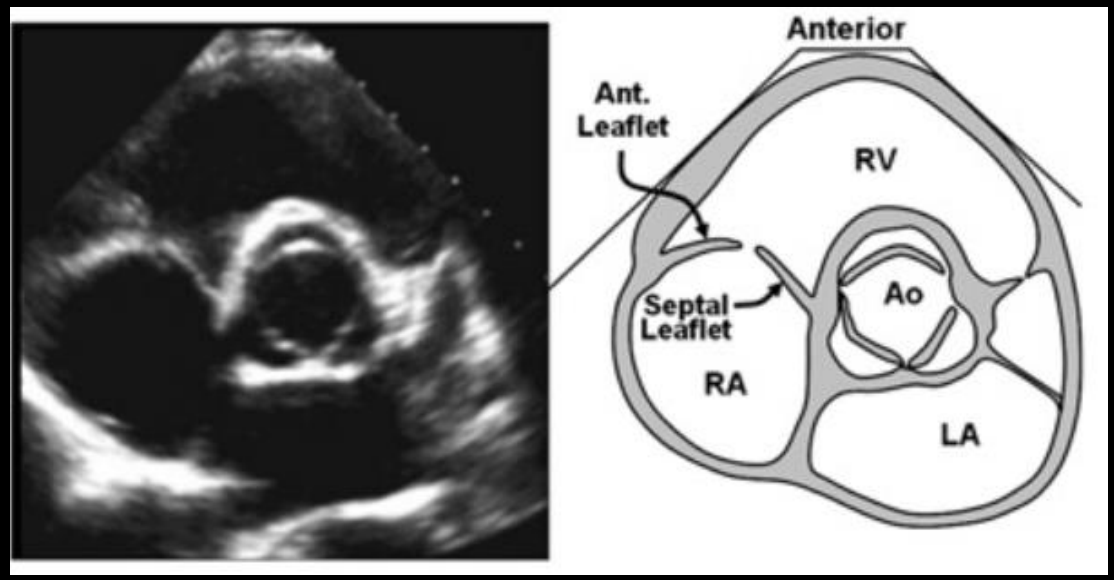
INR 1.2

Parasternal long axis

Parasternal short axis

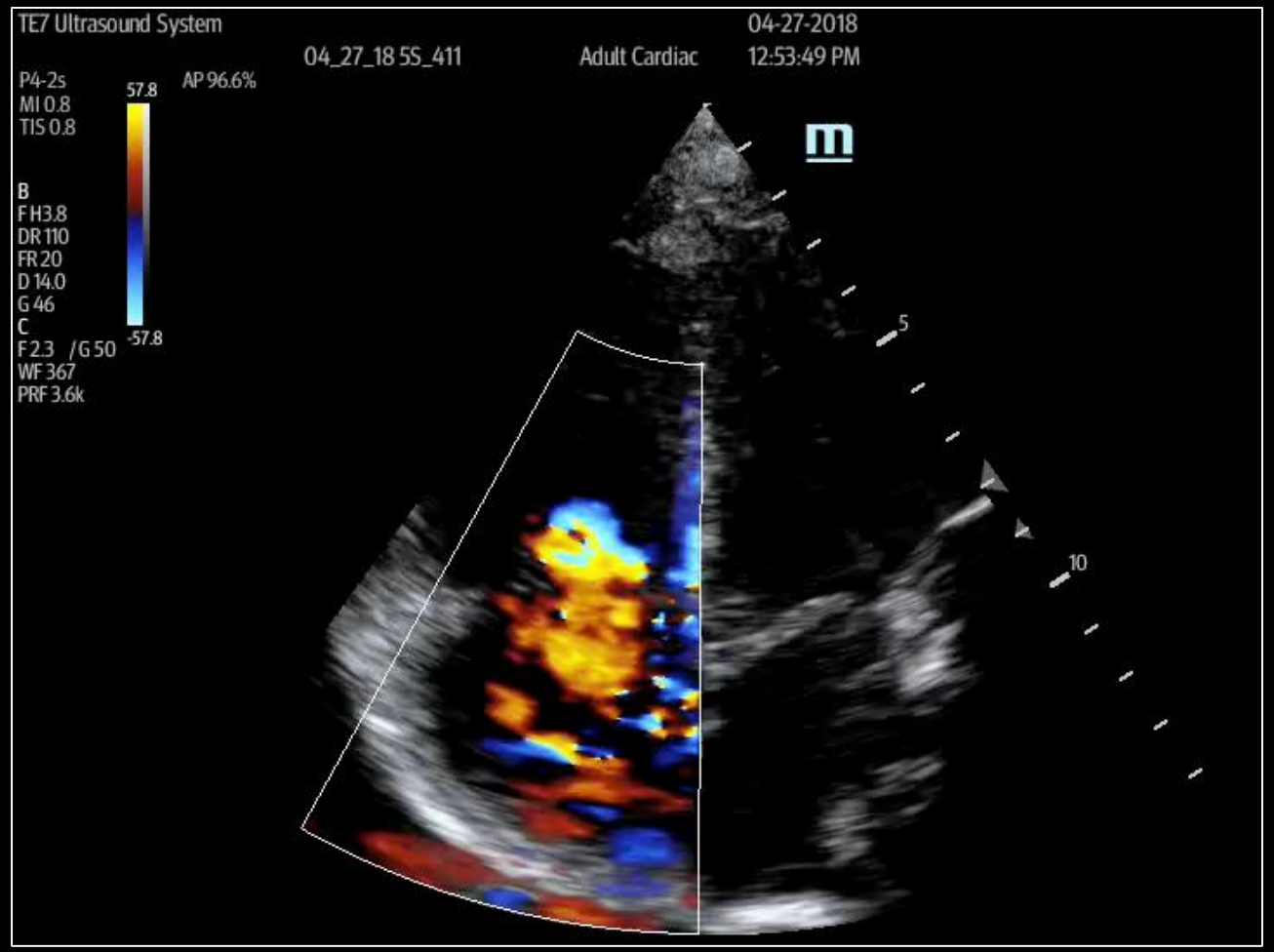


Parasternal short axis: basal RV view

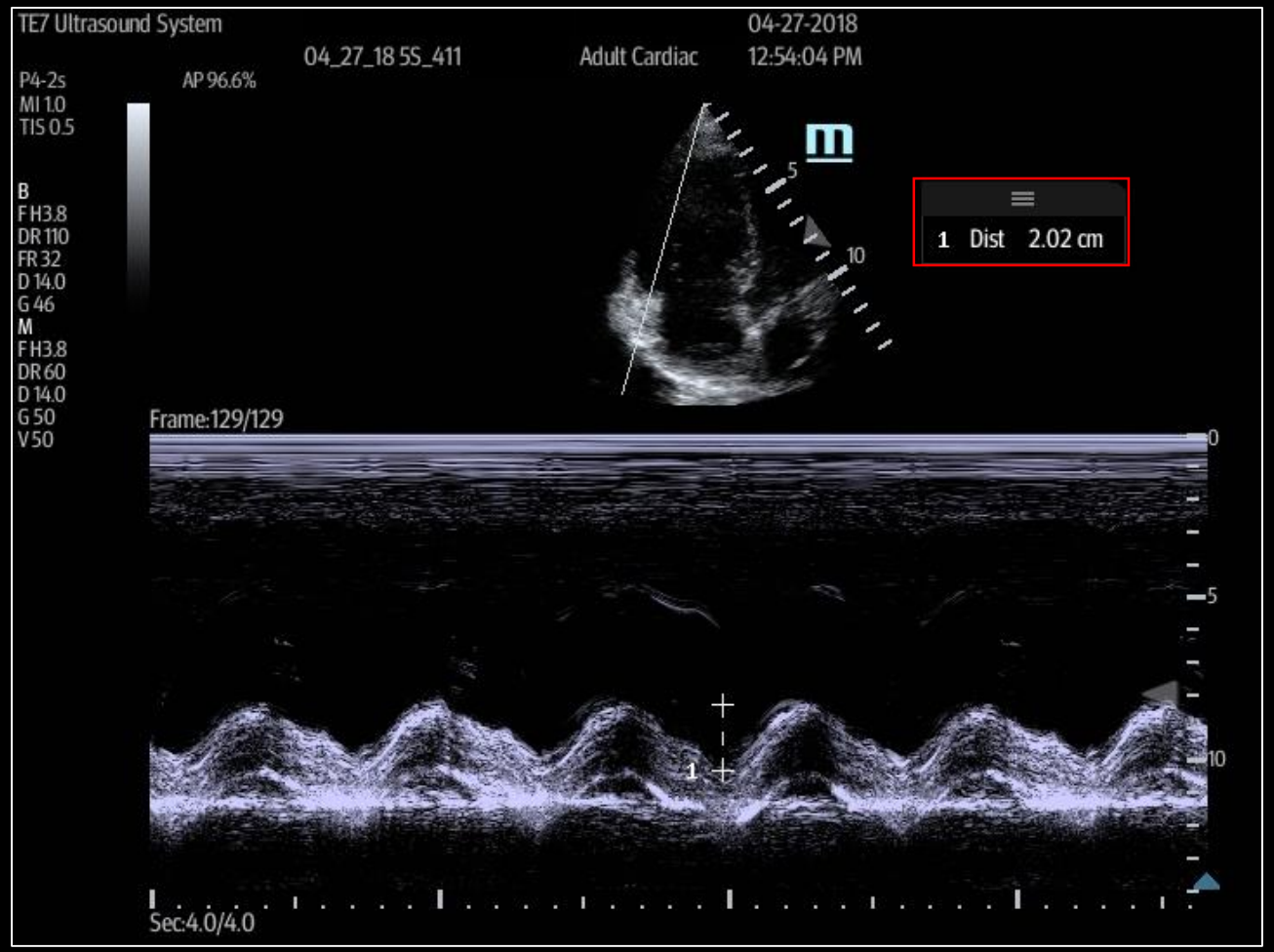


Apical 4-chamber

Apical 4-chamber: color flow Doppler



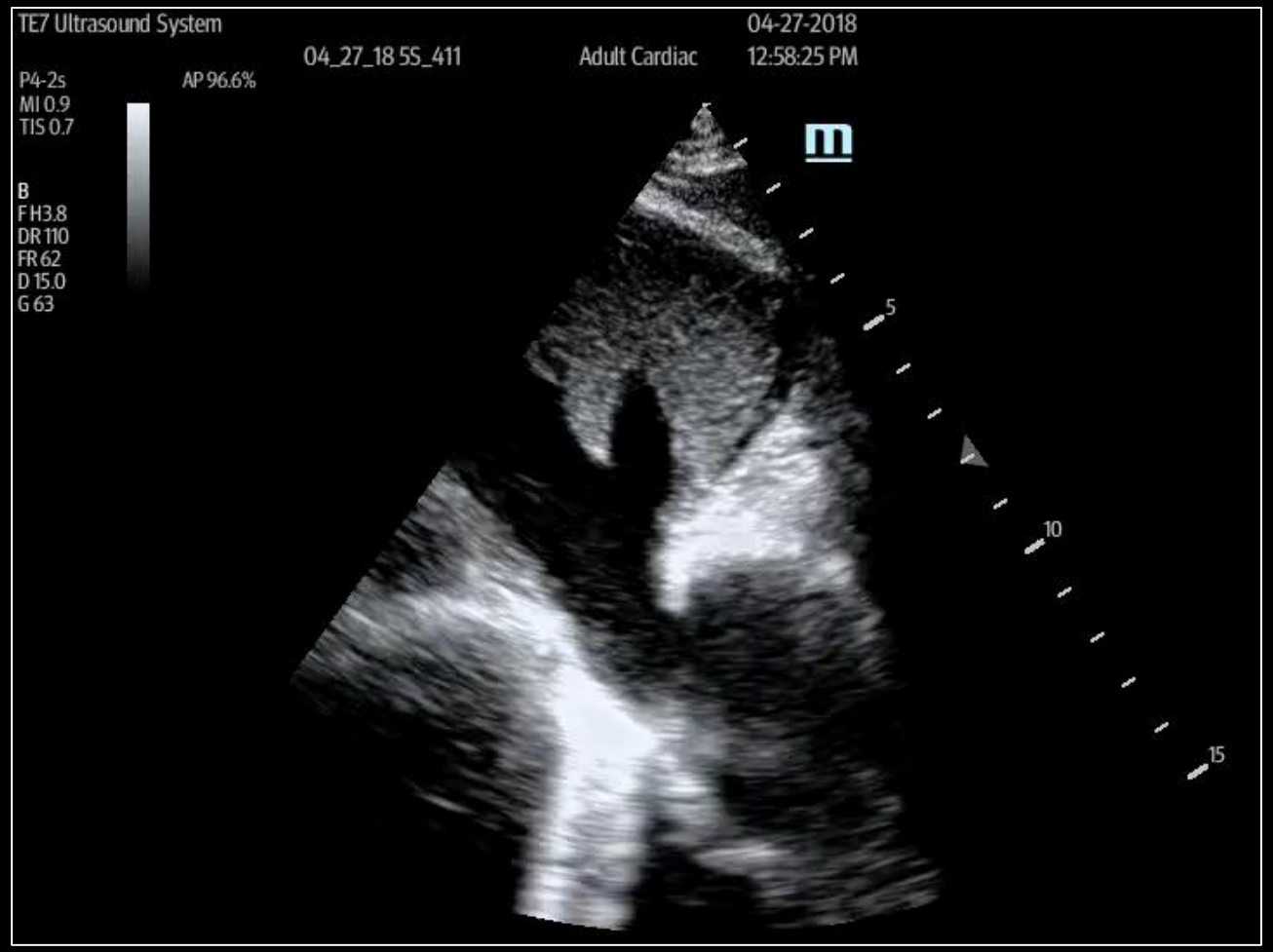
Apical 4-chamber: TAPSE



Sub-xiphoid

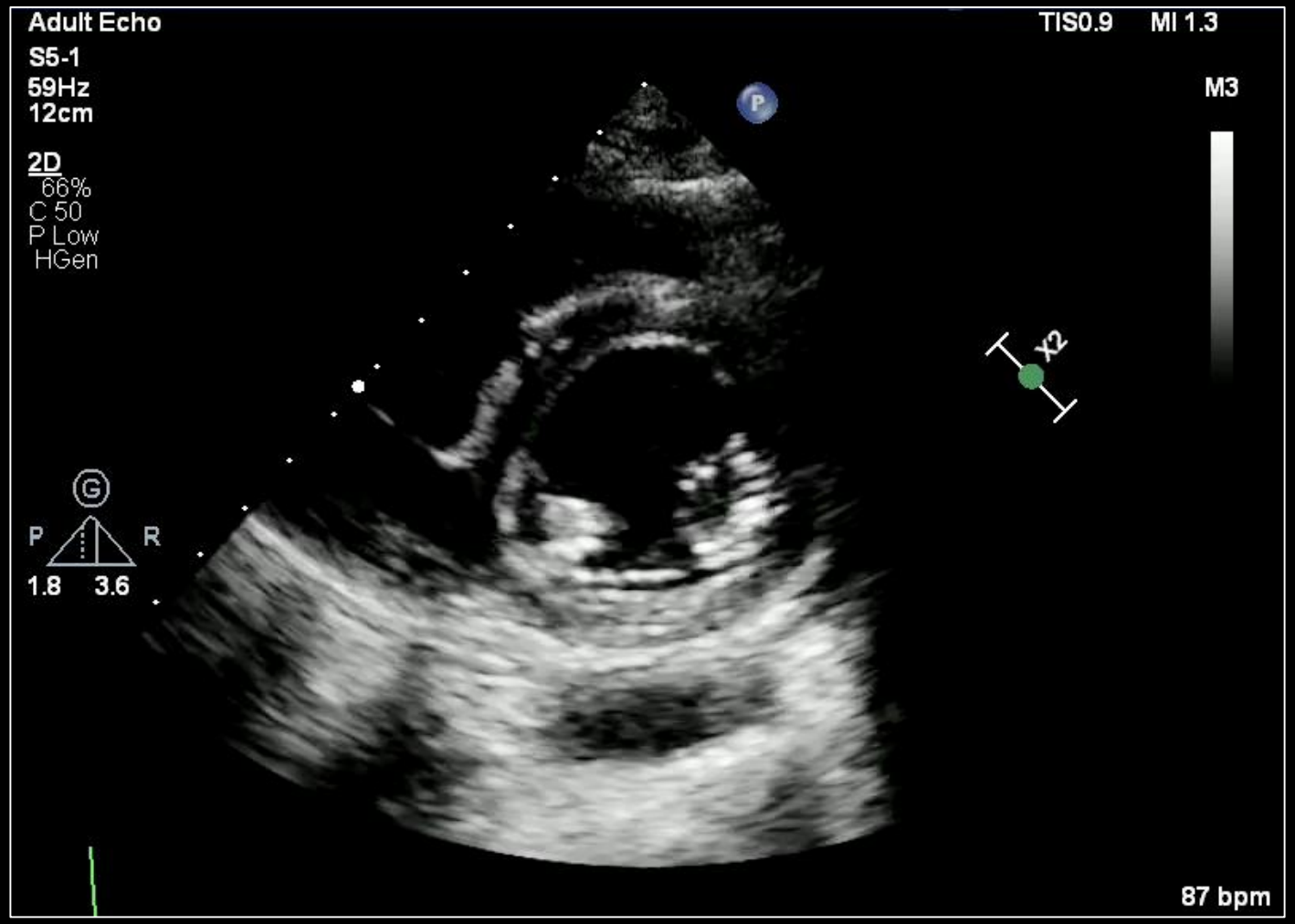

TE7 Ultrasound System
04-27-2018
04_27_18 55_411
Adult Cardiac
12:58:05 PM
P4-2s
AP 96.6%
MI 0.9
TIS 0.8
B
F H3.8
DR 110
FR 48
D 20.0
G 63
5
10
15
20

IVC

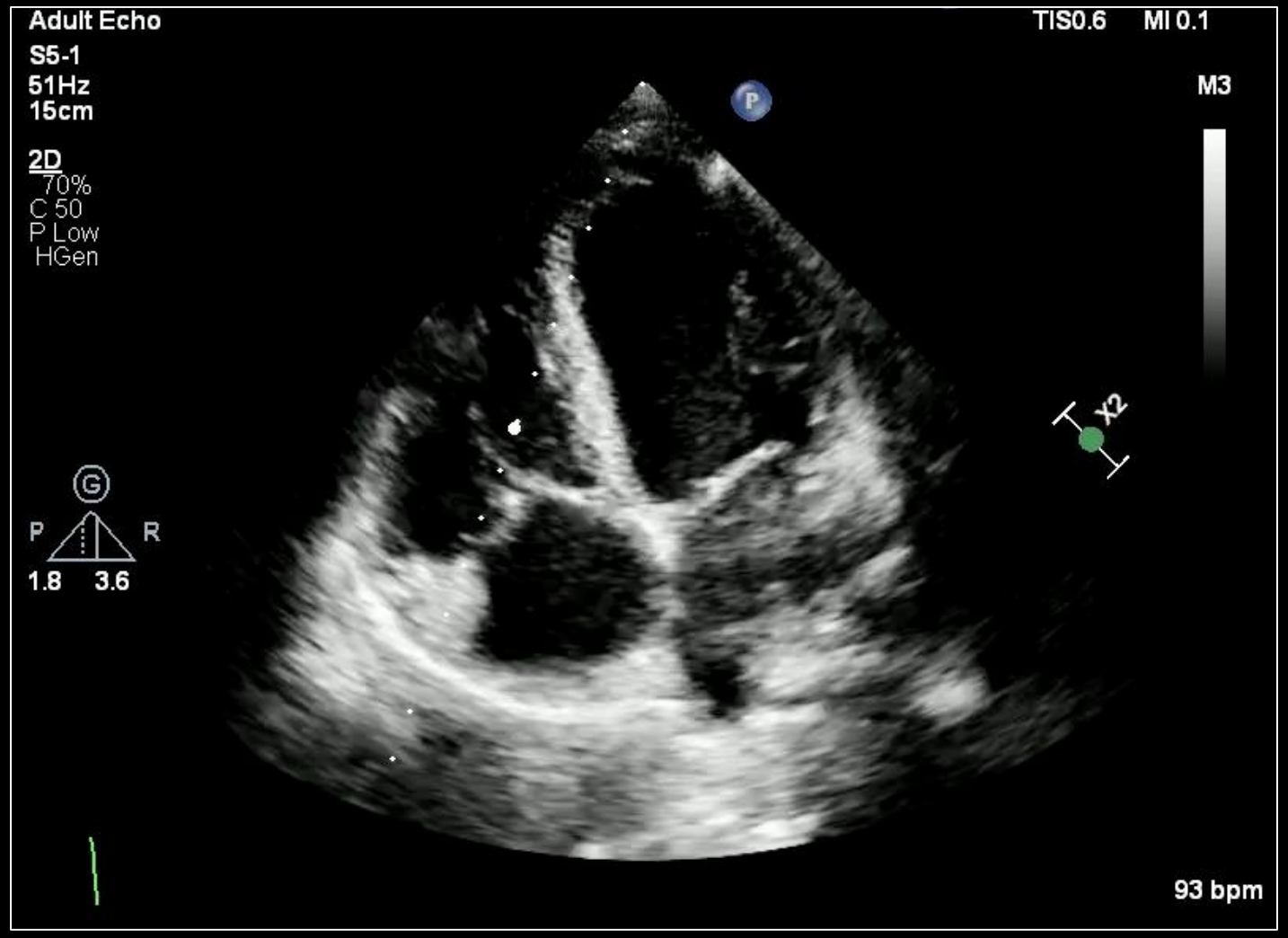

TE7 Ultrasound System
04-27-2018
04_27_18 55_411
Adult Cardiac
12:58:25 PM
P4-2s
MI 0.9
TIS 0.7
AP 96.6%
B
F H3.8
DR 110
FR 62
D 15.0
G 63
5
10
15

Catheter-directed thrombolysis

Parasternal short axis



Apical 4-chamber



Follow up

- CDTL for 24 hours with systolic PA pressures 40 and 33 -> 31 and 22
- Catheters removed and extubated following day
- Intact neurological function, pregnancy intact with normal fetal exam
- Walked out of step down 5 days later

Let’s tweak the case a little…

Young female G1P0 at 9 weeks presents with acute onset shortness of breath and dizziness and is found to have unilateral calf swelling. Doppler of the LE is positive for DVT in the common femoral vein and a follow up CT-PE of the chest shows a saddle pulmonary embolus. Her SBP remains above 90 mmHg throughout her initial evaluation and she is awake and talking to you.

You are asked to help decide if the patient is a candidate for advanced therapy for pulmonary embolism…

Right heart TTE is complex

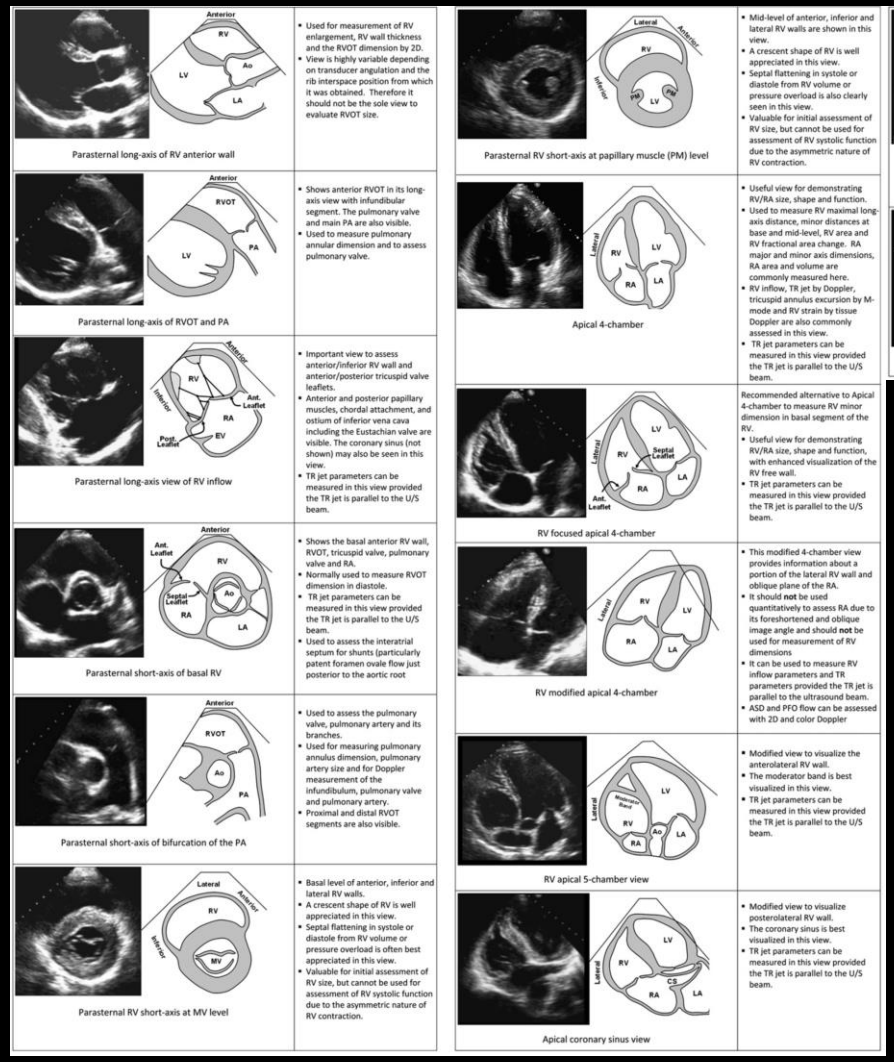


Table 1 Summary of reference limits for recommended measures of right heart structure and function

Variable	Unit	Abnormal	Illustration
Chamber dimensions			
RV basal diameter	cm	>4.2	Figure 7
RV subcostal wall thickness	cm	>0.5	Figure 5
RVOT PSAX distal diameter	cm	>2.7	Figure 8
RVOT PLAX proximal diameter	cm	>3.3	Figure 8
RA major dimension	cm	>5.3	Figure 3
RA minor dimension	cm	>4.4	Figure 3
RA end-systolic area	cm^2	>18	Figure 3
Systolic function			
TAPSE	cm	<1.6	Figure 17
Pulsed Doppler peak velocity at the annulus	cm/s	<10	Figure 16
Pulsed Doppler MPI	—	>0.40	Figure 16
Tissue Doppler MPI	—	>0.55	Figures 16 and 18
FAC (%)	%	<35	Figure 9
Diastolic function			
E/A ratio	—	<0.8 or >2.1	
E/E′ ratio	—	>6	
Deceleration time (ms)	ms	<120	

FAC, Fractional area change; *MPI*, myocardial performance index; *PLAX*, parasternal long-axis; *PSAX*, parasternal short-axis; *RA*, right atrium; *RV*, right ventricle; *RVD*, right ventricular diameter; *RVOT*, right ventricular outflow tract; *TAPSE*, tricuspid annular plane systolic excursion.

Rudski LJ et al. *J Am Soc Echocardiogr 2010;23:685-713*

Luckily it is less so in acute PE…

Table 2 Echocardiographic determinations

Determinations	Overall population		Hospital survival	Hospital death	*P* (Student *t* or Fisher exact test)
	n	Mean ± SD or %	Mean ± SD or *n* (%)	Mean ± SD or *n* (%)	
n	211		173 (82)	38 (18)	
RA end-systolic diameter (cm)	211	4.5 ± 1.1	4.5 ± 1.1	4.7 ± 1.2	.44
RA end-systolic area (cm^2)	211	14.7 ± 6.4	14.7 ± 6.4	14.9 ± 6.3	.83
RV basal diameter (cm)	211	4.2 ± 0.9	4.2 ± 0.9	4.1 ± 0.9	.54
RV midventricular diameter (cm)	211	3.8 ± 0.9	3.7 ± 0.9	4.0 ± 1.0	.21
RV longitudinal dimension (cm)	211	8.0 ± 1.0	8.0 ± 1.2	7.9 ± 0.9	.78
RV wall thickness, subcostal view (cm)	211	0.17 ± 0.20	0.18 ± 0.23	0.13 ± 0.17	.20
TAPSE (cm)	211	1.7 ± 0.5	1.7 ± 0.5	1.5 ± 0.4	.02
RV ejection fraction (%)	211	46.3 ± 14	47 ± 14	45 ± 14	.50
Maximum TR jet velocity (m/sec)	166	3.5 ± 1.4	3.3 ± 1.3	4.1 ± 1.5	.01
Estimated RVSP (mm Hg)	164	44 ± 19	42 ± 17	52 ± 23	.01
RVOT TVI (cm)	103	13.9 ± 4.4	14.0 ± 4.6	13.1 ± 3.9	.43
TRV/RVOT TVI	102	0.23 ± 0.11	0.23 ± 0.11	0.26 ± 0.09	.32
RVOT diameter (cm)	211	3.6 ± 0.6	3.6 ± 0.6	3.6 ± 0.6	.81
Peak systolic lateral RV annular velocity (cm/sec)	165	13.2 ± 5.0	13.4 ± 4.7	12.1 ± 5.4	.19
RV/LV EDD ratio	211	0.91 ± 0.27	0.88 ± 0.26	1.01 ± 0.31	.01
LV EDD (cm)	211	4.3 ± 0.7	4.3 ± 0.7	4.1 ± 0.8	.02
LVEF (%)	211	55.8 ± 10	56.2 ± 9.3	53.8 ± 11.5	.18
McConnell's sign[9]	211				
Absent	181	86	151 (87)	30 (79)	.20
Present	30	14	22 (13)	8 (21)	
RV free wall hypokinesia	211				
Absent	150	71	127 (73)	23 (61)	.12
Present	61	29	46 (27)	15 (39)	
Leftward shifting of the interventricular septum	211				
Absent	172	82	146 (84)	26 (68)	.04
Present	39	18	27 (16)	12 (32)	
IVC size (cm)	139	2.1 ± 0.5	2.1 ± 0.5	2.1 ± 0.5	.98
Patients not on MV	99	2.0 ± 0.5	2.1 ± 0.5	2.0 ± 0.4	.75
Patients on MV	40	2.2 ± 0.5	2.3 ± 0.4	2.1 ± 0.6	.28
IVC collapsibility ≥ 50%*	99				
Absent	33	33	28 (30)	5 (71)	.04
Present	66	67	64 (70)	2 (29)	

EDD, End-diastolic diameter; *IVC*, inferior vena cava; *LV*, left ventricular; *LVEF*, left ventricular ejection fraction; *MV*, mechanical ventilation; *RA*, right atrial; *RV*, right ventricular; *RVOT*, RV outflow tract; *RVSP*, right ventricular systolic pressure; *TAPSE*, tricuspid annular plane systolic excursion; *TR*, tricuspid regurgitation; *TRV*, tricuspid regurgitation velocity; *TVI*, time-velocity integral.
P values are for the comparison between hospital survivors and patients who died during hospitalization.
*Only in patients not on MV.

- 211 patients admitted to the ICU with acute pulmonary embolus
- 22 separate TTE variables examined
- 3 found to be significantly associated with death, and 1 with survival
  - **TAPSE 1.5cm or less**
  - **PASP of 52 mmHg or higher**
  - **RV:LV EDD ratio 1.01 or greater**
  - **IVC collapsibility of > 50%**

Khemasuwan et al. *J Am Soc Echocardiogr 2015;28:355-362*
Schmid et al. *Heart, Lung and Vessels. 2015; 7(2): 151-158*

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- TTE pe
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TABLE 2. Diagnostic Accuracy of Pulmonary Critical Care Fellows, Experienced Intensivists, and Traditional Measurements of Right Ventricular Dysfunction

Variables	Sensitivity (%)	Specificity (%)	False-Negative Rate (%)	Negative Predictive Value (%)	Area Under Curve (95% CI)
RV dilatation					
PCCMF	83	88	6	91	0.83 (0.75–0.90)
Intensivist 1	92	83	3	96	0.87 (0.80–0.93)
Intensivist 2	93	90	2	96	0.88 (0.82–0.95)
RV systolic function					
PCCMF	71	94	10	87	0.83 (0.75–0.90)
Intensivist 1	83	89	6	91	0.87 (0.80–0.93)
Intensivist 2	85	91	5	92	0.88 (0.82–0.95)
Any RV abnormality					
PCCMF	71	89	11	83	0.81 (0.74–0.89)
Troponin > 0.08	57	82	17	75	0.70 (0.62–0.79)
B-type natriuretic peptide > 100	59	65	15	73	0.62 (0.53–0.71)
CT pulmonary angiogram right ventricular dysfunction	58	84	16	76	0.75 (0.66–0.83)

PCCMF = Pulmonary Critical Care Medicine Fellow, RV = right ventricle.

Filopei et al. *Crit Care Med. 2017; 45(12).*

Focused TTE for RH dysfunction in acute PE

1. RV:LV ratio
2. IVC collapsibility
3. Tricuspid annular plane systolic excursion (TAPSE)
4. Estimation of PA systolic pressure

RV:LV ratio

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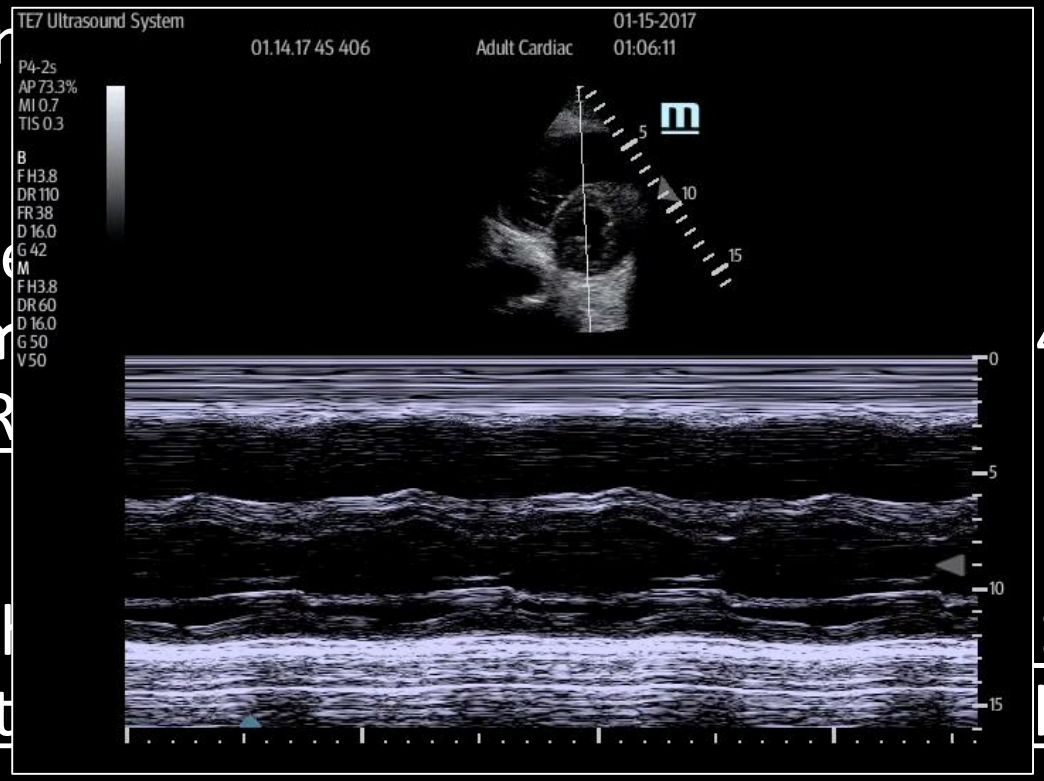
  Wel
  RV:L
- Frer
  0.9



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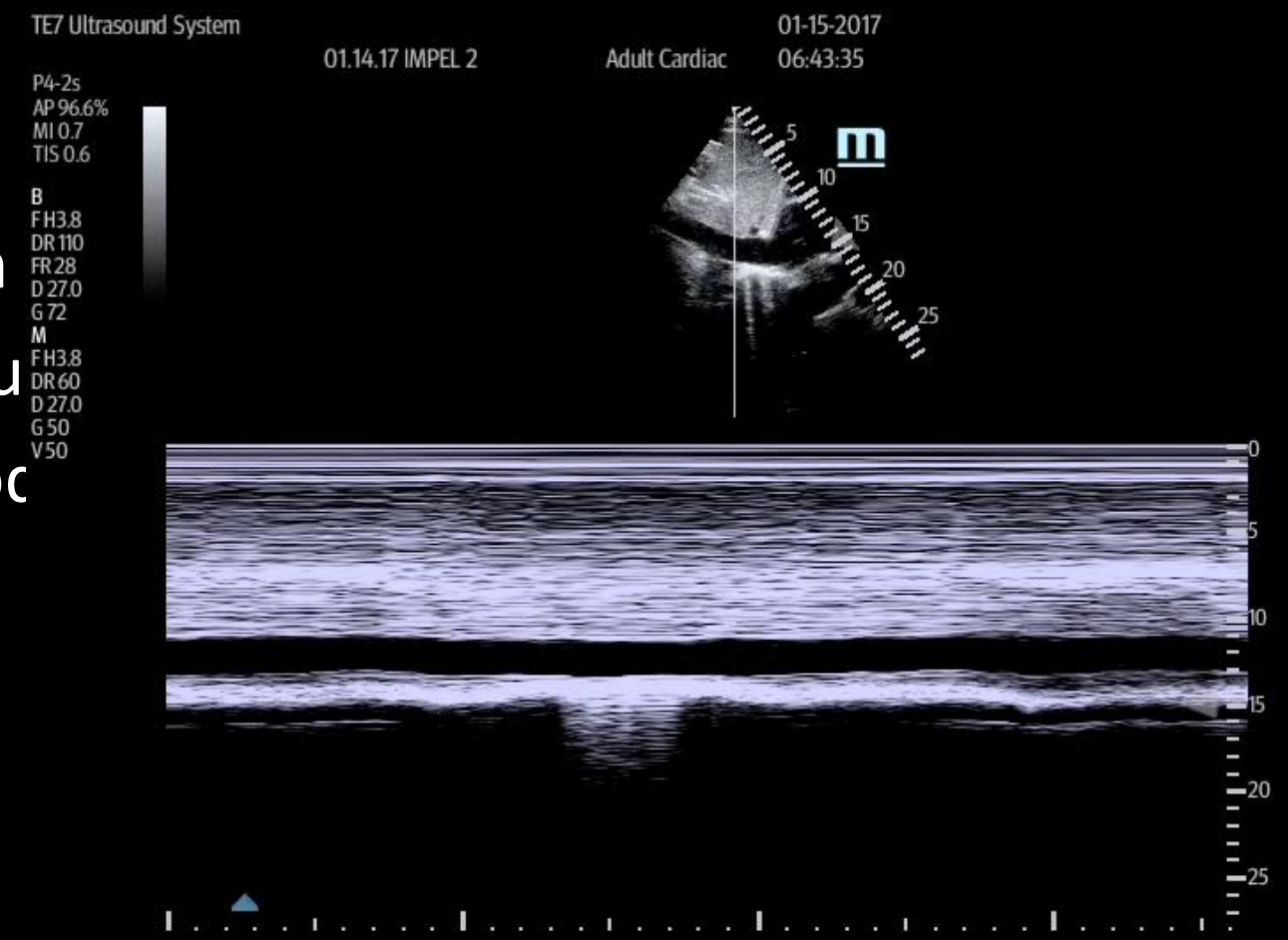
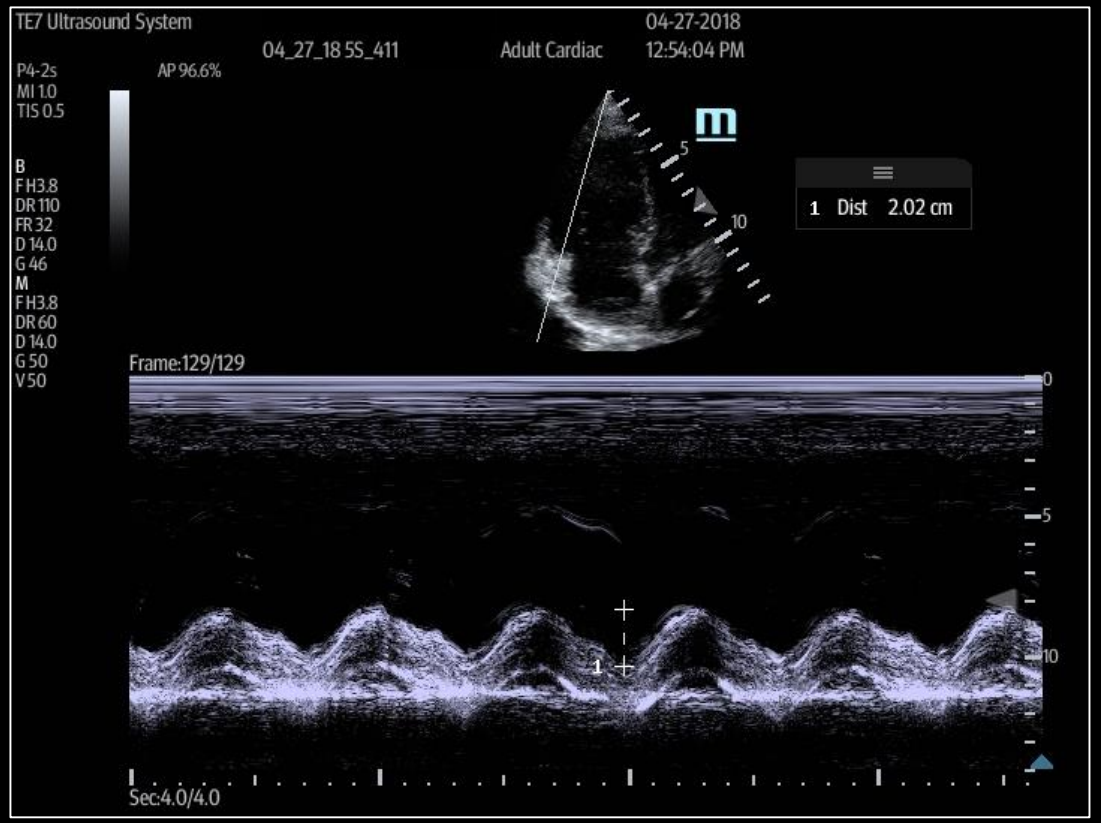
IVC collapsibility

- 2-3cm
- Measu
- M-moc



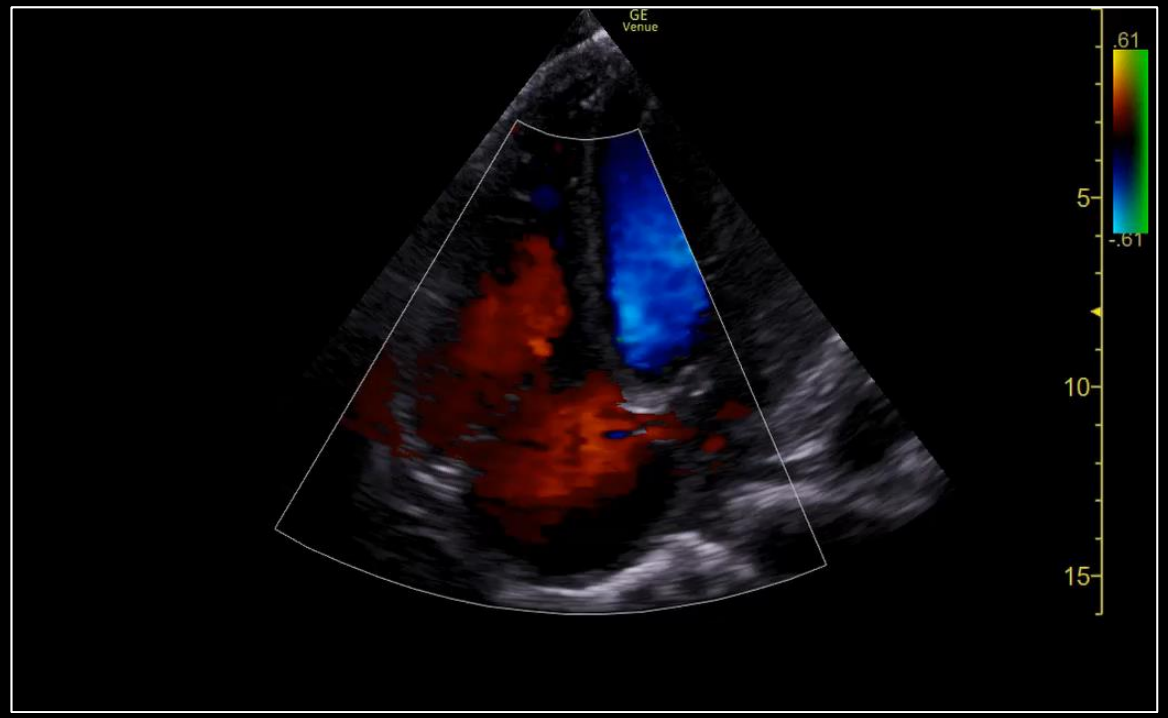
TAPSE



- M-mode through lateral tricuspid annulus
- More reproducible than other measures between operators
- Less tightly correlated with RVEF as measured by cMRI
- Must take care not to foreshorten apical 4-chamber

van der Zwaan et al. *European J Echo (2011) 12, 656–664*

Estimating PASP



- Pulsed wave through TR jet
- Best measured in multiple views
- Highly susceptible to multiple forms of error
- Must use averaging if not in sinus rhythm

Conclusions

Comprehensive evaluation of the right heart is difficult

But…

Focused evaluation of RV dysfunction in PE is easier

RV:LV ratio, TAPSE, estimated PASP

Perhaps just ”eyeballed” RV:LV and TAPSE is good enough with experience?

References

Rudski LJ et al. Guidelines for the Echocardiographic Assessment of the Right Heart in Adults: A Report from the American Society of Echocardiography *J Am Soc Echocardiogr 2010;23:685-713.*

Khemasuwan et al. Right ventricular echocardiographic parameters are associated with mortality after acute pulmonary embolism. *J Am Soc Echocardiogr 2015;28:355-362.*

Schmid et al. Tricuspid annular plane systolic excursion (TAPSE) predicts poor outcome in patients undergoing acute pulmonary embolectomy. *Heart, Lung and Vessels. 2015; 7(2): 151-158.*

Filopei et al. Diagnostic Accuracy of Point-of-Care Ultrasound Performed by Pulmonary Critical Care Physicians for Right Ventricle Assessment in Patients With Acute Pulmonary Embolus. *Crit Care Med. 2017; 45(12).*

van der Zwaan et al. Right ventricular quantification in clinical practice: two-dimensional vs. three-dimensional echocardiography compared with cardiac magnetic resonance imaging. *European J Echo (2011) 12, 656–664*