

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 vision 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

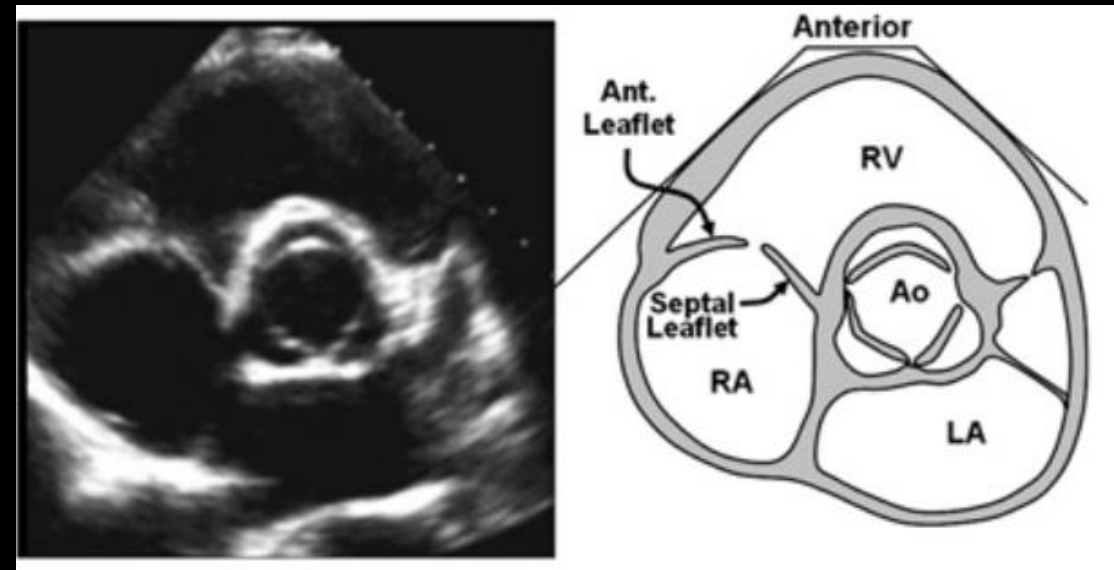
Parasternal long axis



Parasternal short axis



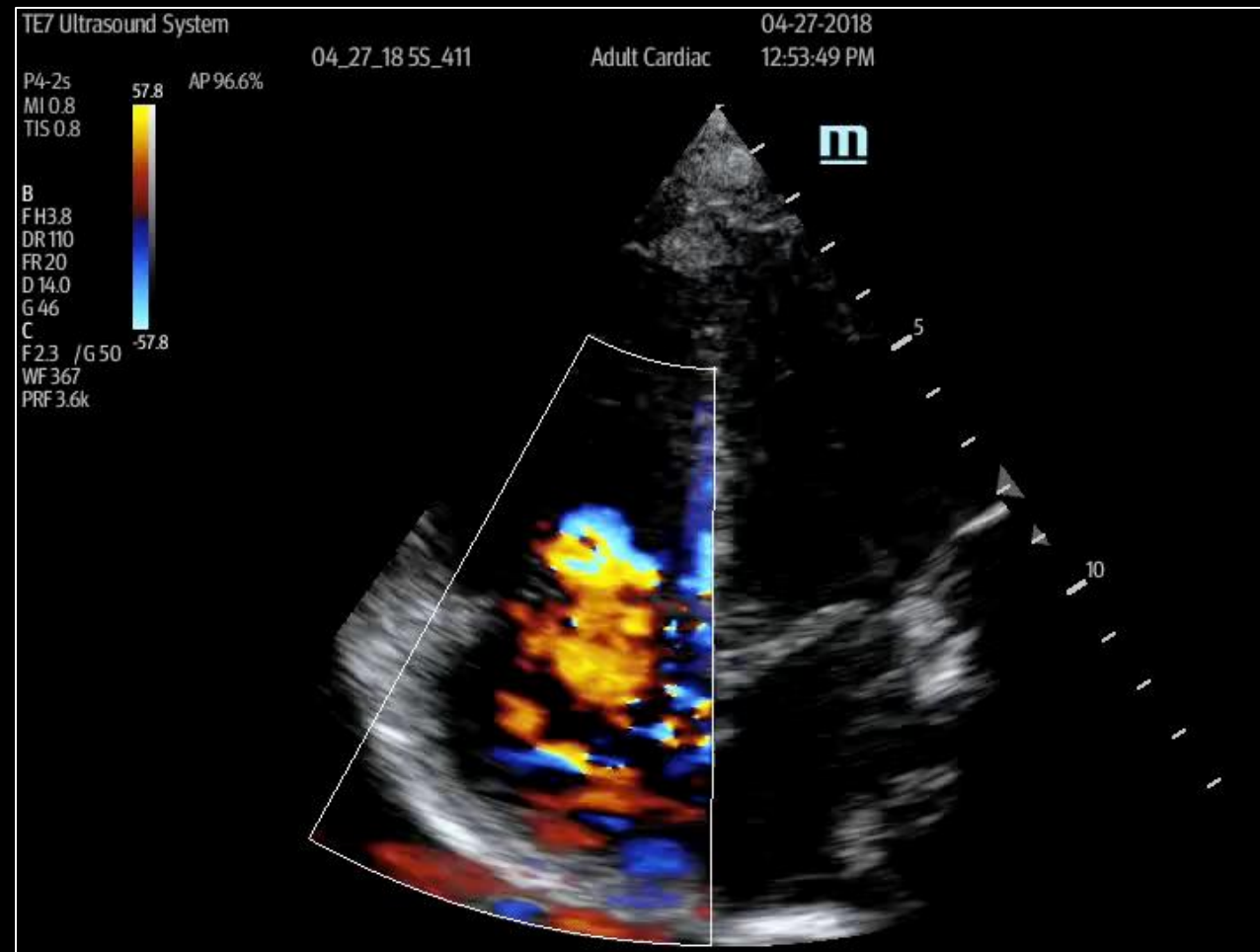
Parasternal short axis: basal RV view



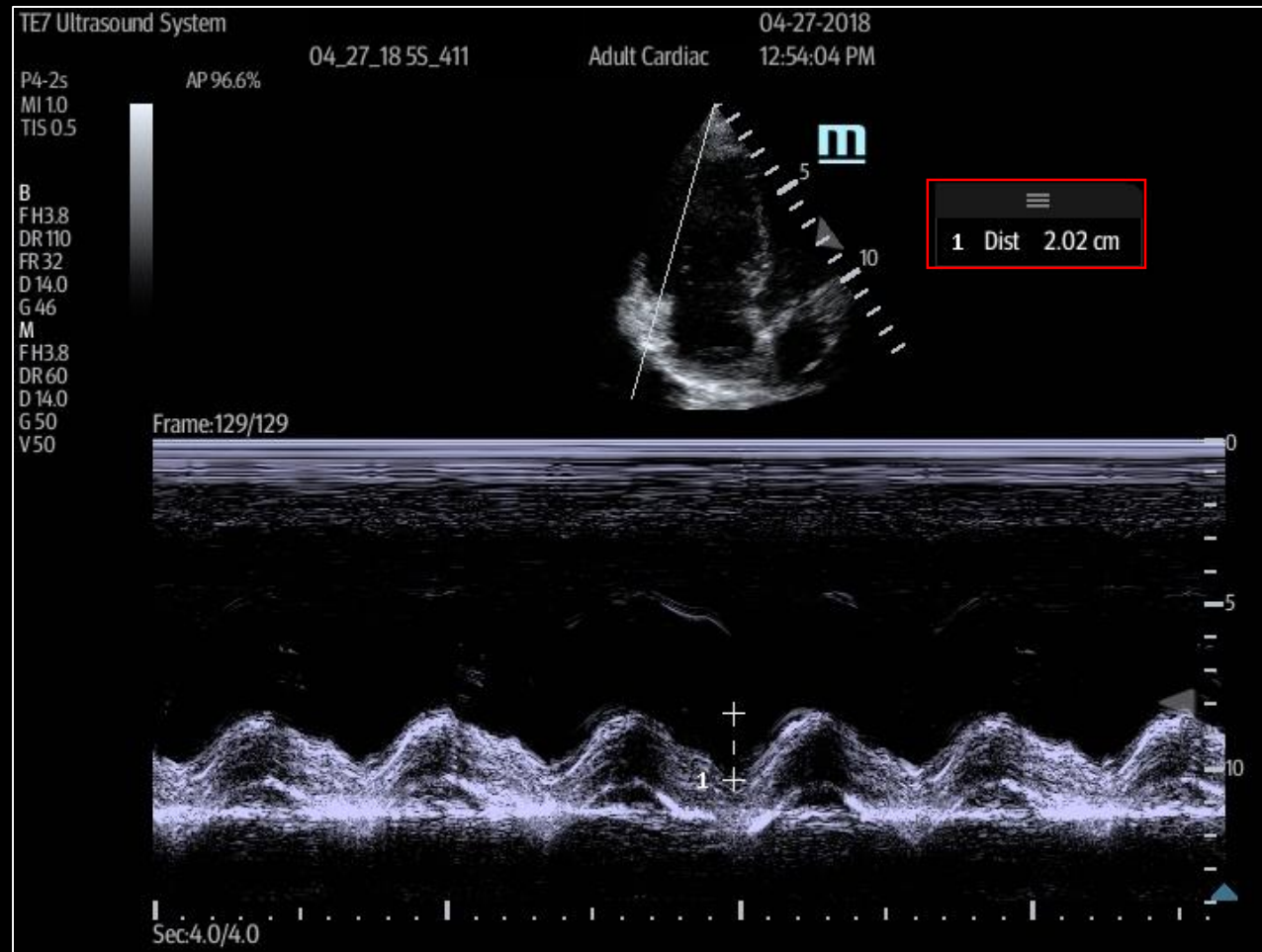
Apical 4-chamber



Apical 4-chamber: color flow Doppler



Apical 4-chamber: TAPSE



Sub-xiphoid



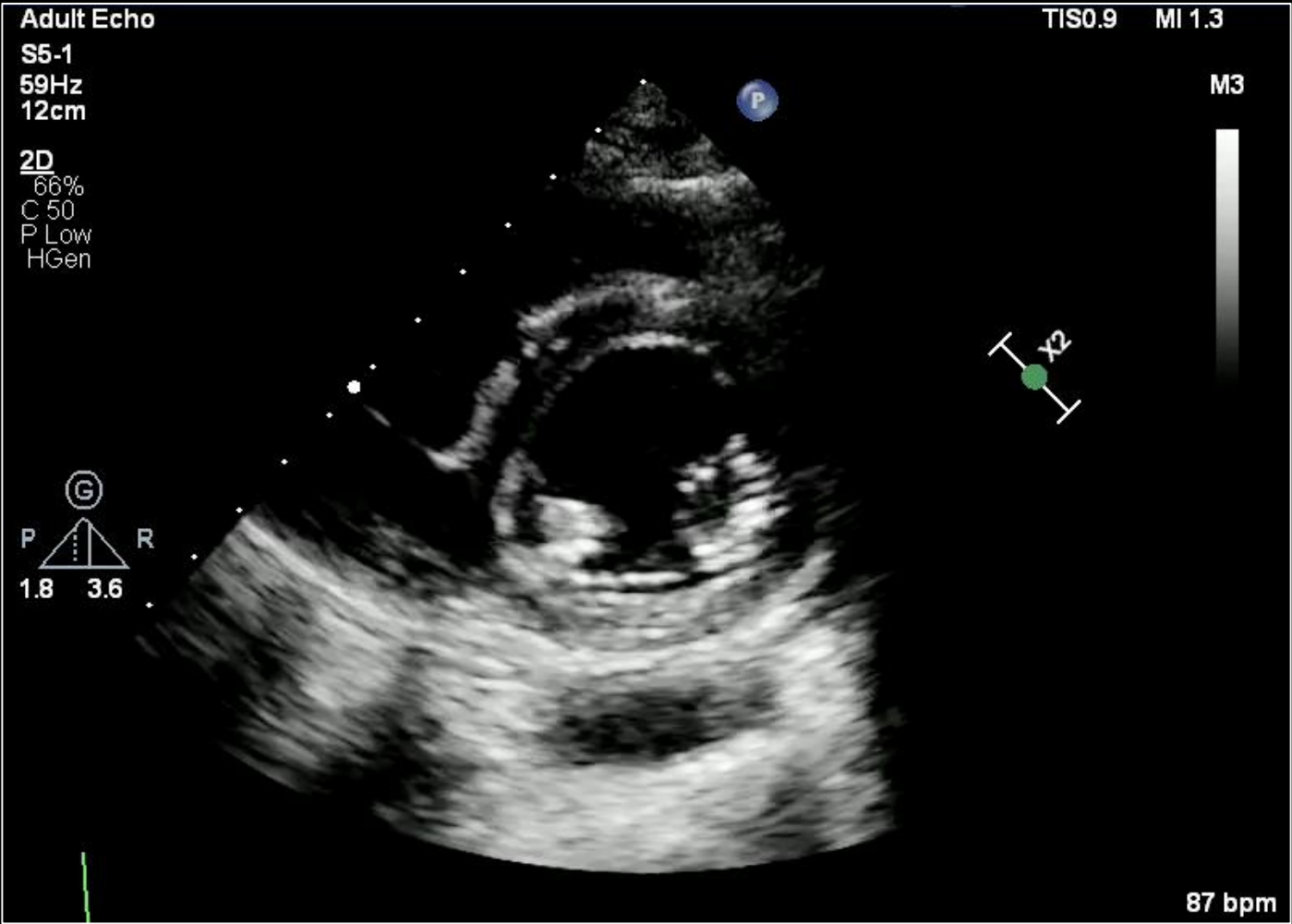
IVC



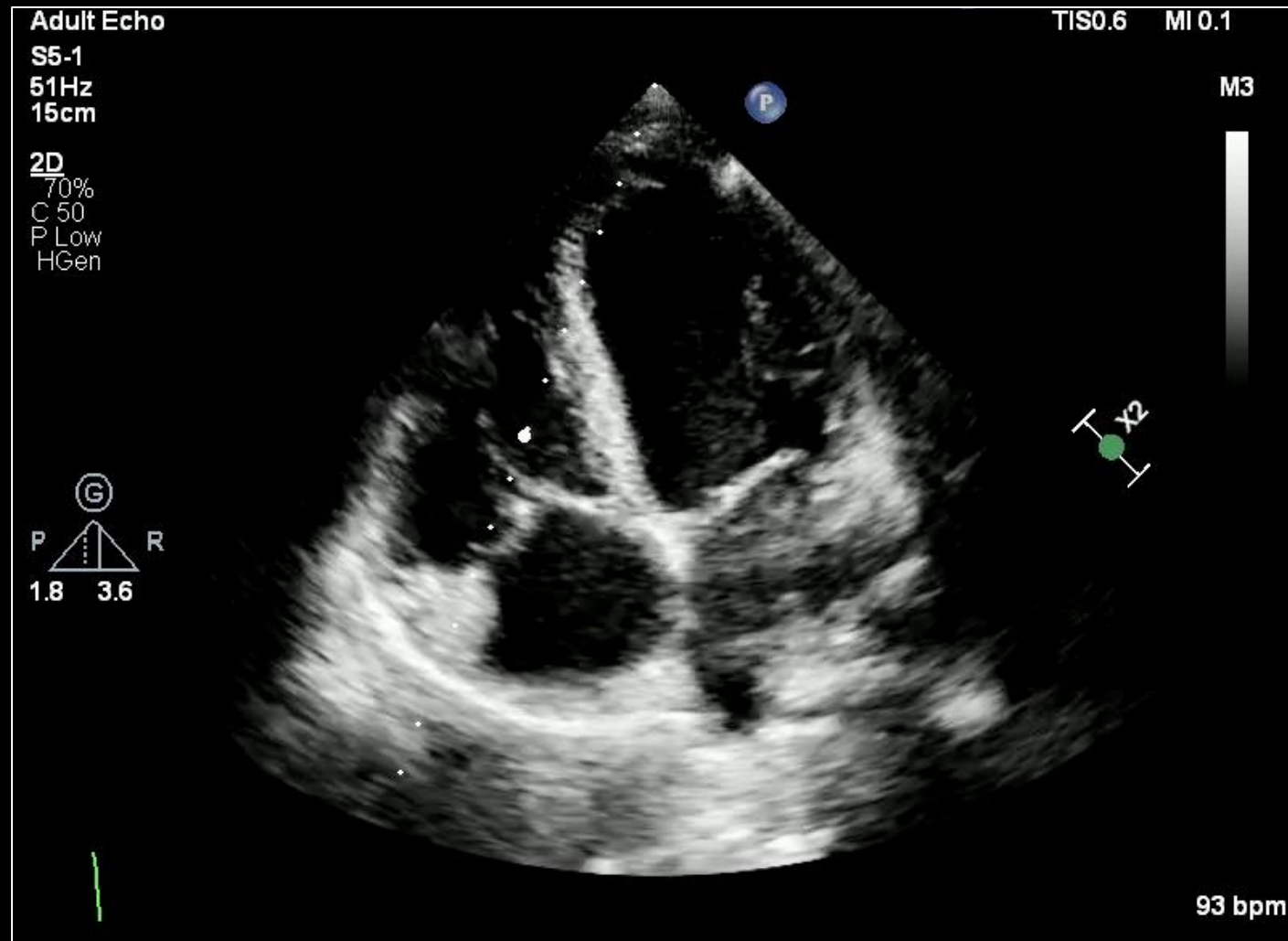
Catheter-directed thrombolysis



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


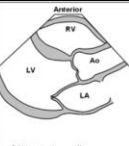

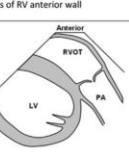

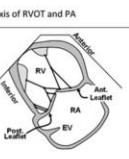

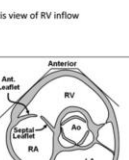

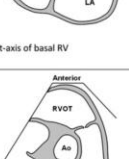

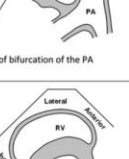
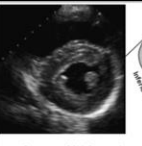
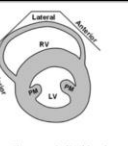

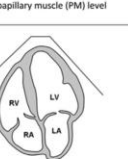
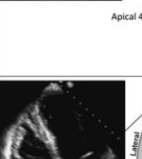

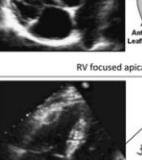
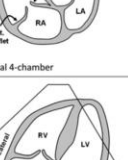

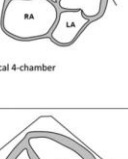

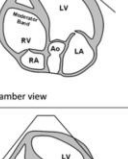

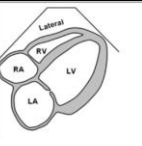

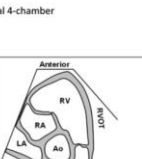
		<ul style="list-style-type: none"> Used for measurement of RV enlargement, RV wall thickness and the RVOT dimension by 2D. View is highly variable depending on transducer angulation and the rib interspace position from which it was obtained. Therefore it should not be the sole view to evaluate RVOT size.
		<ul style="list-style-type: none"> Shows anterior RVOT in its long-axis view with infundibular segment. The pulmonary valve and main PA are also visible. Used to measure pulmonary annular dimension and to assess pulmonary valve.
		<ul style="list-style-type: none"> Important view to assess anterior/inferior RV wall and anterior/posterior tricuspid valve leaflets. Anterior and posterior papillary muscles, chordal attachment, and ostium of inferior vena cava including the Eustachian valve are visible. The coronary sinus (not shown) may also be seen in this view. TR jet parameters can be measured in this view provided the TR jet is parallel to the U/S beam.
		<ul style="list-style-type: none"> Shows the basal anterior RV wall, RVOT, tricuspid valve, pulmonary valve and RA. Normally used to measure RVOT dimension in diastole. TR jet parameters can be measured in this view provided the TR jet is parallel to the U/S beam. Used to assess the interatrial septum for shunts (particularly patent foramen ovale flow just posterior to the aortic root).
		<ul style="list-style-type: none"> Used to assess the pulmonary valve, pulmonary artery and its branches. Used for measuring pulmonary annular dimension, pulmonary artery size and for Doppler measurement of the infundibulum, pulmonary valve and pulmonary artery. Proximal and distal RVOT segments are also visible.
		<ul style="list-style-type: none"> Basal level of anterior, inferior and lateral RV walls. A crescent shape of RV is well appreciated in this view. Septal flattening in systole or diastole from RV volume or pressure overload is often best appreciated in this view. Valuable for initial assessment of RV size, but cannot be used for assessment of RV systolic function due to the asymmetric nature of RV contraction.
		<ul style="list-style-type: none"> Mid-level of anterior, inferior and lateral RV walls are shown in this view. A crescent shape of RV is well appreciated in this view. Septal flattening in systole or diastole from RV volume or pressure overload is also clearly seen in this view. Valuable for initial assessment of RV size, but cannot be used for assessment of RV systolic function due to the asymmetric nature of RV contraction.
		<ul style="list-style-type: none"> Useful view for demonstrating RV/RA size, shape and function. Used to measure RV maximal long-axis distance, minor distances at base and mid-level, RV area and RV fractional area change. RA major and minor axis dimensions, RA area and volume are commonly measured here. RV inflow, TR jet by Doppler, tricuspid annulus excursion by M-mode and RV strain by tissue Doppler are also commonly assessed in this view. TR jet parameters can be measured in this view provided the TR jet is parallel to the U/S beam.
		<p>Recommended alternative to Apical 4-chamber to measure RV minor dimension in basal segment of the RV.</p> <ul style="list-style-type: none"> Useful view for demonstrating RV/RA size, shape and function, with enhanced visualization of the RV free wall. TR jet parameters can be measured in this view provided the TR jet is parallel to the U/S beam.
		<ul style="list-style-type: none"> This modified 4-chamber view provides information about a portion of the lateral RV wall and oblique plane of the RA. It should not be used quantitatively to assess RA due to its foreshortened and oblique image angle and should not be used for measurement of RV dimensions. It can be used to measure RV inflow parameters and TR parameters provided the TR jet is parallel to the ultrasound beam. ASD and PFO flow can be assessed with 2D and color Doppler.
		<ul style="list-style-type: none"> Modified view to visualize the anterolateral RV wall. The moderator band is best visualized in this view. TR jet parameters can be measured in this view provided the TR jet is parallel to the U/S beam.
		<ul style="list-style-type: none"> Modified view to visualize posterolateral RV wall. The coronary sinus is best visualized in this view. TR jet parameters can be measured in this view provided the TR jet is parallel to the U/S beam.
		<ul style="list-style-type: none"> The RV wall thickness is best measured in this view. It is useful for evaluation of the RV/RA wall inversion/collapse in diagnosing patients with cardiac tamponade. ASD and PFO are often best shown in this view with 2D and color Doppler. Used to visualize but not quantify RV/RA sizes due to its foreshortened and oblique angle. TR jet parameters can be measured in this view provided the TR jet is parallel to the U/S beam.
		<ul style="list-style-type: none"> Base of the RV wall including RV inflow, RV outflow, pulmonary valve, pulmonary artery and its branches are well visualized. RVOT dimension can also be measured in this view. Used for Doppler measurement of the infundibulum, pulmonary valve and pulmonary artery.

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.

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 ^a	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

Luckily it is less so in acute PE...

- 110 pa

- TTE pe

- Presenta
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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.

Focused TTE for RH dysfunction in acute PE

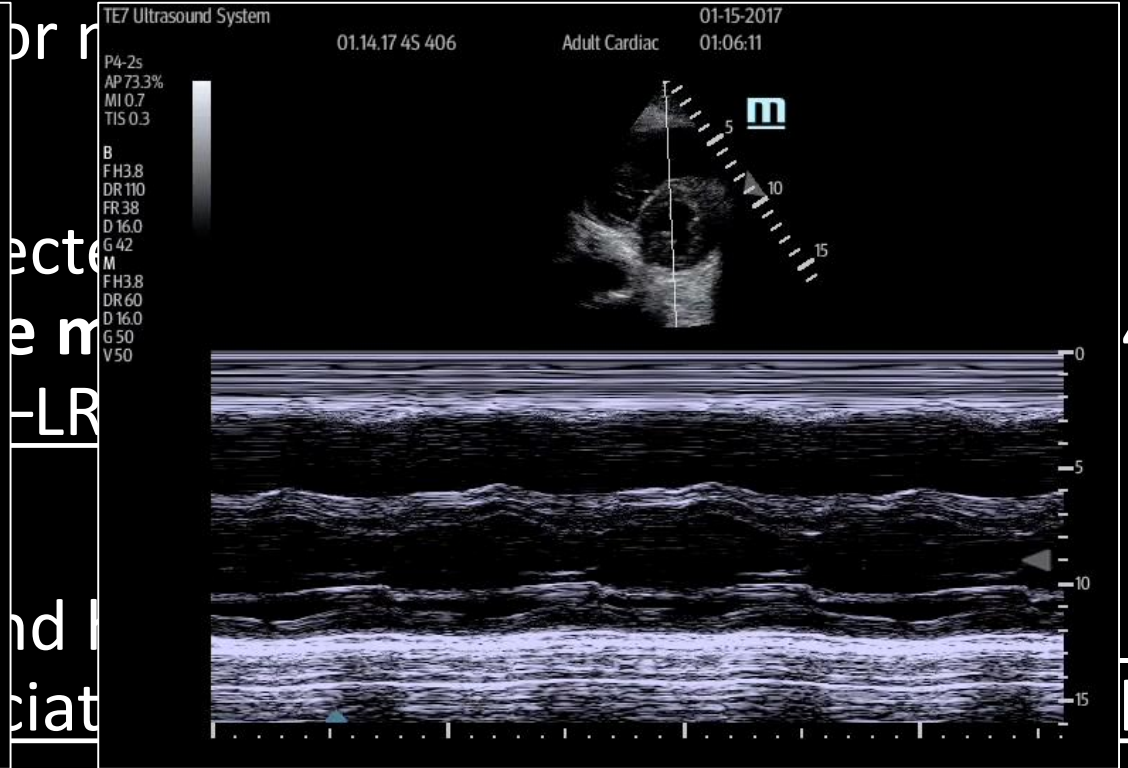
1. RV:LV ratio
2. IVC collapsibility
3. Tricuspid annular plane systolic excursion (TAPSE)
4. Estimation of PA systolic pressure

RV:LV ratio

- Normal

- Dressing Well
- RV:LV

- Frequency
- 0.9

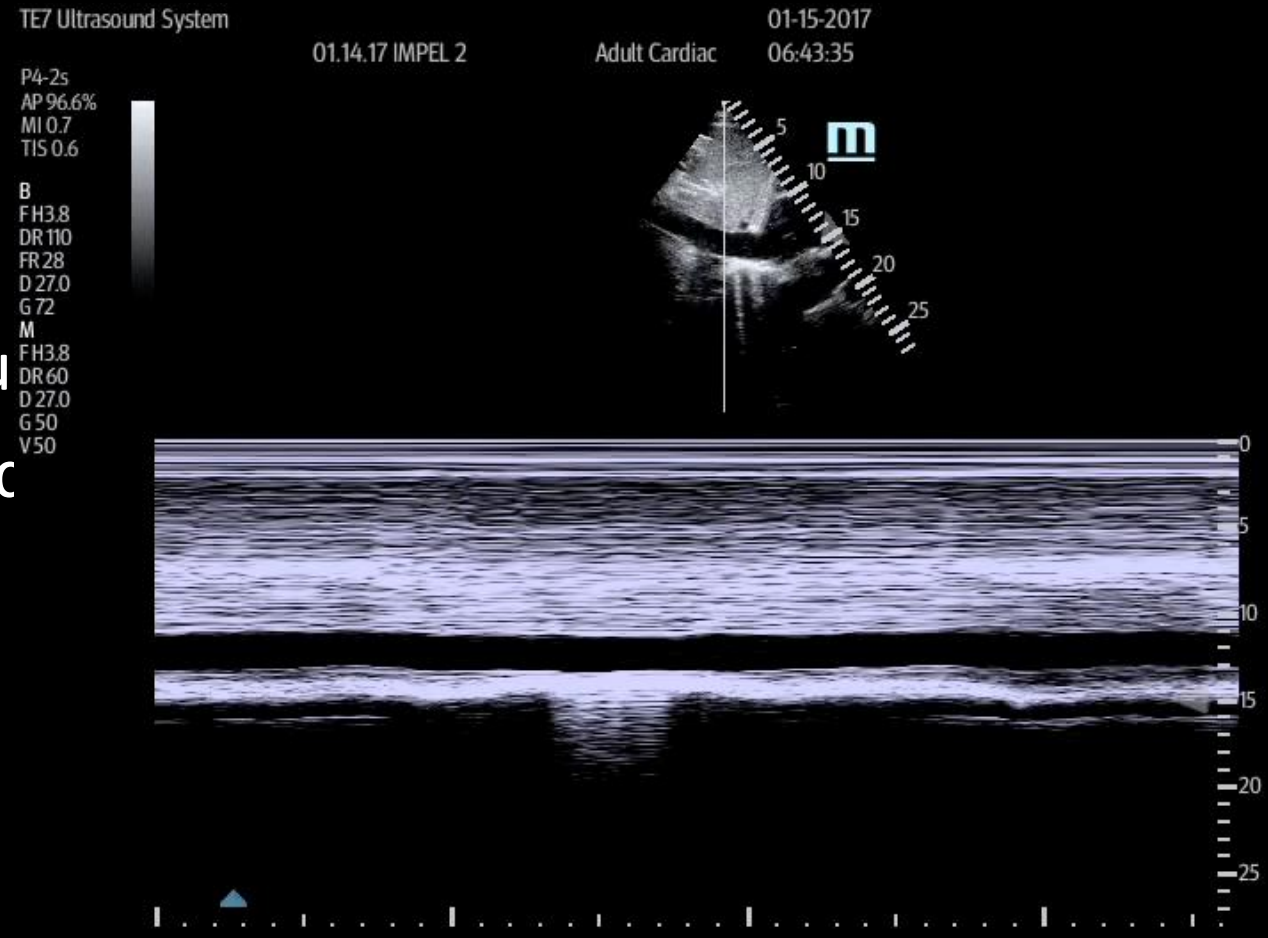


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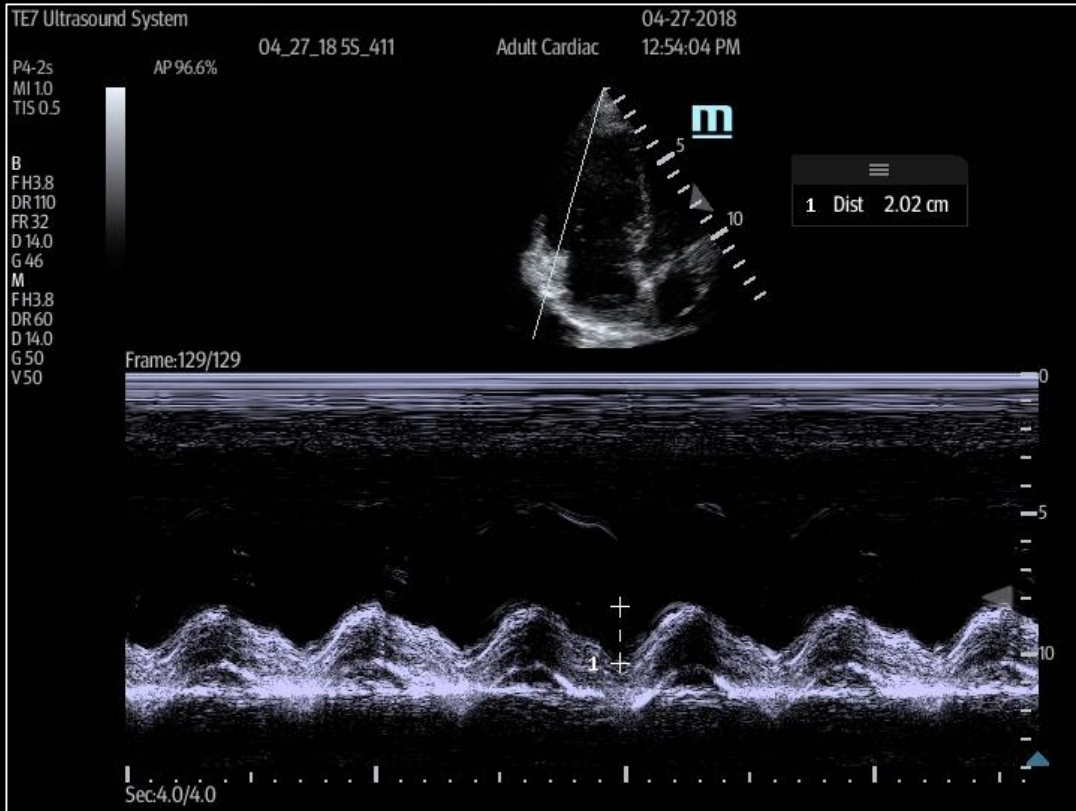
IVC collapsibility

- 2-3cm
- Measu
- M-moc



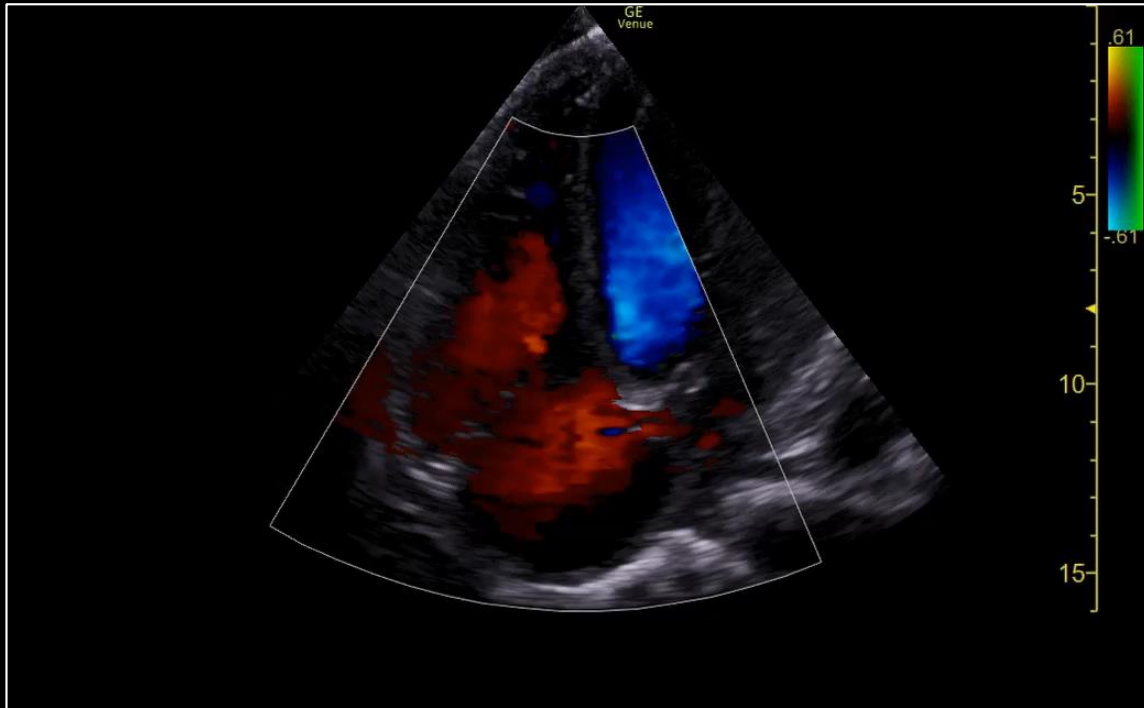
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TAPSE



- 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

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

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