

CT ATRIAL MEASUREMENTS: *CAN THEY PREDICT ADVERSE EVENTS IN PATIENTS WITH ACUTE PE?*

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Current literature on risk stratifying acute PE patients

Existing data:

- **Septal bowing** and increasing **pulmonary artery diameter** are associated with **5-day adverse outcomes** (all-cause mortality, acute decompensation, or need for emergent treatment)⁽¹⁾
- **Increased risk of adverse events** (30-day PE-related mortality or the need for advanced therapy) when there is evidence of **right heart strain on ECHO, ECG and CTA** together⁽²⁾
- **Reduced left atrial volume (<62 mls)** is associated with a significantly higher 30-day all-cause mortality⁽³⁾
- **Increased right/left atrial (RA/LA) volume ratio (>1.2)** is associated with a significantly higher 30-day all-cause mortality⁽³⁾

¹. M Lyhne (2019); ². B Carroll (2018); ³. G Aviram (2016)

Aims

To determine:

- **Which atrial measurement(s)** (volume, area, diameter, ratios) is/are associated with **30-day PE-related adverse events** in patients with acute PE
- **If any atrial measurement(s)** is/are a better predictor of **30-day PE-related adverse events** compared to the combination of ECHO, ECG, and CTA
- Whether increasing **pulmonary artery diameter** , **septal bowing**, or **reflux of contrast into the IVC** are associated with **30-day PE-related adverse events**

Methods

501 hospitalised patients diagnosed with acute PE (2007 – 2014) with available echo

1. *Clinical records:*

- Adverse events: 30-day PE-related mortality or the need for advanced therapy i.e. thrombolysis, thrombectomy, vasopressors

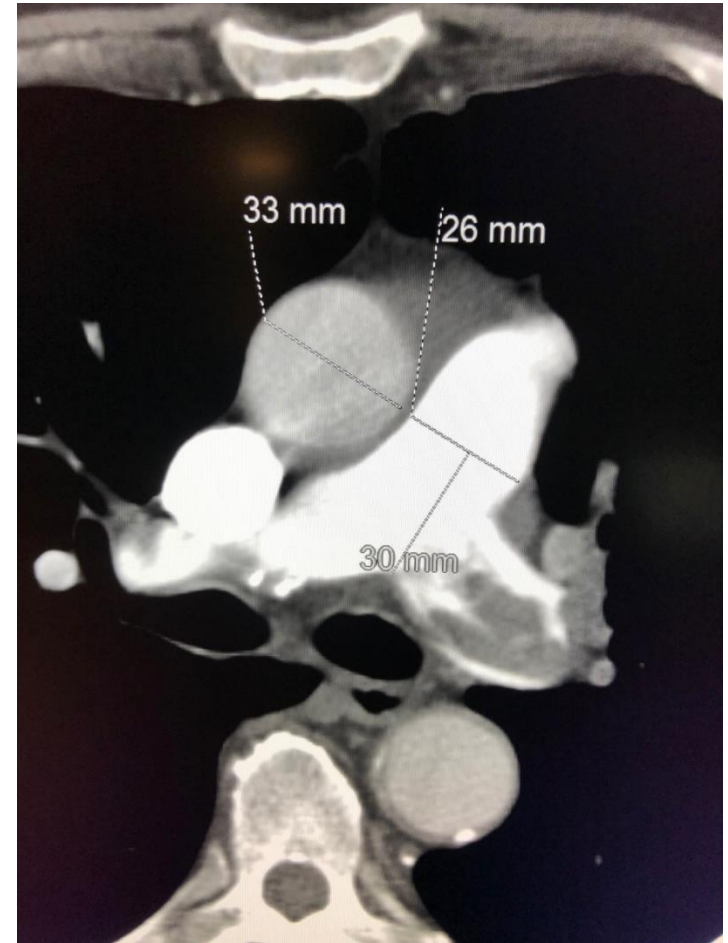
2. *Evidence of right heart strain:*

- Echo - Tricuspid annular plane systolic excursion (TAPSE) measurement (performed within 24hrs before or 48hrs after the diagnostic CT scan)
- ECG
- Chest CTA (gated or non-gated) – RV/LV diameter ratio measured

Methods

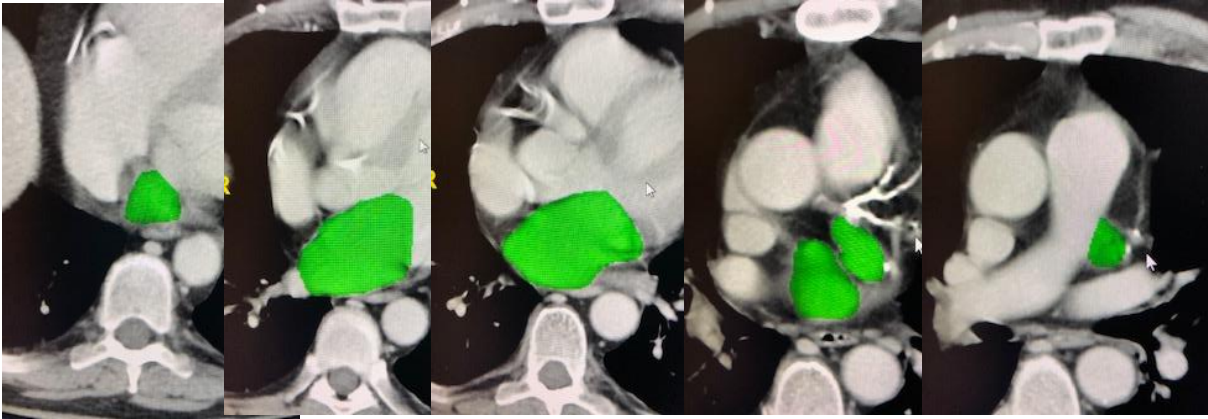
3. *Measurements obtained - TeraRecon:*

- Right and left atrial volume, area and diameters
- Main PA diameter and ascending aorta
- Ventricular septal bowing
- Reflux of contrast into the IVC

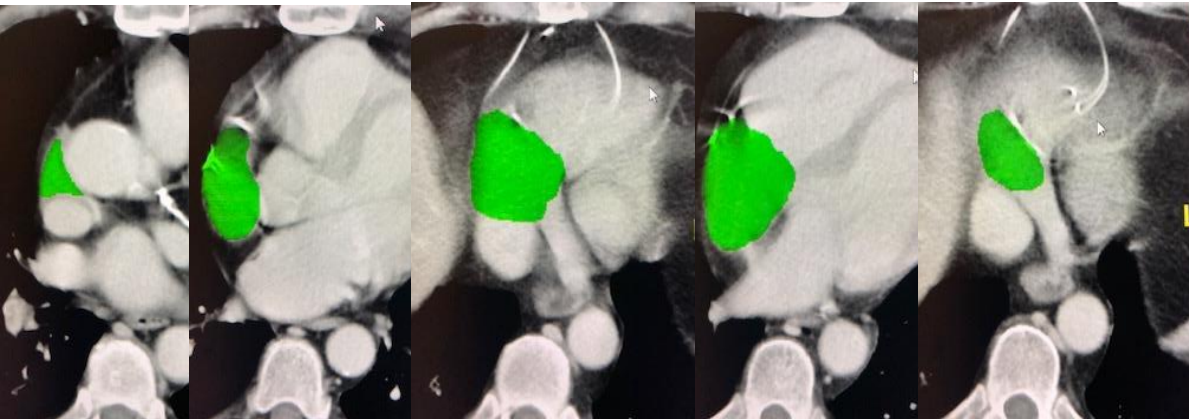


Methods: Atrial Volume

Left atrium (including appendage):



Right atrium (including appendage):



Measurements

Left atrial volume

Right atrial volume

RA/LA volume ratio

Left atrial area

Right atrial area

RA/LA area ratio

Left atrial short-axis diameter

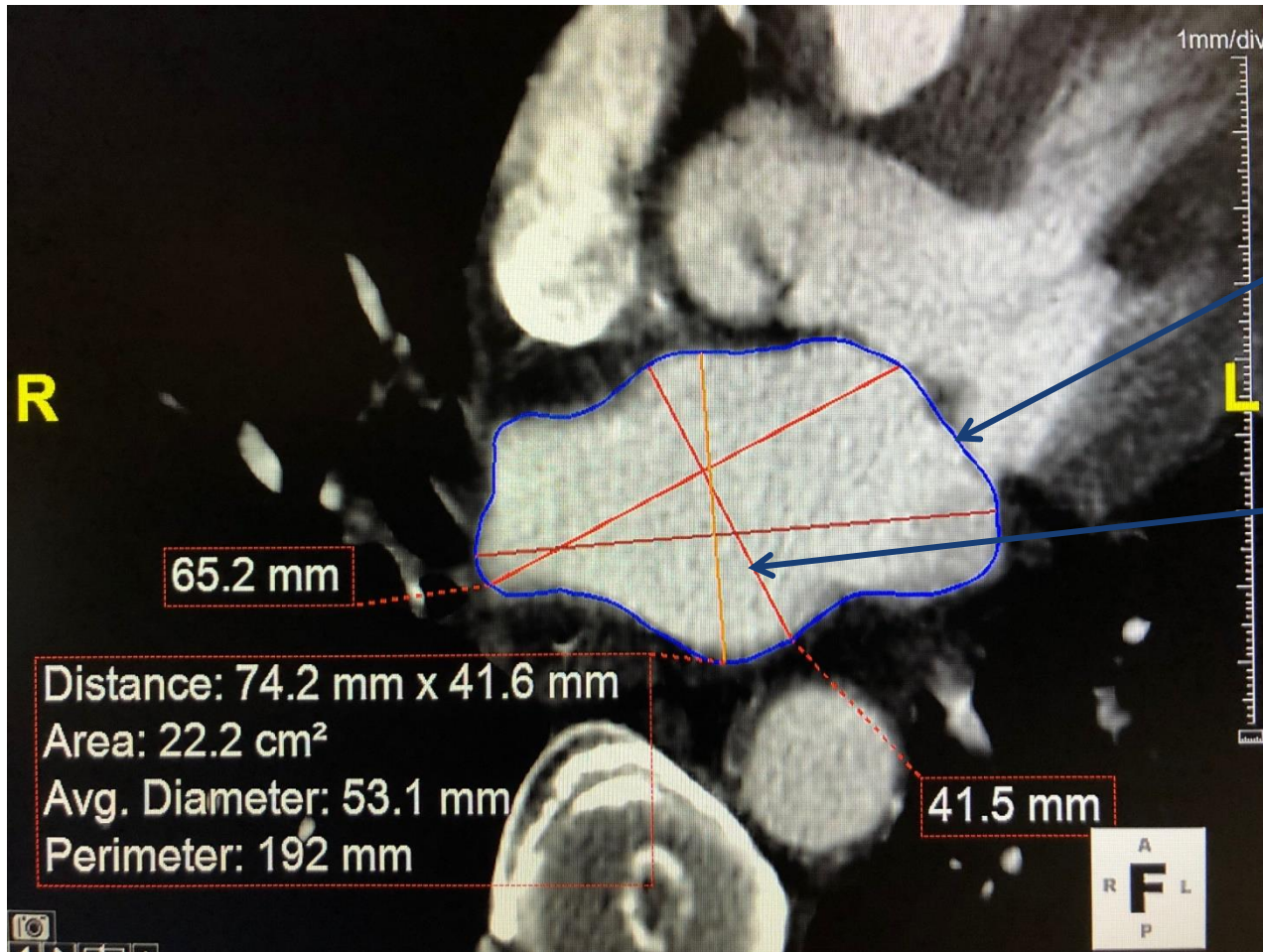
Right atrial short-axis diameter

RA/LA short-axis diameter ratio

PA diameter

RV/LV diameter ratio

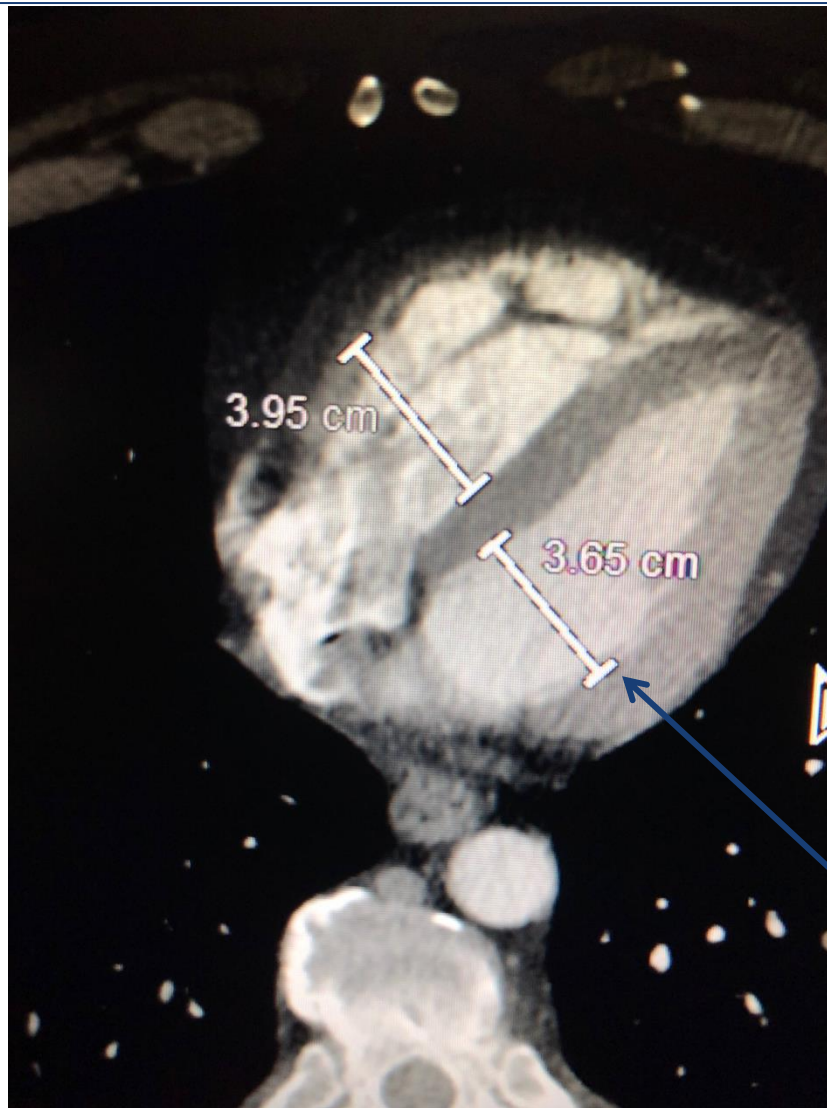
Methods: Left atrial area and diameter



Measurements

Left atrial volume
Right atrial volume
RA/LA volume ratio
Left atrial area
Right atrial area
RA/LA area ratio
Left atrial short-axis diameter
Right atrial short-axis diameter
RA/LA short-axis diameter ratio
PA diameter
RV/LV diameter ratio

Methods: Ventricular diameters



Measurements

Left atrial volume

Right atrial volume

RA/LA volume ratio

Left atrial area

Right atrial area

RA/LA area ratio

Left atrial short-axis diameter

Right atrial short-axis diameter

RA/LA short-axis diameter ratio

PA diameter

RV/LV diameter ratio

Statistical Analysis

- Comparison of subsets (with and without adverse events) was done using **Mann-Whitney U** and **Chi-squared tests**
- Prediction analysis was done by calculating the **area under the curve (AUC)** for receiver operating characteristic (ROC) curves, and **Delong's test** was used to compare AUC for paired ROC curves
- **Multivariate logistic regression** was performed to determine the best predictors of adverse outcomes

Results

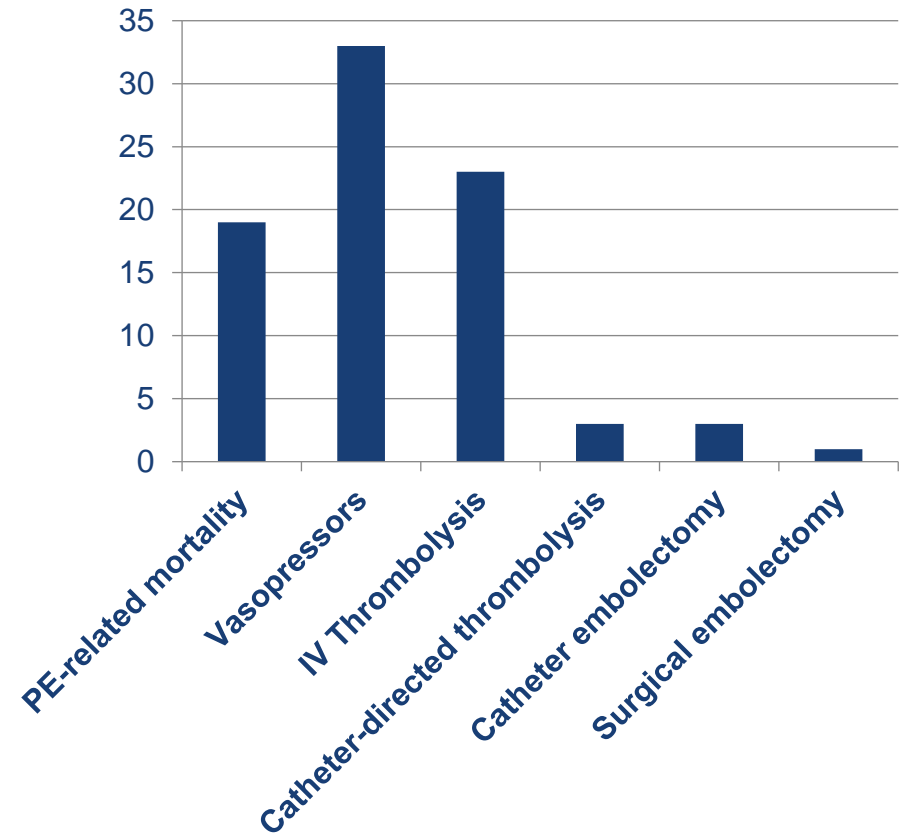
Demographics

- N = 493 pts (8 excluded)
- Adverse events = 62/493 pts (12.6%)
- Median age = 65, IQR = 53-76 (p=0.2)
- Male 48%; Female 52% (p=0.6)

Comorbidities

- Hypertension – 82%
- Coronary artery disease – 18.2%
- Chronic heart failure – 9.4%
- Malignancy – 31.6%
- Smoking – 10.5% current, 36.9% former

Number of patients with 30-day adverse events



Results: Association between measurements and adverse events

Measurements	No Adverse Event (Median)	Adverse Event (Median)	p-value
Left atrial volume	82 mls	62 mls	<0.001
RA/LA volume ratio	1.15	1.46	<0.001
Left atrial area	21 cm ²	18 cm ²	0.001
RA/LA area ratio	1.19	1.45	<0.001
Left atrial short-axis diameter	42 mm	37 mm	0.001
RA/LA short-axis diameter ratio	1.41	1.62	<0.001
RV/LV diameter ratio	1.0	1.21	<0.001

Results: Association between measurements and adverse events

Measurements	No Adverse Event <i>Median (N = 431)</i>	Adverse Event <i>Median (N = 62)</i>	P-value
TAPSE (Echo)	18 mm	14.5 mm	<0.001
PA diameter	30 mm	30 mm	0.88

Measurements	No Adverse Event <i>(% of group)</i>	Adverse Event <i>(% of group)</i>	P-value
ECG	40%	55%	0.02
Septal Bowing	3%	10%	0.01
Reflux of contrast into IVC	26%	50%	<0.001

Results: Prediction of adverse events

Measurements	AUC
Left atrial volume	0.67
TAPSE+ECG+(RV/LV)	0.71

No sig difference between them ($P>0.07$)

Limitations

- **Retrospective study**
- Slightly **limited precision** of measurements due to:
 - Motion artefact
 - Varying quality of contrast opacification in atria
 - Streak artefact from contrast/lines in the right atrium
- **Non-ECG gated** studies therefore unable to account for systole/diastole
- Measurements performed by a **single reader**, using a single software

Conclusions

- **LA measurements** are associated with 30-day PE-related adverse events in patients with acute PE
- **LA volume** is an equivalent predictor of 30-day PE-related adverse events compared to the combination of modalities (TAPSE, ECG, and RV/LV diameter ratio)
- **Reflux of contrast into the IVC** and **septal bowing** are associated with 30-day PE-related adverse events, however **PA diameter** is not

Ongoing and Future Work

- Assess **inter-rater variability** with a randomly selected subset
- Assess the association of atrial measurements with **90-day and 1-year mortality**
- Repeat the measurements using the same **automatic software** as *Aviram et al* (2016) for our cohort to see if our results are reproducible

References

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Questions?



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Further Measurements

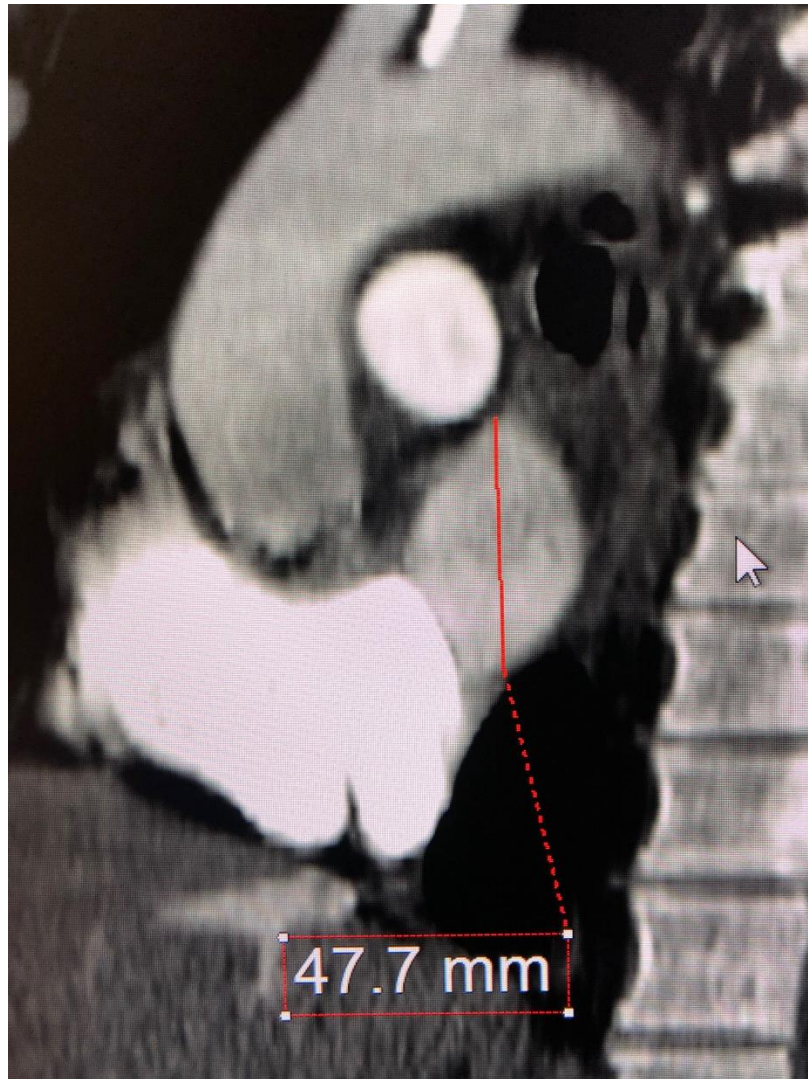
Atrial Appendages:

- Volume measurements without the atrial appendages were also performed in a subset of patients
- Near perfect correlation between measurements with and without appendage ($r = 0.99$) for both right and left atria

Body Surface Area (BSA):

- Adjusting the atrial measurements for BSA did not significantly impact the AUC values

Further Measurements: Craniocaudal measurements



Evidence of Right Heart Strain from B Carroll *et al* (2018)

Right heart strain was counted present if:

- **TAPSE:** <16 mm

(Tricuspid annular plane systolic excursion (TAPSE) is a parameter of global RV function which describes apex-to-base shortening . TAPSE correlates closely with the RVEF, and has been found to be both highly specific and easy to measure.)¹

- **ECG:**
 - 1) S wave in lead I, Q wave in lead III, and T-wave inversion in lead III
 - 2) Right bundle branch block (RBBB)
 - 3) T-wave inversion in the early precordial leads (V1-2, V1-3, V1-4)
- **RV/LV diameter ratio:** >0.9 and >1.0

¹Schmid *et al* (2015)

Independent clinical predictors of short-term mortality

Clinical Predictor	Adjusted Risk Ratio
Age > 70 years	1.6
Male gender	1.2
African American race	1.3
Heart failure	1.4-2.6
Cancer	2.3-9.5
Chronic lung disease	1.3-1.8
Prior deep vein thrombosis	2.8

Aujesky *et al* (2009)

Background

B Carroll et al (2018). *Am J Cardiol.*

- 477 patients with acute pulmonary embolism (PE)
- Risk of adverse events (30-day PE-related mortality or the need for advanced therapy) was only elevated when there was evidence of right heart strain on all three modalities (Echo, ECG, CTA)

G Aviram et al (2016). *Chest.*

- Automatic segmentation of cardiac chamber volumes in 636 patients with acute PE
- Reduced left atrial volume was the best predictor of 30-day all-cause mortality
- Left atrial volume <62 mls and atrial volume ratio of >1.2 were associated with a significantly higher mortality rate (19.6% vs 8.9% [HR = 2.44], 17% vs 9.4% [HR = 2.1] respectively)

Background

Lyhne et al (2019). *Emergency Radiology*.

- 261 patients with acute PE
- Septal bowing and increasing pulmonary artery diameter are associated with 5-day adverse outcomes (mortality, acute decompensation, or need for emergent treatment)
- RV/LV diameter ratio >1 and reflux of contrast into the IVC did not predict adverse outcomes

Results: Prediction of adverse events

Measurements	AUC
Left atrial volume	0.67
RA/LA volume ratio	0.65
Left atrial area	0.63
RA/LA area ratio	0.64
Left atrial short-axis diameter	0.63
RA/LA short-axis diameter ratio	0.63
RV/LV diameter ratio	0.65
TAPSE	0.67
TAPSE+ECG+(RV/LV)	0.71

No sig difference between them ($P>0.05$)

Mortality

Mortality (30-day):

- All-cause mortality = 42/493 (8.5%)
- PE-related mortality = 19/493 (3.9%)