ATRIAL MEASUREMENTS:

CAN THEY PREDICT ADVERSE EVENTS IN PATIENTS WITH ACUTE PE?

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Background: Existing data

- **Reduced left atrial volume (<62 mls) and increased atrial volume ratio (>1.2)** is associated with a significantly higher 30-day all-cause mortality(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)

- **Septal bowing** and increasing **pulmonary artery diameter** are associated with **5-day adverse outcomes** (all-cause mortality, acute decompensation, or need for emergent treatment)(3)

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

Aims

- Determine **which atrial measurement(s**) (volume, area, diameter) is/are associated with **30-day PE-related adverse events** in patients with acute PE

- Determine **if any atrial measurement(s)** is/are a better predictor of **30-day PE-related adverse events** compared to the combination of TAPSE, ECG, and RV/LV ratio

- Determine 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 patients diagnosed with acute PE between 2007 – 2014

1. Clinical records:

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

2. Imaging and test records:

- Gated or non-gated chest CTA
- Tricuspid annular plane systolic excursion (TAPSE) echo result (from 24hrs before or 48hrs after the diagnostic CT scan)
- ECG result

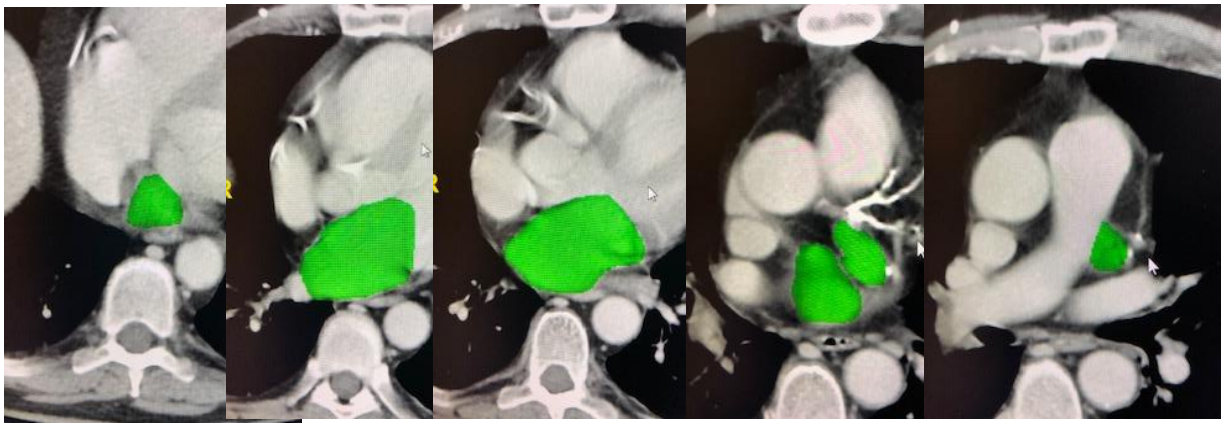
Methods

3. Measurements obtained - TeraRecon:

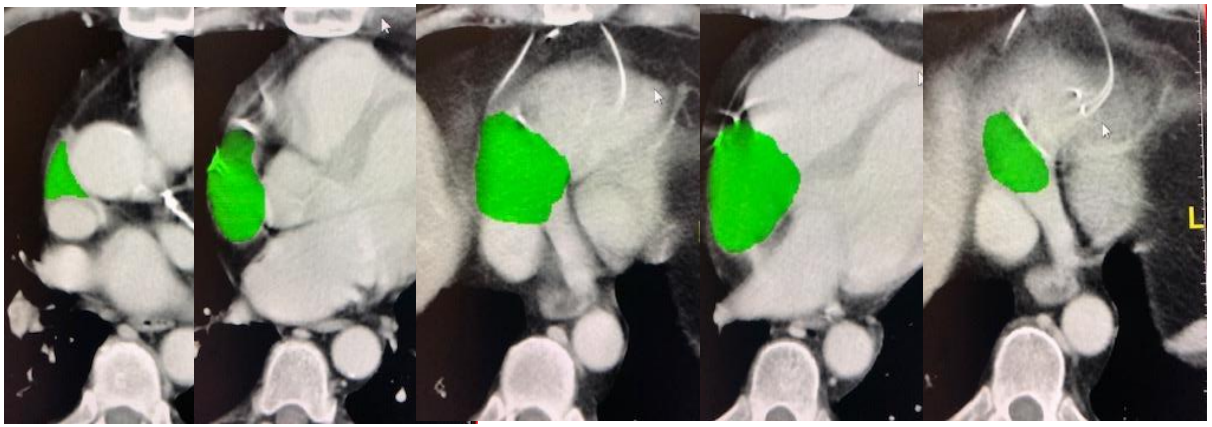
- Right and left atrial volume, area and diameters
- Main PA diameter
- RV/LV diameter ratio
- Ventricular septal bowing
- Reflux of contrast into the IVC

Methods: Atrial Volume

Left atrium (including appendage):

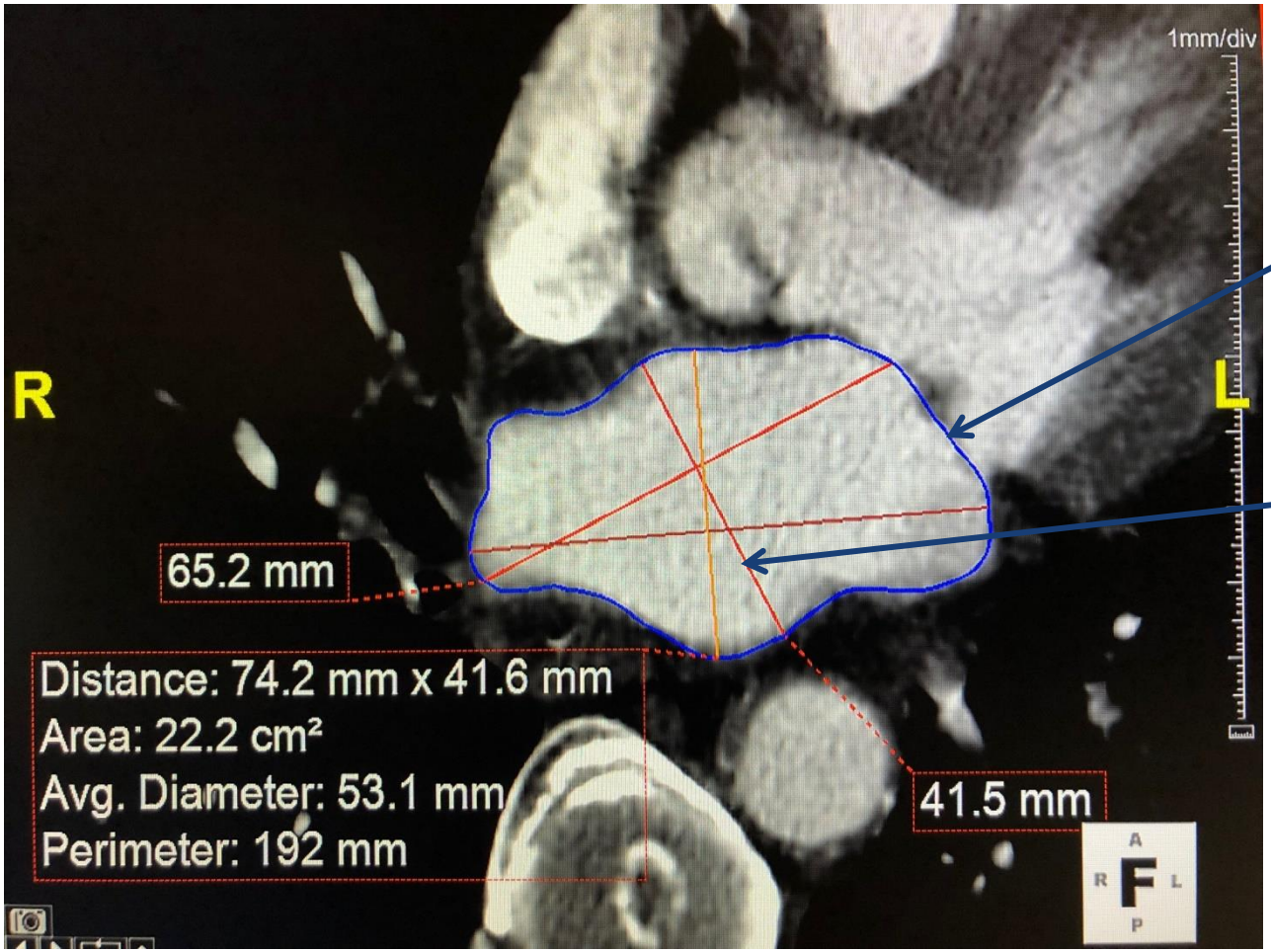


Right atrium (including appendage):



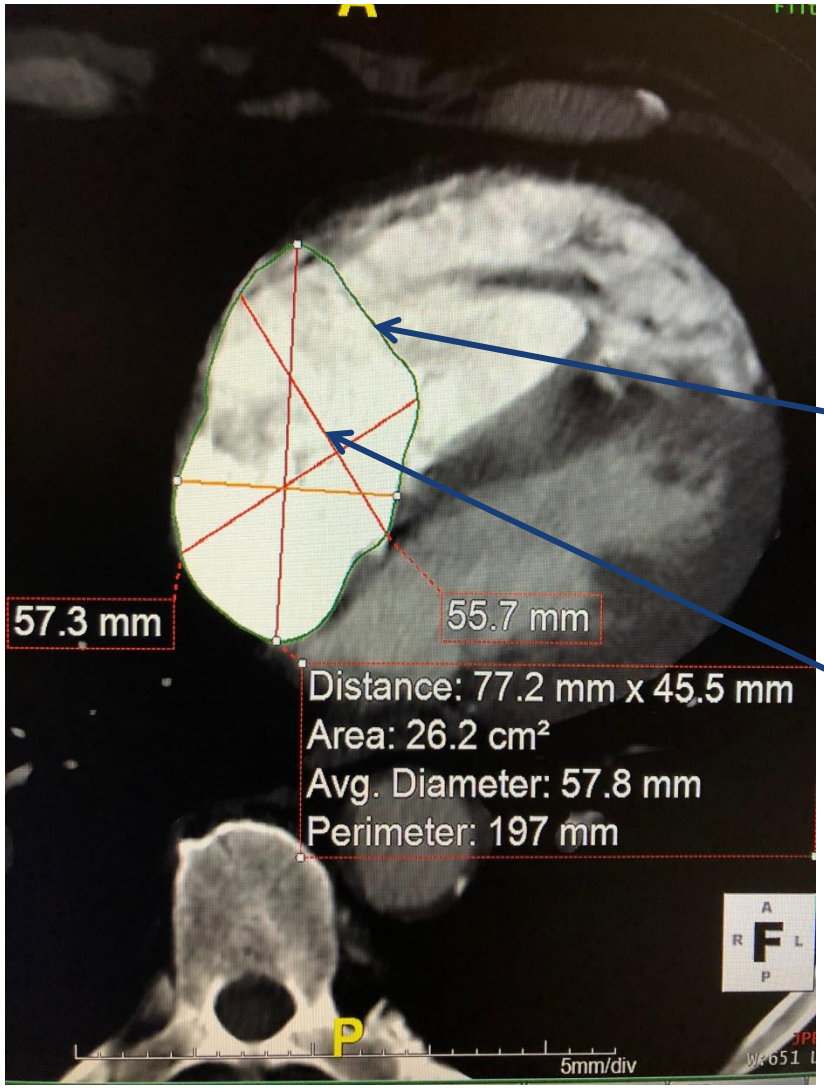
Measurements
Left atrial volume
Right atrial volume
RA/LA volume ratio
Left atrial area
Right atrial area
RA/LA area ratio
Left atrial short-axis diameter
Right atrial short-axis diameter
RA/LA short-axis diameter ratio
PA diameter
RV/LV diameter ratio

Methods: Left atrial area and diameter



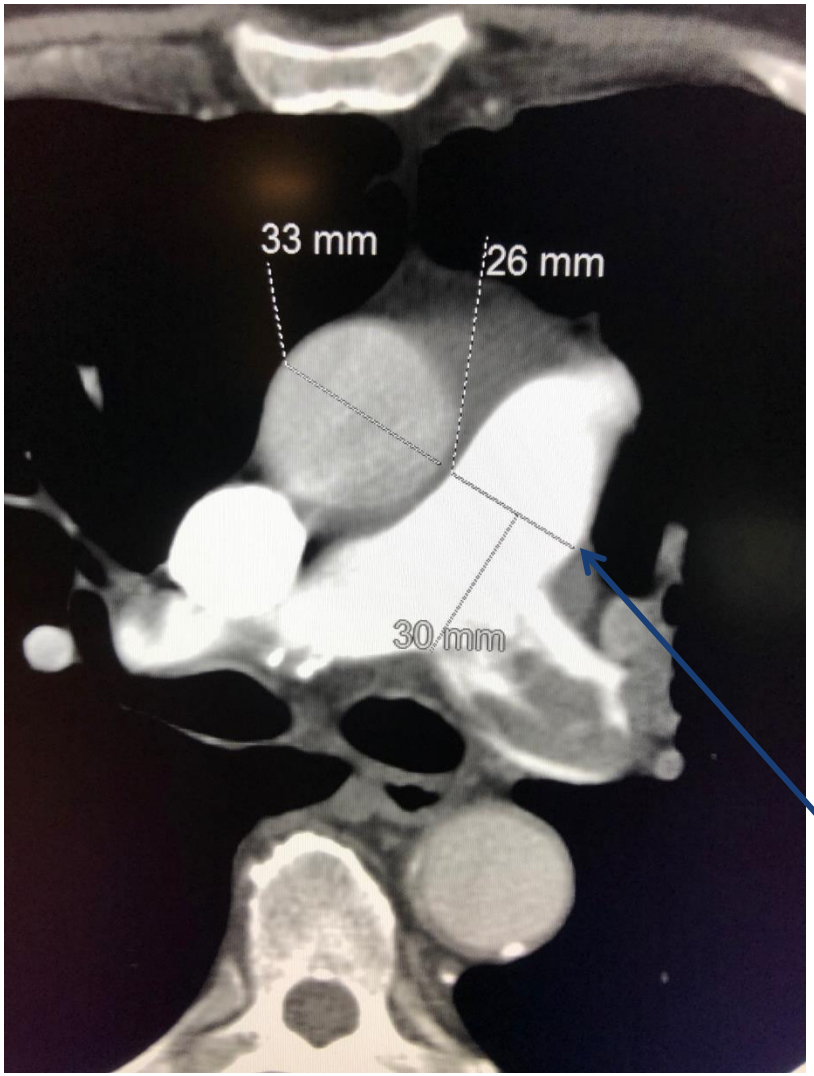
Measurements
Left atrial volume
Right atrial volume
RA/LA volume ratio
Left atrial area
Right atrial area
RA/LA area ratio
Left atrial short-axis diameter
Right atrial short-axis diameter
RA/LA short-axis diameter ratio
PA diameter
RV/LV diameter ratio

Methods: Right atrial area and diameter



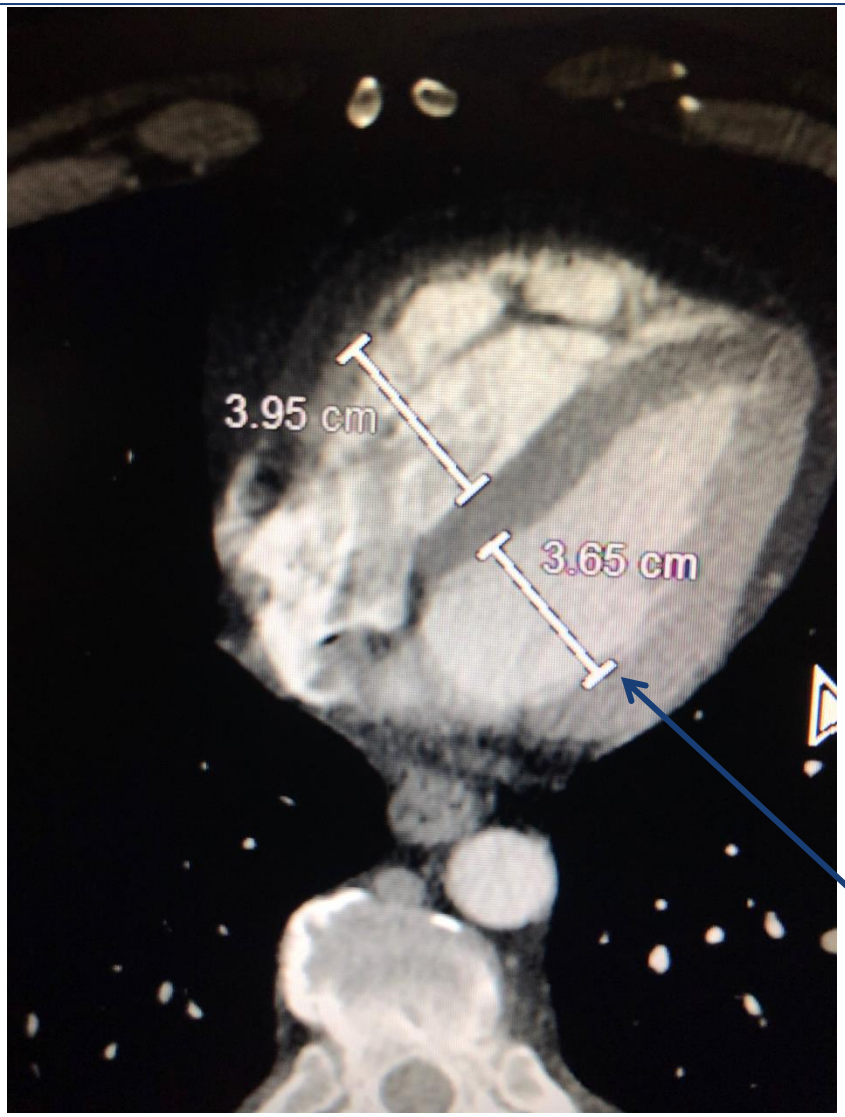
Measurements
Left atrial volume
Right atrial volume
RA/LA volume ratio
Left atrial area
Right atrial area
RA/LA area ratio
Left atrial short-axis diameter
Right atrial short-axis diameter
RA/LA short-axis diameter ratio
PA diameter
RV/LV diameter ratio

Methods: Pulmonary artery



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

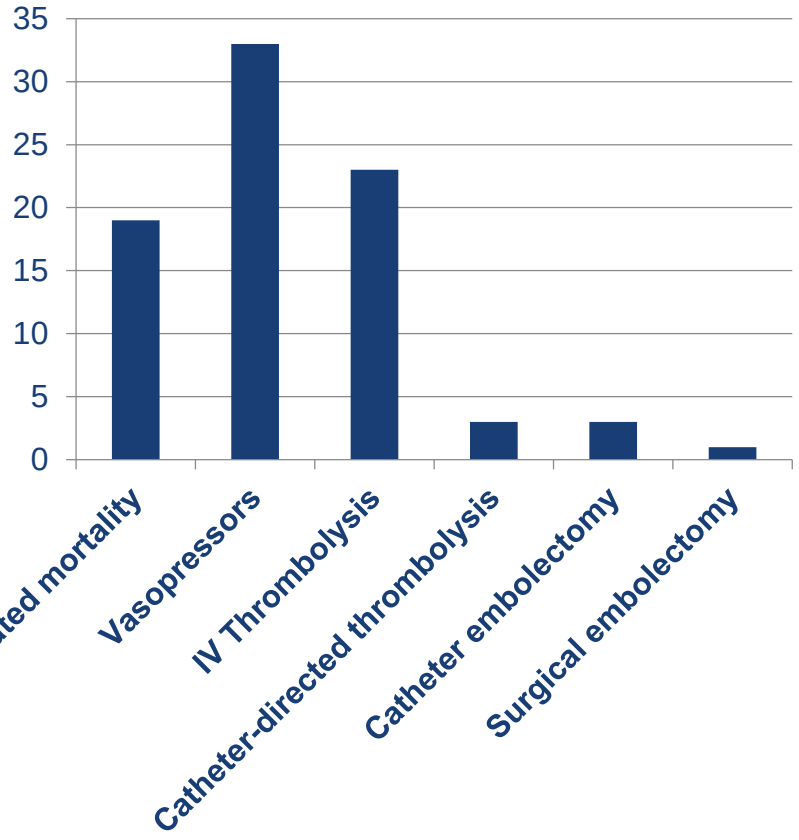
- **Multivariate logistic regression** was performed to determine the best predictors of adverse outcomes

Results

Demographics

- N = 493 pts (8 excluded)
- Adverse events = 62/493 pts (12.6%)
- Mean age = 63±16 years (p=0.2)
- Male 48%; Female 52% (p=0.6)

Number of patients with 30-day adverse events

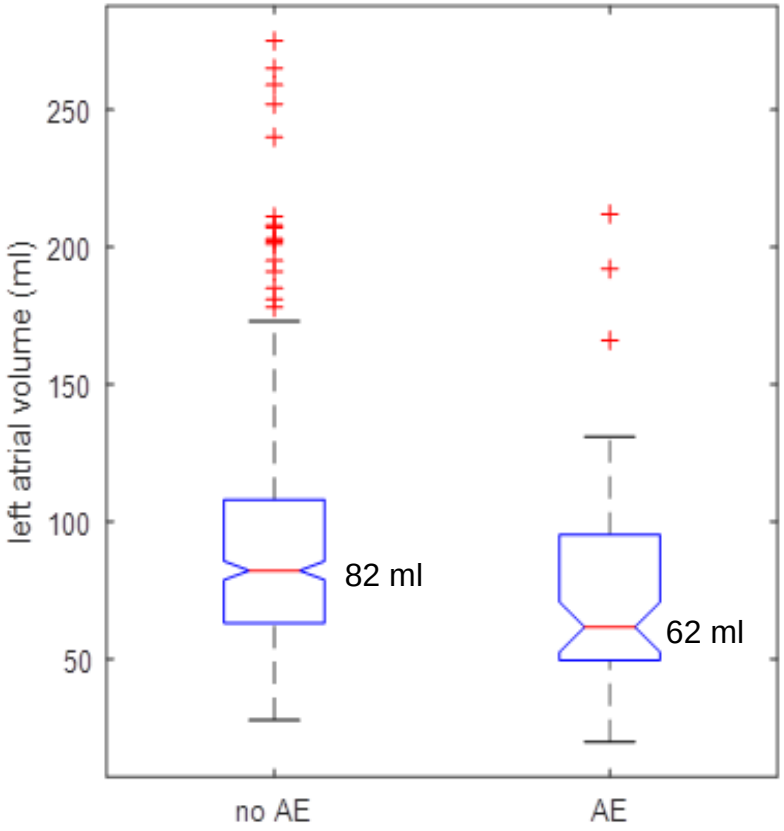


Results: Association between measurements and adverse events

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

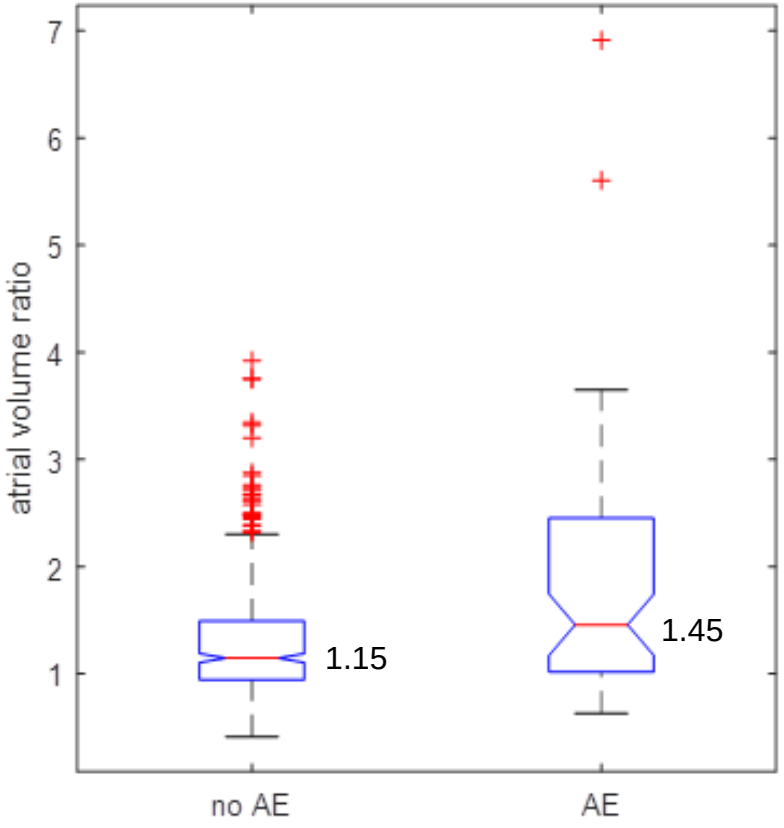
Results: Left atrial volume

LA volume in patients with and without adverse events (AE)



P<0.001

RA/LA volume ratio in patients with and without adverse events (AE)



P<0.001

Results: Association between measurements and adverse events

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

Measurements	No Adverse Event (% of group)	Adverse Event (% of group)	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**

- **Selection bias:**
  - Acute PE only
  - Original database only included patients with an echo performed

- 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

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 **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

Carroll, B. J., Heidinger, B. H., Dabreo, D. C., Matos, J. D., Mohebali, D., Feldman, S. A.,McCormick, I., Litmanovich, D., Manning, W. J. (2018). Multimodality Assessment of Right Ventricular Strain in Patients With Acute Pulmonary Embolism. *American Journal of Cardiology*, *122*(1), 175–181.

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Aujesky, D., Hughes, R., Jimenez, D. (2009). Short-term prognosis of pulmonary embolism. *Journal of Thrombosis and Haemostasis*. 7 (suppl. 1):318-21

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Questions?

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Further Measurements

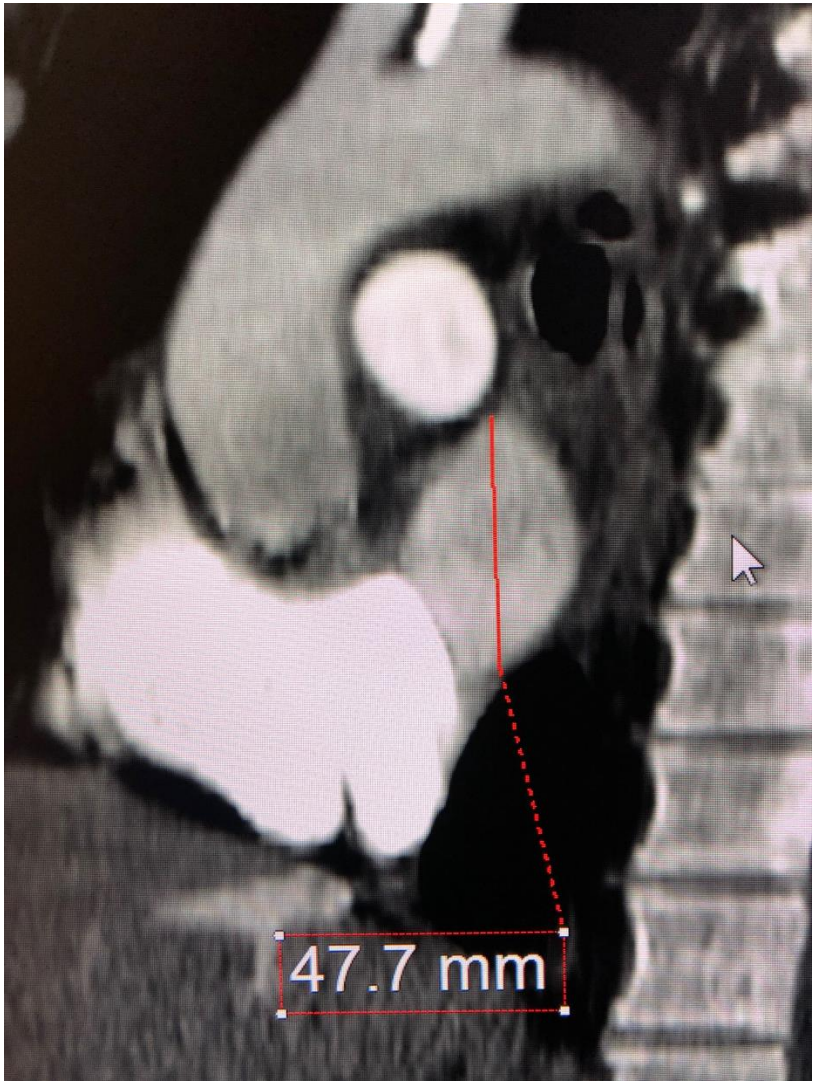
Atrial Appendages:

- 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

[1]Schmid *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%)