

# Teaching Nonradiologists to Identify Right Heart Strain on Computed Tomography Scans of Acute Pulmonary Embolism

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Acute pulmonary embolism management is centered on the presence of right ventricular (RV) strain. Patients with RV strain have a greater than twofold increase in 30-day mortality (1, 2). RV strain is present in  $\geq 25\%$  in patients with pulmonary embolism (3). This is associated with adverse outcomes even in patients with low pulmonary embolism severity index (3). RV dilation on computed tomography pulmonary angiography (CTPA) was associated with increased 30-day mortality in patients with acute pulmonary embolism (4).

European Society of Cardiology guidelines allow the use of CTPA and/or echocardiography in pulmonary embolism risk stratification (5). Even though echocardiography is invaluable in

pulmonary embolism management, it is often delayed (6).

RV/left ventricular (LV) ratio on CTPA is a clinical endpoint in clinical trials involving catheter-directed treatments in patients with intermediate-risk pulmonary embolism (7–11). Identifying RV strain on CTPA facilitates treatment decisions. Measurements of the RV/LV ratio on CTPA by trained radiologists tend to be very accurate and reproducible (12). The accuracy and reproducibility of measurements obtained by other medical professionals have not been well described.

## METHODS

We selected 93 patients from the Temple University Hospital Pulmonary Embolism

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(Received in original form November 3, 2021; accepted in final form April 20, 2022)

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This article has a data supplement, which is accessible from the table of contents of this issue at [www.atsjournals.org](http://www.atsjournals.org).

ATS Scholar Vol 3, Iss 2, pp 175–179, 2022  
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DOI: 10.34197/ats-scholar.2021-0128BR

Response Team registry (institutional review board 26021). All patients had confirmed pulmonary embolism on CTPA during their hospitalization.

Two instructional sessions led by an expert chest radiologist, one 30-minute live session and one 30-minute recorded video session, were attended by three internal medicine residents (two postgraduate year 2 [PGY-2], one PGY-3) and five pulmonary critical care fellows (three PGY-5, two PGY-6). The recorded session was first, during which the radiologist described how to measure the RV/LV ratio at the maximum diameters of the ventricles. Features of RV strain, including dilatation and septal flattening, were described and examples provided. For inferior vena cava (IVC) reflux, assessment of the attenuation of contrast in the IVC was described. *See* the data supplement for a video by our expert radiologist detailing how to obtain these measurements with examples. During the in-person session, trainees measured parameters with the radiologist. The radiologist was available to help with technique and answer questions. All participants had measured at least five test images with acceptable results before participating in the study.

All trainees independently and in a blinded manner measured the right ventricle and left ventricle at their maximum diameters at the levels of the tricuspid and mitral valves, respectively, to calculate the RV/LV ratio.

Furthermore, they subjectively determined if the right ventricle and the ventricular septum appeared normal or abnormal (flattened or bowed) as well as the subjective appearance of RV dilatation. To assess IVC reflux, the cohort assessed the attenuation of contrast in the IVC and the hepatic veins.

The primary objective of this study was to assess the accuracy of trainees in determining RV/LV ratio, RV dilation, IVC reflux, and septal flattening. The primary endpoints were Cohen's kappa statistic for binary variables and the intraclass correlation coefficient (ICC) for the continuous variable of RV/LV ratio.

## RESULTS

### RV/LV Ratio

We defined an elevated RV/LV ratio as  $\geq 1.0$ . The ICC was assessed. Each of our trainees was measured against the expert radiologist. Three trainees had excellent correlations, and five had good correlations (Table 1).

### Accuracy of Binary Variables

Binary variables studied included IVC reflux, RV dilatation, and septal flattening. In measuring RV dilatation, one trainee had substantial agreement with the expert radiologist, four had moderate agreement, and three had fair agreement. In measuring septal flattening, two trainees had substantial agreement, three had moderate agreement, and three had fair agreement. For IVC reflux, five trainees had substantial agreement, one had moderate agreement, one had fair agreement, and one had slight agreement (Table 2).

## DISCUSSION

In our study, we showed that after 1 hour of instruction, all participants could identify and measure the RV/LV ratio. ICCs were assessed and indicated good to excellent correlations. The participants had no prior training in assessing CTPA imaging. We showed that our instructional sessions were effective at various points in training, from junior resident to senior fellow. This supports our hypothesis that

**Table 1.** Intraclass correlation coefficients for average measurements of right ventricular/left ventricular ratio for trainees versus radiologist ( $n = 93$ )

ICC for Average RV/LV Ratio Measurements	
PGY-2 vs. radiologist	0.71
PGY-2 vs. radiologist	0.89
PGY-3 vs. radiologist	0.81
PGY-5 vs. radiologist	0.72
PGY-5 vs. radiologist	0.74
PGY-5 vs. radiologist	0.73
PGY-6 vs. radiologist	0.65
PGY-6 vs. radiologist	0.83

*Definition of abbreviations:* ICC = intraclass correlation coefficient; LV = left ventricular; PGY = postgraduate year; RV = right ventricular.

ICCs are interpreted as follows: <0.40 indicates poor correlation, 0.40–0.59 indicates fair correlation, 0.60–0.74 indicates good correlation, and 0.75–1.00 indicates excellent correlation.

trainees can be taught to reliably measure RV/LV ratio on CTPA. One of the limitations of our study was that there was no “control group”: no assessment of trainees’ ability to measure RV/LV ratio beforehand or of subjects who were not involved in the study. The ICCs obtained did show good correlations but did not

reach the level of experienced radiologists. A retrospective study looking at cardiovascular and thoracic radiologists’ assessments of RV parameters on CTPA consistently showed ICCs >0.95 (13). Comparatively, a recent study of artificial intelligence software measuring RV/LV ratio in patients with acute pulmonary

**Table 2.** Cohen’s kappa statistics of agreement comparing residents and fellows with chest radiologist ( $n = 93$ )

	RV Dilatation	Septal Flattening	IVC Reflux
PGY-2 vs. radiologist	0.58	0.53	0.63
PGY-2 vs. radiologist	0.38	0.59	0.04
PGY-3 vs. radiologist	0.31	0.33	0.76
PGY-5 vs. radiologist	0.50	0.43	0.28
PGY-5 vs. radiologist	0.66	0.63	0.66
PGY-5 vs. radiologist	0.48	0.66	0.53
PGY-6 vs. radiologist	0.45	0.32	0.64
PGY-6 vs. radiologist	0.24	0.25	0.74

*Definition of abbreviations:* IVC = inferior vena cava; PGY = postgraduate year; RV = right ventricular.

Kappa coefficients are interpreted as follows: 0.81–1.0 indicates almost perfect agreement, 0.61–0.80 indicates substantial agreement, 0.41–0.60 indicates moderate agreement, 0.21–0.40 indicates fair agreement, 0.01–0.20 indicates slight agreement, and <0.00 indicates poor agreement.

embolism showed an ICC of 0.83 compared with a radiologist standard (14). This was defined as a “very good” correlation and is consistent with the correlation we found between our trainees and the standard.

Subjective measurements were much less consistent when compared with the standard (Table 2). Measurements by trainees mostly showed “slight” to “moderate” degrees of agreement, indicating that trainees were not as consistent in identifying these variables as in measuring RV/LV ratio. Given this variability, efforts to educate trainees in risk stratifying pulmonary embolism should be more focused on assessing RV/LV ratio, a more reproducible variable.

CTPA is often the first diagnostic study in the evaluation of a patient with suspected pulmonary embolism. It can be used to assess for RV strain and enlargement (5). One meta-analysis showed that an RV/LV ratio of  $>1.0$  on computed tomography, as

assessed in our study, was associated with a 2.5-fold risk of mortality (15). Higher RV/LV ratios increase specificity for decompensation (16–18) regardless of the patient’s hemodynamic stability. Therefore, RV/LV ratios of  $>1.0$  should be used to risk stratify patients (15). This is as recommended in current clinical practice guidelines, as outlined in the 2019 European Society of Cardiology recommendations (3).

### Conclusions

Measurement of RV/LV ratio on CTPA is a clinically relevant skill to risk stratify patients with acute pulmonary embolism. We demonstrated that this skill was easily taught to trainees at all levels with simple instruction and was reproducible when viewing clinical images. Developing a teaching strategy for trainees at academic institutions to measure RV/LV ratio in these patients could substantially affect patient care, triage, and resource use.

**Author disclosures are available with the text of this article at [www.atsjournals.org](http://www.atsjournals.org).**

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