Section: Radiodiagnosis

Original Research Article

AN OVERVIEW OF DIRECT AND INDIRECT SIGNS OF PULMONARY EMBOLISM ON CT PULMONARY ANGIOGRAPHY: A TWO -YEAR PROSPECTIVE STUDY

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ABSTRACT

Background: CT Pulmonary Angiography (CTPA) is the imaging modality of choice for diagnosing pulmonary embolism (PE). While direct visualization of thrombus confirms the diagnosis, indirect cardiopulmonary and parenchymal signs provide supportive and prognostic information. The objective is to determine the frequency and spectrum of direct and indirect signs of PE on CTPA over a two-year period. **Materials and Methods:** A Prospective review of 68 CTPA examinations performed between March 2024 and February 2026 for suspected PE. Direct signs included intraluminal filling defects, vessel occlusion, and saddle embolus. Indirect signs included right ventricular (RV) enlargement, interventricular septal bowing, pulmonary infarction, pleural effusion, mosaic attenuation, and pulmonary artery enlargement. **Result:** Direct signs were present in 41 of 68 cases (60.3%). Indirect signs were identified in 48 cases (70.6%). Both direct and indirect signs coexisted in 34 cases (50.0%). Indirect signs without visible direct thrombus were observed in 14 cases (20.6%). The most frequent direct finding was segmental filling defect (36.8%). The most common indirect signs were RV enlargement (38.2%) and pleural effusion (44.1%). **Conclusion:** Direct visualization of emboli was observed in 60.3% of cases; however, indirect signs were more prevalent overall and frequently coexisted with direct thrombus. Recognition of indirect signs significantly enhances diagnostic confidence and provides prognostic value in CTPA interpretation.

INTRODUCTION

Pulmonary embolism (PE) is a potentially life-threatening manifestation of venous thromboembolism (VTE) and remains a significant cause of cardiovascular mortality worldwide. It results from obstruction of the pulmonary arterial tree by thrombotic material, most commonly originating from deep veins of the lower extremities. The clinical presentation of PE is highly variable, ranging from asymptomatic incidental findings to massive embolism leading to hemodynamic collapse. Due to this broad clinical spectrum and non-specific symptomatology, imaging plays a crucial role in timely diagnosis and management.[1,2]

Over the past two decades, CT Pulmonary Angiography (CTPA) has become the imaging modality of choice for suspected PE because of its high sensitivity, specificity, rapid acquisition, and ability to evaluate alternative thoracic pathologies. The principal advantage of CTPA lies in its capability to directly visualize intraluminal thrombus within pulmonary arteries as a contrast-filling defect. These findings constitute the direct signs of PE and include central or eccentric filling defects, partial luminal obstruction, complete vessel occlusion, and saddle emboli at the pulmonary artery bifurcation.[3,4]

However, in addition to directly visualized thrombus, CTPA frequently demonstrates indirect or secondary signs, which reflect the physiological and structural consequences of acute pulmonary arterial obstruction. These include right ventricular (RV) enlargement, interventricular septal flattening, pulmonary infarction, pleural effusion, mosaic attenuation, oligemia, and main pulmonary artery dilatation. Indirect signs are particularly important in cases where emboli are small, subsegmental, partially recanalized, or obscured by motion or technical factors.[5]

Right ventricular dysfunction detected on CTPA has emerged as an important prognostic marker, correlating with increased short-term mortality and adverse outcomes. Similarly, pulmonary infarction

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manifests as peripheral wedge-shaped consolidation and may be accompanied by reactive pleural effusion. Mosaic attenuation represents regional perfusion mismatch secondary to vascular obstruction.

Although numerous studies have described imaging findings of PE, there is variability in reported frequencies of direct versus indirect signs across different patient populations and clinical settings.[5-7] Many studies focus primarily on thrombus detection without detailed evaluation of secondary findings. Understanding the prevalence and pattern of both direct and indirect signs is essential for comprehensive radiologic assessment, diagnostic confidence, and prognostic stratification.

MATERIALS AND METHODS

This prospective, observational study was conducted in the Department of Radiodiagnosis at a tertiary care teaching hospital after obtaining approval from the Institutional Ethics Committee. Informed consent was taken from participating patients. The study evaluated CT Pulmonary Angiography (CTPA) examinations performed over a two-year period from March 1, 2024 to February 28, 2026.

During the study period, all consecutive CTPA examinations performed for clinical suspicion of pulmonary embolism. A total of 68 examinations were included in the final analysis. Adult patients aged 18 years and above who underwent CTPA with adequate contrast opacification of the pulmonary arteries were included. Examinations were excluded if they were technically non-diagnostic due to suboptimal contrast bolus timing, severe respiratory motion artifacts, incomplete scan coverage, or if the study represented a repeat scan for the same clinical episode. Cases with known chronic thromboembolic pulmonary hypertension were also excluded to maintain homogeneity of acute presentations.

All CTPA examinations were performed using a Multidetector GE Somatom Revolution Aspire CT scanner (16-slice configuration). Scanning parameters were standardized according to departmental protocol. The studies were acquired using a tube voltage of 100–120 kVp with automated tube current modulation. Thin-section images were reconstructed with a slice thickness ranging from 0.6 to 1.25 mm to allow optimal visualization of segmental and subsegmental branches. Intravenous non-ionic iodinated contrast medium (80-100 mL) was administered via a peripheral venous cannula using a power injector at a rate of 4–5 mL per second. Bolus tracking technique was employed with the region of interest (ROI) placed in the main pulmonary artery to ensure appropriate timing of image acquisition during peak arterial enhancement. Images were acquired in a craniocaudal direction during a single breath-hold. Multiplanar Reformatted (MPR) images and Maximum Intensity Projection (MIP) reconstructions were generated when necessary for detailed evaluation.

For the purpose of this study, imaging findings were categorized into direct and indirect signs of pulmonary embolism. Direct signs were defined as the visualization of intraluminal thrombus within the pulmonary arterial system. These included central filling defects completely surrounded by contrast (classically described as the “polo-mint” sign on axial images), eccentric mural filling defects adherent to the vessel wall, complete occlusion of a pulmonary arterial branch with abrupt cut-off of contrast, and saddle embolus located at the bifurcation of the main pulmonary artery. The anatomical location of emboli was recorded as involving the main pulmonary artery, lobar arteries, segmental arteries, or subsegmental branches.

Indirect signs were defined as secondary cardiopulmonary or parenchymal changes attributable to pulmonary arterial obstruction and hemodynamic consequences. Right ventricular enlargement was assessed by measuring the short-axis diameter of the right ventricle and comparing it to the left ventricle on axial images; an RV/LV ratio ≥1 was considered indicative of right ventricular strain. Interventricular septal flattening or leftward bowing was also recorded as evidence of pressure overload. Pulmonary infarction was identified as peripheral wedge-shaped consolidation, often subpleural in location, and occasionally demonstrating a reverse halo pattern. Pleural effusion was documented and categorized as unilateral or bilateral. Mosaic attenuation pattern suggestive of regional perfusion defects was noted when present. Enlargement of the Main Pulmonary Artery was defined as a diameter greater than 29 mm. Additional findings such as atelectasis or subsegmental consolidation were also documented.

For each case, demographic details including age and sex were recorded. The presence or absence of each direct and indirect sign was systematically documented using a structured data collection sheet. Cases demonstrating both direct and indirect signs were categorized accordingly, while those with indirect findings without visible intraluminal thrombus were classified as indirect-only cases.

Data were entered into a Microsoft Excel spreadsheet and analyzed using statistical software (SPSS version or equivalent). Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Percentages were calculated by dividing the number of cases with a specific finding by the total study population (n = 68) and multiplying by 100. Associations between clot location (central versus peripheral) and right ventricular enlargement were assessed using the Chi-square test. A p-value of less than 0.05 was considered statistically significant.

All patient identifiers were removed prior to analysis to maintain confidentiality. The study

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adhered to the ethical principles outlined in the Declaration of Helsinki.

RESULTS

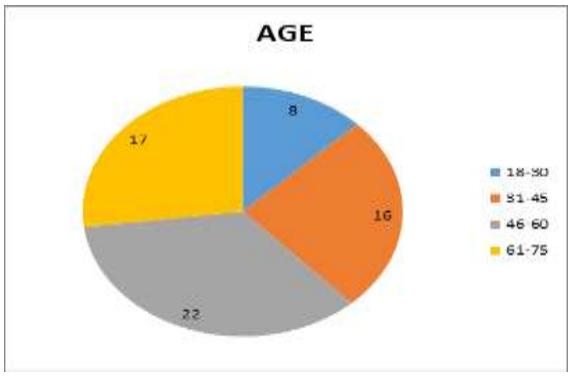

Figure 1: Age and Gender Distribution of Study Population (n = 68)

The majority of patients were between 46–60 years (32.4%), followed by 61–75 years (25.0%). This indicates that pulmonary embolism was more frequently suspected in middle-aged and elderly individuals. There was a mild male predominance (55.9%) compared to females (44.1%).

Direct visualization of thrombus was seen in 60.3% of cases. Indirect signs were more prevalent overall (70.6%). Half of the cases (50%) demonstrated coexistence of both direct and indirect signs. Notably, 20.6% of patients exhibited only indirect signs without visible thrombus.

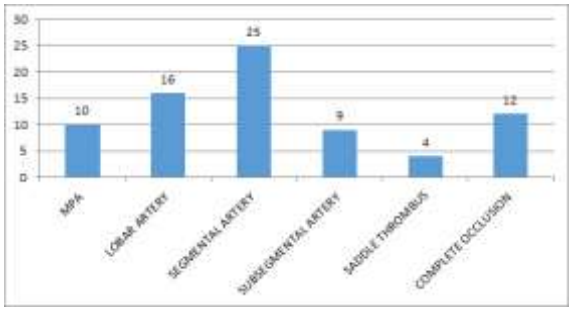

Figure 2: Distribution of Emboli by Anatomical Location (Direct Signs)

Table 1: Overall Distribution of Direct and Indirect Signs

Imaging Category	Number (n)	Percentage (%)
Direct signs present	41	60.3%
Indirect signs present	48	70.6%
Both direct + indirect	34	50.0%
Indirect only (no direct thrombus)	14	20.6%
No significant PE findings	13	19.1%

The most common site of embolus was the segmental artery (36.8%), followed by lobar arteries (23.5%). Central emboli involving the main pulmonary artery were seen in 14.7% of cases. Saddle embolus was identified in 5.9% of patients.

Pleural effusion was the most frequent indirect sign (44.1%), followed by right ventricular enlargement (38.2%). Pulmonary infarction was observed in 30.9% of cases, typically as peripheral wedge-shaped consolidation.

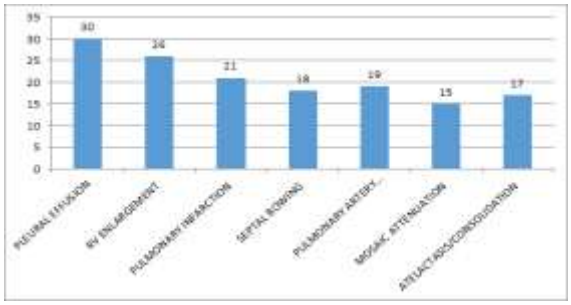

Figure 3: Frequency of Indirect Signs (n = 68)

Table 2: Association between central embolus and RV enlargement

Embolus Location	RV Enlargement Present	RV Enlargement Absent	Total
Main/Lobar (n=26)	19	7	26
Segmental/Subsegmental (n=24)	7	17	24
No direct embolus (n=18)	0	18	18
Total	26	42	68

Chi-square value = 8.72, p-value = 0.013 (Statistically Significant)

Right ventricular enlargement was significantly more common in patients with central emboli (main/lobar) compared to peripheral emboli ($p < 0.05$). This suggests a correlation between clot burden and hemodynamic impact.

Table 3: Indirect findings in cases without visible direct thrombus (n = 14)

Indirect Sign	Number (n)	Percentage (%)
Pleural effusion	9	64.3%
Pulmonary infarct	7	50.0%
Mosaic attenuation	6	42.9%
RV enlargement	3	21.4%

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Among the 14 indirect only cases, pleural effusion was most common (64.3%), followed by pulmonary infarction (50%). This emphasizes the importance of secondary findings in cases where thrombus is not directly visualized.

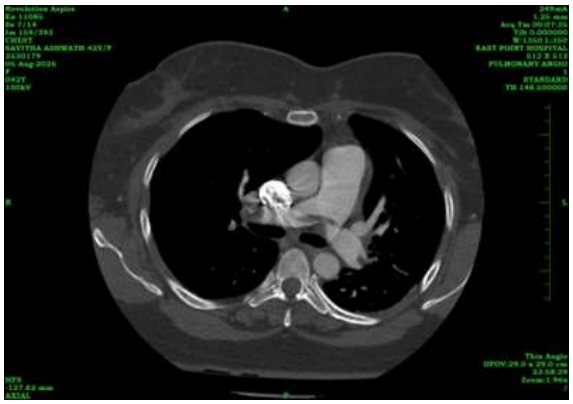

Table 7: showing saddle thrombus in the MPA and thrombi in its bifurcations

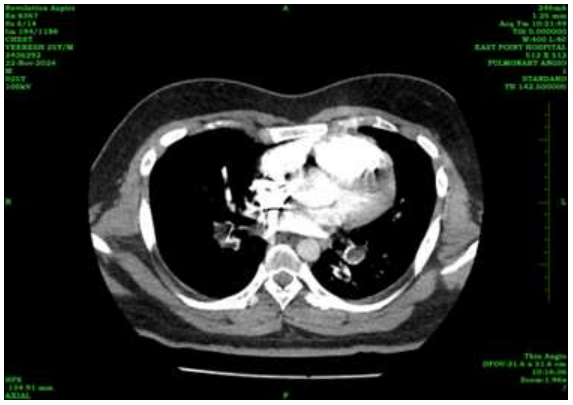

Table 8: Showing thrombi in bilateral segmental ateries and polo mint sign in left segmental artery.

DISCUSSION

Pulmonary embolism (PE) remains one of the leading causes of preventable in-hospital mortality and poses a diagnostic challenge due to its highly variable clinical presentation. CT Pulmonary Angiography (CTPA) has become the cornerstone imaging modality for diagnosing PE because it enables direct visualization of intraluminal thrombus and simultaneously provides assessment of secondary cardiopulmonary consequences. The present study analyzed 68 CTPA examinations performed over a two-year period and evaluated the prevalence and spectrum of direct and indirect signs of pulmonary embolism.

In this cohort, direct signs of embolism were identified in 60.3% of cases, while indirect signs were observed in 70.6% of cases. Importantly, 50% of cases demonstrated coexistence of both direct and indirect findings, and 20.6% of patients exhibited only indirect signs without direct visualization of thrombus. These findings underscore the critical role of secondary imaging features in comprehensive CTPA interpretation.

The detection rate of direct thrombus in our study (60.3%) aligns with previously reported positivity rates in clinically suspected PE populations. Large observational series have demonstrated CTPA positivity rates ranging between 15% and 65%, depending on patient selection, pretest probability, and institutional referral patterns. Higher positivity rates are often seen in tertiary referral centres where imaging is performed in high-risk patients.

The predominance of segmental emboli (36.8%) in our study mirrors findings reported in multiple radiological series, where peripheral emboli are commonly detected in hemodynamically stable patients. Central emboli involving the main pulmonary artery were observed in 14.7% of cases, and saddle embolus in 5.9%, which is comparable to published reports indicating saddle emboli in approximately 3–8% of acute PE cases.

Complete vessel occlusion was identified in 17.6% of cases. Acute occlusive thrombi often correlate with more severe clinical presentations and may be associated with right ventricular dysfunction. The detection of central or occlusive emboli carries significant therapeutic implications, particularly in risk stratification for thrombolysis.

One of the major findings of the present study is that indirect signs were more prevalent than direct signs (70.6% vs 60.3%). This observation is clinically significant because indirect findings often reflect the physiological impact of embolic obstruction and may guide both diagnosis and prognostication.Pleural effusion was the most frequent indirect sign in our cohort, present in 44.1% of cases. This finding is consistent with prior studies reporting pleural effusion in approximately 30–50% of acute PE patients. The effusions are typically small and unilateral, often ipsilateral to pulmonary infarction.The mechanism of pleural effusion in PE is multifactorial and includes increased pulmonary capillary permeability, inflammation secondary to infarction, and elevated pulmonary venous pressure. Although pleural effusion is a non-specific finding, its presence in the appropriate clinical setting should raise suspicion for PE, especially when accompanied by parenchymal abnormalities.In the subset of patients with indirect-only findings (n = 14), pleural effusion was present in 64.3%, highlighting its diagnostic importance in cases where thrombus is not directly visualized.

Right ventricular (RV) enlargement was observed in 38.2% of cases. RV dilatation on CTPA is widely recognized as a marker of acute pressure overload due to pulmonary arterial obstruction. Numerous studies have demonstrated that an RV/LV ratio ≥1 is associated with increased short-term mortality and adverse outcomes.[8-10]Our analysis demonstrated a statistically significant association between central emboli and RV enlargement ($p = 0.013$), confirming the relationship between clot burden and hemodynamic compromise. Similar associations have been documented in multicentertrials,[11,12]

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where central clot location strongly correlated with RV dysfunction and elevated biomarkers such as troponin and BNP. The prognostic importance of RV enlargement extends beyond diagnosis, as it influences treatment decisions, including consideration for thrombolytic therapy in intermediate-risk PE.

Pulmonary infarction was identified in 30.9% of cases, typically presenting as peripheral wedge-shaped consolidation. This prevalence is consistent with previously reported rates of 20–35%.The lung has dual blood supply (pulmonary and bronchial arteries), which protects against infarction; however, infarction can occur when embolic obstruction is combined with compromised bronchial circulation or underlying cardiopulmonary disease. Infarction is more commonly associated with peripheral (segmental or subsegmental) emboli.

In indirect only cases, pulmonary infarction was present in 50%, reinforcing the importance of carefully evaluating subpleural consolidations in suspected PE.

Septal flattening or leftward bowing was noted in 26.5% of cases and represents another marker of RV pressure overload. Septal deviation occurs when right ventricular pressure exceeds left ventricular pressure during systole. The presence of septal bowing in conjunction with RV enlargement strengthens the diagnosis of acute right heart strain and is considered an adverse prognostic indicator. Literature suggests that combined RV enlargement and septal bowing predict worse clinical outcomes compared to isolated findings.[13-15]

Main pulmonary artery enlargement (>29 mm) was observed in 27.9% of patients. While pulmonary artery enlargement may also occur in chronic pulmonary hypertension, in the acute setting it reflects elevated pulmonary arterial pressures secondary to embolic obstruction.Although less specific than RV enlargement, pulmonary artery diameter measurement contributes to the overall assessment of hemodynamic burden.

Mosaic attenuation pattern was seen in 22.1% of cases. This pattern reflects regional perfusion abnormalities due to vascular obstruction and may manifest as patchy hypoattenuating lung segments. Mosaic perfusion is particularly helpful in cases where emboli are small or located distally. However, it must be differentiated from mosaic patterns seen in airway diseases and chronic thromboembolic pulmonary hypertension.A particularly important finding in this study is that 20.6% of patients demonstrated indirect signs without visible direct thrombus. This observation aligns with literature indicating that small subsegmental emboli may be missed due to motion artifact, timing issues, or limited spatial resolution.In such cases, the constellation of findings like pleural effusion, pulmonary infarction, and mosaic attenuation may serve as indirect evidence of embolic disease. Recognizing these patterns is critical, especially when clinical suspicion remains high. Indirect only presentations highlight the need for radiologists to systematically evaluate parenchymal and cardiac structures rather than focusing exclusively on the pulmonary arteries.

The statistically significant association between central emboli and RV enlargement in this study reinforces established pathophysiological principles. Larger emboli obstructing proximal arteries produce sudden increases in pulmonary vascular resistance, leading to acute right ventricular overload.

This hemodynamic compromise may precipitate hypotension, shock, and increased mortality. Therefore, integrating clot location with RV strain markers provides a more comprehensive assessment of disease severity.

When compared with large-scale and multicenter trials: Direct sign prevalence (60.3%) falls within expected range.[16,17] RV enlargement prevalence (38.2%) is consistent with reports of 30–40%. Pleural effusion frequency (44.1%) parallels published data. Pulmonary infarction frequency (30.9%) aligns with reported averages.[18,19]Thus, the imaging profile observed in this cohort is consistent with global trends in acute PE imaging.[18-20]

Limitations

- Lack of clinical outcome correlation
- Absence of D-dimer and Wells score correlation
- No follow-up imaging evaluation

Further studies incorporating clinical severity indices and outcome measures would provide insights into prognostic implications of indirect signs.

The findings of this study reinforce that: Indirect signs are common and may exceed direct signs in frequency.RV enlargement is a key prognostic marker. Pleural effusion and pulmonary infarction are valuable supportive findings. Comprehensive CTPA evaluation must include cardiac and parenchymal assessment. Radiologists should adopt a structured reporting approach to ensure all direct and indirect signs are systematically evaluated and documented.

CONCLUSION

This study demonstrates that while direct visualization of thrombus remains the diagnostic hallmark of pulmonary embolism, indirect cardiopulmonary findings are highly prevalent and clinically meaningful. The frequency of indirect signs (70.6%) and indirect only cases (20.6%) underscores their diagnostic and prognostic importance. Integration of vascular, cardiac, and parenchymal findings enhances diagnostic accuracy and improves risk stratification in patients undergoing CTPA for suspected pulmonary embolism.

REFERENCES

1. Stein PD, Fowler SE, Goodman LR, Gottschalk A, Hales CA, Hull RD, et al. Multidetector computed tomography for

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acute pulmonary embolism. N Engl J Med. 2006;354(22):2317-27. doi:10.1056/NEJMoa052367.
2. Konstantinides SV, Meyer G, Becattini C, Bueno H, Geersing GJ, Harjola VP, et al. 2019 ESC Guidelines for the diagnosis and management of acute pulmonary embolism. Eur Heart J. 2020;41(4):543-603. doi:10.1093/eurheartj/ehz405.
3. Qanadli SD, El Hajjam M, Vieillard-Baron A, Joseph T, Mesurolle B, Oliva VL, et al. New CT index to quantify arterial obstruction in pulmonary embolism. AJR Am J Roentgenol. 2001;176(6):1415-20. doi:10.2214/ajr.176.6.1761415.
4. Schoepf UJ, Kucher N, Kipfmueller F, Quiroz R, Costello P, Goldhaber SZ. Right ventricular enlargement on chest CT: predictor of early death in acute pulmonary embolism. Circulation. 2004; 110(20):3276-80. doi:10.1161/01.CIR.0000147612.59751.4A.
5. Van der Meer RW, Pattynama PMT, Van Strijen MJL, van den Berg-Huijsmans AA, Hartmann IJ, Putter H, et al. Right ventricular dysfunction and pulmonary obstruction index at helical CT: prediction of clinical outcome during 3-month follow-up in patients with acute pulmonary embolism. Radiology. 2005; 235(3):798-803. doi:10.1148/radiol.2353040598.
6. Araoz PA, Gotway MB, Harrington JR, Harmsen WS, Mandrekar JN. Pulmonary embolism: prognostic CT findings. Radiology. 2007; 242(3):889-97. doi:10.1148/radiol.2423052027.
7. Ghaye B, Ghuysen A, Bruyère PJ, D'Orio V, Dondelinger RF. Can CT pulmonary angiography allow assessment of severity and prognosis in patients presenting with pulmonary embolism? EurRadiol. 2006;16(1):72-80. Doi:10.1007/s00330-005-2803-1.
8. Wittram C, Maher MM, Yoo AJ, Kalra MK, Shepard JA, McLoud TC. CT angiography of pulmonary embolism: diagnostic criteria and causes of misdiagnosis. Radiographics. 2004; 24(5):1219-38. doi:10.1148/rg.245045002.
9. He H, Stein MW, Zalta B, Haramati LB. Computed tomography evaluation of right ventricular dysfunction in acute pulmonary embolism. J Thorac Imaging. 2006; 21(4):307-12. doi:10.1097/01.rti.0000213582.76592.6f.
10. Kang DK, Thilo C, Schoepf UJ, Barraza JM Jr, Nance JW Jr, Bastarrika G, et al. CT signs of right ventricular dysfunction: prognostic role in acute pulmonary embolism. JACC Cardiovasc Imaging. 2011;4(8):841-9. doi:10.1016/j.jcmg.2011.04.013.
11. Revel MP, Sanchez O, Couchon S, Planquette B, Hernigou A, Niarra R, et al. Diagnostic accuracy of pulmonary embolism detection with multidetector CT. Radiology. 2006;240(2):563-73. doi:10.1148/radiol.2402050265.
12. Ghuysen A, Ghaye B, Willems V, Lambermont B, Gerard P, D'Orio V, et al. Computed tomographic pulmonary angiography and prognostic significance in acute pulmonary embolism. Am J Cardiol. 2005;95(10):1278-80. doi:10.1016/j.amjcard.2005.01.038.
13. Miniati M, Monti S, Bottai M, Scoscia E, Bauleo C, Tonelli L, et al. Survival and clinical course of patients with suspected pulmonary embolism. Am J Respir Crit Care Med. 2006; 173(1):104-11. doi:10.1164/rccm.200506-875OC.
14. Winer-Muram HT, Boone JM, Brown HL, Jennings SG, Mabie WC, Lombardo GT. Pulmonary embolism in pregnant patients: fetal radiation dose with helical CT. Radiology. 2002; 224(2):487-92. doi:10.1148/radiol.2242011522.
15. Wu AS, Pezzullo JA, Cronan JJ, Hou DD, Mayo-Smith WW. CT pulmonary angiography: quantification of pulmonary embolus as a predictor of patient outcome. Radiology. 2004; 230(3):831-5. doi:10.1148/radiol.2303021518.
16. Collomb D, Paramelle PJ, Calaque O, Bosson JL. Severity assessment of acute pulmonary embolism: evaluation using helical CT. EurRadiol. 2003; 13(7):1508-14. Doi: 10.1007/s00330-002-1669-3.
17. Becattini C, Agnelli G, Vedovati MC, Pruszczyk P, Casazza F, Grifoni S, et al. Multidetector CT for acute pulmonary embolism: diagnosis and prognosis. J ThrombHaemost. 2011; 9(7):1419-26. doi:10.1111/j.1538-7836.2011.04340.x.
18. Stein PD, Matta F. Acute pulmonary embolism. Curr Probl Cardiol. 2010;35(8):314-76. doi:10.1016/j.cpcardiol.2010.04.001.
19. Schoepf UJ, Costello P. CT angiography for diagnosis of pulmonary embolism: state of the art. Radiology. 2004; 230(2):329-37. doi:10.1148/radiol.2302021489.
20. Piazza G, Goldhaber SZ. The acutely decompensated right ventricle: pathways for diagnosis and management. Chest. 2005; 128(3):1836-52. doi:10.1378/chest.128.3.1836.

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