Large serpiginous thrombus straddling the patent foramen ovale and traversing through mitral and tricuspid valves into both ventricles: a therapeutic dilemma of impending paradoxical embolism and recurrent pulmonary embolism.

Yasmin S. Hamirani[1], Oleh Hnatiuk[2], Stuart Pett[3], Carlos A. Roldan[1*]

1. Division of Cardiology, University of New Mexico School of Medicine, New Mexico VA Healthcare System, Albuquerque, NM, USA

2. Cardiovascular Surgery division, University of New Mexico School of Medicine, New Mexico VA Healthcare System, Albuquerque, NM, USA

3. Pulmonary, Critical Care and Sleep Medicine Sectio, University of New Mexico School of Medicinen, New Mexico VA Healthcare System, Albuquerque, NM, USA

* **Correspondence:** Carlos A. Roldan, MD. University of New Mexico School of Medicine, New Mexico VA Healthcare System, 1501 San Pedro Dr SE, Albuquerque, NM 87108, USA
(*croldan@salud.unm.edu*)

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ABSTRACT

A 51-year-old male with history of resected renal cell carcinoma and prior pulmonary embolism presented with tachypnea, tachycardia and progressive dyspnea on exertion. Chest computed tomography revealed bilateral acute pulmonary embolism. Transthoracic echocardiogram showed severe pulmonary hypertension with severe cor-pulmonale and presence of a large worm-like thrombus extending across the foramen ovale, entering both ventricles through the mitral and tricuspid valves. The risks of anti-coagulation, pharmacologic thrombolysis, and surgical thrombectomy, in a hemodynamically stable patient, posed a significant therapeutic dilemma. Ultimately, a collective decision was made to start anticoagulation, without incident. At 1 month follow up, complete resolution of the intracardiac thrombus, pulmonary hypertension, and cor-pulmonale were observed with full clinical recovery of the patient.

CASE REPORT

CASE REPORT

A 51- year- old obese male with right-sided renal cell carcinoma, resected 1.5 year ago, presented to our emergency department with tachypnea, tachycardia and progressive dyspnea on exertion. He had history of pulmonary embolism (PE) approximately one year prior to admission, treated with warfarin, which had been self-discontinued two months prior to admission. Initial heart rate was 97 bpm, blood pressure was 117/88 mm Hg and O2 saturation was 95% on room air. Physical examination was only remarkable for elevated jugular venous pressure. The electrocardiogram was unremarkable. Troponin I was mildly elevated at 0.13 ng/ml (normal <0.034).

Imaging Findings

Contrast enhanced chest-computed tomography (CT), timed for the pulmonary artery, showed bilateral PE with saddle thrombus in the main pulmonary artery (Figure 1-A&B). A two- and three-dimensional transthoracic echocardiogram (TTE) performed the next day, revealed a large worm-like thrombus straddling across the foramen ovale (FO) and extending through both mitral and tricuspid valves into the respective ventricles (Figure 2 A-D). Severe right-sided chamber dilatation, severe right ventricular (RV) systolic dysfunction and severe pulmonary hypertension (pulmonary artery systolic pressure of 70-75 mm Hg) were also noted

(Figure 3 A-D). Limited visualization of the cardiac chambers due to the non-electrocardiographic gated prior chest CT scan (per PE protocol), precluded assessment of intracardiac thrombus. Although the patient had remote history of renal cell carcinoma with partial right nephrectomy, no evidence of recurrence on chest, abdominal and pelvic CT was identified. A lower extremity venous Doppler study demonstrated a focal, acute, right soleal deep venous thrombosis (DVT) (Figure 4).

Management

In hemodynamically stable patients at risk for recurrent fatal pulmonary and systemic embolism, the management strategy is not clearly defined. This is due to the significant risks associated with thrombolytics and surgical thrombectomy compared to anticoagulation. In our patient there was a clear potential for arterial and pulmonary embolization due to the left and right atrial highly mobile thrombus. The significant pulmonary hypertension and severe right ventricular dysfunction raised concerns of the patient's ability to tolerate repeat pulmonary embolism, risk of thrombolytics, or difficult weaning from cardiopulmonary bypass with thrombectomy. Similarly, no literature or guidelines are available on different anticoagulation strategies other than heparin followed by warfarin in patients with impending paradoxical embolism. After consultative consensus, conservative therapy with heparin 1150 units/hr and warfarin 5 mg po once a day was instituted. Patient remained hemodynamically stable and was discharged home after 5 days with therapeutic INR.

Follow up

At one month, follow up TTE revealed complete resolution of biatrial thrombus with normalization of RV size and function and pulmonary artery pressures. A saline contrast study confirmed the presence of a patent foramen ovale with right to left shunt during Valsalva maneuver (Figure 5 A-D). To date, patient remains clinically stable on warfarin therapy.

DISCUSSION

Etiology & demographics

Paradoxical embolism [1] is characterized by a venous thrombus entering the systemic arterial circulation through a right to left shunt. The shunt can be intra-cardiac: i.e. patent foramen ovale [PFO], atrial septal defect [ASD], ventricular septal defect [VSD]; or extra-cardiac: i.e. pulmonary arteriovenous (AV) fistula. The venous thrombus can originate in lower extremity veins, pelvic veins, in the atria during atrial fibrillation or flutter, in the atria in patients with central venous catheters, in an atrial septal aneurysm or from the edges of a PFO. Impending paradoxical embolism (IPE) is characterized by a thrombus trapped and in transit through a right to left shunt, i.e. a thrombus seen in a PFO but without clinical evidence of systemic arterial emboli.

Conheim [2] reported the first suspected case of paradoxical embolism in 1877. The first case of impending paradoxical embolism was published in 1985 initially documented by transesophageal echocardiography (TEE) and confirmed at surgery [3]. With improvements in both invasive and non-invasive imaging techniques, the diagnosis in living patients has been facilitated [4-6]

Loscalzo et al [7] presented a review of 30 patients with paradoxical embolism. 66% and 43% of their patients respectively had evidence of PE and DVT. DVT was attributed to post-operative state, obesity, myocardial infarction and congestive heart failure. Systemic arterial embolism was peripheral vs. cerebral in 49% vs. 37% of the patients. PFO was found to be the etiology for right to left shunt in 72% of the patients, while in 10%, 10% and 3% had ASD, pulmonary AV fistulas and VSDs respectively. Reports have been published of PFO with a straddling thrombus, some with and some without evidence of systemic embolism. Fauveau E eta l [8] published a nice review of 93 such cases and added 4 new cases to this report. The mean age of these patients was 58 ± 15 years and 42% were male. Impending embolism was identified in 56% while 44% indeed had paradoxical embolism.

We searched PubMed, since the publication of this comprehensive review of, from 2009 to 2013 and we found few more cases. A brief review of these cases of 'impending paradoxical embolus' through thrombus bestriding the PFO is presented in Table 1[9-20]. Of note, all except 2 had presence of DVT, 2 patients had confirmation of cerebral emboli and one each had renal and coronary emboli.

Clinical & imaging findings

In patients presenting with DVT or PE in the presence of right to left shunt, it is important to have a high index of suspicion for silent left-sided emboli. Elevated right-sided pressures or pulmonary hypertension (PH) in the above setting greatly increases the risk of paradoxical systemic emboli. PH is commonly seen in patients with chronic obstructive airway disease (COPD) and in patients with obstructive sleep apnea (OSA). An unusual case of elevated right-sided pressure from tricuspid stenosis due to thrombus obstructing the tricuspid valve has also been reported [21]. Temporary increase in right-sided pressures with cough, vomiting, defecation or shivering in a patient with straddling thrombus in the PFO, increase the likelihood of dislodgement.

Non-invasive cardiovascular imaging helps identify the presence of PFO, intra-cardiac thrombus, PE, DVT as well as, presence of PH. TTE with Doppler allows us to estimate pulmonary arterial pressures (PAP). In the absence of pulmonary flow obstruction, the tricuspid regurgitation (TR) peak velocity is linearly correlated with increased in systolic PAP (SPAP) against the gold standard, invasive cardiac catheterization [22]. Similarly, peak diastolic and end-diastolic velocities of pulmonary regurgitation (PR) correlate with mean PAP (MPAP) and pulmonary arterial end-diastolic pressure (PA-EDP) respectively[22]. Pulmonary vascular resistance (PVR) is estimated by dividing TR peak velocity by the time velocity integral of RV outflow tract [22]. According to European Society of Cardiology guidelines, PH is likely present in the presence of TR velocity >3.4 m/sec and SPAP >50 mm Hg with and without additional signs of PH [23]. The other signs of PH include: enlarged right sided cardiac chambers, increased interventricular septal thickness, reduced

global RV systolic function and flattening of the interventricular septum during late systole and early diastole, but can persists throughout diastole when volume overload from secondary moderate or worse tricuspid and pulmonary regurgitation are present [24]. On contrast-enhanced chest CT, the signs of PH include: Enlargement of main pulmonary artery, RV hypertrophy and dilatation, RV dysfunction (identified if gated cardiac scan is performed) and bronchial artery dilatation. Cardiac CT and magnetic resonance imaging (CMR) also help evaluate for presence of anomalous pulmonary venous return, intracardiac shunt or pulmonary AV malformation [25]. CT also helps to diagnose pulmonary causes of pulmonary hypertension. [26] [Figure 6]. Doppler ultrasonography of peripheral veins helps identify presence of venous thrombus and doppler arterial examination can help localize arterial embolism.

Treatment & prognosis

General consensus is lacking regarding optimal treatment of impending paradoxical embolism, particularly in a hemodynamically stable patient [27]. In patients with acute pulmonary embolism with severe hypoxia, significant right heart dysfunction, or hemodynamic instability, thrombolytics, extracorporeal membrane oxygenation (ECMO), or surgical thrombectomy [5] can be considered. Similarly, thrombolytics or thrombectomy can be entertained when there is evidence of peripheral arterial embolism.

In stable patients with impending paradoxical embolism, however, treatment options include: IV and oral anticoagulation vs. anticoagulation with intravenous (IV) thrombolytics [28-31] vs. thrombectomy/embolectomy [32-35] with or without PFO/ASD closure (surgical or percutaneous). Although the risk exists for thrombus fragmentation and embolization when IV thrombolytics are employed, the true incidence of this complication is unknown.

In Fauveau's [8] case series, inclusive of patients with impending systemic embolism, 55 patients were treated surgically, 21 with heparin, and 11 with thrombolysis. Their mortality rates were 13%, 14%, and 36% respectively. However, a bias was noted towards treatment with heparin in older patients and in patients with stroke, while patients who received thrombolytics were more likely to have hemodynamic compromise. Bonvinie et al [36], reported the mortality rate of thrombolytic treatment between 16% and 22%.

In the recent systematic review of 154 patients by Myers et al [37], the 30-day mortality rate of impending paradoxical embolism was found to be 18.4%. On multivariate analysis, none of the treatment choices (surgery, thrombolytics or anticoagulation) had a significant survival advantage. Surgically treated patients were found to have a nonsignificant trend towards decreased mortality (OR, 0.65, p=0.65) while patients treated with thrombolytics had a nonsignificant trend towards increased mortality (OR, 1.62, p =0.47), but had fewer systemic embolic events (OR 0.13, p=0.02). The combined endpoint of systemic emboli and death was significantly lower with surgery (OR, 0.26, p=0.001). It appears that when immediate surgery is not available to a hemodynamically unstable patient, thrombolysis may be a viable option [38].

In our review of recent 13 cases (Table 1) of impending systemic embolism, four of which eventually had systemic emboli, 4 received thrombolytics, 6 underwent surgical thrombectomy, and 3 received anticoagulation.

Differential Diagnoses

The differential diagnosis of impending systemic embolism in patients with DVT or PE includes cardiomyopathy with right and left sided mural thrombi, atrial fibrillation with intracardiac thrombi, right ventricular myocardial infarction with a right ventricular thrombus, central venous catheter with associated atrial thrombi, left or right - sided non-infective (Libman-Sacks or thrombotic vegetations) or infective endocarditis, atrial myxoma, or papillary fibroelastoma. In the presence of systemic embolism in a patient with venous thrombosis, mechanism of paradoxical embolism, via intra-cardiac or intrapulmonary shunting needs to be determined. This can be accomplished by either non-invasive (contrast echocardiography, CT or MRI) or invasive (cardiac catheterization) means. Contrast agents and provocative maneuvers i.e. Valsalva or cough can improve the diagnostic yield for diagnosing shunt with both non-invasive imaging modalities (Contrast 2D with or without 3 D transthoracic or trans-esophageal echocardiography or contrast cardiac CT or cardiac magnetic resonance imaging with provocative maneuvers) or invasive imaging modalities (e.g. invasive right heart catheterization with oxymetries). [39,40].

Future studies required in this area:

To our knowledge, this is the first case of large pulmonary emboli complicated by severe cor-pulmonale with a large thrombus straddling the PFO and extending into both ventricles in addition to a saddle pulmonary emboli. The success of anticoagulation alone in our case also supports a conservative approach to similar patients. However, the only definitive way to establish the ideal therapy is to perform an appropriately stratified, randomized controlled trial on patients with IPE. Such a trial would obviously have to be a multi-center study, due to the small incidence of IPE.

TEACHING POINT

Acute pulmonary embolism with impending paradoxical systemic embolism is an entity that may be recognized more frequently due to the availability of echocardiography in most of clinical centers. Despite numerous case reports, optimal management of impending paradoxical emboli is unknown. Anticoagulation therapy might be an effective and safe therapeutic alternative in patients with impending paradoxical systemic embolism.

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FIGURES

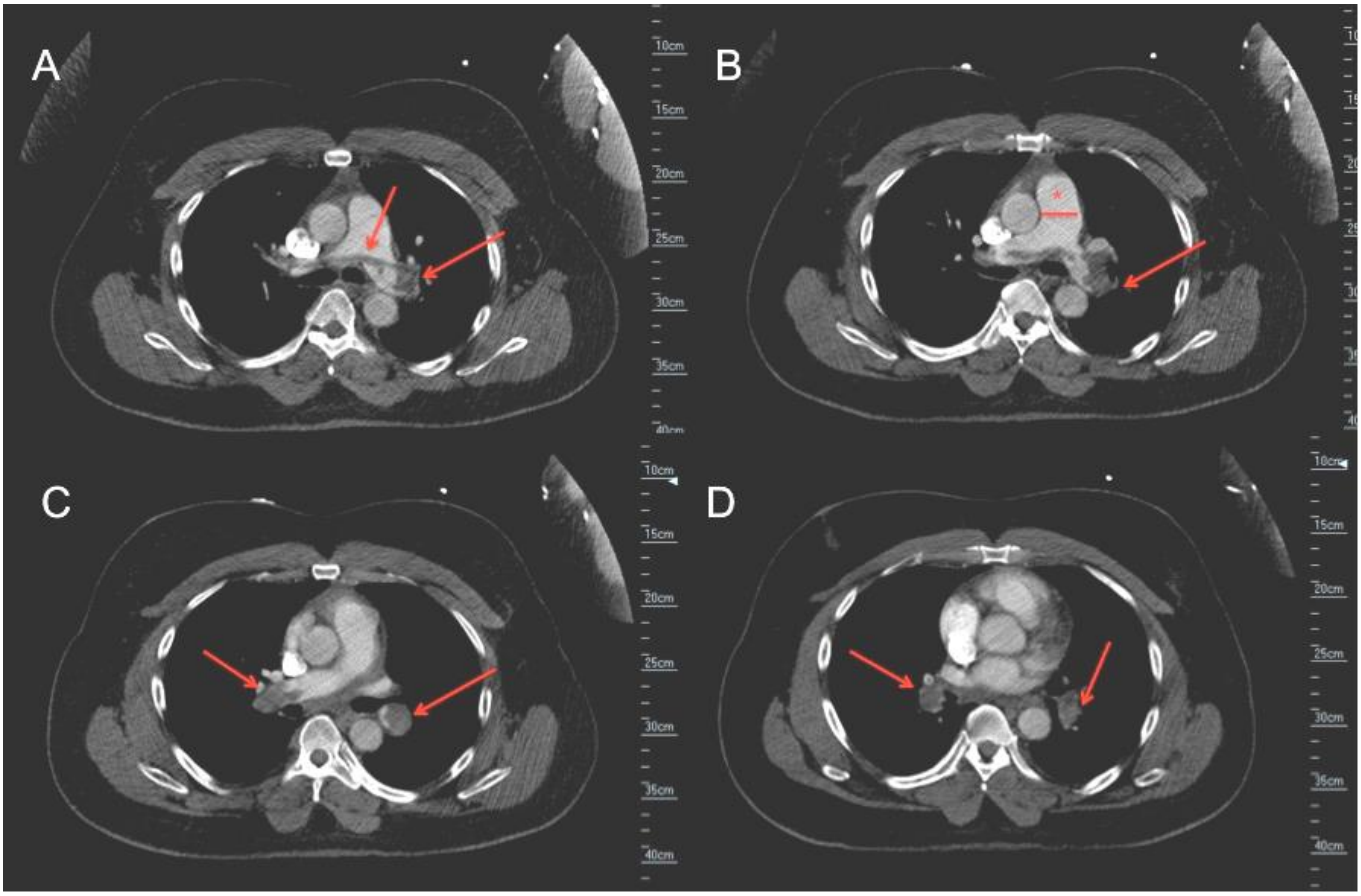

Figure 1: 51 year old male with saddle pulmonary embolus. Findings: Axial images from contrast enhanced computed tomography (CT) scan of chest in venous phase showing saddle pulmonary embolus (arrows indicating pulmonary artery embolus at the bifurcation of the main pulmonary artery and into the right and left main pulmonary artery branches, asterisk indicates dilated main pulmonary artery) Technique: GE-High definition CT scanner, 1 mm slice thickness, 120 KVP, 500 mAmp, Iohexol, 60 cc contrast dose).

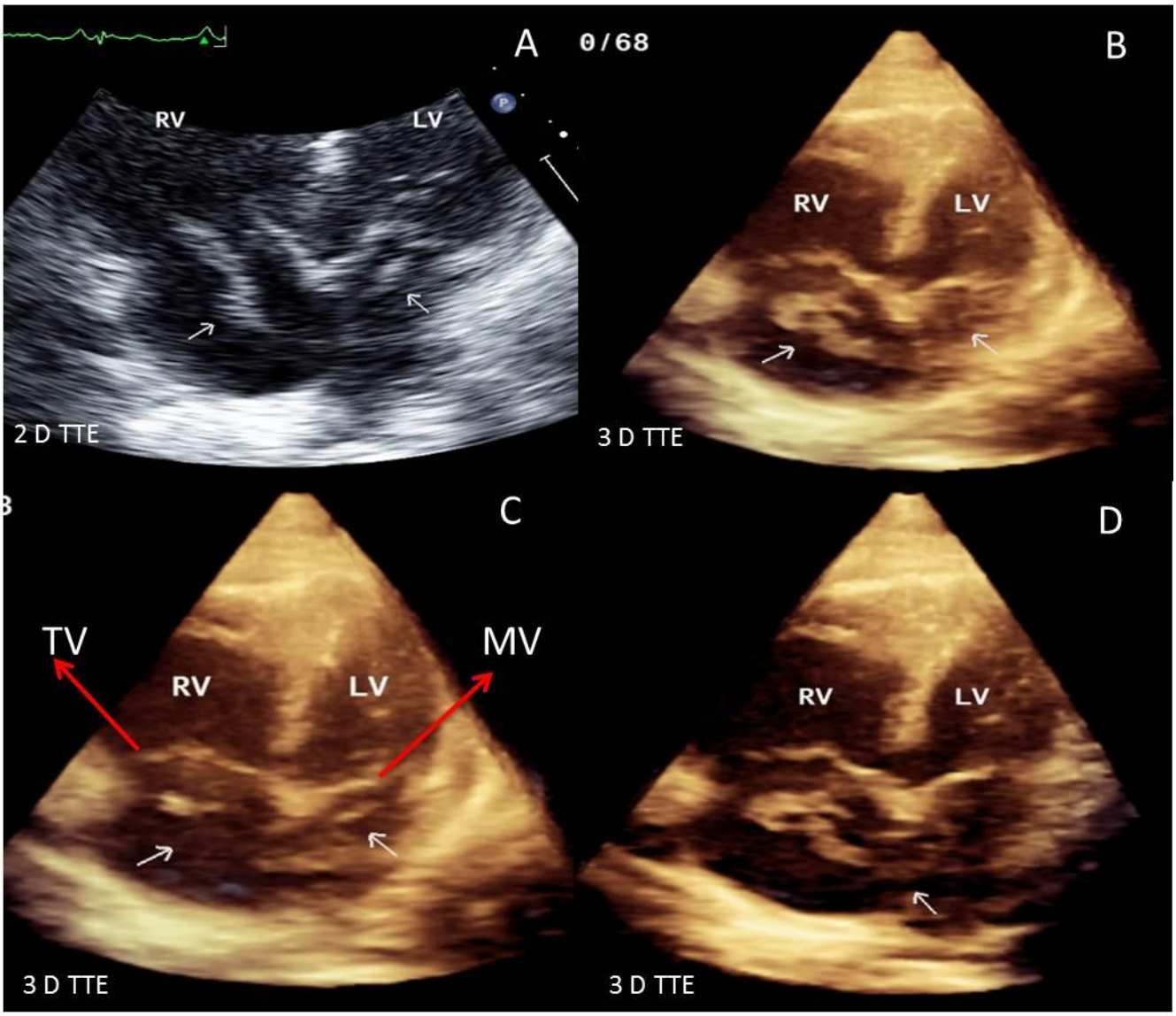

Figure 2: 51 year old male with straddling thrombus in the patent foramen ovale (PFO) and impending paradoxical embolism. Findings: 2D and 3D-TTE images showing a large serpiginous thrombus (arrows) straddling across the inter-atrial septum and extending through the mitral and tricuspid valves into the left and right ventricles. Technique: IE-33 Philips echocardiography machine, 2 MHz transducer. [Abbreviations: RV: right ventricle; LV: left ventricle; 3 D: three dimensional; 2 D: two dimensional, TTE: Transthoracic echocardiogram: TEE: Trans-esophageal echocardiogram; PFO: Patent foramen ovale]

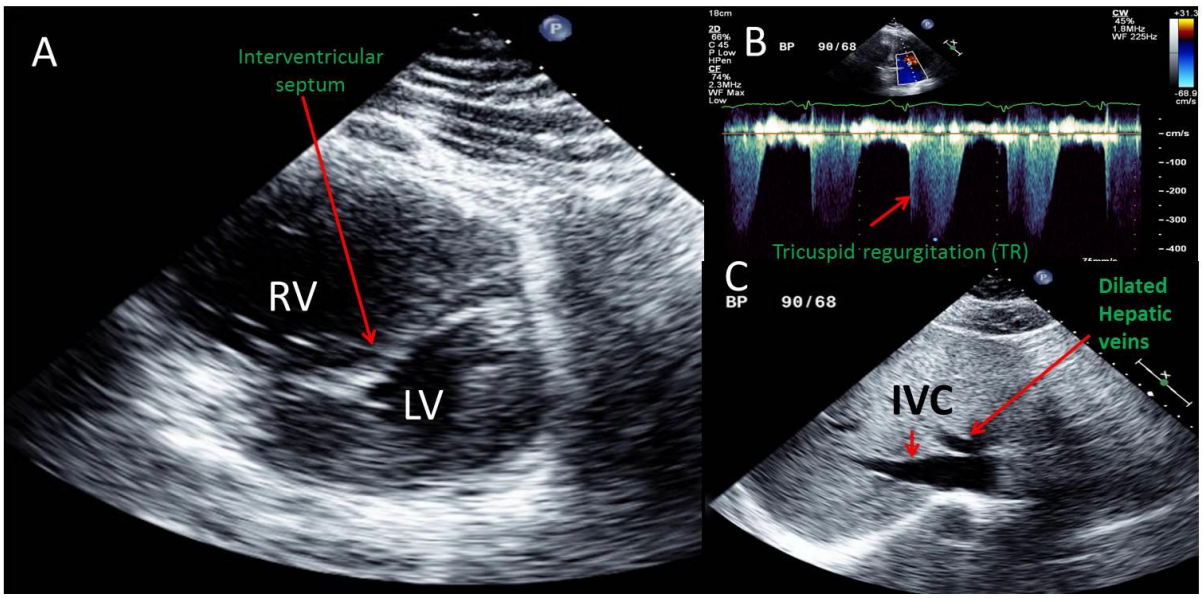

Figure 3: A 51 year old male with saddle pulmonary embolus and impending paradoxical embolism. Transthoracic echocardiographic (TTE) images are shown. Findings: A. Parasternal short axis view showing a severely dilated right ventricle (RV) severely compressing and deforming the left ventricle (LV) into a D shape due to marked deformity of the interventricular septum during late systolic and throughout diastole indicative of severe right ventricular pressure and volume overload.
B. Continuous wave Doppler of tricuspid regurgitation obtained from an off axis apical view demonstrating tricuspid regurgitation (TR) with a peak velocity 3.7 m/sec which using the simplified Bernoulli equation would correspond to an RV systolic pressure of 54 mmHg. Note that TR peak velocity is higher with every other beat and represent an equivalent of pulsus alternans due to severe RV systolic dysfunction. With the addition of an estimated right atrial pressure of 15-20 mmHg, the estimated pulmonary artery systolic pressure was 70-75 mmHg.
C. Subcostal view illustrating a plethoric inferior vena cava (IVC) with minimal collapse to inspiration indicating an estimated right atrial pressure of 15-20 mmHg. Also, note plethora of the hepatic veins also consistent with significantly elevated right atrial pressure. Technique: IE_33 Philips echocardiography machine, 2 MHz transducer

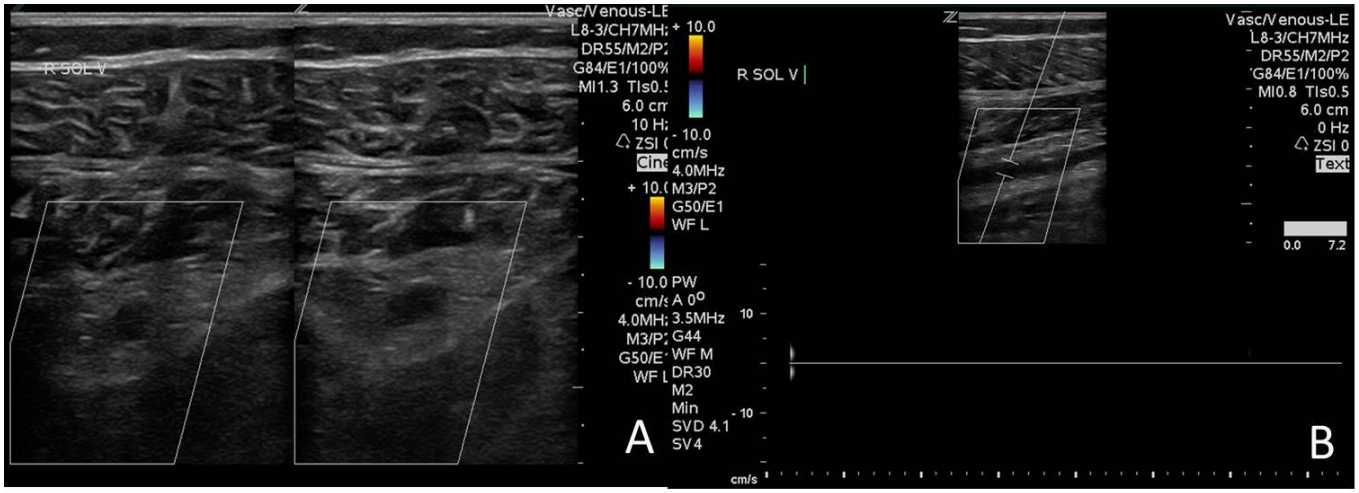

Figure 4: A 51 year old male with saddle pulmonary embolism and soleal vein thrombosis. Venous ultrasound examination of the right leg shows A. Cross-sectional views of the right soleal vein. On the left image note the distended soleal vein filled by thrombus. On the right image note the distended soleal being non-compressible due to thrombus. B. Long axis view of the right soleal vein with Doppler showing no flow due to vessel thrombosis. Technique: Philips ultrasound machine. 4 MHz transducer

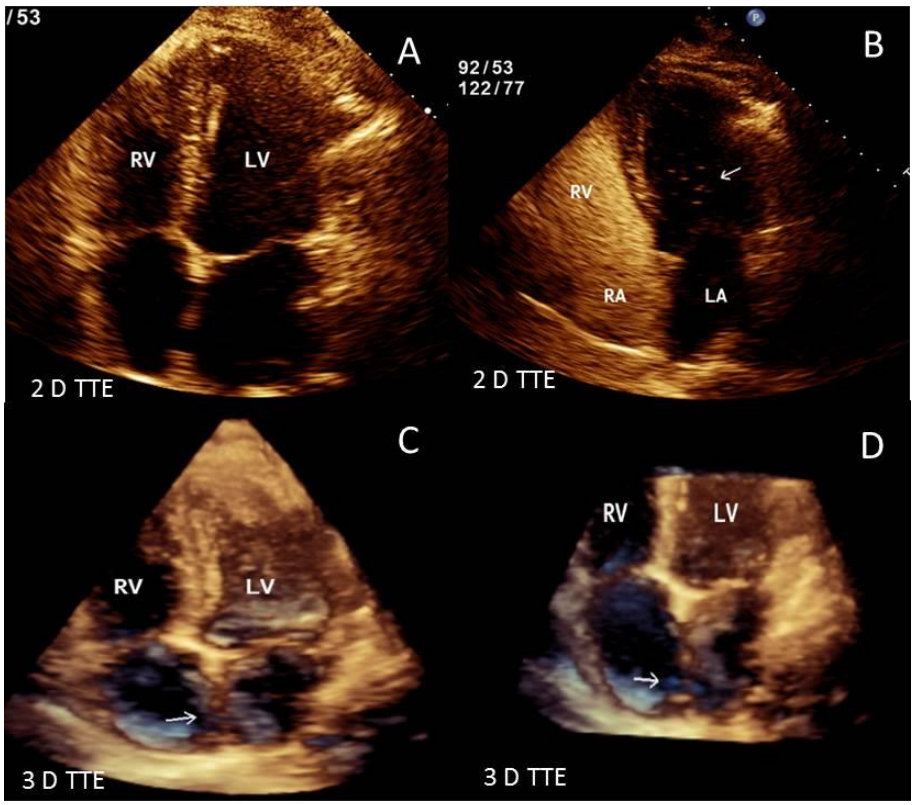

Figure 5: 51 year old male with saddle pulmonary embolism and patent foramen ovale with intracardiac thrombus managed with anti-coagulation. TTE images from 1 month follow up. Findings: A. 2D-TTE four chamber view at 1 month follow up showing complete resolution of the large straddling and biatrial thrombus with normalization of the right heart chambers size and function as well as pulmonary artery pressure. B. Follow-up 2D-TTE four chamber view showing a positive saline contrast study with right to left shunt- consistent with a patent foramen ovale (arrow points toward immediate appearance of bubbles from the right atrium through PFO to the left sided cardiac chambers) C,D. Follow-up 3D-TTE four chamber views further defining the inter-atrial septum and bi-atria with no evidence of thrombus which was clearly seen in the images 1 month ago. Technique: IE-33 Philips echocardiography machine, 2 MHz transducer.

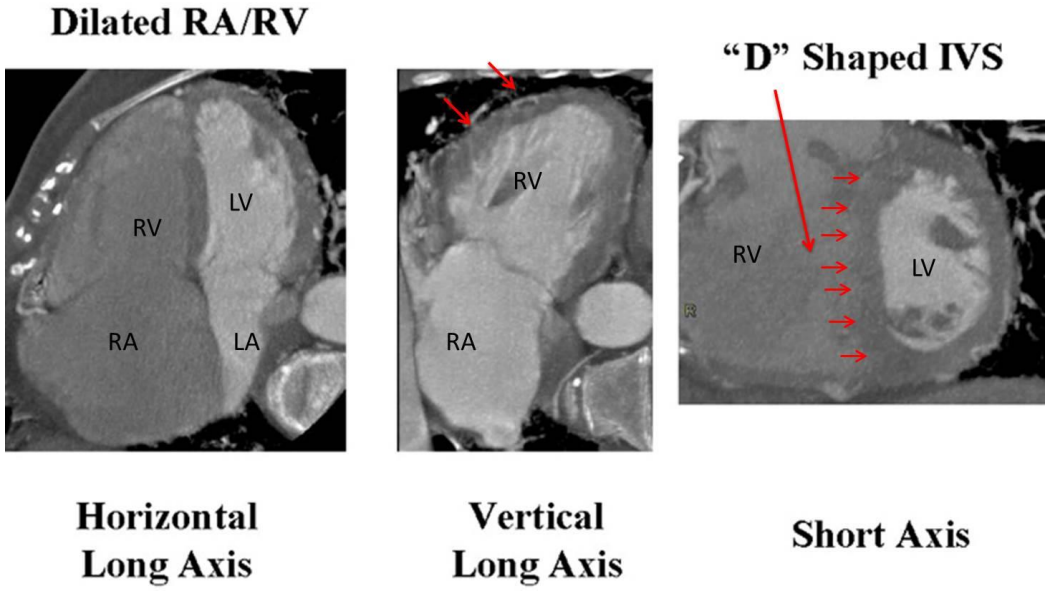

Figure 6: Contrast enhanced Computed tomography (CT) scan (ECG gated) indicating signs of pulmonary hypertension. A) 4 chamber view showing dilated RA and RV. B) 2 chamber view indicating right ventricular hypertrophy (arrows), C) Short axis view at the mid ventricular level showing markedly enlarged right ventricle and D shaped septum indicating right ventricular pressure overload. Adapted with permission from [26] [Abbreviations: RV: right ventricle; LV: left ventricle; RA: right atrium; LA: Left atrium; IVS: Interventricular septum

Reference	Demographics	Hemodynamics	DVT	Treatment	Systemic Embolism	Follow up
Mintz,2013, J Emerg Med[9]	54 year old AA M	BP: 144/99 mmHg, Pulse: 87/min RR: 19/min 97% on RA	Yes, Right LE	-UF Heparin -IVC filter -Coumadin on discharge	Yes, renal infarct TPA was given, patient discharged on Coumadin	No events
Faustino, 2012, BMJ Case Rep[10]	42 year old F	BP: 100/69 mm Hg Pulse: 110/min 95% on RA PASP: 83 mm Hg	Yes, Right LE	-Alteplase -UF Heparin -PFO closure -Coumadin on discharge	Cerebral embolism (multiple small strokes on MRI)	Not given Stable at discharge
Forkman,2012, Clin Res Cardiol[11]	77 year old F	BP: 150/80 mm Hg Pulse: 105/min RR: 25/min TTE RVSP: 50 mmHg	Yes, Left LE	-UF Heparin -Surgical embolectomy from right and left atria - Surgical PFO closure -Coumadin on discharge	Not documented	Stable at discharge No follow up given
Turfan, 2012, Heart Lung Circ[12]	72 year old F	BP: 60/40 mm Hg 80% on RA	Yes, B/L LE	-streptokinase -unfractionated heparin -Coumadin on discharge	Not documented	Stable at discharge No follow up given
Chow, 2012, J Clinic Ultrasound[13]	35 year old F	Not given	History of DVT	-Surgical embolectomy from right and left atria - Surgical PFO closure -IVC filter -Coumadin on discharge	Left middle cerebral artery stroke	Stable at discharge No events at 4 months follow up
Shah, 2011, J Card Surg[14]	78 year old M	88% on RA Pulse: 103/min Tachypnea	Yes, Right LE	-UF Heparin - Surgical embolectomy from right and left atria - Surgical PFO closure -IVC filter -Coumadin on discharge	Not documented	Stable at discharge No follow up given
Citro, 2010, J Cardiovasc Med[15]	69 year old F	BP: 10/70 mm Hg Pulse: 110/min PASP: 81 mm Hg	None	- Surgical embolectomy from right and left atria and from pulmonary artery - Surgical PFO closure -Coumadin on discharge	Not documented	Stable at discharge No events at 1 year follow up
Fontanella, 2010, Kardiol[16]	81 year old F	BP: 130/80 mm Hg Pulse: 100/min 86% on RA PaO2: 57 mm Hg RVSP: 50 mm Hg	Yes, Right LE	-TPA IV X 2 - Unfractionated Heparin	Not documented	Stable at discharge No events at 1 year follow up
Ruiz-Bailen, 2009, Interact Cardiovasc Thorac Surg[17]	81 year old F	BP: 78/42 mm Hg Pulse: 115/min Tachypnea PASP: 90 mm Hg	Yes, Right LE	-Alteplase -Enoxaparin	Not documented	Stable at discharge No events at 1 month follow up
Younker, 2009, Anesthesiology [18]	46 year old M	BP: 110/70 to 85/50 mm Hg Pulse: 85 - 45/min 100%-88% on RA Followed by cardiac arrest during anesthesia induction	Yes, Left LE	- RA, LA and distal PA surgical embolectomy. -IVC filter -Coumadin on discharge	Not documented	Stable at discharge No follow up given
Mascarenhas, 2009, J Am Coll Cardiol[19]	66 year old F	Not documented	Not documented	-Anti coagulation	Not documented	Not documented
Dietz,2013 J of Cardiol Cases [20]	54 years old M	Not documented	Yes, Left LE	-UF Heparin - IVC filter -Surgical thrombectomy -Surgical PFO closure	Yes, Left anterior descending coronary artery embolism leading to acute STEMI	Stable at 3 weeks follow up.

Table 1: Clinical presentation and management of identified recent cases (2009-2013) of impending paradoxical embolism indexed in PubMed.

Abbreviations: AA: African American: DVT: deep venous thrombosis, LE: Lower extremity; PFO: Patent foramen ovale; IPE: Impending paradoxical embolism; MRI: Magnetic resonance imaging; M: Male; F: Female; BP: Blood pressure; RR: respiratory rate; TTE: transthoracic echocardiogram; RVSP: right ventricular systolic pressure; IVC: Inferior vena cava; PASP: Pulmonary artery systolic pressure; RA: Room air; B/L: Bilateral; UF: unfractionated; RA: right atrium; LA: left atrium; PA: pulmonary artery; IVC: inferior vena cava filter; STEMI: ST elevation Myocardial infarction

Etiology	Patent foramen ovale, atrial septal defect, ventricular septal defect, pulmonary arterio-venous malformation
Incidence	Rare, not completely known rate.
Gender ratio	1:1.5 (M:F) [10]
Age predilection	58±15 years (45-75 years) [10],
Risk factors	Postoperative state, obesity, hypercoagulable conditions including malignancy, myocardial infarction, prolonged immobilization, congestive heart failure.
Treatment	Anticoagulation with heparin or Bivalirudin, intravenous thrombolytics, surgical thrombectomy and embolectomy along with surgical closure of right of left shunt e.g. patent foramen ovale or atrial septal defect) followed by oral anticoagulants
Prognosis	Depends on the presence of hemodynamic collapse. 18% mortality was noted by Myers et al[2]. Amongst survivors the following can happen: systemic embolism, cardiac arrest, cardiogenic shock, right heart failure, acute myocardial ischemia or infarct, seizures, stroke and peripheral vascular ischemia.
Findings on imaging	-TTE or TEE with saline contrast study with and without provocative maneuvers (straining, cough, Valsalva) revealing presence of PFO, ASD or VSD with right to left or bidirectional shunt. A thrombus will be visualized straddling the fossa ovale extending from the right to left atrium. Delayed (after 4 cardiac cycles) presence of bubbles on the left side may indicate presence of pulmonary AV connection. -CT scan of chest with contrast, showing presence of right to left shunt, presence of PFO, ASD or VSD and presence of thrombus in the cardiac chambers and through the intracardiac shunt. CT scan will also show presence of pulmonary embolism. -CMR (cardiac magnetic resonance) with and without gadolinium, showing presence of right to left shunt, presence of PFO, ASD or VSD and presence of thrombus in the cardiac chambers and through the intracardiac shunt. -Arterial and venous Doppler ultrasonography of the extremities will reveal presence of thrombus. -VQ scan showing presence of segmental or subsegmental pulmonary embolism.

Table 2: Summary table for impending paradoxical embolism
Abbreviations: TTE: Transthoracic echocardiogram; TEE: Transesophageal echocardiogram; CT: Computed tomography; PFO: patent foramen ovale; ASD: Atrial septal defect: VSD: Ventricular septal defect: CMR: Cardiac magnetic resonance.

Differential Diagnosis	X-Ray	Ultrasound (US)	Echocardiogram	Computed Tomography (CT)	Magnetic Resoance Imaging (MRI)
Paradoxical embolism	Enlarged right sided cardiac chambers	DVT and/or arterial thrombosis	-Presence of PFO, ASD or VSD with right to left or bidirectional shunt. -A thrombus will be visualized through the right to left shunt. -Delayed presence of bubbles on the left side may indicate presence of pulmonary AV connection.	-Presence of right to left shunt, presence of PFO, ASD or VSD and presence of thrombus in the cardiac chambers and through the intracardiac shunt. -CT scan will also show presence of pulmonary embolism.	-Presence of right to left shunt, presence of PFO, ASD or VSD and presence of thrombus in the cardiac chambers and through the intracardiac shunt.
Cardiomyopathy with right and left heart thrombi	-Cardiac chambers may appear to be dilated -Pulmonary congestion	-DVT and/or arterial thrombosis	-Cardiac chamber dilatation -Presence of masses in the right and left side of the heart- -Segmental wall motion abnormality in the heart -Reduction of in the right and/or left ventricular systolic function	-Cardiac chamber dilatation -Presence of masses in the right and left side of the heart- -Segmental wall motion abnormality in the heart -Reduction of the right and/or left ventricular systolic function -The Hounsfield unit of a thrombus is around 40.	-Cardiac chamber dilatation -Presence of masses in the right and left side of the heart- -Segmental wall motion abnormality in the heart -Reduction in the right and/or left ventricular systolic function -A thrombus is T2 hypointense and isointense on T1 weighted images with no hyperenhancement on late gadolinium enhanced images. -A thrombus also lacks fat saturation.
Atrial fibrillation with intracardiac thrombi	-Cardiac, especially atrial chambers may appear to be dilated -Pulmonary congestion	-DVT and/or arterial thrombosis	-Cardiac, especially atrial chamber dilatation -Presence of masses in the right and left side of the heart (atrial thrombi), TEE needed for detection of most common left atrial appendage thrombi	-Cardiac, especially atrial chamber dilatation -Presence of masses in the right or and left atrial side of the heart. -Characteristic of thrombus as above	-Cardiac, especially atrial chamber dilatation -Presence of masses in the right or left atrial side of the heart. -Characteristics of thrombus as above

Table 3 (continued on next page): Differential diagnosis table of intracardiac masses with simultaneous venous thrombosis
Abbreviations: MI: Myocardial infarction; DVT: Deep venous thrombosis; TTE: Transthoracic echocardiogram; TEE: Trans-esophageal echocardiogram; SSFP: Steady State Free precession images; US: Ultrasound: CT: Computed tomography; MRI: Magnetic resonance Imaging: PFO: Patent foramen ovale; ASD: Atrial septal defect; VSD: Ventricular septal defect.

Differential Diagnosis	X-Ray	Ultrasound (US)	Echocardiogram	Computed Tomography (CT)	Magnetic Resoance Imaging (MRI)
Cardiac tumors including biatrial myxomas, papillary fibroelastoma and metastatic cardiac tumor	Cardiac chambers usually normal, may appear dilated -Usually negative pulmonary findings (negative congestion)	-DVT	-Usually normal cardiac chambers -Presence of masses in the right and left side of the heart- -Myxoma most commonly arises in the left atrial from side of the interatrial septum but they rarely can be present in both the atria as well as in the ventricles. -Papillary fibroelastoma most commonly occur on the cardiac valves with predilection for left sided cardiac valves. They are usually located away from the free edges of the valves. -Are rarely associated with valve stenosis or regurgitation.	-Usually normal cardiac chambers -Presence of masses in the right and left side of the heart- -Cardiac Myxoma appears more heterogeneous on CT scan.	-Usually normal cardiac chambers -Presence of masses in the right and left side of the heart -Cardiac Myxoma is hypo or isointense on T1 and hyper intense on T2 weighted images, it is bright on perfusion images and shows a heterogeneous pattern of hyper enhancement on late gadolinium enhanced images. -Papillary fibroelastoma appears as a hypo intense mass on cine gradient echo or SSFP images and have a thin stalk usually. -Are rarely associated with valve stenosis or regurgitation.
MI with LV thrombus and simultaneous DVT	Cardiac chambers may appear dilated -Pulmonary congestion	-DVT and/or arterial thrombosis	-Cardiac chamber dilatation and/or LV aneurysm -Presence of mass in the left ventricle (usually apex) -LV segmental wall motion abnormality in the myocardium -Reduction in the right and/or left ventricular systolic function	-Cardiac chamber dilatation and/or LV aneurysm -Presence of mass in the left ventricle (usually apex) -LV segmental wall motion abnormality in the myocardium -Reduction in the right and/or left ventricular systolic function -Thrombus characteristics as above	-Cardiac chamber dilatation and/or LV aneurysm -Presence of mass in the left ventricle (usually apex) -LV segmental wall motion abnormality in the myocardium -Reduction in the right and/or left ventricular systolic function -Thrombus characteristics as above
Right heart thrombus associated with central lines, PICC lines, Swan Ganz catheters and pacemakers/defibrillators in patient who has atrial septal defect or patent foramen ovale	Cardiac chambers may appear dilated. Leads/catheters visualized on x ray	-DVT and/or arterial thrombosis	-Right heart thrombus will be seen on TTE -Presence of pacemaker/catheter/ leads. Dilated right-sided cardiac chambers. -Presence of atrial septal defect	-Cardiac chamber dilatation. -Presence of thrombus in right atrium, inferior or superior vena cava -Presence of ASD or PFO. -Presence of pacemaker/catheter/ leads.	-MRI can be performed in the presence of Swan Ganz catheter or other central lines but is contraindicated in the presence of pacemakers/defibrillators. -Cardiac chamber dilatation. -Presence of thrombus in right atrium, inferior or superior vena cava -Presence of ASD or PFO -Presence of pacemaker/catheter/ leads.
Left sided non-infective and infective endocarditis	-Cardiac chambers may be dilated if associated significant valve regurgitation. -Pulmonary congestion	-DVT and/or arterial thrombosis	-Cardiac chambers may appear dilated if associated significant valve regurgitation. -Presence of masses in the right and left side of the heart valves- -Vegetations most commonly arise from the side of the valve from where the blood enters the valve i.e. on the atrial side in case of mitral and tricuspid valves and on the ventricular side in the aortic and pulmonic valves. -Frequently associated with valve stenosis or regurgitation.	-Cardiac chamber dilatation -Presence of masses in the right and left side of the heart- -Vegetations are usually associated with destruction of valve leaflets. -Frequently associated with valve stenosis or regurgitation. Could be associated with valve stenosis or regurgitation.	-Cardiac chamber dilatation -Presence of masses in the right and left side of the heart- -Vegetations are usually associated with destruction of valve leaflets. -Frequently associated with valve regurgitation. Could be associated with valve stenosis or regurgitation.

Table 3 (continued): Differential table of intracardiac masses with simultaneous venous thrombosis

Abbreviations: MI: Myocardial infarction; DVT: Deep venous thrombosis; TTE: Transthoracic echocardiogram; TEE: Trans-esophageal echocardiogram; SSFP: Steady State Free precession images; US: Ultrasound: CT: Computed tomography; MRI: Magnetic resonance Imaging: PFO: Patent foramen ovale; ASD: Atrial septal defect; VSD: Ventricular septal defect.

ABBREVIATIONS

ASD = Atrial Septal Defect
AV = Arterio-venous
Bnp = Brain Natriuretic Peptide
CMP = Cardiomyopathy
CT = Computed Tomography
DVT = Deep Venous Thrombosis
ECMO = Extracorporeal Membrane Oxygenation
FO = Foraman Ovale
IPE = Impending Paradoxial Embolism
IVS = Interventricular Septum
LA = Left Atrium
LV = Left Ventricle
MI = Myocardial Infarction
MRI = Magnetic Resonance Imaging
PFO = Patent Foramen Ovale
RA = Right Atium
RV = Right Ventricle
TEE = Trans-esophageal Echocardgiogram
TTE = Trans Thoracic Echocardiogram
VSD = Ventricular Septal Defect

KEYWORDS

Thrombus; paradoxical emboli; patent foramen ovale; pulmonary embolism; echocardiography