Transesophageal Echocardiography Diagnosis of Tricuspid Valve Injury During AngioVac Percutaneous Pulmonary Embolectomy

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INTRODUCTION

Catheter-directed therapies are increasingly employed for acute pulmonary embolism (PE) using a variety of devices and techniques.[1] We present a case of catheter suction embolectomy highlighting the incremental value of transesophageal echocardiography (TEE) over fluoroscopic imaging during these complex interventions.

CASE PRESENTATION

A 26-year-old male with history of craniotomy for intracranial abscess 13 days prior acutely developed tachypnea, dyspnea, hypoxemia, and sinus tachycardia; blood pressure was normal. PE was confirmed on computed tomographic (CT) angiography, which demonstrated a large clot in the right pulmonary artery (PA; Figure 1) as well as bilateral subsegmental pulmonary emboli and right ventricular (RV) dilation. A transthoracic echocardiogram showed RV dilation (Figure 2) but normal RV systolic function based on tricuspid annular plane systolic excursion (TAPSE) and tissue Doppler S′ (Figure 3). Tricuspid regurgitation was trace, with a peak tricuspid regurgitant velocity of 2.4 m/sec and estimated PA systolic pressure = 33 mm Hg. Systemic thrombolysis was deemed too high risk for bleeding from a neurosurgical perspective. Anticoagulation with unfractionated heparin was begun. After multidisciplinary discussion, percutaneous suction embolectomy was planned using the AngioVac (Angiodynamics, Latham, NY) system in the hybrid operating suite.

After induction of general anesthesia and placement of left internal jugular vein and radial artery catheters, preprocedure TEE was performed showing mild RV dilation, RV free wall hypokinesis with preserved apical function, and mild tricuspid regurgitation (Video 1). Upper esophageal views showed a right PA echodensity (Figure 4). A 26-Fr right internal jugular vein introducer sheath was placed. Pulmonary arteriography confirmed a complete filling defect of the right PA (Figure 5). Under TEE and fluoroscopic guidance, a guide wire was advanced into the right PA through a wedge catheter. The wedge catheter was removed, leaving the wire in position in the main PA. A 16-Fr left femoral venous reinfusion cannula was placed. Then the 22-Fr AngioVac aspiration cannula with balloon-actuated, expandable, funnel-shaped tip was advanced over the guide wire into the proximal right PA using TEE. The AngioVac distal balloon was inflated and the centrifugal pump was activated, beginning suction aspiration with return of blood to the femoral venous cannula using an extracorporeal circuit with bubble trap and in-line filter (Figure 6).

Postprocedure TEE showed the right pulmonary embolus was no longer present, and reperfusion of the right PA was confirmed by pulmonary arteriogram (Figure 7). However, TEE revealed a flail tricuspid valve anterior leaflet with severe, eccentric tricuspid regurgitation (see Video 2, Figures 8 and 9) accompanied by hepatic vein systolic flow reversal. The mean central venous pressure was 20 mm Hg with large V waves >30 mm Hg, and an epinephrine infusion was required to maintain systemic arterial pressure.

At this point, cardiac surgery was consulted intraoperatively. Surgical repair or replacement of the tricuspid valve was discussed with the patient's representatives. The neurosurgical team, after repeating a head CT that was negative for intracranial bleeding, concurred that the risk of full heparinization for cardiopulmonary bypass was acceptable.

Median sternotomy, bicaval cannuation, and cardiopulmonary bypass with cardioplegic arrest were instituted. Surgical inspection of the triscupid valve via right atriotomy revealed flail anterior tricuspid leaflet with avulsion of a septal papillary muscle originating within the RV outflow tract. This papillary muscle was unable to be reimplanted. Repair was achieved employing two artifical chordae implanted from the base of the anterior papillary muscle to the leading edge of the anterior leaflet and a tricuspid annuloplasty ring. The heart was reanimated, and after separation from cardiopulmonary bypass, significant tricuspid regurgitation was noted (Video 3) associated with excessive anterior leaflet motion. Beating heart rerepair was performed consisting of tightening the neochords, with resultant trivial tricuspid regurgitation (Video 4). The patient recovered uneventfully and was discharged home. At follow-up, a transthoracic echocardiogram showed normal RV size and function and trace tricuspid regurgitation with no evidence of pulmonary hypertension.

DISCUSSION

RV dysfunction or enlargement on CT or echocardiographic imaging identifies a subgroup of PE patients with elevated risk of shock and early (30-day) mortality.[2,3] Various echocardiographic parameters (RV dilation, right-to-left ventricular dimensional ratio, decreased TAPSE, increased tricuspid regurgitant peak velocity) have been examined, with limited sensitivity but reasonable specificity.[4,5] RV enlargement by CT angiography four-chamber view (right-to-left ventricular dimensional ratio ≥0.9) as was present in this case is a predictor of 30-day mortality, including in the normotensive (not high-risk) PE population[6,7] and has been used as an inclusion criterion for fibrinolytic trials.[8] Current guidelines on the diagnosis and management of PE advocate a therapeutic strategy based on risk as assessed by

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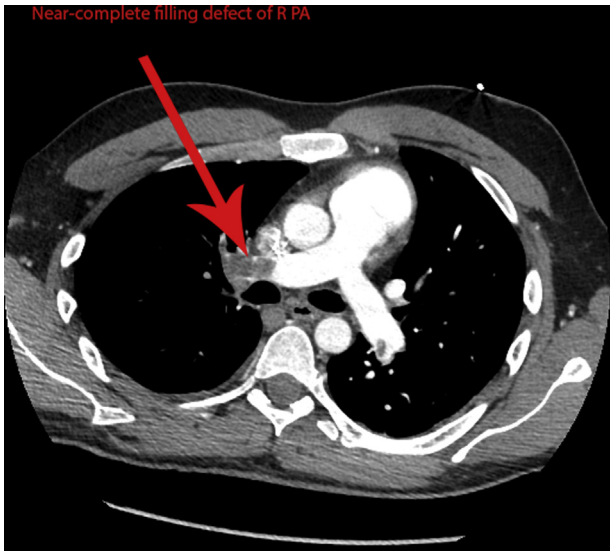

Figure 1 Axial CT pulmonary angiogram demonstrating right PA thrombus (*arrow*).

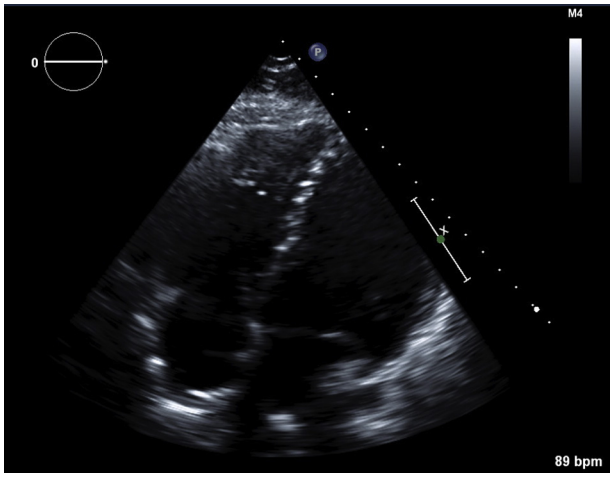

Figure 2 In this transthoracic apical four-chamber view, the RV/left ventricular ratio is > 1 and the RV basal diameter is > 4.2 cm, indicating RV enlargement.

clinical severity, imaging evidence of RV dysfunction, and cardiac biomarkers.[8,9]

The goals of managing massive and submassive PEs are to restore normal cardiac function and hemodynamics, which is not accomplished immediately by unfractionated or low-molecular-weight heparin alone. In patients with contraindications to systemic thrombolysis, catheter-directed mechanical or pharmacomechanical therapies have attracted attention as a less-invasive alternative to surgical embolectomy. One of several available percutaneous devices, the AngioVac system, was approved by the Food and Drug Administration in 2009 for removal of material from the vena cavae, right heart, and PAs. The reader is referred to a recent review by Ram *et al.*[10] for detailed descriptions of the AngioVac procedure, intraprocedural imaging, and reported complications.

The authors' approach to interventional imaging for catheter-directed PE interventions is to use fluoroscopy alone for thrombus

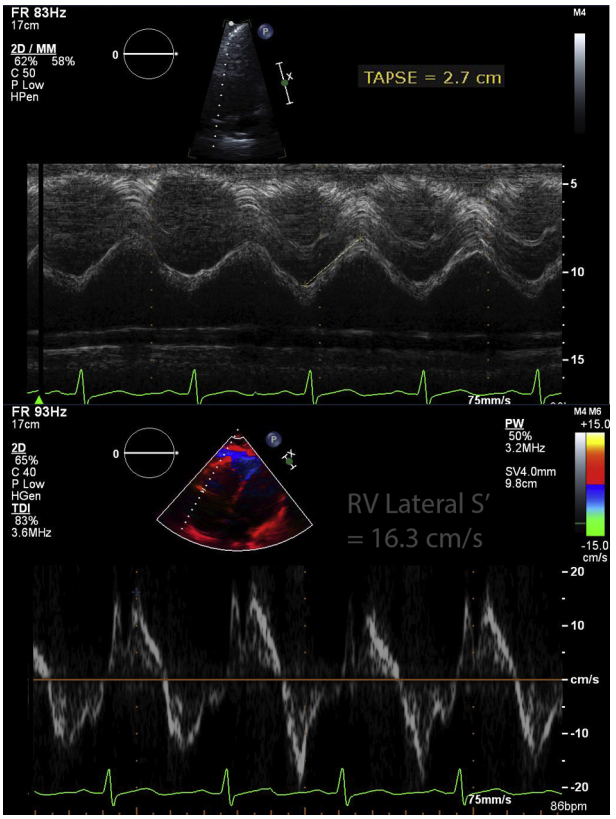

Figure 3 Transthoracic RV TAPSE equal to 2.7 cm (abnormal < 1.6. cm) and tricuspid annulus tissue Doppler velocity equal to 16.3 cm/sec (abnormal < 10 cm/sec) consistent with normal RV systolic function.

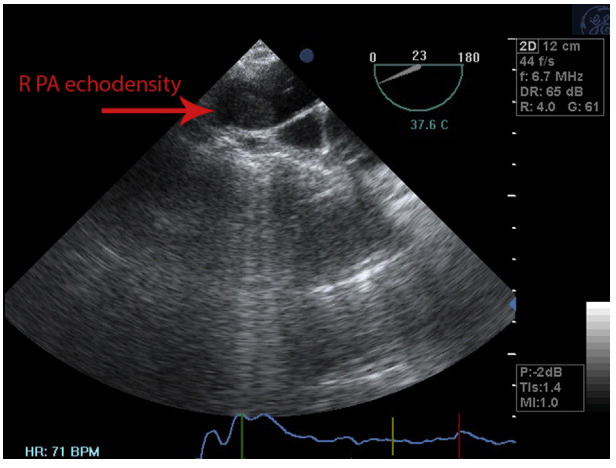

Figure 4 This transesophageal upper esophageal view (obtained with clockwise rotation from the upper esophageal ascending aorta short-axis view) shows the right PA (R PA) in long axis with large echodensity (*arrow*) just distal to the level of the superior vena cava.

limited to iliac and caval veins and for catheter-directed pharmacotherapy (local lysis). For intracardiac or PA procedures involving mechanical thrombectomy, we use TEE and fluoroscopy in combination based on (1) risk of perforation and tamponade and (2) the high

Figure 5 Preprocedure pulmonary angiogram confirming right PA occlusion (*arrow*).

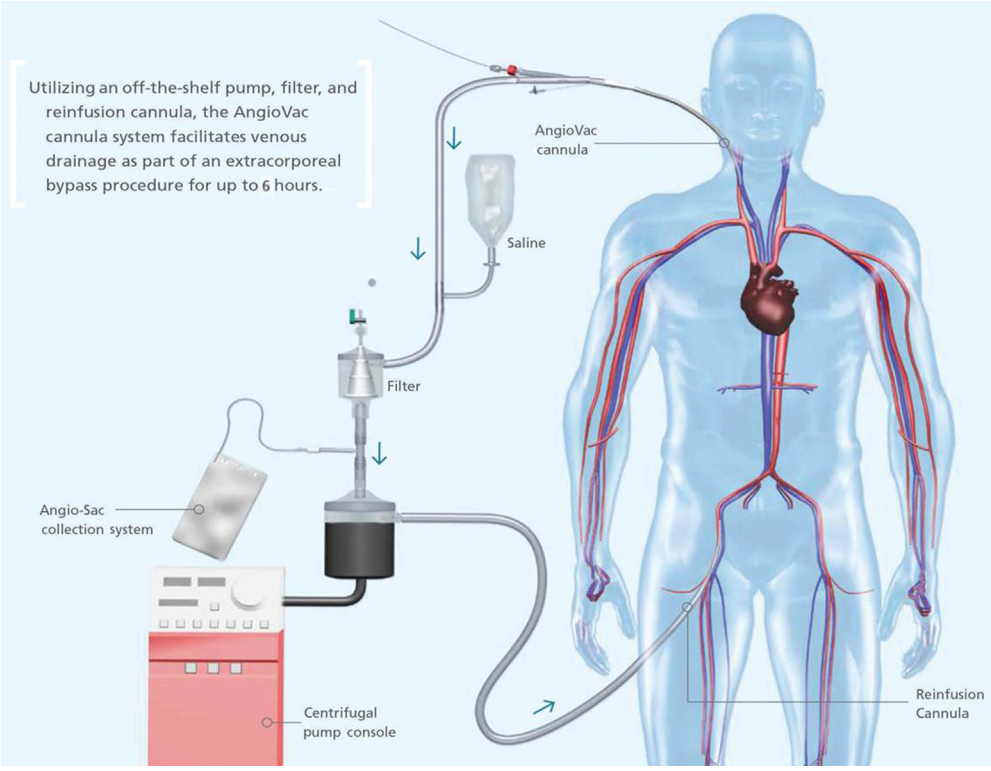

Figure 6 The AngioVac system with 22-Fr aspiration cannula, extracorporeal circuit with centrifugal pump, bubble trap and in-line filter, and venous reinfusion cannula. (Reproduced with permission from Ram et al. 2017.)[10]

incidence of extrapulmonary thrombi in these patients—in one series, TEE changed the management in 10% of patients in this manner.[11] Echocardiography should also be considered early in the evaluation of hemodynamic instability or hypoxemia (to exclude right-to-left shunting through a patent foramen ovale), and serial echocardiographic assessments are useful in following cardiac function and hemodynamics in response to interventions. A technical point is that, whereas the main and right PAs are reliably imaged from the upper esophageal TEE window, the proximal left PA is not because of interposition of the tracheobronchial tree. However, the distal left PA can

Figure 7 Postprocedure pulmonary angiogram showing opacification of right PA (*arrow*) with contrast. Also note the size of the AngioVac cannula relative to the PAs.

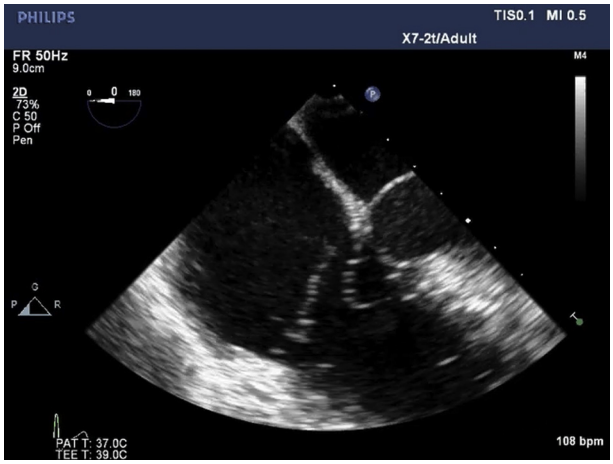

Figure 8 Midesophageal four-chamber view with flail tricuspid leaflet (also see Video 2) following thrombectomy.

be imaged in most patients (92%), and proximal parts of the lobar arteries can be imaged bilaterally.[12]

While the published AngioVac experience suggests high success rates (>80%) for removal of vegetations and thrombi from the iliocaval system and right heart, much lower success rates (12.5%) are associated with pulmonary embolectomy.[13] A possible reason for this is the relative rigidity of the 22 Fr AngioVac cannula, which limits maneuverability into more distal locations. A second-generation AngioVac cannula is now available with a 20° angled distal tip and in an 18-Fr size, potentially aiding maneuverability.

Tricuspid valve injury during AngioVac embolectomy appears rare, with one other published case.[14] In our case, the operator used a balloon-tipped wedge catheter to navigate across the tricuspid valve, but it is likely that the large, stiff cannula encountered a tendinous

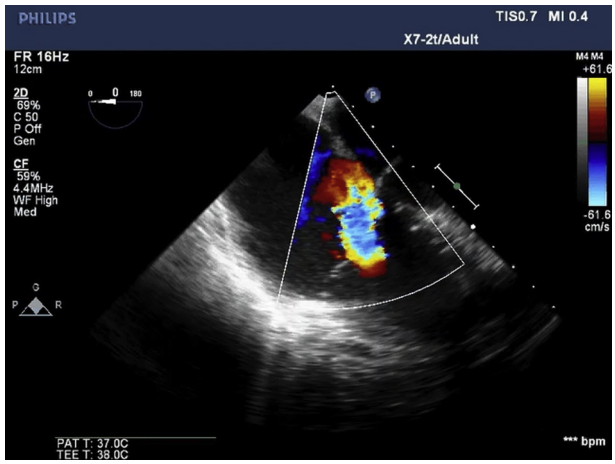

Figure 9 Midesophageal four-chamber view with color Doppler displaying a large flow convergence and vena contracta indicating severe tricuspid regurgitation (also see Video 2).

chord in the RV outflow tract. Rapid diagnosis and surgical repair produced a good patient outcome.

CONCLUSION

Cardiovascular imaging plays a prominent diagnostic and prognostic role in acute PE. Imaging findings of RV dysfunction, along with biomarkers, are used to risk-stratify patients and select a therapeutic strategy. Percutaneous catheter-based embolectomy, as an alternative to open surgical embolectomy or systemic fibrinolysis in intermediate- or high-risk patients, is enhanced by TEE imaging to facilitate positioning of devices, to detect residual intracardiac or PA thrombus, and to detect major procedure-related complications. In this case, intraoperative TEE permitted timely diagnosis of iatrogenic tricuspid valve injury, allowing for prompt surgical management.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.case.2018.05.003.

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