INTRODUCTION

The incidence of venous thromboembolism (VTE), which includes pulmonary embolism (PE) and deep venous thrombosis (DVT), has steadily increased over the past decade.\(^1\) PE remains the third most common cause of cardiovascular mortality in the United States, with an estimated 60,000 to 100,000 deaths annually.\(^2\) Given the formidable clinical challenge associated with PE, the focus has shifted to rapid and accurate diagnosis to aid in early therapeutic intervention. Although computed tomography (CT) angiography is widely utilized in the evaluation of PE, transthoracic echocardiography (TTE) has gained favorability as specific findings may guide immediate management in cases where CT angiography is not feasible, such as the emergency or intensive care settings.

CASE REPORT

A 59-year-old man presented to the emergency department with myalgia and cough worsening over a period of 1 week. He reported that the symptoms started after attending a large family gathering where he may have had multiple sick contacts. He was in his usual state of health prior to the gathering, and had no underlying medical conditions. On evaluation, he was hypoxemic with pulse oximetry of 86% on room air, which improved to 100%
The patient’s clinical course was complicated by worsening acute hypoxic respiratory failure due to pneumonia, with progression to severe acute respiratory distress syndrome (ARDS) requiring endotracheal intubation and mechanical ventilation. The patient had a period of clinical improvement; however, he acutely decompensated with worsening hypoxemia, as well as hypotension requiring vasopressor support. Repeat chest radiography showed similar bilateral infiltrates as seen prior. Given the abrupt clinical change, PE was suspected; however, transport and CT imaging was deemed unsafe due to hemodynamic instability. Nuclear medicine lung ventilation/perfusion (V/Q) scan was deferred in the setting of pulmonary infiltrates. D-dimer was 1780 ng/mL; however, the trend was fluctuating in the 1,000 to 1,600 ng/mL range, showing similar bilateral infiltrates as seen prior. Given the patient’s clinical status deteriorated over the next several weeks due to multiorgan failure, and he remained ventilator-dependent via tracheostomy in the setting of progressive pulmonary fibrosis. A CT angiogram of the chest was obtained once the patient was clinically stable, and it did demonstrate a persistent small filling defect of the pulmonary artery branches supplying the left lingula (Figure 2). A repeat TTE done 3 weeks after thrombolytic therapy demonstrated resolved RV abnormalities, with restoration of normal RV contractility and normalization of RVSP to 31 mm Hg (Figure 3, Video S2). The patient’s family transitioned goals of care to comfort-focused measures, and the patient passed away with cause of death attributed to COVID-19.

3 | DISCUSSION

Rapid and diagnostically accurate imaging is essential in the management of PE as both the disease burden and therapeutic intervention carry considerable morbidity and mortality. Although pulmonary angiography is recognized as the gold standard, most centers instead utilize CT angiography due to its accessibility and comparable diagnostic accuracy. Echocardiography, specifically TTE, has gained consideration in the emergency and intensive care settings given its noninvasiveness, portability, and short acquisition time. Limitations of TTE, including low sensitivity, present challenges to widespread adoption; however, TTE can provide objective qualitative and quantitative data to guide clinical decision-making for therapeutic interventions such as anticoagulation, thrombolysis, or thrombectomy.

The echocardiographic features of acute PE naturally focus on the RV and RV outflow tract as these are the primary targets of initial hemodynamic perturbations. Some findings include the following:

- An enlarged RV in the parasternal long-axis and apical 4-chamber views, often markedly dilated compared to the LV, with elevated RV-to-LV ratio.
- A flattened interventricular septum with paradoxical motion in the parasternal short-axis and apical 4-chamber views.
- Distended inferior vena cava (IVC) with poor collapsibility, represented by an elevated RVSP or elevated RV end-diastolic diameter (RVEDD).
- A “60/60 sign” when there is a coexistence of a pulmonary flow acceleration time of <60 ms with a tricuspid regurgitant pressure gradient less than 60 mm Hg.
- Visualization of thrombus in the RV or extending into the RV outflow tract into the pulmonary artery.
- M-mode may demonstrate a decreased tricuspid
annular plane systolic excursion (TAPSE) of <16 mm or pulmonary artery mid-systolic notching.

Each of these findings has varying sensitivities and specificities and is often used in conjunction with patient-specific clinical data.\(^4\)

Although described in studies as early as 1986, it was the work of McConnell et al evaluating RV wall motion of patients with acute PE that led to the identification of a constellation of findings known as McConnell’s sign: akinesia of the RV mid free wall with normal excursion of the RV apex.\(^5\) Typically, this is best viewed over three or more cardiac cycles on an apical 4-chamber view as a relatively fixed RV free wall, with characteristic anterior-posterior “bouncing” of the apex due to its otherwise preserved contractility (Video S1). This finding has relatively low sensitivity, but is highly specific for acute PE.\(^6\) A recent meta-analysis of twenty-two studies by Fields et al demonstrated TTE had a sensitivity of 22% (confidence interval 0.16–0.29) and specificity of 97% (confidence interval 0.95–0.99) for the detection of acute PE.\(^4\) The sensitivity is notably affected by alternate causes for McConnell’s sign, including acute elevations in RV afterload, RV infarction, or extrinsic compression of pulmonary vasculature.\(^7\) The exact pathophysiology of McConnell’s sign in acute PE is not well understood; however, the originally proposed mechanisms include (1) tethering of the RV apex to the hyperdynamic LV resulting in perceived apical sparing, (2) bulging of the mid free wall during systole as a result of spherical force redistribution, and (3) segmental ischemia of the RV free wall.\(^5\) Some studies cite a functional ischemia of the RV as the underlying unifying mechanism.\(^7\) Also noteworthy is that these proposed mechanisms may not be prevalent until later in the pathophysiological continuum, representing relatively late findings when greater than 25% of the flow-through pulmonary vasculature is already obstructed.\(^8,9\)

Definitive studies comparing the utility of echocardiographic findings in acute PE are unlikely to be performed, leaving clinicians to decipher its utility on a case-by-case basis. The European Society of Cardiology (ESC) has recently updated its guidelines for the diagnosis and management of acute PE and gives TTE a Class I (LOE C) recommendation for diagnosis in high-risk PE.\(^3\) Numerous case reports also endorse the utility of TTE in individualized cases as being useful when rapid presumptive diagnosis is required to justify thrombolytic therapy.\(^5,8\) Given that the degree of RV dysfunction can serve as a predictor of mortality, cases with RV dysfunction on TTE may benefit from aggressive therapeutic strategies including thrombolyis.\(^10\) In our patient, TTE proved to be beneficial in the clinical decision-making process, yielding a favorable outcome given a rapid resolution of obstructive shock following thrombolysis. This supports a position that TTE is an invaluable tool in the diagnosis of acute PE, and can be used in conjunction with adjunctive objective data in the appropriate setting to improve sensitivity and pre-test probability. Moreover, additional integration of TTE or focused bedside cardiac ultrasound can be a vital tool in the multidisciplinary approach to PE management, and should become routinely used in Pulmonary Embolism Response Teams (PERT) within a stepwise diagnostic pathway. Furthermore, additional retrospective studies on the individual and combined specificities and sensitivities of echocardiographic findings can be useful and may influence the next iteration of societal recommendations.

In conclusion, we presented a case of acute PE diagnosed and managed successfully on the basis of the specific
The finding of McConnell’s sign on TTE. The utility of TTE in acute PE remains to be further characterized; however, incorporation continues to gain momentum as more cases demonstrate favorable outcomes in the otherwise clinically challenging domain of venous thromboembolism.

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CONFLICT OF INTEREST
None.

AUTHOR CONTRIBUTIONS
Vishal I. Patel, MD, Michelle Miles, DO, Sharareh Shahangian, MD, and John Javien, MD, have made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; been involved in drafting the manuscript or revising it critically for important intellectual content; given the final approval of the version to be published; and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

ETHICAL APPROVAL
None.

CONSENT
Available upon request.

DATA AVAILABILITY STATEMENT
Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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SUPPORTING INFORMATION
Additional supporting information may be found in the online version of the article at the publisher’s website.

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