Bilateral Emboli and Highest Heart Rate Predict Hospitalization of Emergency Department Patients With Acute, Low-Risk Pulmonary Embolism

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Study objective: Some patients with acute pulmonary embolism (PE) will suffer adverse clinical outcomes despite being low risk by clinical decision rules. Emergency physician decisionmaking processes regarding which low-risk patients require hospitalization are unclear. Higher heart rate (HR) or embolic burden may increase short-term mortality risk, and we hypothesized that these variables would be associated with an increased likelihood of hospitalization for patients designated as low risk by the PE Severity Index.

Methods: This was a retrospective cohort study of 461 adult emergency department (ED) patients with a PE Severity Index score of fewer than 86 points. Primary exposures were the highest observed ED HR, most proximal embolus location (proximal vs distal), and embolism laterality (bilateral vs unilateral PE). The primary outcome was hospitalization.

Results: Of 461 patients meeting inclusion criteria, most (57.5%) were hospitalized, 2 patients (0.4%) died within 30 days, and 142 (30.8%) patients were at elevated risk by other criteria (Hestia criteria or biochemical/radiographic right ventricular dysfunction). Variablesassociated with an increased likelihood of admission were highest observed ED HR of ≥110 beats/minute (vs HR <90 beats/min) (adjusted odds ratio [aOR] 3.11; 95% confidence interval [CI] 1.07 to 9.57), highest ED HR 90 to 109 (aOR 2.03; 95% CI 1.18-3.50) and bilateral PE (aOR 1.92; 95% CI 1.13 to 3.27). Proximal embolus location was not associated with the likelihood of hospitalization (aOR 1.19; 95% CI 0.71 to 2.00).

Conclusions: Most patients were hospitalized, often with recognizable high-risk characteristics not accounted for by the PE Severity Index. Highest ED HR of ≥90 beats/min and bilateral PE were associated with a physician's decision for hospitalization. [Ann Emerg Med. 2023;■:1-13.]

Please see page XX for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background

Clinical decision rules are commonly used to risk-stratify patients with acute pulmonary embolism (PE) when deciding on site of care.[1] However, some patients with acute PE will suffer adverse clinical outcomes despite being designated as low risk by these rules.[2-5] Factors that physicians use to decide which low-risk patients will nonetheless require hospitalization are unclear, although recent studies have identified several key predictors of adverse outcomes.[5-7]

The European Society of Cardiology recommends an assessment for PE severity, comorbidities, and contraindications to home treatment for patients being considered for outpatient management.[1] The PE Severity Index is a validated decision rule that stratifies patients according to risk and can be used to identify patients at low risk of 30-day mortality (PE Severity Index Classes I and II).[8] The Hestia criteria assess suitability for outpatient management based on PE severity, medical comorbidities, and social factors.[1,9] The presence of any Hestia criteria indicates a contraindication to outpatient management, and hospitalization is recommended. Although both are validated approaches to identifying low-risk patients, both the PE Severity Index and Hestia criteria contain failure rates inherent to clinical decision rules (ie, the PE Severity Index considers a 30-day mortality risk of 3.5% to be low risk). In addition, meta-analysis data suggest that right ventricular dysfunction demonstrated on echocardiography or biochemically through laboratory assessment is

Editor's Capsule Summary

What is already known on this topic

Patients categorized as "low-risk" by the pulmonary embolism (PE) Severity Index may occasionally suffer adverse outcomes after emergency department (ED) discharge.

What question this study addressed

Are emergency clinicians more likely to hospitalize PE patients with certain clinical findings despite "low-risk" categorization?

What this study adds to our knowledge

In this retrospective study in 21 community-based EDs in an integrated health system, elevated heart rate and bilateral emboli were associated with hospitalization.

How this is relevant to clinical practice

Knowing these perceived influential factors can help address hospitalization decisions in patients with low-risk PE.

associated with higher all-cause and PE-related short-term mortality.[5,7] The prognostic role of right ventricular dilatation on computed tomography (CT) angiography is much less clear, however, and several studies show no association between right ventricular dilatation on CT angiography and adverse events or mortality.[5,10,11] The PE Severity Index does not include a right ventricular dysfunction/dilatation variable, and physicians may be more likely to hospitalize patients with these findings regardless of nuance in prognosis.

Site of care medical decisionmaking for patients with acute PE is incompletely understood but is influenced by facility-, physician- and patient-level factors.[4] Patients in this study setting have access to prompt primary care follow-up, anticoagulation pharmacotherapy, and specialty consult, which addresses several key facility-level barriers. Physician-level barriers have been previously addressed in the study setting through the implementation of a clinical decision support system providing risk-based recommendations for site of care disposition decisionmaking for ED patients with acute PE.[12,13] Lastly, patient-level factors prompting hospitalization of low-risk patients are incompletely understood although the literature has identified several characteristics that may portend worse clinical outcomes in this subset of patients.[5-7,9,14-17]

Heart rate (HR) is an important prognostic vital sign for patients with acute PE, and an important component of several clinical decision rules predicting PE likelihood, PE-related mortality, and PE-related clinical deterioration.[8,15,16,18] The PE Severity Index incorporates HR directly into its risk assessment by employing an explicit criterion of $\geq$110 beats/min, whereas the Hestia criteria combine HR and blood pressure into its assessment of hemodynamic instability. A recent study demonstrated an association between increased HR and 30-day mortality over a large continuum of HRs (30 to 200 beats/min) in patients with acute PE.[6] The HR is an important reflection of hemodynamic stability and may prompt more hospital admissions when abnormal, even in patients deemed to be low risk by clinical decision rules.

On the other hand, the prognostic value of the radiographic embolic burden on mortality in acute PE is conflicting.[14,17,19-25] Embolic distribution (unilateral embolism vs bilateral emboli), most proximal embolism location, and degree of arterial obstruction all contribute to embolic burden. The CT obstruction index quantifies embolic burden by considering the number of lung segments affected (1 to 20) and their degree of arterial obstruction (partial or complete).[24] Embolic burden information does not appear in any clinical PE risk stratification tool, and it is unclear to what extent physicians incorporate this readily available radiographic information into their site of care decisionmaking.

Importance

A more thorough understanding of predictors of hospitalization and patient-level contributors to this decision may guide quality improvement initiatives for outpatient PE management, provide insight into site of care decisionmaking in a real-world setting, and inform new inquiries into the prognostic significance of key patient-level variables.

Goals of This Investigation

Our goal was to understand the characteristics of patients with acute, low-risk PE who were selected for outpatient management vs. hospitalization and the prognostic values of highest observed ED HR, most proximal embolism location, and embolism distribution on the likelihood of a physician's decision to hospitalize a low-risk patient.

MATERIALS AND METHODS

This study was approved by the Kaiser Permanente Northern California institutional review board with a

waiver of informed consent. This manuscript adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.[26]

Study Design and Setting

We conducted a retrospective cohort study from January 2019 to February 2020 of all 21 community-based EDs of Kaiser Permanente Northern California, an integrated health system that serves over 4.5 million members representing the surrounding racial, ethnic, and socioeconomic diversity of California.[27] The 21 EDs are staffed by board-certified (or board-eligible) emergency physicians. Patients with acute PE usually receive their diagnosis in the ED, whereas those diagnosed in the clinic setting are commonly referred to the ED for definitive care.[28] The system recommended direct oral anticoagulants for the treatment of most patients with acute PE. Patients receive timely follow-up [29] and have access to oral anticoagulants with long-term monitoring by a pharmacy-led telephone-based Anticoagulation Management Service, which contacts patients for education shortly after ED discharge.[30-32]

All ED sites had access throughout the study period to a web-based, electronic health record-embedded clinical decision support system (named RISTRA-PE for "risk stratification of PE") after diagnostic confirmation. The clinical decision support system use is physician-driven and entirely voluntary. The clinical decision support system provides an auto-populating version of the PE Severity Index with risk-based recommendations to inform site of care decisionmaking.[12] Outpatient exclusion criteria derived from the early Canadian criteria and the validated Hestia clinical decision rule are also provided.[9,33] The clinical decision support system recommended consideration of hospitalization for patients with right ventricular dysfunction (right ventricular strain on echocardiography or right ventricular dilatation on CT angiography); however, troponin, B-type natriuretic peptide (BNP) and echocardiography were not mandated.[5] We implemented RISTRA-PE as a pragmatic trial called eSPEED over an 8-month period in 2015, as previously described.[13] Four years after the aforementioned interventions, a subsequent retrospective cohort study demonstrated the sustainability of the original eSPEED interventions in the outpatient management of low-risk PE: former intervention EDs continued to discharge home more patients with acute low-risk (PE Severity Index class I-II) PE compared with former control EDs.[34] However, approximately 60% of low-risk patients were still hospitalized. Our current study examines the subset of patients with acute low-risk PE (PE Severity Index classes I-II) in the subsequent retrospective cohort study. We were unable to capture clinical decision support system use in our study population. However, it was used for the minority of eligible patients (11.3% at former intervention EDs and 7.4% at former control EDs) as previously reported.[34]

Study Participants

This study included patients 18 years of age or older who had at least one eligible ED visit from 01/2019 through 02/2020 with an ED diagnosis of nongravid PE (International Classification of Disease, Tenth Edition [ICD-10], codes: I26.02, I26.09, I26.92, I26.93, I26.94, I26.99, O88.23). Included patients also had an accompanying CT angiography or scintigraphy imaging study that was positive for PE either in the ED or within the prior 12 hours.[35] Patients with one of the following were excluded: a diagnosis of acute venous thromboembolism in the previous 90 days, taking anticoagulants at diagnosis (or an elevated ED international normalized ratio more than 2.0), lack of adequate health plan membership in the prior 12 months (as this affects the completeness of medical history), leaving the ED against medical advice, absence of any documented ED vital signs (precluding calculation of the PE Severity Index) with the exception of temperature, non-PE diagnosis requiring hospitalization and known pregnancy (Figure 1). Variables of the PE Severity Index were extracted from the electronic health record as previously described.[12]

Data Collection and Study Outcomes

We obtained hospital site, clinical and demographic variables directly from the health system's electronic health record using automated electronic data extraction. Two emergency physicians performed a structured chart review for manually abstracted data. Abstractors were not blinded to the study hypothesis and abstracted data using a standardized, piloted form. Five percent of charts were dually extracted for ascertainment of accuracy, and interrater reliability was assessed for patient disposition, highest observed ED HR, presence of one or more Hestia criteria, and embolic burden. Missing data were excluded from the analysis.

We used the validated PE Severity Index to estimate 30-day all-cause mortality and identify low-risk patients (PE Severity Index score <86 points) as previously described.[12] Altered mental status was the only component of the PE Severity Index that was not reliably available. For our analysis, we assumed it was negative, as other studies have

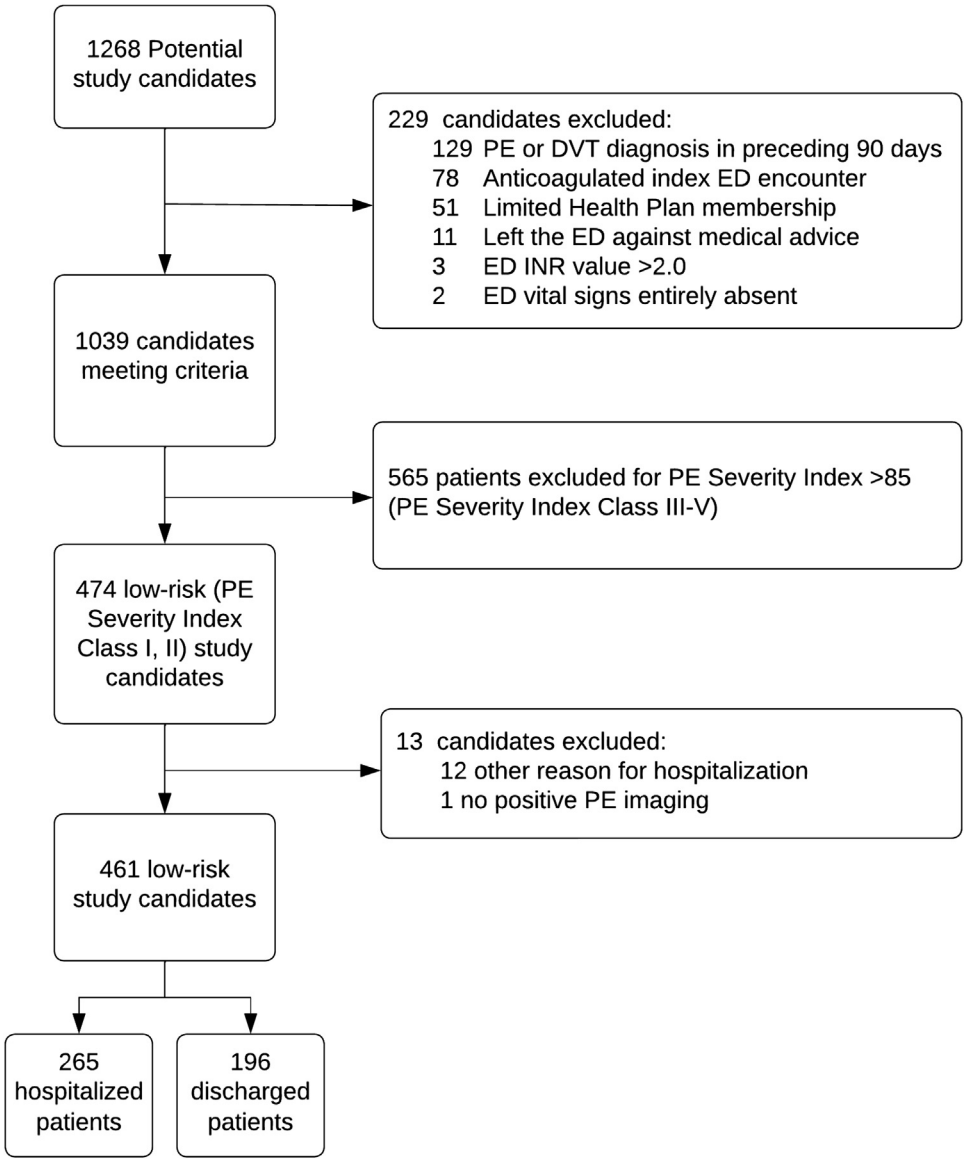

Figure 1. Low-risk PE cohort assembly. *DVT*, deep venous thrombosis; *INR*, International normalized ratio.

done, including the original validation studies.[36,37] Missing patient temperature data was also presumed to be normal for the PE Severity Index calculation.

Measurements

We developed a data collection tool using predefined variable definitions to guide the manual abstraction of patient data (Appendix E1, available online at http://www.annemergmed.com). We collected other variables potentially associated with hospitalization including: age (in years), patient-reported sex, body mass index, race/ethnicity, hospital site (former intervention or former control site in our pragmatic trial), chronic lung disease, heart failure (systolic or diastolic), cancer, history of prior venous thromboembolism, dementia, active substance abuse, acute psychiatric crisis, hospitalization within 30 days, major surgery within 30 days, major hemorrhage within 30 days, ischemic or hemorrhagic stroke within 30 days, non-PE-related diagnosis requiring admission, thrombophilia, hemiplegia, presence of an indwelling vascular catheter, arrival by ambulance, PE symptoms (shortness of breath, chest pain, cough, palpitations, deep venous thrombosis symptoms, syncope or presyncope, hemoptysis, ED vital signs lowest systolic blood pressure, highest observed HR, highest respiratory rate, lowest oxygen saturation, lowest temperature, diagnosis by CT angiography, diagnosis by scintigraphy imaging, diagnosis

made in ED (vs less than 12 h prior in the outpatient setting), presence of pulmonary infarct, right ventricular strain on echocardiography, right ventricular dilatation on CT angiography, most proximal embolism location, embolic distribution (bilateral vs unilateral PE), presence of ≥1 Hestia criteria, troponin, BNP, hemoglobin, platelet count, glomerular filtration rate (GFR) and lack of fixed residence.

Outcomes

Our primary study outcome was hospitalization which was defined as admission to inpatient status from the ED. Thirteen EDs had a short-term (less than 24 hours) outpatient observation unit based in the ED that was managed by emergency physicians or adult medicine hospitalists. We considered admission to an outpatient observation unit as a hospitalization.

Analysis

We used multivariate logistic regression analysis to examine the association between our predictor variables selected a priori (highest observed HR, most proximal embolism location, and bilateral PE) and the likelihood of hospitalization. Variables included in our model were previously demonstrated to be of prognostic significance in the literature and included: age, sex, comorbidities (chronic lung disease history, hospitalization within 30 days), clinical data (PE Severity Index class II, arrival by ambulance), assignment as an intervention or control site in our previous pragmatic trial, troponin elevation, radiographic data (proximal embolism location, bilateral PE, right ventricular dilatation) and ED vital signs (highest ED respiratory rate, lowest ED oxygen saturation, highest observed ED HR). The number of cases during the study period determined the sample size. Statistical analyses and graphics were generated using the software environment R (4.2.1) using the ggplot2 (v3.3.3; Wickham, 2016) and Epitools (v0.5-10.1; Aragon, 2020) packages.[38]

RESULTS

After excluding 807 patients, we identified 461 eligible candidates from our previous retrospective cohort study who met the inclusion criteria (Figure 1). Manual chart review interrater reliability for key study variables (final disposition, presence of Hestia criteria, highest observed ED HR, embolus laterality, and most proximal embolus location) was excellent with a Cohen's Kappa of 1.0.

Characteristics of Study Subjects

Characteristics of included patients (n=461) are shown in Table 1. Most patients in our study (n=265, 57.5%) were hospitalized, and the remainder (n=196, 42.5%) were managed as outpatients with a median ED length of stay of 5.8 hours (IQR=3.9 to 7.7). There were 142 patients (30.8%) in our low-risk cohort who met one or more Hestia criteria or had biochemical/radiographic right ventricular dysfunction (Figure 2). There were 2 deaths (0.4%) observed in the study, which ocurred in hospitalized patients belonging to a PE Severity Index class II (Appendix E2, available online at http://www.annemergmed.com). Both patients were admitted for their acute PE, with one patient expiring during catheter-directed thrombolysis and another expiring from unknown causes nearly one month after hospital discharge.

Unadjusted analysis of our main variables of interest demonstrated that HR≥110 beats/min and HR 90 to 109 beats/min were associated with the likelihood of admission (unadjusted OR 2.12; [95% CI 1.21 to 3.87] and OR 2.06; [95% CI 1.42 to 3.02]), compared with HR <90 beats/min. The presence of bilateral PE (vs unilateral PE) was also associated with the likelihood of hospitalization (unadjusted OR 2.64; [95% CI 1.79 to 3.89]). Proximal embolism location (vs distal) was associated with an unadjusted likelihood of hospitalization (unadjusted OR 1.86; 95% CI, 1.27 to 2.72). Comparing unadjusted data, 72% and 67% of patients with an HR ≥110 beats/min and an HR of 90 to 109, respectively, were hospitalized, compared with 41% of patients with an HR <90. Also, 67% of patients with bilateral PE were hospitalized compared with 43% of patients with unilateral PE.

Main Results

Multivariate analysis (Table 2) demonstrated that HR ≥110 beats/min or more and an HR of 90 to 109 beats/min were independently associated with a likelihood of admission (OR 3.11; [95% CI 1.07 to 9.57] and OR 2.03; [95% CI 1.18 to 3.50]), respectively] compared with HR <90 beats/min. The presence of bilateral PE (vs unilateral PE) was independently associated with the likelihood of hospitalization (OR 1.92; [95% CI 1.13 to 3.27]). Proximal embolism location (vs distal) was not independently associated with the likelihood of hospitalization (OR 1.19; 95% CI, 0.71 to 2.00).

LIMITATIONS

We described the clinical context available for emergency physicians when deciding to hospitalize a patient with an acute, low-risk PE within one health care setting. Our study setting included a population that had access to prompt primary care follow-up, anticoagulation pharmacotherapy, and specialty consultation, and our

Table 1. Characteristics of Emergency Department Patients With Acute Low-Risk, Pulmonary Embolism, Stratified by Initial Site of Care.

	Hospitalized (n=265; 57.5%) n (%)	Outpatient (n=196; 42.5%) n (%)
Patient characteristics		
Age (y), median (IQR)	56 (44.5-67.5)	53 (41.5-64.5)
Female	140 (52.8)	120 (61.2)
Male	125 (47.2)	76 (38.8)
BMI (kg/m^2), median	31.5	31.1
Race/ethnicity, self-reported*		
Black	49 (18.5)	35 (17.9)
Asian	21 (7.9)	11 (5.6)
Hispanic or Latinx	39 (14.7)	24 (12.2)
White	152 (57.4)	125 (63.8)
Other	4 (1.5)	1 (0.5)
Hospital site†		
Former intervention site	115 (43.4)	113 (57.7)
Former control site	150 (56.6)	83 (42.3)
Comorbidities		
Chronic lung disease	34 (12.8)	37 (18.9)
Heart failure (systolic or diastolic)	3 (1.1)	3 (1.5)
Cancer (active only)	1 (0.4)	9 (4.6)
History of venous thromboembolism	46 (17.4)	57 (29.1)
Dementia	0	6 (3.1)
Active substance abuse‡	—	—
Acute psychiatric crisis‡	—	—
Hospitalization within 30 days	39 (14.7)	24 (12.2)
Major surgery within 30 days	28 (10.6)	17 (8.7)
Major hemorrhage within 30 days	5 (1.2)	1 (0.5)
Ischemic stroke within 30 days	1 (0.4)	2 (1.0)
Thrombophilia	14 (5.3)	12 (6.1)
Bed-bound or hemiplegia	3 (1.1)	2 (1.0)
Indwelling vascular catheter	2 (0.7)	0
Arrival by ambulance	35 (13.2)	11 (5.6)
PE symptoms		
Shortness of breath	213 (80.4)	127 (64.8)
Chest pain	158 (59.6)	126 (64.3)
Cough	57 (21.5)	26 (13.3)
Palpitations	17 (6.1)	7 (3.6)
Deep venous thrombosis symptoms	79 (29.8)	48 (24.5)
Syncope/presyncope	21 (7.9)	3 (1.5)
Hemoptysis	7 (2.6)	7 (3.6)
ED vital signs		
Systolic blood pressure (mmHg)		
≥110	196 (74.0)	166 (84.7)
<110	69 (26.0)	30 (15.3)

Table 1. Continued.

	Hospitalized (n=265; 57.5%) n (%)	Outpatient (n=196; 42.5%) n (%)
Heart rate (beats/min)		
≥110	47 (17.7)	18 (9.2)
≥90 and <110	146 (55.1)	73 (37.2)
<90	72 (27.2)	105 (53.6)
Respiratory rate (breaths/min)		
≥24	101 (38.1)	25 (26.0)
≥20 and <24	106 (40.0)	77 (39.3)
<20	58 (21.9)	94 (48.0)
Pulse oximetry, %[§]		
≥95	122 (46.0)	156 (79.6)
<95	143 (54.0)	40 (24.5)
Temperature (°C)		
Temperature <36.5	43 (16.2)	31 (15.8)
Temperature ≥36.5	215 (81.1)	163 (83.2)
Temperature not recorded	7 (2.5)	2 (1.0)
Diagnostic imaging		
Diagnosed by scintigraphy	3 (1.5)	1 (0.5)
Diagnosed by CT in ED	244 (92.1)	162 (82.7)
Pre-arrival imaging study (<12h)	21 (7.9)	34 (17.3)
Embolism location on CT		
Proximal	176 (66.4)	101 (51.5)
Distal	89 (33.6)	95 (48.5)
Pulmonary infarct	48 (18.1)	20 (10.2)
Embolic distribution		
Unilateral PE	76 (28.7)	101 (51.5)
Bilateral PE	189 (71.3)	95 (48.5)
RV dilatation by CT	37 (14.0)	4 (2.1)
Echocardiographic RV dysfunction	1 (0.4)	0 (0)
PE Severity Index class		
I (lowest risk)	96 (36.2)	101 (51.5)
II (low risk)	169 (63.4)	95 (48.5)
Hestia Criteria[‖]		
≥1 Hestia criteria	35 (13.2)	13 (6.6)
No Hestia criteria	230 (86.8)	183 (93.4)
Laboratory values		
Troponin concentration (ng/L[¶]**)**		
Within reference range (<0.04)	174 (65.7)	143 (73.0)
Elevated (≥0.04)	56 (21.1)	6 (3.1)
Not performed	35 (13.2)	47 (24.0)
BNP (ng/L)		
BNP<100	131 (49.4)	74 (37.8)
BNP≥100	37 (14.0)	7 (3.6)
Not performed[#]	97 (36.6)	115 (58.7)

Table 1. Continued.

	Hospitalized (n=265; 57.5%) n (%)	Outpatient (n=196; 42.5%) n (%)
Hemoglobin (g/dL)		
Hemoglobin ≥ 11	238 (89.8)	173 (88.3)
Hemoglobin < 11	27 (10.2)	20 (10.2)
Not performed[#]	1 (0.36)	3 (1.5)
Platelets (K/μL)		
Platelets ≥150	243 (91.7)	188 (95.9)
Platelets <150	22 (8.3)	5 (2.6)
Not performed[#]	0	2 (1.0)
GFR (mL/min/1.73m^2)		
GFR≥60	240 (90.6)	187 (95.4)
GFR<60	25 (9.4)	7 (3.6)
Not performed[#]	0 (0)	2 (1.0)
Psychosocial barriers to outpatient care		
Lack of fixed residence[‡]	–	–

BMI, body mass index; BNP, B-type natriuretic peptide; GFR, glomerular filtration rate.
*Race and ethnicity were self-reported. Other race/ethnicity includes Native American and Hawaii and Pacific Islander.
[†]EDs were assigned to the intervention (10 EDs) or control (11 EDs) in the 2014/2015 pragmatic trial based on the presence of an on-site physician champion.
[‡]Cells replaced with '–' indicate cell counts of less than 10 patients or cell counts that could be used to derive cell counts with less than 10 patients; these cells were suppressed to protect patient identity.
[§]With or without oxygen supplementation.
[‖]The Hestia criteria comprise a bedside checklist of exclusions to outpatient PE management.
[¶]Highest Troponin I concentration during the ED encounter.
[#]Missing values were common with only 53.5% of patients having a BNP value obtained during their ED stay.

results may not be generalizable to other settings. Whereas we used strategies to minimize bias, our study is subject to limitations inherent in retrospective studies.[39] Given our observational study design, we cannot infer a causal relationship between variables and our outcome of interest, and there may have been potential confounders not accounted for in our multivariate analysis. Our abstractors were unblinded to the study's hypothesis. Additionally, we did not use a standardized definition for right ventricular dilatation on CT interpretations. Right ventricular dilatation was interpreted to be present if it was reported on by the interpreting radiologist, but specific right ventricular: left ventricular ratios were rarely reported. The study period also occurred before the SARS-CoV-2 pandemic. Given the high rate of thromboembolic complications in patients with COVID-19, it is unclear if concurrent COVID-19 disease affects site of care decisionmaking in patients with acute, low-risk PE.[40,41]

DISCUSSION

Most patients in our study were hospitalized despite being classified as low risk by a validated risk stratification tool and members of a health system well-resourced to accomplish outpatient management. We found that a substantial fraction of patients who were low risk by the PE Severity Index (class I or II; fewer than 86 points) had clinical, laboratory, or radiographic findings that might place them at increased risk of adverse clinical events. Additionally, we found that tachycardia and bilateral PE were independently associated with the likelihood of hospital admission.

Approximately 30% of the patients in our low-risk cohort met one or more Hestia criteria or had biochemical/radiographic indicators of right ventricular dysfunction (elevated BNP/troponin, right ventricular dilatation, or strain). Patients who met ≥1 Hestia criteria in our study had at least one contraindication to outpatient management, and it is not surprising that the majority were hospitalized, in accordance with expert consensus statements.[7,42] A recent study demonstrated that over half of patients who were hospitalized for low-risk PE met ≥1 Hestia criteria.[43]

The hospitalization of low-risk patients who had biochemical and/or radiographic right ventricular dysfunction observed in our study represents a more

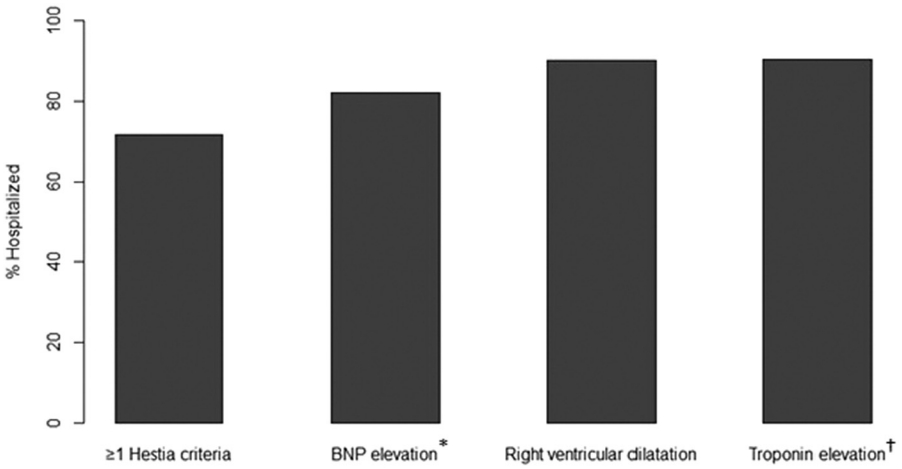

Figure 2. Other high-risk criteria and the percentage of patients meeting these criteria who were hospitalized. Overall n=142. *BNP*, B-type natriuretic peptide. * ≥100 ng/L. † ≥0.04 ng/L.

conservative approach to acute PE management than using the PE Severity Index alone.[1,5,44,45] Prosperi-Porta and colleagues' recent meta-analysis of over 17,000 patients with acute PE found echocardiographic right ventricular dysfunction to be associated with increased risk of mortality (PE-related and all-cause) and adverse events.[7] An individual patient-level meta-analysis by Becattini et al. found an increased risk of short-term mortality for patients with biochemical/echocardiographic right ventricular dysfunction or elevated troponin.[5,46,47] Interestingly, however, right ventricular dilatation on CT angiography was not associated with all-cause or PE-related mortality in this study, and the prognostic value of this finding is unclear.[1,5,10] Our results suggest that physicians perceive patients with right ventricular dilatation on CT angiography to be at higher risk.

The percentage of patients in our study population chosen for outpatient management was higher than in similar studies of outpatient low-risk PE management, likely reflecting the sustained effects of our pragmatic trial of clinical decision support system implementation.[13,34,48,49] Notably, although most studies of outpatient PE management allowed for extended periods of observation before the final disposition decision, physicians in our study achieved a median time to the final disposition of less than 6 hours using an unstructured triage strategy for site of care decisionmaking.[9,49-56]

Tachycardia at any time during the ED stay was independently associated with the likelihood of admission. Tachycardia has been established as an independent risk factor for adverse clinical outcomes for patients with acute PE and is included in many rules for PE prediction (Geneva score, Wells' criteria), PE exclusion (PE rule-out criteria), PE risk stratification (PE Severity Index, Bova score, PE short-term clinical outcomes risk estimation) and suitability for outpatient management (Hestia).[6,16,57-59] Our results suggest that physicians may assign incrementally increasing amounts of risk with increasing HRs rather than adhering to a strict binary cut-off, such as the ≥110 beats/min criterion used in the PE Severity Index score calculation. A recent study of patients included in the Registro Informatizado de la Enfermedad TromboEmbólica (RIETE) registry may support this practice. In this study, Jaureguízar et al. demonstrated increased PE-related and all-cause mortality with increasing HRs over a wide spectrum of HRs for patients with acute PE.[6] Abnormal respiratory rate and oxygen saturation, both of which are components of the PE Severity Index, were also associated with increased likelihood of hospital admission in our study, although the thresholds we used (respiratory rate of over 24 breaths/min, oxygen saturation less than 95%) were more conservative than those used in the PE Severity Index score (respiratory rate of 30 breaths or more per minute, oxygen saturation <90%). Our results suggest that physicians perceive patients with these vital sign abnormalities to be of higher risk, although they may not meet PE Severity Index score thresholds.

After adjustment for patient demographic and clinical characteristics, the presence of bilateral PEs was statistically significantly associated with hospitalization, and proximal embolism location was not. Numerous reports in the radiology literature have identified an increased CT obstruction index to be a predictor of PE-related mortality and adverse clinical outcomes.[17,19-24] The CT obstruction index is calculated based on the number of lung segments affected by PE and their degree of obstruction. Although radiologists in our health system do not report CT

Table 2. Adjusted Odds Ratios from multivariable model for likelihood of hospitalization.

	Adjusted OR for Hospitalization	95% CI
Highest HR ≥110 (vs <90 beats/min)	3.11	1.07-9.57
Highest HR 90-109 (vs <90 beats/min)	2.03	1.18-3.50
Bilateral PE*	1.92	1.13-3.27
Proximal embolism location†	1.19	0.71-2.00
Age (per 1-year increment)	0.99	0.97-1.02
Female sex‡	0.82	0.48-1.41
Chronic lung disease history	0.77	0.39-1.51
Hospitalization within 30 days	1.78	0.82-4.02
PE Severity Index class II§	1.85	0.90-3.84
Arrival by ambulance	2.48	1.04-6.32
Former intervention site‖	0.39	0.23-0.65
Troponin elevation (≥0.04 ng/L)	2.79	1.09-8.20
RV dilatation by CT angiography	3.55	1.22-13.01
Lowest oxygen saturation <95%	2.76	1.61-4.78
Highest respiratory rate >24 beats/min	2.47	1.33-4.72

*Compared to unilateral PE.
†Compared to distal location. Proximal emboli are those that were clearly lobar in location or more proximal.
‡Patient-reported sex.
§Compared to PE Severity Index Class I.
‖Compared to former control site in our 2015 pragmatic trial.

obstruction index, it is plausible that physicians perceive bilateral emboli to be a higher risk than unilateral embolism. The actual risk of bilateral PE, however, is unclear, although one small study found an unadjusted higher prevalence of echocardiographic right ventricular dysfunction in patients with acute bilateral PE compared to patients with unilateral PE (64% vs. 16%).[60] It is unclear why proximal embolism location did not predict hospital admission in our study, given that this variable would also contribute to the CT obstruction index. Embolism location's prognostic significance is unclear in the literature as most studies of outpatient PE management do not report embolism location. Our finding that proximal embolic location does not predict hospitalization conflicts with a recent study that found the opposite; however, this study included all PE Severity Index risk classes.[61]

Our results raise the possibility that the highest observed ED HR and the presence of bilateral PE are being used by physicians to guide site of care decisionmaking. With increasing literature support for outpatient management of suitable patients, our work provides insight into clinician decisionmaking in low-risk patients, including factors outside of traditional PE severity risk scores that may be driving site of care decisionmaking. Thus, initiatives aimed at increasing outpatient management of patients with low-risk PE should be aware that physicians may attribute increased perceived risk to patients with higher HRs and bilateral PE.

In summary, more than half of patients with acute, low-risk PE were admitted during the study period to a health system well-resourced to facilitate outpatient management. A substantial fraction of these patients had clinical, laboratory, or radiographic findings associated with adverse clinical outcomes, and hospitalization was likely justified. Physicians may perceive patients with higher HRs and bilateral PE to be at elevated risk during disposition decisionmaking.

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Author contributions: SDC and DRV conceived and designed the study. SDC and LZ performed manual data abstraction. SDC

performed the statistical analysis, and SDC, DRV, MER, and LMW analyzed and interpreted the results. SDC drafted the manuscript, which was critically reviewed by DRV, MER, and LMW. MJS provided technical and administrative support. SDC takes responsibility for the paper as a whole.

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Editor's Capsule Summary *What question this study addressed*: Are emergency clinicians more likely to hospitalize pulmonary embolism patients with certain clinical findings despite "low-risk" categorization? *What this study adds to our knowledge*: In this retrospective study in 21 community-based emergency departments in an integrated health system, elevated heart rate, proximal embolism, and bilateral embolism were associated with hospitalization.