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Real World Practices of Interhospital Transfer in Pulmonary Embolism: A Pulmonary Embolism Response Teams Consortium Observational Study

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ABSTRACT

Treatment options for acute pulmonary embolism (PE) have evolved rapidly, with an increasing number of interventional options, necessitating interhospital transfer for consideration of advanced therapies and optimal care. Utilizing the National PERT Consortium database, this study analyzed 12,346 patients from 35 institutions between October 16, 2015 and June 1, 2024. Patients were categorized as directly presenting to a PERT hospital or transferred from a referring hospital. Demographics, clinical presentations, treatments, and outcomes were compared. Multivariable logistic regression was used to evaluate the association between transfer status and outcomes. Transferred patients ($n = 3277$) were younger, more frequently White, more often obese, and had lower malignancy rates. They were more likely to be classified as high-risk PE (16.7% vs. 13.8%, $p < 0.01$) and intermediate–high risk PE (55.9% vs. 54.3%, $p < 0.01$). Transferred patients more frequently received advanced therapies, including ECMO (2.8% vs. 1.1%, $p < 0.01$), surgical embolectomy (2.0% vs. 0.8%, $p < 0.01$), systemic thrombolysis (5.3% vs. 3.8%, $p < 0.001$), and catheter-based interventions (32.3% vs. 17.1%, $p < 0.01$). After adjustment, transfer was associated with lower odds of 30-day mortality (OR 0.82, 95% CI 0.69–0.98), 1-year mortality (OR 0.77, 95% CI 0.67–0.89), and in-hospital mortality (OR 0.78, 95% CI 0.65–0.97), with no significant difference in major bleeding risk. Subgroup analysis showed mortality benefits were most evident among intermediate–low and high-risk patients. In conclusion, acute PE patients transferred to PERT hospitals were more likely to receive advanced therapies and had improved short- and long-term survival, with no increase in bleeding risk, despite presenting with higher clinical severity.

1 | Introduction

Acute pulmonary embolism (PE) is the third leading cause of cardiovascular death, with annual incidences ranging from 0.75

to 2.69 per 1000 individuals across the world [1]. In the United States, between 300,000 and 600,000 cases of acute PE occur each year [2], contributing to at least 40,000 deaths [3]. Literature suggests that patients with acute PE tend to benefit when

Abbreviations: ECMO, extracorporeal membrane oxygenation; PE, pulmonary embolism; PERT, Pulmonary Embolism Response Team.

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treated at high-volume centers and by experienced physicians [4, 5]. This is particularly pertinent given the increasing complexity of PE management and advancement in treatment options, warranting the interhospital transfer of patients with high-risk features to tertiary care facilities that have access to advanced therapies, often under the guidance of multidisciplinary Pulmonary Embolism Response Teams (PERT) [6]. In contrast to other acute medical conditions such as myocardial infarction and stroke, the comparative outcomes of patients with acute PE transferred for advanced care versus those directly admitted to hospitals with PERT have yet to be studied. This multicenter observational study aims to describe the demographics, treatment, and outcomes of acute PE patients who directly present to PERT hospitals with acute PE patients transferred from local referring hospitals and subsequently evaluated by PERT.

2 | Methods

The PERT Consortium Registry, maintained by the PERT Consortium, is a multicenter database of patients admitted to the hospital with PE for whom the PERT team has been consulted. Deidentified patient data were entered into a HIPPA-compliant web-based application by study members at their respective institutions. The Institutional Review Board in each site approved enrollment in PERT Registry and data entry.

In this study, we analyzed all cases between October 16, 2015 and June 1, 2024, including a total of 12,346 patients. The cohort was divided into patients directly presenting to PERT hospitals and those transferred from referring hospitals. As PERT protocols vary among institutions, transfer decisions were made on an individual basis. General transfer criteria have been discussed in detail by Rali et al. [6]. All data were submitted by participating institutions and aggregated by the PERT Consortium. A list of contributing institutions is provided in the [Supporting File](#).

Data analyzed included demographics, clinical presentations, treatments, and outcomes. Patients were classified by PE risk severity according to predefined criteria by the European Society of Cardiology [7, 8].

χ^2 tests were used to assess differences between categorical variables. For differences in distributions for continuous variables, Student's *t*-test was used. Logistic regression was used to evaluate the associations of transfer status and mortality at 30 days and 1 year, as well as major bleeding events. Logistic models were adjusted for age, sex, race, BMI, malignancy, reduced mobility, hypoxia, concomitant DVT, syncope, and risk classification. Due to numerical rounding, column percentages in each table may not add to 100%. Statistical significance was set a priori at $\alpha = 0.05$. Statistical analysis was performed with R 4.4.0 [9].

3 | Results

3.1 | Baseline Demographics and Patient Characteristics

Among the 12,346 patients with acute PE, 73.5% ($n = 9,069$) presented directed to PERT hospitals, while 26.5% ($n = 3,277$)

were transferred from referring hospitals (Table 1). Transferred patients were younger (62.5 vs. 63.8 years, $p < 0.01$) and more frequently male (52.1% vs. 49.8%, $p = 0.02$). Racial distribution differed significantly ($p < 0.01$), with a higher proportion of White ethnicity (69.9% vs. 62.8%, $p < 0.01$) among transfers and fewer Black (16.8% vs. 23.0%) and Hispanic patients (3.4% vs. 6.1%). Transferred patients had a higher rate of obesity (BMI 33.0 ± 8.4 vs. 31.20 ± 8.2 , $p < 0.001$) and were more likely to have hypertension (73.7% vs. 71.3%, $p = 0.01$), but less likely to have malignancy (23.4% vs. 27.8%, $p < 0.01$) or reduced mobility (27.9% vs. 31.4%, $p < 0.01$). Clinical presentations also differed, with transferred patients more frequently presented with dyspnea (77.9% vs. 72.2%, $p < 0.01$), dizziness (14.9% vs. 13.3%, $p = 0.02$), and syncope (11.7% vs. 9.4%, $p < 0.01$).

3.2 | PE Risk Classification

In comparison to acute PE patients who directly presented to a PERT hospital, a higher proportion of transferred patients were categorized as having high-risk PE (16.7% vs. 13.8%, $p < 0.01$) or intermediate-high risk PE (55.9% vs. 54.3%, $p < 0.01$). Transferred patients had higher rates of elevated right ventricular systolic pressure (RVSP, 45.4 vs. 44.0 mmHg, $p = 0.02$), greater prevalence of concomitant DVT (51.8% vs. 49.5%, $p = 0.03$), more frequent hemodynamic collapse (3.9% vs. 2.8%, $p = 0.03$), and need for vasopressors (8.5% vs. 7.2%, $p = 0.02$).

3.3 | Advanced Therapies and Clinical Outcomes

Transferred patients were more likely to receive advanced therapies, including extracorporeal membrane oxygenation (ECMO, 2.8% vs. 1.1%, $p < 0.01$), surgical embolectomy (2.0% vs. 0.8%, $p < 0.01$), systemic thrombolysis (5.3% vs. 3.8%, $p < 0.01$), and catheter-based interventions (32.3% vs. 17.1%, $p < 0.01$). There was no statistically significant difference in the types of catheters used between the two groups (Table 2).

In unadjusted analyses, transferred patients had significantly lower odds of 30-day mortality (OR 0.67, 95% CI 0.57–0.77), 1-year mortality (OR 0.64, 95% CI 0.57–0.72), and in-hospital mortality (OR 0.84, 95% CI 0.70–0.98), with no significant difference in 1-year major bleeding (OR 1.05, 95% CI 0.88–1.27). These associations persisted after adjustment for baseline characteristics, with transfer associated with lower odds of 30-day mortality (OR 0.82, 95% CI 0.69–0.98), 1-year mortality (OR 0.77, 95% CI 0.67–0.89), and in-hospital mortality (OR 0.78, 95% CI 0.65–0.97). No significant difference was found in major bleeding risk post-adjustment (OR 1.01, 95% CI 0.82–1.25). Table 3 shows logistic regression results for the association between transfer status and outcomes.

Subgroup analysis stratified by PE risk severity showed that the mortality benefit of transfer was most prominent among intermediate-low and high-risk patients (Table 4). Among intermediate-low risk patients, transfer was associated with significantly lower odds of 30-day mortality (OR 0.42, 95% CI 0.02–0.80), 1-year mortality (OR 0.48, 95% CI 0.29–0.78), and in-

TABLE 1 | Demographics and clinical characteristics of the PERT cohort by transfer status ($N = 12,346$).

	<i>n</i>	Direct admit to PERT hospital (<i>n</i> = 9069)	Transferred to PERT hospital (<i>n</i> = 3277)	<i>p</i>
Age	11,698	63.84 (15.78)	62.52 (15.55)	< 0.01
Male (%)	12,346	4512 (49.8)	1707 (52.1)	0.02
Race (%)	12,346	—	—	< 0.01
American Indian, Alaska Native		59 (0.7)	42 (1.3)	
Asian, Pacific Islander		107 (1.2)	22 (0.7)	
Black or African American		2085 (23.0)	551 (16.8)	
Hispanic or Latino		556 (6.1)	111 (3.4)	
Other		571 (6.3)	260 (7.9)	
White		5691 (62.8)	2291 (69.9)	
BMI	10,041	31.20 (8.24)	33.02 (8.44)	< 0.01
Hypertension (%)	11,890	6211 (71.3)	2342 (73.7)	0.01
Diabetes (%)	11,605	1596 (19.1)	623 (19.1)	0.93
Malignancy (%)	11,605	2317 (27.8)	766 (23.4)	< 0.01
DVT, prevalent (%)	11,605	1568 (18.8)	556 (17.0)	0.03
Concomitant DVT (%)	11,606	4128 (49.5)	1693 (51.8)	0.03
Smoker (%)	11,605	1201 (14.4)	541 (16.5)	< 0.01
Reduced mobility (%)	11,605	2618 (31.4)	912 (27.9)	< 0.01
Recent hospitalization (%)	11,605	1505 (18.1)	584 (17.9)	0.83
Pregnancy (%)	11,605	46 (0.6)	23 (0.7)	0.41
Dyspnea (%)	11,605	6020 (72.2)	2546 (77.9)	< 0.01
Chest pain, dull achy (%)	11,605	1036 (12.4)	412 (12.6)	0.82
Chest pain, pleuritic (%)	11,605	1823 (21.9)	681 (20.8)	0.23
Back pain (%)	11,605	435 (5.2)	142 (4.3)	0.06
Palp (%)	11,605	453 (5.4)	163 (5.0)	0.36
Dizziness/lightheadedness (%)	11,605	1109 (13.3)	488 (14.9)	0.02
Syncope (%)	11,605	783 (9.4)	382 (11.7)	< 0.01
Cough (%)	11,605	1516 (18.2)	600 (18.4)	0.85
Hemoptysis (%)	11,605	165 (2.0)	65 (2.0)	1
Leg pain (%)	11,605	978 (11.7)	385 (11.8)	0.97
Leg swell (%)	11,605	1608 (19.3)	608 (18.6)	0.41
Hemodynamic collapse (%)	11,605	233 (2.8)	127 (3.9)	0.03
Fever (%)	11,605	352 (4.2)	125 (3.8)	0.36
Altered mental status (%)	10,643	1147 (14.9)	377 (12.7)	0.04
RVSP max by echo	3344	44.00 (16.36)	45.39 (15.34)	0.02
Vasopressor (%)	11,534	597 (7.2)	277 (8.5)	0.02
BNP, elevated (%)	8157	4129 (70.4)	1815 (79.3)	< 0.01
Troponin, elevated (%)	9849	3201 (45.1)	1190 (43.3)	0.12
Risk categorization (%)	11,162	—	—	< 0.01
High risk		1154 (13.8)	547 (16.7)	
Intermediate–high risk		4562 (54.3)	1829 (55.9)	

(Continues)

TABLE 1 | (Continued)

	<i>n</i>	Direct admit to PERT hospital (<i>n</i> = 9069)	Transferred to PERT hospital (<i>n</i> = 3277)	<i>p</i>
Intermediate–low risk		1639 (19.6)	575 (17.6)	
Low risk		1022 (12.3)	320 (9.8)	

Note: Results reported as mean (SD) or frequency (%).

Abbreviations: BMI = body mass index, BNP = B-type natriuretic peptide, DVT = deep vein thrombosis, ECHO = echocardiography, RVSP = right ventricular systolic pressure, SD = standard deviation.

TABLE 2 | Treatments and outcomes by transfer status for PERT cohort.

	<i>n</i>	Direct admit to PERT hospital (<i>n</i> = 9069)	Transferred to PERT Hospital (<i>n</i> = 3277)	<i>p</i>
ECMO (%)	11,560	90 (1.1)	91 (2.8)	< 0.01
Surgical embolectomy (%)	11,560	66 (0.8)	65 (2.0)	< 0.01
Systemic thrombolysis (%)	12,346	341 (3.8)	175 (5.3)	< 0.01
Catheter-based intervention (%)	12,346	1555 (17.1)	1059 (32.3)	< 0.01
Catheter-directed thrombolysis (%)	2614	597 (38.4)	416 (39.3)	0.68
Mechanical thrombectomy (%)	2614	912 (58.6)	625 (59.0)	0.88
Other (%)	2614	48 (3.1)	20 (1.9)	0.08
Death at 30 days (%)	12,346	1032 (11.4)	259 (7.9)	< 0.01
Death at 1 year (%)	12,346	1528 (16.8)	379 (11.6)	< 0.01
In-hospital mortality (%)	12,346	619 (6.8)	189 (5.8)	0.04
Major bleed at 1 year (%)	12,346	415 (4.6)	158 (4.8)	0.60

Abbreviation: ECMO = extracorporeal membrane oxygenation.

TABLE 3 | Logistic regression results for the association of transfer status and outcomes (mortality, major bleed).

	OR	95% CI
Unadjusted		
30-day mortality	0.67	(0.57, 0.77)
1-year mortality	0.64	(0.57, 0.72)
In-hospital mortality	0.84	(0.70, 0.98)
1-year major bleed	1.05	(0.88, 1.27)
Adjusted		
30-day mortality	0.82	(0.69, 0.98)
1-year mortality	0.77	(0.67, 0.89)
In-hospital mortality	0.78	(0.65, 0.97)
1-year major bleed	1.01	(0.82, 1.25)

Note: Logistic models were adjusted for age, sex, race, BMI, malignancy, reduced mobility, hypoxia, concomitant DVT, syncope, and risk classification. Bold values are statistically significant.

hospital mortality (OR 0.37, 95% CI 0.16–0.75). For high-risk PE patients, transfer was associated with lower 30-day mortality (OR 0.71, 95% CI 0.53–0.94) and 1-year mortality (OR 0.74, 95% CI 0.68–0.97). No significant differences were observed in low-risk or intermediate–high-risk groups.

4 | Discussion

This large, multicenter study evaluated the demographics, treatment strategies, and outcomes of patients with acute PE who were transferred to tertiary centers with PERT compared to those who presented directly to a PERT hospital. Transferred patients exhibited a higher risk of clinical deterioration and more frequently received advanced therapies, including systemic thrombolysis, surgical embolectomy, catheter-based interventions, and ECMO. Despite their higher risk profile, transferred patients demonstrated significantly lower rate of 30-day mortality and 1-year mortality, with no increase in major bleeding events, when compared to patients who directly presented to PERT-equipped centers.

Previous studies have investigated outcomes of interhospital transfers in PE and have drawn different conclusions. Carroll and colleagues reported a single-center experience of transferred patients with PE and found a higher rate of definite PE-mortality in the transferred group, although overall survival was similar between groups [10]. Notably, their study included patients largely before the establishment of PERT, and even during later years when PERT was available, only 29% of transferred patients were evaluated by PERT. Using the National Readmission Database, Sedhom and colleagues analyzed outcomes among 11,341 patients with acute high-risk PE who were transferred [11]. Transferred patients in that cohort

TABLE 4 | Logistic regression results for the association of transfer status and outcomes, stratified by assessed risk.

Risk classification	Low		Intermediate-Low		Intermediate-High		High	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
30-day mortality	0.72	(0.26, 1.67)	0.42	(0.20, 0.80)	1.08	(0.84, 1.40)	0.71	(0.53, 0.94)
1-year mortality	0.79	(0.42, 1.40)	0.48	(0.29, 0.78)	0.87	(0.70, 1.07)	0.74	(0.68, 0.97)
In-hospital mortality	0.99	(0.41, 2.14)	0.37	(0.16, 0.75)	0.79	(0.58, 1.04)	0.96	(0.69, 1.32)
1-year major bleed	0.82	(0.34, 1.72)	1.08	(0.59, 1.88)	0.94	(0.67, 1.28)	1.14	(0.79, 1.63)

Note: Logistic models were adjusted for age, sex, race, BMI, malignancy, reduced mobility, hypoxia, concomitant DVT, syncope, and risk classification.

were more likely to present with saddle PE and cor pulmonale, and were more likely treated with advanced therapies. However, they reported no major difference in in-hospital mortality, major bleeding rates and cardiac arrest between transferred and nontransferred patients. In contrast, our study demonstrated improved mortality outcomes among transferred patients when compared to those directly admitted. We hypothesize that these survival benefits may be attributable to the greater use of advanced therapies and the involvement of PERTs in coordinating timely, individualized care and mobilizing specialized resources. Future prospective or quasi-experimental studies will be critical to assess whether the availability of PERT and access to advanced interventions directly contribute to improved outcomes.

Our findings also raise relevant clinical questions regarding the optimal design of systems of care. While the improved survival associated with transfer supports the hub-and-spoke model of centralizing advanced PE therapies within expert centers, broader decentralization of catheter-based therapies to select community hospitals may also be considered, particularly in regions where geography or population density pose challenges for timely transfer. Further studies incorporating transfer timing, risk of deterioration during transport, and rescue scenarios after failed initial therapy will be essential to guide the development of efficient and equitable PE care systems.

Importantly, we observed demographic differences between transferred patients and those who directly presented to PERT centers. Black and Hispanic patients were less frequently transferred. This underrepresentation may reflect systemic barriers, geographic limitations, or unconscious referral biases. While root causes of this finding remain unclear, it highlights the presence of potential racial disparities in access to advanced PE care [12]. Further research is necessary to uncover and understand the inequities in care for all patients presenting with acute PE.

4.1 | Limitations

This study has several limitations. First, its observational design and lack of randomization limit causal inference. In addition, the data are self-reported and may underestimate the incidence of some adverse events. Selection bias represents a major limitation, particularly given that the study excludes patients with PE who were managed locally and not transferred to a PERT center. No data are available for patients who were not transferred to PERT institutions.

Importantly, the registry does not capture peritransfer metrics such as time from symptom onset to transfer initiation, transfer duration, delay to advanced therapy, or adverse events occurring during transport. Thus, we cannot assess transfer logistics or safety, which are critical factors for risk-benefit assessment. As the status and treatment of patients prior to transfer are not included, it is unclear if pretransfer treatment affected intervention utilization or outcomes and may have influenced results. For example, whether patients were transferred after failed systemic thrombolysis with persistent shock or RV dysfunction could not be determined. Similarly, data on thrombus-in-transit or intracardiac thrombi were not systematically collected, limiting our ability to evaluate their role in transfer decisions or outcomes.

The geographic distance and time to transfer were also not accounted for in this analysis. Finally, heterogeneity in PERT composition, institutional activation protocols, and availability of advanced therapies (e.g., surgical embolectomy) across centers likely influenced patterns of transfer and may explain, in part, why some low- or intermediate-low-risk patients were transferred.

5 | Conclusion

In this large, multicenter registry of patients with acute PE evaluated by PERT, transferred patients had higher baseline risk profiles and were more likely to receive advanced therapies. Despite this, transferred patients experienced significantly lower 30-day and 1-year mortality compared to those directly admitted to PERT hospitals, without an increase in major bleeding. These findings suggest that interhospital transfer to specialized centers with PERT availability may improve outcomes for selected patients with acute PE. However, potential disparities in transfer patterns—particularly by race—highlight the need for further investigation into equitable access to specialized PE care. Prospective studies are warranted to confirm whether PERT-directed care and advanced interventions directly contribute to improved survival in this high-risk population.

Author Contributions

Ka U. Lio is the guarantor of the manuscript. Ka U. Lio, Michael McDaniel, Parth Rali, and Charles B. Ross were responsible for manuscript outline and content development. Michael McDaniel, Parth Rali, and Ka U. Lio wrote the first draft. Paul Yacono, Belinda Rivera-Lebron,

Rachel Rosovsky, Mary Jo Farmer, and Charles B. Ross contributed to concept, critical revision, and final approval of the manuscript. The manuscript was circulated among all authors, and revisions were discussed in monthly meetings of protocols, educational, and the CHEST Pulmonary Vascular Disease Network Committee. All authors take full responsibility for the integrity of the submission.

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Ethics Statement

The Institutional Review Board in each participating site approved enrollment in the PERT Registry and data entry.

Conflicts of Interest

The authors declare no conflicts of interest.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.
Supplemental File 1.