ORIGINAL INVESTIGATION

Predictors of Early Hospital Readmission After Acute Pulmonary Embolism

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Background: Risk factors for early mortality after pulmonary embolism (PE) are widely known. However, it is uncertain which factors are associated with early readmission after PE. We sought to identify predictors of readmission after an admission for PE.

Methods: We studied 14 426 patient discharges with a primary diagnosis of PE from 186 acute care hospitals in Pennsylvania from January 1, 2000, to November 30, 2002. The outcome was readmission within 30 days of presentation for PE. We used a discrete proportional odds model to study the association between time to readmission and patient factors (age, sex, race, insurance, discharge status, and severity of illness), thrombolysis, and hospital characteristics (region, teaching status, and number of beds).

Results: Overall, 2064 patient discharges (14.3%) resulted in a readmission within 30 days of presentation for PE. The most common reasons for readmission were venous thromboembolism (21.9%), cancer (10.8%), pneumonia (5.2%), and bleeding (5.0%). In multivariable analysis, African American race (odds ratio [OR], 1.19; 95% confidence interval [CI], 1.02-1.38), Medicaid insurance (OR, 1.54; 95% CI, 1.31-1.81), discharge home with supplemental care (OR, 1.40; 95% CI, 1.27-1.54), leaving the hospital against medical advice (OR, 2.84; 95% CI, 1.80-4.48), and severity of illness were independently associated with readmission; readmission also varied by hospital region.

Conclusions: Early readmission after PE is common. African American race, Medicaid insurance, severity of illness, discharge status, and hospital region are significantly associated with readmission. The high readmission rates for venous thromboembolism and bleeding suggest that readmission may be linked to suboptimal quality of care in the management of PE.

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ACUTE PULMONARY EMBOLISM (PE) is a major health problem, with an estimated annual incidence of up to 69 cases per 100 000 persons.[1] More than 122 000 patients with a primary diagnosis of PE were discharged from US hospitals in 2004.[2] Risk factors for short-term mortality have been extensively studied,[3,4] but risk factors for early readmission after an admission for PE are unknown. Knowledge of these risk factors is important, as early readmission rates may represent measures of quality of care during the initial hospitalization.[5] For several medical diseases, such as heart failure, diabetes, and obstructive lung disease, early readmission was found to be associated with a lower inpatient quality of care.[6] According to a prior study based on US administrative claims data, nearly half of readmissions for venous thromboembolism occur within the first 30 days among patients with an index hospitalization for venous thromboembolism, and costs for hospital readmission are high.[7] Given the magnitude of the clinical and economic impact of PE in the United States and other industrialized countries, it is important to examine the reasons for readmission and factors that are associated with readmission after hospitalization for PE. To our knowledge, no prior study has used population-based data to identify the predictors of readmission after PE. The goals of this study were (1) to assess the reasons for readmission during the first 30 days after hospitalization for PE and (2) to identify the patient and hospital characteristics that are independently associated with readmission.

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METHODS

PATIENT IDENTIFICATION AND ELIGIBILITY

We identified patients with PE who were discharged from 186 nongovernmental (ie, non–Veterans Affairs) acute care hospitals in Pennsylvania (January 1, 2000 to November 30, 2002) using the Pennsylvania Health Care Cost Containment Council (PHC4) database. This database contains information on demographic characteristics; insurance status; *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnosis and procedure codes; hospital region and number of beds; and length of hospital stay for all patients.

Table 1. Most Frequent Reasons for Readmission Within 30 Days of Presentation for Pulmonary Embolism

Reason for Readmission[a]	Readmissions, No. (%)[b]	Days Between Discharge and Readmission, Median (IQR)
Venous thromboembolism	453 (21.9)	8.0 (4.0-14.0)
Cancer	222 (10.8)	11.0 (7.0-17.0)
Pneumonia (including aspiration pneumonia)	108 (5.2)	8.5 (4.0-15.0)
Bleeding	104 (5.0)	9.0 (4.5-14.0)
Unspecific chest pain	103 (5.0)	10.0 (5.0-15.0)
Heart failure	79 (3.8)	11.0 (5.0-18.0)
COPD or asthma	51 (2.5)	9.0 (3.0-14.0)
Ischemic heart disease	43 (2.1)	11.0 (6.0-17.0)
Volume depletion	42 (2.0)	8.5 (3.0-15.0)
Arrhythmias	41 (2.0)	9.0 (3.0-17.0)
Other conditions	818 (39.6)	9.0 (5.0-15.0)
Total	**2064** (100)	9.0 (5.0-15.0)

Abbreviations: COPD, chronic obstructive pulmonary disease; IQR, interquartile range.
[a] Based on the primary *International Classification of Diseases, Ninth Revision, Clinical Modification*, discharge diagnosis.
[b] Percentages may not sum to 100 because of rounding.

We included inpatients aged 18 years and older who were discharged with a primary diagnosis of PE based on the following *ICD-9-CM* codes: 415.1, 415.11, 415.19, and 673.20-24. To ensure that we identified the most severely ill patients with PE as the primary reason for hospitalization, we also included inpatients with a secondary diagnosis code for PE and one of the following primary codes that may represent complications or treatments of this condition: respiratory failure (518.81), cardiogenic shock (785.51), cardiac arrest (427.5), secondary pulmonary hypertension (416.8), syncope (780.2), thrombolysis (99.10), and intubation or mechanical ventilation (96.04, 96.05, and 96.70-96.72).

We excluded all other patients who had a secondary *ICD-9-CM* code for PE and those who were transferred from another health care facility, because such patients are more likely to have PE as a complication of hospitalization. We excluded hospitalizations for patients who subsequently were transferred to other hospitals or hospice care, died during the hospital stay, or stayed in the hospital for more than 30 days. We also excluded patients without the identifiers required to link the necessary clinical data and those for whom the readmission date or mortality information was not available. The institutional review board at the University of Pittsburgh, Pittsburgh, Pennsylvania, approved the study.

PATIENT AND HOSPITAL CHARACTERISTICS

Patient demographic characteristics, insurance status, discharge status, hospital region, number of beds per site, and annual number of PE admissions for each site were abstracted from the PHC4 database. Hospital teaching status was ascertained from the Council of Teaching Hospitals of the Association of American Medical Colleges. Baseline clinical variables were obtained by linking eligible patients to the Atlas database (MediQual, Malborough, Massachusetts), which includes clinical findings at presentation for all inpatients treated at nongovernmental acute care hospitals in Pennsylvania. The PHC4 and Atlas databases were linked by PHC4 staff using unique patient identifiers (patient date of birth, sex, and Social Security number); we had no access to personal patient identifiers. Severity of illness at the time of presentation for each hospitalization was quantified using the Pulmonary Embolism Severity Index (PESI). The PESI is a validated prognostic model for patients with PE that was developed using these clinical data from the PHC4 and Atlas databases.[4,8] Based on the PESI, each patient is classified into 1 of 5 classes (I-V), with 30-day mortality ranging from 1.1% to 24.5%.[4] To ascertain whether patients received thrombolysis, we used *ICD-9-CM* procedure codes (99.10) from the PHC4 and Atlas databases.

STUDY OUTCOMES

The primary outcome was hospital readmission for any reason to any acute care hospital in Pennsylvania within 30 days of presentation during the study period. This information was abstracted from the PHC4 database. Secondary outcomes were readmission for recurrent venous thromboembolism (PE or deep vein thrombosis) and bleeding, both known complications of PE or anticoagulant treatment. Cases of recurrent venous thromboembolism[9] and bleeding[10] were identified using primary *ICD-9-CM* codes in a manner similar to that used in prior studies. Other causes of readmission were identified from the primary *ICD-9-CM* codes and were grouped into clinically meaningful categories.

STATISTICAL ANALYSES

We calculated the frequency of patients who were readmitted within 30 days of presentation for those with and without various patient and hospital factors, including demographic characteristics, clinical and procedure-related factors (eg, thrombolysis), hospital region within Pennsylvania, hospital teaching status, number of hospital beds, and average annual number of PE admissions. Fisher exact and χ^2 tests were used to compare proportions readmitted across each of these factors. A P value of less than .05 was considered statistically significant.

We used a discrete proportional odds model to examine the association between the time since discharge from the index hospitalization to first readmission within 30 days and demographic, clinical, and hospital factors. Patients who died after discharge from the index hospitalization but before readmission were censored at the time of death. Follow-up was censored 30 days after each admission. These analyses accounted for the small number of possible event times, patient-specific time at risk for readmission owing to differing length of stay, patient deaths, and varying time until readmission. To account for the correlation between hospitalizations at the same site, we treated hospital site as a random effect using the xtlogit command in Stata 10.0 (Stata Corp, College Station, Texas). Predictors that were tested included patient race, insurance status, severity of illness using PESI risk class (which incorporates age, sex, history of cancer, history of chronic lung disease, history of heart failure, systolic arterial blood pressure $<$100 mm Hg, pulse $\geq$110 beats/min, respiratory rate $\geq$30 breaths/min, body temperature $<$36°C, arterial oxygen saturation $<$90%, and altered mental status), administration of thrombolysis in the hospital, discharge status, and hospital-related factors (hospital region within Pennsylvania, teaching status, and number of beds) (**Table 1**). Variation across sites was assessed by comparing the estimated site-level variance component with its χ^2 mixture distribution. In sensitivity analyses, the quartiles of length of stay were included in the models to assess whether this additional adjustment for length of stay altered the estimated associations of the other predictors with readmission. We also assessed time trends by including indicator variables for year.

Because recurrent venous thromboembolism and anticoagulation-related bleeding are common complications after PE, we conducted secondary analyses using the same methods to identify predictors associated with readmission for (1) venous thromboembolism and (2) bleeding. In these secondary analy-

ses, readmissions for reasons other than the diagnosis of interest (ie, venous thromboembolism or bleeding) were excluded.

RESULTS

REASONS FOR READMISSION

From 17 733 patient discharges that met our inclusion criteria, the final study cohort comprised 14 426 live patient discharges with a diagnosis of PE from 186 hospitals in Pennsylvania (**Figure**). Overall, we excluded 3307 patient discharges, most commonly because the patients were transferred from or to another hospital (n=1032) or died during the initial hospitalization (n=926). A total of 2064 patient discharges (14.3%) resulted in readmission within 30 days after presentation for PE, with a median time between discharge to readmission of 9 days (interquartile range, 5-15 days). Of these, 453 patients (21.9% of readmissions or 3.1% of discharges) were readmitted for venous thromboembolism and 104 (5.0% of readmissions or 0.7% of discharges) were readmitted for bleeding (Table 1). Other common reasons for readmission were cancer (10.8%), pneumonia (5.2%), and unspecific chest pain (5.0%). A total of 187 patients (9.1%) died after readmission.

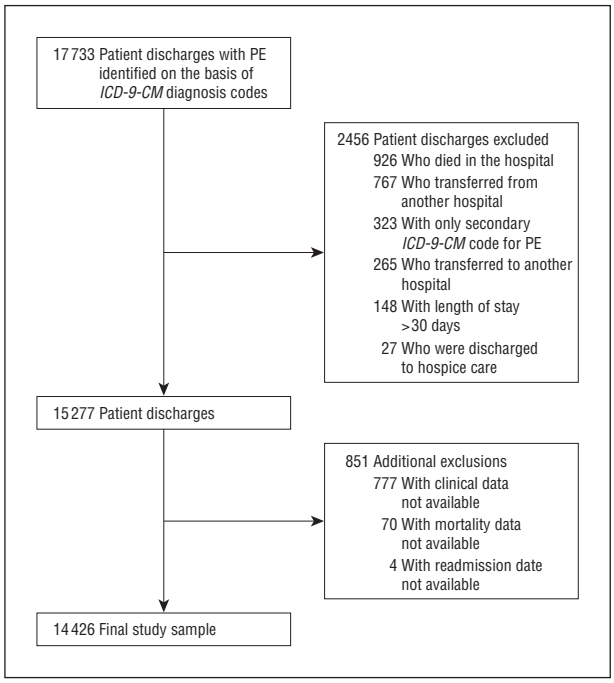

Figure. Selection of study sample. PE indicates pulmonary embolism; *ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.*

FACTORS ASSOCIATED WITH READMISSION

Baseline patient and hospital characteristics, as well as the corresponding proportions of readmissions for each subpopulation, are summarized in **Table 2**. African Americans, patients without private health insurance, and those discharged home with supplemental care or who left the hospital against medical advice were relatively more likely to be readmitted, as were more severely ill patients (ie, those with comorbid conditions and signs of cardiorespiratory instability). Hospitals in northern and southern central Pennsylvania, smaller hospitals (<204 beds), and nonteaching hospitals had lower readmission rates. The median length of stay at the index hospitalization was identical for patients who were readmitted and those who were not (6 days; interquartile range, 4-8 days for both groups).

After adjustment for hospital and patient factors, the odds of readmission were significantly higher if the patients were African American (odds ratio [OR], 1.19; 95% confidence interval [CI], 1.02-1.38), received Medicaid (OR, 1.54; 95% CI, 1.31-1.81), were discharged home with supplemental care (OR, 1.40; 95% CI, 1.27-1.54), or left the hospital against medical advice (OR, 2.84; 95% CI, 1.80-4.48) (**Table 3**). The odds of readmission increased with increasing severity of illness, with the OR of readmission for a patient with PESI risk class V being 2.04 (95% CI, 1.73-2.40) compared with that of a patient with risk class I. The odds of readmission were significantly lower in northern (OR, 0.73; 95% CI, 0.57-0.94) and southern (OR, 0.73; 95% CI, 0.60-0.89) central Pennsylvania than in Pittsburgh. Administration of thrombolysis in the hospital ($P=.65$), teaching status ($P=.94$), and number of hospital beds ($P=.47$) were not significantly associated with readmission. We observed significant variation in readmission across study sites after adjustment for the predictors in Table 3 ($P<.001$) but no evidence of time trends ($P=.49$). These results were virtually unchanged in sensitivity analyses that included the quartiles of length of stay as a predictor.

FACTORS ASSOCIATED WITH READMISSION FOR VENOUS THROMBOEMBOLISM OR BLEEDING

Few factors were significantly associated with readmission for venous thromboembolism or bleeding, 2 frequent complications after PE. African Americans (OR, 1.63; 95% CI, 1.22-2.18) and Medicaid recipients (OR, 1.76; 95% CI, 1.31-2.37) were significantly more likely to be readmitted for venous thromboembolism (**Table 4**), whereas patients with governmental insurance were less likely to be readmitted (OR, 0.73; 95% CI, 0.58-0.92). The odds of readmission for venous thromboembolism were significantly lower in northern central Pennsylvania than in Pittsburgh (OR, 0.30; 95% CI, 0.16-0.58).

The odds of readmission for bleeding were significantly higher in teaching hospitals than in nonteaching hospitals (OR, 1.95; 95% CI, 1.15-3.29 [**Table 5**]). The odds of readmission for bleeding were significantly lower in southern central (OR, 0.34; 95% CI, 0.14-0.84) and eastern (OR, 0.33; 95% CI, 0.12-0.95) Pennsylvania than in Pittsburgh. Patients in risk classes IV and V appeared to be at higher risk than patients in risk classes I through III ($P=.12$ for the overall test, based on 104 events). For both types of readmissions, we observed no significant variation across sites after adjustment for the predictors in Table 4 or 5, respectively ($P>.48$ for each). There was no evidence of time trends ($P>.44$ for each).

Table 2. Baseline Patient and Hospital Factors, Corresponding Proportions of Readmissions for Each Subcategory, and Univariate Associations With Readmission

Factor	No. (%)[a] Overall	Readmissions	*P* Value[b]
Demographics			
Age, y			.80
≤65	6984 (48.4)	994 (14.2)	
>65	7442 (51.6)	1070 (14.4)	
Sex			.39
Female	8659 (60.0)	1221 (14.1)	
Male	5767 (40.0)	843 (14.6)	
Race			<.001
White	11 703 (81.1)	1634 (14.0)	
African American	1549 (10.7)	291 (18.8)	
Unknown/other	1174 (8.1)	139 (11.8)	
Insurance type			<.001
Private	5328 (36.9)	651 (12.2)	
Government	7761 (53.8)	1165 (15.0)	
Medicaid	1105 (7.7)	216 (19.5)	
None/unknown	232 (1.6)	32 (13.8)	
Discharge status			<.001
Home	8903 (61.7)	1079 (12.1)	
Home with supplemental care	5466 (37.9)	965 (17.7)	
Left hospital against medical advice	57 (0.4)	20 (35.1)	
Comorbid diseases			
Heart failure			<.001
No	12 257 (85.0)	1665 (13.6)	
Yes	2169 (15.0)	399 (18.4)	
Cancer			<.001
No	11 681 (81.0)	1481 (12.7)	
Yes	2745 (19.0)	583 (21.2)	
Chronic lung disease			<.001
No	11 847 (82.1)	1585 (13.4)	
Yes	2579 (17.9)	479 (18.6)	
Physical examination findings			
Pulse ≥110/min			.01
No	12 037 (83.4)	1683 (14.0)	
Yes	2389 (16.6)	381 (15.9)	
Systolic blood pressure <100 mm Hg			.003
No	13 102 (90.8)	1831 (14.0)	
Yes	1324 (9.2)	233 (17.6)	
Respiratory rate ≥30 breaths/min			<.001
No	12 519 (86.8)	1749 (14.0)	
Yes	1907 (13.2)	314 (16.5)	
Temperature <36°C			.83
No	12 156 (84.3)	1736 (14.3)	
Yes	2270 (15.7)	328 (14.5)	
Altered mental status[c]			.02
No	13 605 (94.3)	1924 (14.1)	
Yes	821 (5.7)	140 (17.1)	
Arterial oxygen saturation <90%[d]			.49
No	13 375 (92.7)	1906 (14.3)	
Yes	1051 (7.3)	158 (15.0)	
PESI risk class			<.001
I	2989 (20.7)	327 (10.9)	
II	3240 (22.5)	384 (11.9)	
III	3192 (22.1)	440 (13.8)	
IV	2326 (16.1)	404 (17.4)	
V	2679 (18.6)	509 (19.0)	
Thrombolytic therapy			.52
No	14 141 (98.0)	2027 (14.3)	
Yes	285 (2.0)	37 (13.0)	
Hospital region			<.001
Pittsburgh and surrounding areas	3375 (23.4)	537 (15.9)	
Northwestern Pennsylvania	1026 (7.1)	149 (14.5)	
Southern Laurel Highlands	724 (5.0)	102 (14.1)	
Northern central Pennsylvania	993 (6.9)	114 (11.5)	
Southern central Pennsylvania	2279 (15.8)	243 (10.7)	
Northeastern Pennsylvania	874 (6.1)	110 (12.6)	
Eastern Pennsylvania	1408 (9.8)	184 (13.1)	
Areas surrounding Philadelphia	2047 (14.2)	318 (15.5)	
Philadelphia	1700 (11.8)	307 (18.1)	
Hospital status			.03
Nonteaching	10 705 (74.2)	1491 (13.9)	
Teaching	3721 (25.8)	573 (15.4)	
No. of hospital beds, quartiles			.002
<204	3594 (24.9)	455 (12.7)	
204 to 302	3636 (25.2)	571 (15.7)	
303 to 493	3642 (25.3)	512 (14.1)	
≥493	3554 (24.6)	526 (14.8)	
Average annual No. of PE cases, quartiles			.63
<24	3483 (24.1)	489 (14.0)	
24 to 42	3528 (24.5)	514 (14.6)	
43 to 68	4006 (27.8)	556 (13.9)	
≥68	3409 (23.6)	505 (14.8)	

Abbreviations: PE, pulmonary embolism; PESI, Pulmonary Embolism Severity Index.

[a] Percentages may not sum to 100 because of rounding.

[b] Compares the proportion of readmissions within subcategories of each variable.

[c] Defined as disorientation, lethargy, stupor, or coma.

[d] With or without supplemental oxygen.

COMMENT

Our main findings were that a substantial proportion of patients (14.3%) with PE are readmitted within 30 days of presentation and that several patient and hospital factors are independently associated with early readmission after PE. Although the majority of readmissions are comorbidity related and are frequently the result of underlying cancer or pneumonia, a substantial proportion of patients (26.9%) were readmitted for recurrent venous thromboembolism or bleeding. Because both conditions are closely related to anticoagulation quality, many of these complications could be potentially avoided. According to a recent meta-analysis,[11] 44% of hemorrhages occur when international normalized ratios are above the therapeutic range, and 48% of thromboemboli take place when they are below it. Therefore, improved anticoagulation control could decrease the like-

Table 3. Independent Associations of Baseline Patient and Hospital Factors With Readmission

Factor	Adjusted OR (95% CI)	*P* Value
Race		.01
White	1 [Reference]	
African American	1.19 (1.02-1.38)	
Unknown/other	0.85 (0.70-1.03)	
Insurance		<.001
Private	1 [Reference]	
Government	0.93 (0.83-1.04)	
Medicaid	1.54 (1.31-1.81)	
None/unknown	1.15 (0.80-1.66)	
Discharge status		<.001
Home	1 [Reference]	
Home with supplemental care	1.40 (1.27-1.54)	
Left hospital against medical advice	2.84 (1.80-4.48)	
PESI risk class[a]		<.001
I	1 [Reference]	
II	1.21 (1.04-1.41)	
III	1.41 (1.21-1.65)	
IV	1.87 (1.59-2.20)	
V	2.04 (1.73-2.40)	
Thrombolytic therapy	0.93 (0.67-1.29)	.65
Hospital teaching status	0.99 (0.85-1.16)	.94
Natural logarithm, mean No. of hospital beds	1.04 (0.94-1.15)	.47
Hospital region		.002
Pittsburgh and surrounding areas	1 [Reference]	
Northwestern Pennsylvania	0.98 (0.79-1.22)	
Southern Laurel Highlands	0.91 (0.70-1.18)	
Northern central Pennsylvania	0.73 (0.57-0.94)	
Southern central Pennsylvania	0.73 (0.60-0.89)	
Northeastern Pennsylvania	0.86 (0.67-1.10)	
Eastern Pennsylvania	0.87 (0.70-1.08)	
Areas surrounding Philadelphia	1.02 (0.85-1.22)	
Philadelphia	1.13 (0.94-1.37)	

Abbreviations: CI, confidence interval; OR, odds ratio; PESI, Pulmonary Embolism Severity Index.

[a]The following 11 variables are included in the PESI: age, sex, history of cancer, history of chronic lung disease, history of heart failure, systolic arterial blood pressure less than 100 mm Hg, pulse 110/min or higher, respiratory rate 30 breaths/min or higher, body temperature lower than 36°C, altered mental status, and arterial oxygen saturation less than 90%.

Table 4. Independent Associations of Baseline Patient and Hospital Factors With Readmission for Venous Thromboembolism

Factor	Adjusted OR (95% CI)	*P* Value
PESI risk class[a]		.53
I	1 [Reference]	
II	1.12 (0.84-1.47)	
III	1.11 (0.83-1.50)	
IV	1.34 (0.97-1.85)	
V	1.15 (0.82-1.62)	
Race		.001
White	1 [Reference]	
African American	1.63 (1.22-2.18)	
Unknown/other	0.81 (0.55-1.19)	
Insurance		.001
Private	1 [Reference]	
Government	0.73 (0.58-0.92)	
Medicaid	1.76 (1.31-2.37)	
None/unknown	1.43 (0.79-2.58)	
Discharge status		.19
Home	1 [Reference]	
Home with supplemental care	1.04 (0.85-1.28)	
Left hospital against medical advice	2.28 (0.93-5.60)	
Thrombolytic therapy	1.09 (0.58-2.05)	.79
Hospital teaching status	0.90 (0.70-1.17)	.45
Natural logarithm, mean No. of hospital beds	0.98 (0.82-1.17)	.82
Hospital region		.02
Pittsburgh and surrounding areas	1 [Reference]	
Northwestern Pennsylvania	1.18 (0.81-1.71)	
Southern Laurel Highlands	0.73 (0.44-1.22)	
Northern central Pennsylvania	0.30 (0.16-0.58)	
Southern central Pennsylvania	1.02 (0.76-1.38)	
Northeastern Pennsylvania	0.98 (0.64-1.49)	
Eastern Pennsylvania	0.96 (0.68-1.38)	
Areas surrounding Philadelphia	0.84 (0.61-1.15)	
Philadelphia	0.87 (0.62-1.20)	

Abbreviations: CI, confidence interval; OR, odds ratio; PESI, Pulmonary Embolism Severity Index.

[a]The following 11 variables are included in the PESI: age, sex, history of cancer, history of chronic lung disease, history of heart failure, systolic arterial blood pressure less than 100 mm Hg, pulse 110/min or higher, respiratory rate 30 breaths/min or higher, body temperature lower than 36°C, altered mental status, and arterial oxygen saturation less than 90%.

lihood of almost half of all anticoagulant-associated adverse events[11] as well as readmission rates after PE.

In prior studies, several factors were shown to be associated with early readmission among patients with cardiorespiratory diseases such as heart failure and pneumonia, including social characteristics, comorbid conditions, and inadequate quality of care.[5,6,12,13] To our knowledge, this is the first population-based study of the causes and predictors of readmissions after PE. While the association between increasing severity of illness and readmission observed in our study seems obvious, we cannot entirely explain why African Americans and patients receiving Medicaid were more likely to be readmitted. Prior studies reported higher readmission rates among African Americans and Medicaid recipients with other acute diseases such as heart failure[14] and pneumonia.[15] One explanation is that patients of lower socioeconomic status are overrepresented in these patient groups. Low socioeconomic status has been associated with greater risk of readmission,[14-17] possibly owing to the receipt of substandard quality of care,[14] reduced treatment adherence,[18] or the lack of timely and effective outpatient care.[19] The higher observed readmission rate for venous thromboembolism among African Americans and Medicaid recipients in our study indicates that readmission may be potentially linked to suboptimal anticoagulation practices in these patient groups. Whether quality improvement measures or interventions at the social level can reduce readmission rates in vulnerable populations with PE remains to be elucidated.

The effect of the discharge destination on subsequent hospitalizations is controversial.[20] In our sample, patients discharged home with supplemental care were at higher risk for readmission. Our finding is consistent with a prior study that found a higher readmission rate among patients with heart failure who were discharged with home health care services.[12] A potential explanation is that patients who are discharged with supplemen-

Table 5. Independent Associations of Baseline Patient and Hospital Factors With Readmission for Bleeding

Factor	Adjusted OR (95% CI)	*P* Value
PESI risk class[a]		.12
I	1 [Reference]	
II	1.05 (0.51-2.15)	
III	1.06 (0.51-2.21)	
IV	1.85 (0.89-3.83)	
V	1.86 (0.89-3.91)	
Race		.90
White	1 [Reference]	
African American	1.07 (0.58-1.98)	
Unknown/other	0.85 (0.36-1.99)	
Insurance		.81
Private	1 [Reference]	
Government	1.28 (0.78-2.11)	
Medicaid	1.05 (0.45-2.45)	
None/unknown	NA	
Discharge status		.37
Home	1 [Reference]	
Home with supplemental care	1.21 (0.80-1.82)	
Thrombolytic therapy	0.48 (0.07-3.47)	.47
Hospital teaching status	1.95 (1.15-3.29)	.01
Natural logarithm, mean No. of hospital beds	0.82 (0.56-1.20)	.32
Hospital region		.009
Pittsburgh and surrounding areas	1 [Reference]	
Northwestern Pennsylvania	1.04 (0.48-2.26)	
Southern Laurel Highlands	0.97 (0.37-2.59)	
Northern central Pennsylvania	0.57 (0.22-1.50)	
Southern central Pennsylvania	0.34 (0.14-0.84)	
Northeastern Pennsylvania	0.49 (0.15-1.64)	
Eastern Pennsylvania	0.33 (0.12-0.95)	
Areas surrounding Philadelphia	1.60 (0.92-2.77)	
Philadelphia	1.28 (0.68-2.39)	

Abbreviations: CI, confidence interval; NA, not applicable; OR, odds ratio; PESI, Pulmonary Embolism Severity Index.

[a] The following 11 variables are included in the PESI: age, sex, history of cancer, history of chronic lung disease, history of heart failure, systolic arterial blood pressure less than 100 mm Hg, pulse 110/min or higher, respiratory rate 30 breaths/min or higher, body temperature lower than 36°C, altered mental status, and arterial oxygen saturation less than 90%.

tal care are sicker and therefore at increased risk of readmission. However, another study found that patients with chronic obstructive pulmonary disease who were discharged to nursing homes were less likely to be readmitted than patients discharged to personal homes.[20]

Although only a tiny minority of patients (0.4%) left the hospital against medical advice, these patients had a high overall risk for readmission. Prior evidence suggests that patients who leave the hospital against medical advice are more likely to be socially disadvantaged, have a history of alcohol or other drug abuse, or lack a primary care physician.[21,22] Interventions at the social level may address some of the underlying reasons why these patients leave the hospital against medical advice and should be further studied.

Hospitals in rural southern and northern central Pennsylvania had significantly lower overall readmission rates than hospitals in metropolitan Pittsburgh and surrounding areas, and some hospital regions also had significantly lower readmission rates for venous thromboembolism (northern central Pennsylvania) or bleeding (southern central and eastern Pennsylvania). Whether the lower readmission rates in these hospital regions are a consequence of better inpatient or outpatient quality of care remains to be elucidated. Regional variation in hospital readmission rates has been observed for many cardiovascular diseases and procedures[12,23-25] and has been explained by differences in the availability of outpatient care services and differential hospital admission practices owing to hospital bed availability or local physician practice patterns.[13,23]

Although quality of care and outcomes tend to be generally better in teaching hospitals than in nonteaching hospitals for many surgical and medical conditions,[26] teaching hospitals had a significantly higher risk of readmission for bleeding in our study. One potential, yet unproved, explanation is that the higher proportion of physician trainees in teaching hospitals may lead to a suboptimal anticoagulation-related quality of care[27] and increase the risk of bleeding.

Some of the risk factors that were significant predictors of readmission (eg, African American race and severity of illness) in our study also were shown to be predictors of short-term mortality in patients with PE.[28] Limited evidence from a retrospective study linking processes of care and outcomes in patients with venous thromboembolism suggests that an overlap of heparin and warfarin therapy of fewer than 4 days before heparin therapy is discontinued is associated with worse patient outcomes.[29] However, because we could not examine anticoagulation-related processes of care in this study, we cannot say whether suboptimal anticoagulation practices were associated with higher readmission rates after PE. Therefore, the potential role of hospital readmission after PE as a quality-of-care measure is uncertain and must be further examined.

Our study has several limitations. First, patients in our sample were retrospectively identified using *ICD-9-CM* codes for PE rather than standardized radiographic criteria; therefore, patient eligibility may be subject to study selection biases owing to hospital coding procedures. While prior studies demonstrated that up to 96% of patients with specific *ICD-9-CM* codes for PE had objectively documented disease on the basis of chart review criteria,[30-32] little is known about the sensitivity of these codes for detecting PE. A prior study found that *ICD-9-CM* codes missed 13% of patients with PE.[33] Thus, we cannot entirely exclude the possibility that the potential for variation in the sensitivity of coding represents a threat to the validity of our findings. We also acknowledge that we had no information on the accuracy of the *ICD-9-CM* procedure code for thrombolysis (99.10) and the codes for the reasons for readmission. Second, we could not assess whether the quality of anticoagulation in the hospital and after discharge, the timing and intensity of outpatient care, or the use of newer anticoagulants (eg, low-molecular-weight heparins or fondaparinux) have an impact on readmission. Moreover, we had no information on physician-level factors (eg, experience, specialty training, and annual volume of PE per physician) and several hospital-level factors (eg, hospital proxim-

ity, staff volume, and availability of specialized anticoagulation clinics and intensive care units) with a potential impact on the quality of PE inpatient management and hospital readmission. Therefore, we cannot entirely exclude the possibility that the observed differences in readmission rates are attributable to unmeasured confounding by these factors. Third, we could not distinguish whether a given readmission was planned or identify which individual patient symptoms led to readmission. However, the majority of patients were readmitted because of acute diseases such as venous thromboembolism, pneumonia, bleeding, or chest pain, making a planned hospital admission very unlikely. Finally, we could not ascertain any hospital readmissions outside Pennsylvania. Although the frequency of out-of-state readmissions is likely to be low in patients after acute PE, we cannot exclude the possibility that our results somewhat underestimate the true readmission rate after PE.

In conclusion, our results suggest that early readmission after PE is a common problem and that more than one-fourth of readmissions are attributable to recurrent venous thromboembolism or bleeding. Although we identified a number of patient and hospital factors that were significantly associated with readmission, future research will be needed to evaluate whether hospital readmission is linked to suboptimal quality of care in the management of PE.

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REFERENCES

1. Silverstein MD, Heit JA, Mohr DN, Petterson TM, O'Fallon WM, Melton LJ III. Trends in the incidence of deep vein thrombosis and pulmonary embolism: a 25-year population-based study. *Arch Intern Med*. 1998;158(6):585-593.
2. Kozak LJ, DeFrances CJ, Hall MJ. National Hospital Discharge Survey: 2004 annual summary with detailed diagnosis and procedure data. *Vital Health Stat 13*. 2006;(162):1-209.
3. Heit JA, Silverstein MD, Mohr DN, Petterson TM, O'Fallon WM, Melton LJ III. Predictors of survival after deep vein thrombosis and pulmonary embolism: a population-based, cohort study. *Arch Intern Med*. 1999;159(5):445-453.
4. Aujesky D, Obrosky DS, Stone RA, et al. Derivation and validation of a prognostic model for pulmonary embolism. *Am J Respir Crit Care Med*. 2005;172(8):1041-1046.
5. Weissman JS, Ayanian JZ, Chasan-Taber S, Sherwood MJ, Roth C, Epstein AM. Hospital readmissions and quality of care. *Med Care*. 1999;37(5):490-501.
6. Ashton CM, Kuykendall DH, Johnson ML, Wray NP, Wu L. The association between the quality of inpatient care and early readmission. *Ann Intern Med*. 1995;122(6):415-421.
7. Spyropoulos AC. Direct medical costs of venous thromboembolism and subsequent hospital readmission rates: an administrative claims analysis from 30 managed care organizations. *J Manag Care Pharm*. 2007;13(6):475-486.
8. Aujesky D, Roy PM, Le Manach CP, et al. Validation of a model to predict adverse outcomes in patients with pulmonary embolism. *Eur Heart J*. 2006;27(4):476-481.
9. Spencer FA, Emery C, Lessard D, et al. The Worcester Venous Thromboembolism study: a population-based study of the clinical epidemiology of venous thromboembolism. *J Gen Intern Med*. 2006;21(7):722-727.
10. Arnason T, Wells PS, van Walraven C, Forster AJ. Accuracy of coding for possible warfarin complications in hospital discharge abstracts. *Thromb Res*. 2006;118(2):253-262.
11. Oake N, Fergusson DA, Forster AJ, van Walraven C. Frequency of adverse events in patients with poor anticoagulation: a meta-analysis. *CMAJ*. 2007;176(11):1589-1594.
12. Philbin EF, DiSalvo TG. Prediction of hospital readmission for heart failure: development of a simple risk score based on administrative data. *J Am Coll Cardiol*. 1999;33(6):1560-1566.
13. Benbassat J, Taragin M. Hospital readmissions as a measure of quality of health care: advantages and limitations. *Arch Intern Med*. 2000;160(8):1074-1081.
14. Philbin EF, Dec GW, Jenkins PL, DiSalvo TG. Socioeconomic status as an independent risk factor for hospital readmission for heart failure. *Am J Cardiol*. 2001;87(12):1367-1371.
15. McGregor MJ, Reid RJ, Schulzer M, Fitzgerald JM, Levy AR, Cox MB. Socioeconomic status and hospital utilization among younger adult pneumonia admissions at a Canadian hospital. *BMC Health Serv Res*. 2006;6:152.
16. Glazier RH, Badley EM, Gilbert JE, Rothman L. The nature of increased hospital use in poor neighbourhoods: findings from a Canadian inner city. *Can J Public Health*. 2000;91(4):268-273.
17. Palepu A, Sun H, Kuyper L, Schechter MT, O'Shaughnessy MV, Anis AH. Predictors of early hospital readmission in HIV-infected patients with pneumonia. *J Gen Intern Med*. 2003;18(4):242-247.
18. Ghali JK, Kadakia S, Cooper R, Ferlinz J. Precipitating factors leading to decompensation of heart failure: traits among urban blacks. *Arch Intern Med*. 1988;148(9):2013-2016.
19. Billings J, Zeitel L, Lukomnik J, Carey TS, Blank AE, Newman L. Impact of socioeconomic status on hospital use in New York City. *Health Aff (Millwood)*. 1993;12(1):162-173.
20. Camberg LC, Smith NE, Beaudet M, Daley J, Cagan M, Thibault G. Discharge destination and repeat hospitalizations. *Med Care*. 1997;35(8):756-767.
21. Weingart SN, Davis RB, Phillips RS. Patients discharged against medical advice from a general medicine service. *J Gen Intern Med*. 1998;13(8):568-571.
22. Hwang SW, Li J, Gupta R, Chien V, Martin RE. What happens to patients who leave hospital against medical advice? *CMAJ*. 2003;168(4):417-420.
23. Westert GP, Lagoe RJ, Keskimaki I, Leyland A, Murphy M. An international study of hospital readmissions and related utilization in Europe and the USA. *Health Policy*. 2002;61(3):269-278.
24. Tu JV, Austin PC, Filate WA, et al. Outcomes of acute myocardial infarction in Canada. *Can J Cardiol*. 2003;19(8):893-901.
25. Vanasse A, Niyonsenga T, Courteau J, et al. Spatial variation in the management and outcomes of acute coronary syndrome. *BMC Cardiovasc Disord*. 2005;5(1):21.
26. Kupersmith J. Quality of care in teaching hospitals: a literature review. *Acad Med*. 2005;80(5):458-466.
27. Boddy C. Pharmacist involvement with warfarin dosing for inpatients. *Pharm World Sci*. 2001;23(1):31-35.
28. Ibrahim SA, Stone RA, Obrosky DS, Sartorius J, Fine MJ, Aujesky D. Racial differences in 30-day mortality for pulmonary embolism. *Am J Public Health*. 2006;96(12):2161-2164.
29. Aujesky D, Long JA, Fine MJ, Ibrahim SA. African American race was associated with an increased risk of complications following venous thromboembolism. *J Clin Epidemiol*. 2007;60(4):410-416.
30. Murin S, Romano PS, White RH. Comparison of outcomes after hospitalization for deep venous thrombosis or pulmonary embolism. *Thromb Haemost*. 2002;88(3):407-414.
31. White RH, Gettner S, Newman JM, Trauner KB, Romano PS. Predictors of rehospitalization for symptomatic venous thromboembolism after total hip arthroplasty. *N Engl J Med*. 2000;343(24):1758-1764.
32. White RH, Romano PS, Zhou H, Rodrigo J, Bargar W. Incidence and time course of thromboembolic outcomes following total hip or knee arthroplasty. *Arch Intern Med*. 1998;158(14):1525-1531.
33. Proctor MC, Greenfield LJ. Pulmonary embolism: diagnosis, incidence and implications. *Cardiovasc Surg*. 1997;5(1):77-81.