Predictors of Early Hospital Readmission After Acute Pulmonary Embolism

Drahomir Aujesky, MD, MSc; Maria K. Mor, PhD; Ming Geng, MS; Roslyn A. Stone, PhD; Michael J. Fine, MD, MSc; Said A. Ibrahim, MD, MPH

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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Author Affiliations: Division of General Internal Medicine, University of Lausanne, Lausanne, Switzerland (Dr Aujesky); Veterans Affairs Center for Health Equity Research and Promotion, Pittsburgh, Pennsylvania (Drs Mor, Stone, Fine, and Ibrahim and Ms Geng); and Department of Biostatistics, Graduate School of Public Health (Drs Mor and Stone and Ms Geng), and Division of General Internal Medicine, Department of Medicine (Drs Fine and Ibrahim), University of Pittsburgh.

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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 (785.31), 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 (MediQul, 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. 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%. 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 and bleeding 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 chi-square 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 xtolg4t 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 ≥110 beats/min, respiratory rate ≥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 χ² 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 analyses,...
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 3,307 patient discharges, most commonly because the patients were transferred from or to another hospital (n = 1,032) or died during the initial hospitalization (n = 926). A total of 2,064 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 unexplained chest pain (5.0%). A total of 187 patients (9.1%) died after readmission.

### 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 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 than patients in risk classes I through IV 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).

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**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 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).

**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.

**Table 4.** 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, 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).

**Table 5.** 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). 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).
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 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, improvements in the quality of anticoagulation control could decrease the likelihood of thromboemboli. 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 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-
Embolism Severity Index.

other acute diseases such as heart failure and pneumonia, including social characteristics, comorbid conditions, and inadequate quality of care. 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 and pneumonia. 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, possibly owing to the receipt of substandard quality of care, reduced treatment adherence, or the lack of timely and effective outpatient care. 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 practice 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. 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. A potential explanation is that patients who are discharged with supplemen-
Although quality of care and outcomes tend to be generally better in teaching hospitals than in nonteaching hospitals for many surgical and medical conditions, teaching hospitals had a significantly higher risk of readmission for bleeding in our study. One potential, yet unproven, explanation is that the higher proportion of physician trainees in teaching hospitals may lead to a suboptimal anticoagulation-related quality of care 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. 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. 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, 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. 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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Correspondence: Drahomir Aujesky, MD, MSc, Service de Médecine Interne, BH 10-622, Centre Hospitalier Universitaire Vaudois, 1011 Lausanne, Switzerland (drahomir.aujesky@chuv.ch).

Author Contributions: Study concept and design: Aujesky and Ibrahim. Acquisition of data: Aujesky. Analysis and interpretation of data: Aujesky, Mor, Geng, Stone, Fine, and Ibrahim. Drafting of the manuscript: Aujesky, Geng, and Ibrahim. Critical revision of the manuscript for important intellectual content: Aujesky, Mor, Stone, Fine, and Ibrahim. Statistical analysis: Mor, Geng, and Stone. Obtained funding: Aujesky. Administrative, technical, and material support: Ibrahim. Study supervision: Fine and Ibrahim.

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