Impact of Length of Stay After Coronary Bypass Surgery on Short-term Readmission Rate

An Instrumental Variable Analysis

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Objective: To determine the effect of postoperative length of stay (LOS) on 30-day readmission after coronary artery bypass surgery.

Data Sources/Study Setting: We analyzed a final database consisting of Medicare claims of a cohort (N = 157,070) of all fee-for-service beneficiaries undergoing bypass surgery during 2007–2008, the American Hospital Association annual survey file, and the rural urban commuting area file.

Study Design: We regressed the probability of 30-day readmission on postoperative LOS using (1) a (naive) logit model that controlled for observed patient and hospital covariates only; and (2) a residual inclusion instrumental variable (IV) logit model that further controlled for unobserved confounding. The IV was defined using a measure of the hospital's risk-adjusted LOS for patients admitted for gastrointestinal hemorrhage.

Principal Findings: The naive logit model predicted that a 1-day reduction in median postoperative LOS (ie, from a median of 6–5 d) lowered the 30-day readmission rate by 2 percentage points. The IV model predicted that a 1-day reduction in median postoperative LOS increased 30-day readmission rate by 3 percentage points.

Conclusions: The findings indicate that a reduction in postoperative LOS is associated with an increased risk for 30-day readmission among Medicare patients undergoing bypass surgery, after both observed and unobserved confounding effects are corrected.

Coronary heart disease (CHD) is a leading cause of morbidity and mortality in the United States which accounted for 1 of every 6 deaths in 2007.[1] Invasive cardiac procedures such as coronary artery bypass graft (CABG) surgery are a common treatment option for patients with CHD.[2] In 2007, 408,000 CABG operations were performed in the United States, with mean charges for in-hospital care over $10,000; over half of these procedures were performed on people aged 65 years or older.[1]

During the past several decades, many efforts to contain health care costs have focused on reducing the number of hospital admissions and for those who are admitted, lowering hospital resource use through the reduction in hospital length of stay (LOS). For patients undergoing CABG surgery, efforts to reduce hospital LOS through the introduction of protocols and guidelines[3–6] have been highly successful. From 1988 to 2005, the median LOS for bypass surgery declined from 11 to 8 days nationally,[6] resulting in apparent cost savings in perioperative care associated with the primary procedure.

One concern among clinicians and researchers alike is that, by focusing cost-control efforts largely on the inpatient setting, payers such as Medicare have pushed hospitals to reduce LOS at the expense of increasing premature hospital discharge and putting patients at a higher risk for post-discharge adverse outcomes, such as major complications, short-term readmissions, and mortality. Broad evidence exists that reduced postoperative LOS for revascularization is associated with more discharges to postacute care settings (rather than to home) such as skilled nursing facilities or rehabilitation centers.[5–8] This suggests the increased disease management requirements after "fast-track" discharge and a cost shift from perioperative acute care to postacute care.

Reducing readmissions after initial hospitalization has been an important component of recent federal initiatives, including public reporting, payment incentives, and the Patient Protection and Affordable Care Act,[9–11] to simultaneously improve quality of care and reduce costs. However, the evidence about the relationship between early discharge and short-term readmissions for bypass surgery is mixed,

with previous studies reporting either negative, positive, or no association between LOS of CABG surgery and readmission rate.[3–5,7,12,13]

We conducted this study with an aim to improve the causal inferences about the relationship between postoperative LOS of CABG surgery and 30-day readmission rate. Specifically, we used the instrumental variable (IV) technique to analyze data on a national cohort of Medicare patients receiving bypass surgery. IV analyses are a potential powerful tool to address unobserved confounding in observational studies.[14–16] In the present study, we chose as an IV the average risk-adjusted LOS of patients admitted for a medical condition [gastrointestinal (GI) hemorrhage] in the same hospital. We assumed and to the extent possible, empirically confirmed, that the IV induced exogenous variations of postoperative length of stay (PLOS) (the "treatment" variable) but did not directly affect the outcome (30-d readmission), thereby allowing for consistent estimates of the hypothesized "treatment" effect.

METHODS

Data Sources

We analyzed the 2007 and 2008 Medicare Provider Analysis and Review (MedPAR) inpatient files obtained from the Centers for Medicare and Medicaid Services. The MedPAR data contains uniform administrative and clinical elements obtained from discharge abstracts for acute care hospital stays of all fee-for-service beneficiaries. Patient-level records include demographics (age, gender, race/ethnicity), principal, and up to 9 secondary diagnoses classified by the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes, principal and up to 5 secondary ICD-9-CM procedure codes, LOS, discharge date and disposition, date of surgery (for surgical patients), date of death up to 3 years after discharge, an encrypted patient identifier that allows for identification of patient admissions and readmissions longitudinally, and each hospital's unique identifier allowing for linkage of the MedPAR to external hospital databases.

The MedPAR was merged with (1) the 2007 American Hospital Association annual hospital survey file to obtain variables for hospital characteristics; and (2) the University of Washington rural urban commuting area file to define rural versus urban location of the hospital.[17]

Sample

We identified the cohort of beneficiaries who underwent CABG surgery between January 1, 2007 and September 30, 2008 using ICD-9-CM procedure codes 36.10–36.19. Patients were excluded from the sample if they (1) had a concomitant open-heart procedure such as valve replacement; (2) were younger than 65 years old at admission; (3) were transferred to another acute care hospital; (4) died in hospital; or (5) had a PLOS <1 day or >35 days (the 99 percentile for all patients). PLOS was defined as the number of days between the principal procedure date and the discharge date.

Variables

Our dependent variable was a binary variable taking the value of 1 if the patient had ≥ 1 readmissions within 30 days of discharge after CABG surgery (excluding readmissions for rehabilitation, DRG 462), and 0 otherwise. The primary independent variable was the PLOS during the index hospitalization for CABG surgery. Other patient-level independent variables included age (y), female sex (yes/no), race/ethnicity (non-Hispanic white, black, and other); admission type (elective, emergent, urgent, or other); acute myocardial infarction (principal ICD-9-CM code 410) at admission, cardiogenic shock (principal ICD-9-CM code 785.51) at admission, number of comorbidities (coded as 0, 1, 2, 3, and ≥ 4 comorbidities) with each comorbidity defined using the agency for healthcare research and quality comorbidity algorithm described by Elixhauser and colleagues.[18,19] The comorbidity algorithm defines each of 30 individual comorbidities based on administrative data and is widely used as a tool for estimating hospital outcomes and resource uses. Hospital-level covariates included major teaching hospital (yes/no), ownership status (for-profit, non-for-profit, or government-owned), and rural versus urban location.

Analyses

Naive Logit Analysis

The analyses started with a simple logit model in which the probability of 30-day readmission of patient i receiving CABG in hospital j (P_{ij}) is modeled as a function of the natural-log transformation of PLOS ($PLOS_{ij}^{cabg}$), the vector of patient covariates (X_{ij}), and the vector of hospital covariates (H_j), which are described above and listed in Table 1.

$$\text{logit } P_{ij}=\beta_0+\beta_1 \times \ln(PLOS_{ij}^{cabg})+\beta_2 \times X_{ij}+\beta_3 \times H_j \qquad (1)$$

In this model, the natural-log transformation of PLOS was used to account for the potential nonlinear effect of PLOS on the dependent variable. The logit model given in Eq. (1) does not address the issue that the key independent variable—$PLOS_{ij}^{cabg}$—is endogenous due to unobserved confounders, such as severity of disease, that tend to be correlated with the outcome and the key independent variable. Therefore, the model was labeled naive logit analysis.

IV Analysis

We employed the IV approach recently described by Terza et al[15] to address the issue of endogeneity. Terza et al[15] indicated that correcting for endogeneity with the conventional 2-stage least square method would be biased due to the nonlinearity of the logit model. The authors recommended a 2-stage residual inclusion (2SRI) approach that represents a consistent nonlinear extension of conventional IV analyses.

The IV we used for $PLOS_{ij}^{cabg}$ is hospital j's risk-adjusted LOS (natural-log transformed) for its Medicare patients admitted for GI hemorrhage. We used the risk-adjusted, rather than crude, average $\ln(LOS)$ of hospital j to define the IV because hospitals tend to vary in case mix and the crude log-transformed LOS may reflect largely such case mix variation for GI hemorrhage patients rather than

TABLE 1. Characteristics of Medicare Patients Undergoing Bypass Surgery (n = 157,070)

Characteristics	% or Mean (SD)
Dependent variables	
30-d readmission	17.2
Independent variables	
Postoperative length of stay (d)	7.4 (4.4)
Age (y)	73.8 (5.9)
Female	31.3
Race/ethnicity	
White	90.3
Black	5.3
Other	4.4
Admission type	
Elective	49.0
Emergent	25.0
Urgent	25.7
Other	0.3
Acute myocardial infarction at admission	26.3
Cardiac shock at admission	2.5
No. comorbidities	
0	3.3
1	15.5
2	28.9
3	28.5
≥ 4	23.9
Major teaching hospital	26.5
Ownership status of the hospital	
For-profit	15.0
Non-for-profit	76.7
Government-owned	8.3
Rural hospital	5.6
Instrumental variables	
Risk-adjusted length of stay for GI hemorrhage (natural-log transformed)	0.98 (0.09)

GI indicates gastrointestinal.

the variations of hospital clinical practices and discharge policies.[20]

The choice of the instrument was also based on the assumption that a hospital's clinical practice and discharge polices are a contextual factor that determines the LOS of all patients in the hospital, above and beyond diagnostic groups (eg, GI hemorrhage vs. CHD), procedures received during hospitalization (eg, endoscopy for GI hemorrhage vs. CABG for CHD), and severity of disease. Previous studies supported this presumption by showing that variations in discharge policies across hospitals tended to affect the lengths of stay of multiple common conditions and surgical procedures in a similar way.[21–23] Given this assumed across-the-board impact of hospital practice patterns, the average risk-adjusted, natural-log–transformed LOS of patients admitted for GI hemorrhage is likely associated with the postoperative LOS for patients undergoing CABG in the same hospital *j*.

Moreover, there is no plausible reason to believe that the IV [the risk-adjusted ln(*LOS*) for GI hemorrhage] is directly associated with the 30-day readmission for patients undergoing CABG surgery (ie, other than through the intermediation of post-CABG LOS). In other words, the IV can be appropriately excluded from the outcome equation described in Eq. (4) below.[15]

Finally, we considered alternative candidate IVs in our preliminary analyses. A previous study used the average LOS for all psychiatric admissions of other hospitals in the same zip code as an IV to predict the psychiatric LOS of a particular patient in the hospital.[24] In this study, however, we could not construct the IV in a similar way (eg, as the average PLOS for all CABG procedures performed in other hospitals of the same zip code area) because in the majority cases there is only 1 or no hospital in a zip code that can perform the open-heart surgery. We have also considered as potential IVs the risk-adjusted LOS of other conditions/procedures reported in the 2 previous studies,[21,22] such as congestive heart failure, stroke, pneumonia, or peripheral vascular surgery. However, we were concerned that these thoracic or vascular conditions/ procedures may require similar lines of postdischarge community services to CHD, thus making the hospital LOS of these conditions likely correlated with the 30-day readmission rate after CABG surgery directly. In other words, these conditions/procedures may not meet the exclusion criterion for appropriate IV.[15] For example, the discharge decisions for patients undergoing CABG and patients admitted for congestive heart failure may be determined by common community factors such as accessibility of cardiologists for follow-up care or rehabilitation services.

Thus, we chose to use the hospital's risk-adjusted LOS for patients admitted for GI hemorrhage[21,22]—a condition unrelated to CHD—as the IV. To construct this IV, we identified all admissions of GI hemorrhage (principal ICD-9-CM diagnostic codes 456.0, 530.7, 530.82, 531-535, 537.83, 562.02, 562.03, 562.12, 562.13, 569.3, 569.85, 578) during 2007 and 2008 and excluded them from the following risk-adjustment analyses if the patient (1) was younger than 65 years; (2) was transferred to another acute care hospital; or (3) died in the hospital. We then estimated a patient-level ordinary least squares model of the natural-log–transformed LOS after admission for GI hemorrhage (LOS_{ij}^{gi}), as a function of patient covariates including age, female sex, race, admission type, and number of comorbidities, as the following.

$$ln(LOS_{ij}^{gi}) = \beta_0 + \beta_1 \times X_{ij}^{gi} + \varepsilon_{ij}^{gi} \qquad (2)$$

See appendix for the characteristics of this cohort of patients admitted for GI hemorrhage, and the estimation of the risk-adjustment model. From this model, we obtained the estimated error term $\hat{\varepsilon}_{ij}^{gi}$ for each patient. We then calculated each hospital's risk-adjusted LOS (natural-log transformed) as the average value of $\hat{\varepsilon}_{ij}^{gi}$ for all GI hemorrhage patients in hospital *j* plus the grand mean of the natural-log–transformed LOS for all GI hemorrhage patients in the sample.[20] This variable was used as the IV (IV_j^{gi}) for the 2SRI analyses on patients receiving CABG surgery described below.

The IV analysis was based on the 2SRI approach and had 2 components:

$$ln(PLOS_{ij}^{cabg}) = \alpha_0 + \alpha_1 \times IV_j^{gi} + \alpha_2 \times X_{ij} + \beta_3 \times H_j + \varepsilon_{ij}^{cabg} \qquad (3)$$

$$logit\, P_{ij} = \beta_0 + \beta_1 \times ln(PLOS_{ij}^{cabg}) + \beta_2 \times \hat{\varepsilon}_{ij}^{cabg} + \beta_3 \times X_{ij} + \beta_4 \times H_j \qquad (4)$$

where in Eq. (3), the first-stage equation, the natural-log–transformed PLOS for patients undergoing CABG surgery

($PLOS_{ij}^{cabg}$) was regressed on the IV and exogenous patient and hospital covariates for patients undergoing CABG surgery. Eq. (4), the second-stage equation, is identical to the naive logit model of Eq. (1) except that the estimated residuals from Eq. (3)—$\hat{\varepsilon}_{ij}^{cabg}$—are also included in Eq. (4) to control for endogeneity because of the unobserved confounders. In other words, the 2SRI model partitioned the residual obtained from the naive model (described in the previous subsection) into 2 parts: the residual obtained from the first-stage model that controls for the endogeneity effect, and the residual unique to the second-stage equation. The inclusion of $\hat{\varepsilon}_{ij}^{cabg}$ in the outcome equation offers an opportunity to statistically test for the endogeneity of $PLOS_{ij}^{cabg}$.[15] If the coefficient β_2 of $\hat{\varepsilon}_{ij}^{cabg}$ is statistically significant then $PLOS_{ij}^{cabg}$ is indeed endogenous; otherwise we cannot reject the null hypothesis of the exogeneity of $PLOS_{ij}^{cabg}$.

RESULTS

Table 1 describes the characteristics of the sample of patients undergoing bypass surgery. Approximately 17% of patients were readmitted to an acute care hospital within 30 days of discharge. The PLOS was 7.4 days on average and varied substantially (with skewed distribution, Fig. 1) over individual patients.

Table 2 summarizes the results of the naive logit model and the IV analyses. In the naive logit model, where endogeneity was not controlled for, the natural-log–transformed PLOS showed a positive effect on the likelihood of 30-day readmission [$\beta = 0.69$, odds ratio (OR) = 1.99, 95% confidence interval (CI) of OR 1.93–2.05, $P < 0.001$).

In the 2SRI model, we used the risk-adjusted ln(LOS) for all GI hemorrhage patients in the hospital as the IV (see appendix for the risk-adjusted model). In the first stage of the 2SRI estimates, this IV strongly predicted the ln(PLOS) for individual patients receiving bypass surgery; it was indeed the strongest predictor of the dependent variable compared to other patient and hospital predictors in this equation. The F-statistic of the IV

was 350.72, rejecting the null hypothesis of no association at a highly significant level ($P < 0.001$). Therefore, weak correlation of the instrument with the endogenous key independent variable is unlikely to be a source of bias.[25]

We could not empirically test the exclusion criterion because the system equations were exactly identified. As we mentioned before, there is no theoretical reason that the IV constructed based on the LOS for GI hemorrhage patients in the hospital would directly affect the 30-day readmission rate for patients receiving bypass surgery. In addition, if residual confounding exists, it is plausible that the error would be toward the null, that is, an estimate of positive, rather than negative, association of postoperative LOS and 30-day readmission.
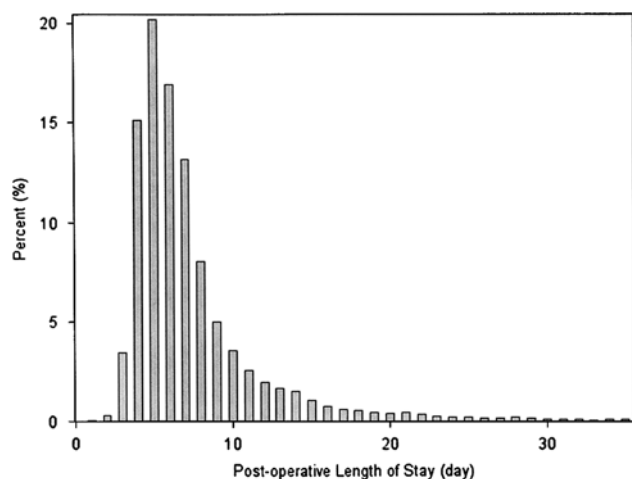
The second-stage equation of the 2SRI model shows a negative association between the natural-log–transformed post-CABG LOS and 30-day readmission ($\beta = -0.75$, OR = 0.47, 95% CI of OR, 0.25–0.90, $P = 0.02$). In addition, the β-coefficient of the residual derived from the first-stage equation is positive and statistically significant ($\beta = 1.44$, OR = 4.21, 95% CI of OR, 2.22–7.99, $P < 0.001$), indicating a strong endogeneity bias in the estimates of the naive logit model; the bias because of unobserved confounding was strong enough to reverse the direction of the estimate toward a positive association between PLOS and 30-day readmission in the naive logit model.

To help better interpret the results, we calculated the predicted probability of 30-day readmission for patients undergoing bypass surgery with 6 days postoperative stays (the median PLOS of the sample) and compared it to the predicted probability of 30-day readmission for patients with 5-day postoperative stays (Table 3). In the predictions we kept patient and hospital covariates at their mean values. The result of the 2SRI model indicates that a 1-day decrease in median PLOS would increase 30-day readmission rate by 3 percentage points. By comparison, the prediction from the naive logit model was that a 1-day decrease in median PLOS would reduce 30-day readmission rate by 2 percentage points.

Finally, we checked the robustness of our findings by repeating the above analyses for a redefined outcome of readmission and/or death within 30 days of discharge. The results remained similar, with the naive logit model showing a positive relationship between the PLOS and 30-day readmission/death ($\beta = 0.79$, OR = 2.19, 95% CI of OR, 2.13–2.26, $P < 0.001$), and the 2SRI model showing a negative relationship ($\beta = -0.54$, OR = 0.58, 95% CI of OR, 0.31–1.11, $P = 0.09$). The predicted changes of 30-day readmission/death rate based on the 2 models are also presented in Table 3.

FIGURE 1. Distribution of postoperative length of stay among Medicare patients undergoing coronary bypass surgery.

DISCUSSION

In this study, we performed an IV analysis to obtain consistent estimates of the effect of PLOS on 30-day readmission rate for Medicare patients undergoing CABG surgery. We demonstrated that the IV we used—the average risk-adjusted LOS for a hospital's patients with GI hemorrhage—strongly and exogenously predicted the PLOS for each patient with bypass surgery. Assuming that by construction the IV affects the 30-day readmission after

TABLE 2. Effect of Postoperative Length of Stay on 30-Day Readmission for Medicare Patients Undergoing Bypass Surgery

| | Naive Logit Model | | 2-Stage Residual Inclusion Model | | | |
| | | | Stage 1 (Eq. 3) | | Stage 2 (Eq. 4) | |
Characteristic	OR	95% CI	β	95% CI	OR	95% CI
ln(PLOS)	1.99	1.93 to 2.05	—	—	0.47	0.25 to 0.90
Residual from Eq. 3	—	—	—	—	4.21	2.22 to 7.99
IV: risk-adjusted ln(LOS) for GI hemorrhage	—	—	0.16	0.15 to 0.18	—	—
Age in 10 y	1.18	1.16 to 1.21	0.11	0.107 to 0.114	1.38	1.29 to 1.49
Female	1.23	1.20 to 1.27	0.06	0.05 to 0.07	1.34	1.28 to 1.41
Race/ethnicity						
Black	1.13	1.07 to 1.19	0.11	0.10 to 0.12	1.32	1.21 to 1.45
Other	1.08	1.01 to 1.15	0.05	0.03 to 0.06	1.15	1.08 to 1.24
Admission type						
Emergent	1.26	1.21 to 1.30	0.07	0.07 to 0.08	1.39	1.32 to 1.48
Urgent	1.11	1.07 to 1.15	0.04	0.03 to 0.04	1.17	1.12 to 1.22
Other	0.86	0.64 to 1.15	0.02	−0.02 to 0.07	0.91	0.68 to 1.22
AMI at admission	1.04	1.00 to 1.07	0.08	0.07 to 0.08	1.16	1.09 to 1.23
Cardiac shock at admission	1.06	0.98 to 1.15	0.47	0.46 to 0.48	2.09	1.53 to 2.85
No. comorbidities						
0	0.63	0.57 to 0.68	−0.07	−0.08 to −0.06	0.57	0.51 to 0.62
1	0.70	0.67 to 0.73	−0.09	0.10 to −0.08	0.61	0.57 to 0.66
2	0.75	0.72 to 0.77	−0.06	−0.07 to −0.06	0.68	0.65 to 0.72
3	0.83	0.80 to 0.86	−0.04	−0.04 to −0.03	0.78	0.75 to 0.82
Major teaching hospital	1.07	1.04 to 1.10	0.04	0.03 to 0.04	1.13	1.09 to 1.18
Hospital ownership						
For-profit	1.05	1.01 to 1.09	0.01	0.00 to 0.02	1.06	1.02 to 1.10
Government-owned	1.02	0.97 to 1.07	0.02	0.01 to 0.03	1.05	1.00 to 1.11
Rural hospital	1.05	0.99 to 1.11	−0.07	−0.08 to −0.06	0.95	0.88 to 1.02
Intercept	—	—	1.01	0.99 to 1.04	—	—

CI indicates confidence interval; LOS, length of stay; OR, odds ratio; PLOS, postoperative length of stay.

bypass surgery only through its impact on PLOS, our consistent estimate indicated that a 1-day shortened median PLOS (from 6 to 5 d) would increase the risk for 30-day readmission by 3 percentage points.

There is growing concern that cost containment efforts in hospital care (such as Medicare's prospective reimbursement system) have reduced hospital LOS to the extent that may harm patient outcomes. In particular, after the widespread adoption of "fast-track" protocols, the length of hospital stays for CABG surgery has been substantially reduced during the past 2 decades.[3–6] The shortened LOS may increase downstream adverse outcomes such as short-term readmissions.

Although the concern is widespread, prior studies attempting to address this issue reported mixed results. For example, Lazar et al[5] found that after the adoption of clinical

TABLE 3. Predicted Effect of a 1-Day Reduction in Median Postoperative Length of Stay (From 6 to 5 d) on 30-Day Readmission Rate After Bypass Surgery

	Naive Logit Model (%)	2-Stage Residual Inclusion Logit Model (%)
Change of		
30-d readmission rate	−2.3	3.3
30-d readmission/death rate	−2.7	2.4

Mean values of patient and hospital covariates were used for each prediction.

pathways, reduced LOS of CABG surgery was associated with substantially increased readmission rate; other studies found that the 30-day readmission rate did not change after the length of hospital stay for bypass surgery declined[3,7]; and still other studies reported in their bivariate and multivariate analyses positive association between PLOS and short-term readmission for patients undergoing CABG surgery.[4,12,13]

These prior studies were based on observational designs that involved analyses of existing patient records, and may have suffered from methodological challenges. In particular, the conventional statistical techniques employed by these studies could have been considerably confounded when failing to control for unmeasured severities of disease that tend to be correlated with both length of hospital stays and the risk for readmission.

Observational studies using readily available data play a pivotal role in understanding contemporary health care issues and providing real-world comparative effectiveness evidence to inform policy development. This is especially true when randomized trials are not feasible or show limited external validity.[26] However, determining the causal effect of shortened LOS on important outcomes such as readmissions is difficult in observational studies. A selection bias exists in observational studies because patients are not randomly assigned to groups with shorter or longer hospital stays. In this case, unmeasured severity of disease is not balanced across "intervention" groups within which patients have the same LOS. Because the unmeasured and unbalanced severity of disease is positively correlated with both postoperative LOS and risk for short-term

readmission, it will confound the negative effect of PLOS on readmission (ie, the effect that shortened PLOS increases 30-d readmission rate after bypass surgery) in a positive way. Because of the positive confounding, the (true) negative effect of PLOS on readmission rate could be underestimated, or when the positive confounding is larger than the true effect, the estimated association could be inverted resulting in a false interpretation of positive relationship between PLOS and readmission rate.

Our results provide empirical evidence supporting the concern of the negative impact of reduced hospital LOS on postdischarge outcomes. Whereas previous studies controlled for observed confounders to various degrees, our study, to the best of our knowledge, is the first that further tried to control for self-selection due to unobserved severity of disease by using IV regression technique. Our improved estimates underscore the need to closely monitor postdischarge clinical outcomes after the initial hospitalization has been the subject of continued cost containment efforts for bypass surgery.

There could be multiple reasons why reduced post-CABG LOS increases 30-day readmission rate. For example, when patients are discharged earlier, their conditions may be less stable at the time of discharge; major complications are more likely to occur after discharge rather than during initial hospital stay; and increased difficulties in arranging appropriate ambulatory follow-up care are more likely to occur as well. All these factors may disrupt the transitioning of patients and underlie the inverse association of PLOS and 30-day readmission for bypass surgery. Similar effects of shortened length of hospital stays have been found in other areas of inpatient care including inpatient psychiatric care,[24,27] hospital care for newborns,[28] and hospital care for children and adolescents.[29]

For many conditions and procedures including bypass surgery, short-term readmissions are common and costly.[30] The findings of our study suggest that optimal cost containment and quality improvement initiatives for bypass surgery should not focus solely on the care during initial hospitalization. Rather, broader attention should be paid to the whole episode of care: there seems to be a tradeoff between care provided at the initial admission and care required later on. Cutting costs and care initially seems to lead to higher costs and worst outcomes downstream. Future research should evaluate the total cost over the full episode to determine if overall costs increase. Among current federal initiatives aimed at reducing hospital readmissions, the Medicare bundled payment established by the Affordable Care Act of 2010 proposes to test a single reimbursement for multiple services incurred before, during, and after an initial hospitalization.[11] The single episode-based payment is expected to provide incentives for improved coordination of care and to lower overall Medicare costs.

This study has several limitations. First, our analyses were based on data of Medicare fee-for-service patients undergoing CABG surgery. Thus, our results may or may not be generalizable to patients of other insurance types. Second, although our IV analyses addressed the issue of self-selection because of unobserved confounders and should be able to mitigate against its resultant biases, the validity of the estimated impact of PLOS on 30-day readmission was dependent on the assumptions required for such analyses. In general, the results in IV analyses using observational data would not be interpreted with the same degree of confidence as those in well-conducted randomized trials. Third, although the Medicare administrative data have been widely used in observational studies and have proved to be of high quality in recording patient administrative and clinical information,[31,32] the data are not error free; errors of the data would lower the accuracy of our estimates in all models. Fourth, the administrative databases do not contain more detailed information necessary for fuller control of confounders, such as quality of in-hospital care (eg, receipt of β-blockers, appropriate use of antibiotics for individual CABG patients) and annual hospital/surgeon volume of CABG cases (as the claims only include Medicare patients). However, we believe that the unobserved confounding effect is dominated by omitted severity of disease—as our results show in Table 2, its effect is strong enough to reverse the association between PLOS and 30-day readmission; our IV analyses successfully addressed the unobserved effect of disease severity. Finally, our study is limited in scope and given our focus on 30-day readmission/mortality, we did not analyze other important outcomes such as postoperative complications.

In conclusion, this study employed IV analyses to determine the impact of PLOS on 30-day readmission rate for Medicare patients undergoing coronary bypass surgery. We found that a 1-day reduction in median PLOS (from 6 to 5 d) resulted in an increase in 30-day readmission rate by 3 percent points. Efforts to improve the outcomes and efficiency of care for bypass surgery should focus on care both during the initial admission and after discharge.

APPENDIX

TABLE 1. The Risk-adjustment Model of Natural-Log–transformed Length of Stay for Medicare Patients Admitted for GI Hemorrhage (n = 391,759)

Characteristics	% or Mean (SD)	Risk-adjustment Model	
		β	P
Length of stay (d)	3.6 (3.0)	—	—
Age (y)	79.4 (8.2)	0.01	< 0.001
Female	57.4	− 0.01	< 0.001
Race/ethnicity			
White	82.0	—	—
Black	12.7	0.07	< 0.001
Other	5.3	− 0.01	0.31
Admission type			
Elective	7.4	− 0.004	0.46
Emergent	72.9	0.08	< 0.001
Urgent	19.5	—	—
Other	0.2	0.15	< 0.001
No. comorbidities			
0	3.5	− 0.23	< 0.001
1	13.9	− 0.19	< 0.001
2	25.2	− 0.13	< 0.001
3	26.9	− 0.07	< 0.001
≥ 4	30.6	—	—
Intercept	—	0.59	< 0.001

GI indicates gastrointestinal.

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