Impact of Medicare's Nonpayment Program on Venous Thromboembolism Following Hip and Knee Replacements

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Objective. To determine whether Medicare's Nonpayment Program was associated with decline in venous thromboembolism (VTE) following hip and knee replacements; and whether the decline was greater among hospitals at risk of larger financial losses from the Program.

Data Sources. State Inpatient Database for New York (NY) from 2005 to 2013.

Study Design. The primary outcome was an occurrence of VTE. Medicare Utilization Ratio (MUR), which is the proportion of inpatient days in a hospital that is financed by Medicare, represented a hospital's financial sensitivity. We used hierarchical logistic regressions with difference-in-differences estimation to study the Program effects.

Principal Findings. A total of 98,729 hip replacement and 111,361 knee replacement stays were identified. For hip replacement, the Program was associated with significant reduction (Range: 44% to 53%) in VTE incidence among hospitals in MUR quartiles 2 to 4. For knee replacement, the Program was associated with significant reduction (47%) in VTE incidence only among quartile 2 hospitals.

Conclusion. Implementation of the Program was associated with a reduction in VTE, especially for hip replacements, in higher MUR hospitals. Payment reforms such as Medicare's Nonpayment Program that withhold payments for complications are effective and should be continued.

Key Words. Nonpayment program, hip and knee replacements, venous thromboembolism

Hip and knee replacements are the most frequently performed inpatient surgeries for older Medicare beneficiaries and the single largest surgical expenditure for Medicare. In 2014, more than 450,000 Medicare beneficiaries

underwent these surgeries, and Medicare reimbursed hospitals more than \$6 billion for inpatient care (Centers for Medicare and Medicaid Services 2018c). With the rapidly aging population and the beneficial effects of these surgeries (Ethgen et al. 2004), the demand for these procedures is expected to grow exponentially (Kurtz et al. 2014). However, despite standardized treatment protocols, there is considerable variation in adverse events following these surgeries. Risk-standardized complication rates following hip and knee replacements range from 2 to 9 percent (Bozic et al. 2014), and 30-day readmission rates following these surgeries range from 5 to 8 percent (Cram et al. 2011, 2012). The incidence of postoperative venous thromboembolism (VTE) (defined as deep vein thrombosis [DVT] and pulmonary embolism [PE]) is 1 to 3 percent of patients receiving appropriate prophylaxis (Streiff and Haut 2009; Januel et al. 2012), and this incidence is greater than 40 percent following hip and knee replacements in patients not receiving prophylactic therapy (Januel et al. 2012). Importantly, evidence suggests that many hospitalized patients do not receive the recommended prophylaxis (Goldhaber, Tapson, and Committee 2004; Cohen et al. 2008; Haut et al. 2015).

Given the importance of hip and knee replacement surgeries, and the need to improve compliance with evidence-based guidelines for VTE prophylaxis, the Centers for Medicare and Medicaid Services (CMS) has initiated several reforms that align financial incentives with outcomes (Centers for Medicare and Medicaid Services 2017a). One such initiative is the Hospital-Acquired Condition (HAC)—Present-on-Admission (POA) Program (hereafter called the Program) of 2008 (Rosenthal 2007), which is a “stick” version of the pay-for-performance strategy. Through this Program, hospitals are not reimbursed for the care of certain hospital-acquired conditions, such as VTE, that develop among Medicare beneficiaries during their hospital stay (Centers for Medicare and Medicaid Services 2017b). Through this Program, hospitals stand to lose an average of \$7,600 for each instance of postoperative VTE that

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occurs among Medicare beneficiaries (Research Triangle Institute International 2012).

While several studies have evaluated the impact of the Program on hospital-acquired infections (Lee et al. 2012; Waters et al. 2015; Thirukumaran et al. 2017), only one study has examined the impact specifically on VTE (Gidwani and Bhattacharya 2015). This study found that the Program was associated with a 35 percent lower incidence of VTE. However, most of these studies have evaluated the overall impact of the Program, without accounting for the differences in the Program impact across hospitals (Markovitz and Ryan 2017). As the Program focuses on Medicare fee-for-service patients, hospitals with a higher Medicare patient load and hence, greater sensitivity to the Program are more likely to invest in risk-reduction strategies compared to hospitals with fewer Medicare patients. This dose-response relationship (in which the Medicare patient load represents the Program dose, and the hospital efforts to reduce VTE represent the response) in pay-for-performance programs is largely unknown (Rosenthal and Frank 2006; Eijkenaar 2013). Ours is among the first studies to address this gap in the literature. Furthermore, the Program is distinct in design and approach from more recent initiatives such as bundled payments and thereby serves as a valuable complement to these newer programs. Hence, a rigorous evaluation of the HAC-POA Program is necessary to understand how this uniquely designed program influences VTE risk.

The objective of our study is to determine the differential impact of the HAC-POA Program on VTE incidence following hip and knee replacements. We hypothesize that the Program was associated with a decline in VTE incidence and that this decrease was greater among hospitals that are at risk of larger financial losses from the Program. The findings of our study will increase the understanding of the Program impact on health care quality and will help to inform the development of future incentive programs.

STUDY DATA AND METHODS

Data

We used the Healthcare Cost and Utilization Project's (HCUP) State Inpatient Database for New York (NY) State from 2005 to 2013 (Agency for Healthcare Research and Quality 2018). NY is one of only two states (the other being California), which has reported the present-on-admission indicator for each diagnosis in an inpatient stay since the mid-1990s. As this indicator is essential for

identifying VTE, using NY data provides a larger baseline cohort than most other states. We linked these databases to hospital-level files such as the Medicare Impact Files (Centers for Medicare and Medicaid Services 2017c), Hospital Compare files (Centers for Medicare and Medicaid Services 2018b), Medicare Cost Reports (Centers for Medicare and Medicaid Services 2018a), Medicare Provider of Services Files (Centers for Medicare and Medicaid Services 2018d), Dartmouth Atlas of Health Care (Dartmouth Atlas Project 2018), and the Hospital Information and Management Systems Society (HIMSS) Analytic database (The Dorenfest Institute for H.I.T. Research and Education – HIMSS Foundation 2017) to obtain hospital-level characteristics.

We defined the primary hip and knee replacement cohort using *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) procedure codes as these are used by the Program to identify the cohort of interest (Centers for Medicare and Medicaid Services 2017b). These include 00.85 (Resurfacing hip, total, acetabulum and femoral head), 00.86 (Resurfacing hip, partial, femoral head), 00.87 (Resurfacing hip, partial, acetabulum), 81.51 (Total hip replacement), 81.52 (Partial hip replacement), and 81.54 (Total knee replacement). The initial dataset included 458,145 inpatient stays undergoing these surgeries. We excluded hospitals that were not reimbursed by the Inpatient Prospective Payment System ($n = 15,348$), were not financed by Medicare Part A ($n = 41,509$), and were for patients younger than 65 years ($n = 190,726$) as the Program does not apply to these hospitals and patients. Although the Program includes hip resurfacing procedures, we excluded these stays due to the relatively small cohort size ($n = 218$). We also excluded stays that were missing key variables such as the hospital linkage indicator and the discharge month for 2008 ($n = 254$). The final cohort comprised of 98,729 inpatient stays for hip replacements, and 111,361 stays for knee replacements from 153 hospitals for the duration from 2005 to 2013.

Variables

Outcome Variable. The primary endpoint was a binary indicator for the presence or absence of VTE. To construct this indicator, we used the Program-specified ICD-9-CM diagnosis codes (Table S1) and present-on-admission indicators (Table S2) to identify VTE that developed during an inpatient stay. For example, if an inpatient stay had one or more of the following ICD-9-CM diagnosis codes for VTE (415.11, 415.13, 415.19, 453.40–453.42) and the present-on-admission indicator for that relevant diagnosis was N or U (Table S2),

then the particular stay was marked as having developed a VTE. The key outcome variable was constructed using the HCUP database.

Key Independent Variable. The key independent variable was an interaction between the Program phase and baseline Medicare Utilization Ratio (MUR) quartile of the hospital. The Program came into effect on October 1, 2008, and hence stays before October 2008 were classified as the pre-Program cohort. The Program phase variable was constructed using the HCUP data. The MUR is the proportion of inpatient days in a hospital that is financed by Medicare (Centers for Medicare and Medicaid Services 2016), which is a function of the number of Medicare and non-Medicare admissions, and the length of stay. We used MUR to model a hospital's sensitivity to the Program's financial disincentives based on the following rationale. Older Medicare inpatients are likely to have longer stays due to their complex physical, cognitive, and functional needs (Weiss and Elixhauser 2014). The longer they stay in the hospital, the greater is their likelihood of developing complications. Thus, hospitals with longer staying patients and consequently higher MUR are more likely to have a higher adverse event load and hence face larger financial losses from the Program. Such hospitals are thus likely to be more sensitive to the Program and may respond by reducing VTE events more effectively. Furthermore, MUR is used by the CMS for calculating annual reimbursement updates for hospitals. We calculated the MUR as a hospital-level mean in the baseline period and specified it as a time-invariant variable to address the endogeneity that may be potentially introduced by the variable (Konetzka et al. 2004). While it is reasonable to state that hospitals with higher MUR are likely to have lower VTEs following the Program, it is also possible that hospitals with lower VTEs, and consequently better quality, may attract a larger proportion of Medicare patients (reverse causality). Furthermore, hospitals with high VTE rates could make efforts to reduce their MUR, instead of their VTEs, as the Program evolves. Thus, by fixing the MUR variable at baseline, we control for the sensitivity of the variable to the Program, and to other quality reforms that may influence VTEs. The MUR thus represents a hospital's exposure to the Program before the Program came into effect. We categorized the baseline MUR into quartiles with higher quartiles including hospitals with greater Medicare patient load as compared to lower MUR quartiles which served as controls. The MUR variable was obtained from the Medicare Impact Files.

Covariates. In the multivariate analyses, we controlled for a set of patient- and hospital-level factors that are likely to confound the association between the

Program and VTE incidence, or partially explain variation in the VTE incidence. Patient-level confounders were obtained from the HCUP database and include age, sex, race, ethnicity, urgency, source of admission, and comorbidities specified using the modified Elixhauser algorithm (Elixhauser et al. 1998; Quan et al. 2005). Hospital-level confounders include medical school affiliation (categorized as yes or no), geographic location (categorized as rural or large urban or other urban), number of beds (categorized as small [<200 beds] or medium [≥ 200 and <400 beds] or large [≥ 400 beds]), disproportionate patient percent (Centers for Medicare and Medicaid Services 2017d), and transfer-adjusted case mix index, all of which were obtained from the Medicare Impact Files. We also used the Medicare Impact Files to construct the Herfindahl–Hirschman Index using the average daily census (categorized as unconcentrated, moderately concentrated, and highly concentrated) (Cutler and Morton 2013). We used the Hospital Compare Files to determine the hospital's ownership (categorized as not-for-profit or government or for-profit [please note that since 2009, NY State does not have for-profit hospitals]) and the Medicare Cost Reports to determine the hospital's operating profit margin. We used the Medicare Provider of Services Files and the Medicare Impact Files to calculate the registered nurse per average daily census ratio (Vahey et al. 2004). We also constructed a measure of a hospital's digital capabilities to match HIMSS's Electronic Medical Record Adoption Model (Appari, Eric Johnson, and Anthony 2013). The definitions and specifications of these covariates are provided in Table S3.

Statistical Analysis

The multivariate analysis used hierarchical logistic regression models with difference-in-differences (DID) estimation (Dimick and Ryan 2014) to determine the Program impact on VTE incidence. The estimate of interest was the interaction between Program phase and MUR. The magnitude, direction, and statistical significance of this estimate indicate how the VTE incidence changed among hospitals in the higher MUR quartiles as compared to hospitals in lower MUR quartiles with the Program implementation. Such a specification would support testing the hypothesis that hospitals at risk of greater financial losses from the Program (higher MUR quartiles) responded more robustly to the Program as compared to hospitals with a lesser risk of financial losses from the Program (lower MUR quartiles). The multivariate models used hospital random effects to account for the clustering of inpatient stays within hospitals, and all models controlled for the confounders described in the preceding

subsection. A key prerequisite for DID estimation is the fulfillment of the parallel trends assumption. We checked for this assumption by testing whether the VTE time trends varied across the MUR quartile groups before the implementation of the Program. This was performed by specifying an interaction term between the year and the MUR quartile in the pre-Program phase.

Sensitivity Analysis

We conducted several sensitivity analyses to confirm the robustness of the study findings. These include (1) varying the specification of the MUR variable (defining it as continuous, quadratic, tertile, and quintile term), (2) reclassifying the pre- and post-Program phases to account for varying Program start points (by excluding stays from 2008, by defining the post-Program phase to start from 2009, and by dividing the post-Program phase into two phases to capture the short- and long-term Program impact), and (3) addressing the potential of low-volume hospitals to skew the estimates (excluding hospitals with less than 20 cases per year). Furthermore, we examined the impact of the Program on VTE rates among hospitals that had higher than median VTE rates in the baseline period to evaluate the impact of the Program on hospitals that required to make larger efforts to reduce VTE occurrences.

We also estimated the impact of the Program on the compliance to optimal VTE prophylaxis in a hospital to determine whether the Program had influenced adherence to this process measure. For this sensitivity analysis, the outcome of interest was the proportion of all surgical patients in a hospital who received appropriate VTE prophylaxis within 24 hours before surgery to 24 hours after surgery end time (Wang et al. 2012). This process measure has been tracked and publicly reported on the Hospital Compare website as a part of the Surgical Care Improvement Project.

STUDY RESULTS

Characteristics of Hospitals and Inpatient Stays—Descriptive Statistics

Table 1 presents the characteristics of 153 NY hospitals and 210,090 inpatient stays for hip and knee replacements from 2005 to 2013. The mean MUR was 47.07 percent (standard deviation [SD]: 13.64). Compared to MUR quartile 1 hospitals, quartile 4 hospitals had a higher proportion of not-for-profit hospitals, small hospitals, and higher registered nurse per average daily census ratio. Furthermore, quartile 4 hospitals had fewer hospitals in large urban

Table 1: Descriptive Statistics for Hospitals Mandated to Participate in the HAC-POA Program for Hip and Knee Replacements in New York State*

<i>Variable/MUR[†] Quartile</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>Total</i>
<i>n</i>	38	38	38	39	153
MUR quartile range (%)	<37.86	>37.86 and ≤47.64	>47.64 and ≤57.28	>57.28	
Hospital control (%) [‡]					
Not-for-profit	65.79	94.74	97.37	100.00	89.54
Government	34.21	5.26	0.00	0.00	9.80
For-profit [§]	—	—	2.63	—	0.66
Number of beds (%)					
Small (<200)	18.42	31.58	55.26	74.36	45.10
Medium (≥200 and <400)	47.37	31.58	39.47	23.08	35.29
Large (≥400)	34.21	36.84	5.26	2.56	19.61
Large urban (%)	94.74	92.11	63.16	33.33	70.59
Medical school affiliation (%)	97.37	68.42	42.11	35.90	60.78
Herfindahl–Hirschman Index (%)					
Unconcentrated	73.68	63.16	65.79	41.03	60.78
Moderately concentrated	7.89	18.42	13.16	23.08	15.69
Highly concentrated	18.42	18.42	21.05	35.90	23.53
Medicare Utilization Ratio [¶]	28.69 (6.62)	42.83 (2.83)	53.40 (2.47)	62.92 (5.81)	47.07 (13.64)
Disproportionate patient percent [¶]	64.77 (25.18)	35.27 (15.19)	23.95 (13.05)	17.79 (6.42)	35.33 (24.30)
Operating profit margin [¶]	−0.06 (0.10)	0.01 (0.05)	−0.01 (0.10)	0.01 (0.05)	−0.01 (0.08)
Transfer-adjusted case mix index [¶]	1.45 (0.19)	1.54 (0.30)	1.37 (0.16)	1.32 (0.24)	1.42 (0.24)

continued

Table 1. *Continued*

<i>Variable/MUR^c Quartile</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>Total</i>
Registered nurse per average daily census ratio ^a	2.13 (0.71)	1.89 (0.72)	2.18 (1.17)	2.97 (2.63)	2.30 (1.57)
Hospital-level VTE rates at baseline (%)					
Hip replacement cohort	0.74	1.07	0.57	0.53	0.80
Knee replacement cohort	1.02	2.35	0.59	0.53	1.36

^aThe cohort of hip and knee replacements comprises of inpatient stays for older Medicare beneficiaries undergoing total or partial hip replacement, or total knee replacement in New York hospitals from 2005 to 2013.

^bMedicare Utilization Ratio is the percent of inpatient days in a hospital that are attributed to Medicare.

^c% refers to percentage of column total.

^dFrom 2005 to 2008, only about 1–2% of the hospitals in New York State were for-profit. Since 2009, there are no for-profit hospitals in New York State.

^eNumbers indicate mean with standard deviation in parentheses.
HAC-POA, Hospital-Acquired Condition – Present-on-Admission Program; MUR, Medicare Utilization Ratio.

Table 2: Descriptive Statistics for Inpatient Stays for Older Medicare Beneficiaries Undergoing Hip and Knee Replacements in New York State Hospitals Mandated to Participate in the HAC-POA Program*

Variable/ MUR [†] Quartile Surgery	Total/Partial Hip Replacement					Total Knee Replacement				
	1	2	3	4	Total	1	2	3	4	Total
<i>n</i>	16,099	43,793	20,067	18,770	98,729	19,923	47,580	22,150	21,708	111,361
MUR quartile range for hospital (%)	<37.86	>37.86 and ≤47.64	>47.64 and ≤57.28			<37.86	>37.86 and ≤47.64	>47.64 and ≤57.28		
Age in years: Mean (SD)	77.46 (8.09)	76.93 (7.82)	78.59 (8.02)	78.02 (7.92)	77.56 (7.95)	73.34 (5.85)	73.97 (6.00)	74.09 (6.09)	74.19 (6.11)	73.92 (6.02)
Female (%) [‡]	66.63	64.91	67.42	66.26	65.96	70.88	67.44	66.33	64.85	67.33
Race and ethnicity (%)										
White, non-Hispanic	74.02	84.41	79.87	86.80	82.25	62.65	75.38	74.60	82.39	74.31
Black, non-Hispanic	10.44	4.46	3.31	1.33	4.61	15.60	7.47	5.43	2.24	7.50
Hispanic	4.92	2.55	4.29	4.71	3.70	10.22	6.35	5.51	6.03	6.81
Other	10.62	8.58	12.53	7.16	9.44	11.53	10.8	14.46	9.34	11.38
Emergent/urgent admission (%) [‡]	41.61	30.06	43.25	38.06	36.14	2.48	1.17	3.59	1.68	1.99
Comorbidities: Mean (SD)	2.25 (1.48)	2.05 (1.44)	2.44 (1.57)	2.32 (1.56)	2.21 (1.50)	2.05 (1.32)	1.92 (1.29)	2.11 (1.36)	2.03 (1.34)	2.00 (1.32)

*The cohort comprises of inpatient stays for older Medicare beneficiaries undergoing total or partial hip replacement, or total knee replacement in New York hospitals from 2005 to 2013.

[†]Medicare Utilization Ratio is the percent of inpatient days in a hospital that are attributed to Medicare.

[‡]% refers to percentage of column total.

HAC-POA, Hospital-Acquired Condition – Present-on-Admission Program; MUR, Medicare Utilization Ratio; SD, standard deviation.

areas, fewer medical school affiliated hospitals, lower mean disproportionate patient percent, lower mean transfer-adjusted case mix index, and lower mean VTE rates at baseline as compared to quartile 1 hospitals. Table 2 presents characteristics of the inpatient stays. In comparison with the knee replacement cohort, the hip replacement cohort had older patients (average age of 77.56 years vs. 73.92 years) and a higher proportion of emergency/urgent stays (36.14% vs. 1.99%).

Figure 1 presents the mean unadjusted VTE percentages by Program phase and MUR quartile. With Program implementation, the decline in VTE incidence ranged from 17.54 to 32.08 percent among MUR quartiles 2 to 4 in the hip replacement cohort. In the knee replacement cohort, the decline in VTE incidence was noted only among MUR quartile 2 (51.91%) and quartile 4 (5.66%) hospitals. Figures S1 and S2 present the unadjusted linear trends in VTE rates for the two cohorts.

Impact of the Program on Risk of VTE—Multivariate Analysis

Table 3 and Figure 2 present the multivariate and marginal estimates, respectively, for the Program effects on VTE. For hip replacement stays, the Program was associated with significant decline in odds of VTE for hospitals in higher MUR quartiles (Estimates for interaction term in Table 3). Compared to quartile 1 hospitals, VTE odds were 52 percent lower for quartile 2 hospitals (Adjusted Odds Ratio [AOR]: 0.48, 95% Confidence Interval [CI]: 0.31 to 0.75, $p < .001$), 44 percent lower for quartile 3 hospitals (AOR: 0.56, 95% CI: 0.32 to 1.00, $p = .05$), and 53 percent lower for quartile 4 hospitals (AOR: 0.47, 95% CI: 0.25 to 0.86, $p = .01$). For the knee replacement cohort, the Program was associated with 47 percent lower odds for quartile 2 hospitals (AOR: 0.53, 95% CI: 0.36 to 0.77, $p < .001$) as compared to quartile 1 hospitals. The findings from the sensitivity analyses were fairly consistent with our inferences from the main analysis (Tables S4–S6). Importantly, the Program was also associated with a significant increase in compliance with VTE prophylaxis process measures for all patients among MUR quartile 4 hospitals (Adjusted beta estimate for MUR quartile 4: 2.70, 95% CI: 0.04 to 5.37, $p = .05$) (Table S7).

DISCUSSION

The prevention of VTE following hip and knee replacements and ensuring compliance to recommended prophylaxis requires a multipronged approach

Figure 1: Mean Unadjusted Venous Thromboembolism Percent by Type of Surgery, Program Phase, and Medicare Utilization Ratio Quartile

Abbreviations: MUR Quartile: Medicare Utilization Ratio Quartile; VTE: Venous Thromboembolism.

Notes: The bars represent unadjusted VTE percent in the pre- and post-Program phase. The pre-Program phase includes inpatient stays from October 2005 to September 2008. The post-Program phase includes inpatient stays from October 2008 to December 2013.

(Mont et al. 2011). Payment reforms such as Medicare’s Nonpayment Program are one of the several strategies that may be used to motivate hospitals to align their VTE prevention programs with evidence-based guidelines. However, little is known about whether such payment reforms have achieved their intended goals. Furthermore, whether different hospitals respond similarly to such programs or whether there is variation in their response based on the dollars at stake (dose–response relationship) is largely unknown. Ours is among the first studies to evaluate this variation in hospital response to the Program and is only the second study to assess the impact of the Program on VTE among hip and knee replacement patients. The findings demonstrate that hospitals at risk of larger financial losses from the Program were more effective in reducing their VTE incidence among hip replacement patients following Program implementation. Among knee replacement patients, we noted a modest decline in VTE incidence among MUR quartile 2 hospitals only.

There are some potential explanations for the Program-associated reduction in VTE incidence. First, the framing of the Program endpoints as negative outcomes or financial disincentives only may have motivated hospitals to take measures to prevent the occurrence of VTE (Rosenthal 2007; Milstein 2009; Werner et al. 2011). There is considerable research that demonstrates that the risk of loss associated with the negative framing of choices is a powerful motivator (Kahneman and Tversky 1979), and this may

Table 3: Multivariate Estimates for the Impact of the Hospital-Acquired Condition – Present-on-Admission (HAC-POA) Program on the Risk of Venous Thromboembolism in the Study Cohort*

Variables [†]	Total or Partial Hip Replacement		Total Knee Replacement	
	Adjusted Odds Ratio	95% Confidence Interval	Adjusted Odds Ratio	95% Confidence Interval
HAC-POA Program [‡] effects: Interaction term				
Post- × MUR [§] Quartile 2	0.48**	[0.31, 0.75]	0.53***	[0.36, 0.77]
Post- × MUR Quartile 3	0.56*	[0.32, 1.00]	1.30	[0.78, 2.17]
Post- × MUR Quartile 4	0.47*	[0.25, 0.86]	1.06	[0.62, 1.81]
<i>p</i> -Value for joint test of interaction term	.01		<.001	
Program: Main effect				
Pre-	Ref		Ref	
Post-	1.27	[0.68, 2.36]	1.28	[0.77, 2.14]
Medicare Utilization Ratio (MUR) [§] Quartile: Main effect				
Quartile 1: ≤35.3%	Ref		Ref	
Quartile 2: >35.3% and ≤46.6%	1.86**	[1.17, 2.96]	1.83*	[1.02, 3.28]
Quartile 3: >46.6% and ≤56.9%	1.46	[0.82, 2.61]	1.14	[0.55, 2.34]
Quartile 4: >56.9%	1.73	[0.94, 3.20]	1.42	[0.67, 3.04]
Model parameters				
Inpatient observations	98,064		111,098	
Hospitals	152		151	

*The cohort comprises of inpatient stays for older Medicare beneficiaries undergoing total or partial hip replacement and total knee replacement in New York hospitals from 2005 to 2013.

[†]Multivariate models controlled for patient level (age, sex, race and ethnicity, urgency and source of admission, and comorbidities) and hospital-level (hospital ownership, medical school affiliation, geographic location, number of beds, operating profit margin, Herfindahl–Hirschman Index, disproportionate patient percent, transfer-adjusted case mix index, and a measure of the digital capabilities of a hospital to match HIMSS' Electronic Medical Record Adoption Model).

[‡]Program phase: Prephase includes stays from October 2005 to September 2008. Postphase includes stays from October 2008 to December 2012.

[§]Medicare Utilization Ratio is the percent of inpatient days in a hospital that are attributed to Medicare.

****p* < .001, ***p* < .01, **p* < .05.

have encouraged hospitals to actively minimize avoidable revenue losses. Such a response supports our hypothesis that hospitals that are at risk of larger losses are likely to have greater motivation to reduce their VTE incidence. Second, the HAC-POA Program was the first pay-for-performance program to directly target VTE for hip and knee replacements, and the Program effects we note may likely be the “low-hanging” fruit that the Program has targeted. Third, before the HAC-POA Program, the only other pay-for-performance

Figure 2: Adjusted Changes in Venous Thromboembolism Incidence (Medicare Utilization Ratio Quartiles 2 to 4 vs. Quartile 1)

Abbreviations: MUR Q: Medicare Utilization Ratio quartile; VTE: Venous thromboembolism; wrt: with respect to.

Notes: The bars represent adjusted changes in VTE incidence (results from multivariate analyses) among MUR quartiles 2 to 4 as compared to MUR quartile 1 after Program implementation. Changes expressed as VTEs per 1,000 stays. Multivariate models controlled for patient- (age, sex, race and ethnicity, urgency and source of admission, and comorbidities), and hospital-level (hospital ownership, medical school affiliation, geographic location, number of beds, operating profit margin, Herfindahl-Hirschman Index, disproportionate patient percent, transfer-adjusted case mix index, and a measure of the digital capabilities of a hospital to match HIMSS' Electronic Medical Record Adoption Model); *** $p < .001$, ** $p < .01$, * $p < .05$.

program that focused on VTE was the Surgical Care Improvement Project (SCIP) initiative which was in effect since 2005 was not specific to hip and knee replacements and included two process measures related to VTE prevention (Centers for Medicare and Medicaid Services 2017a). These measures mainly related to the ordering and administering of appropriate thromboprophylaxis, and financial incentives were associated with reporting measure compliance and not with achieving a reduction in VTE. It is likely that in response to the HAC-POA Program, hospitals may have updated their practices to include risk assessment for VTE as a part of their protocols in addition to updating pharmacological and mechanical treatment regimens, and those benefits are captured by our analyses. Moreover, since our study uses data from 2005 onward, the empirical models account for the SCIP effect in the baseline period, and the incremental changes in VTE occurrence that we note in the post-2008 period can be attributed to the HAC-POA Program. Fourth, studies have shown that the availability of evidence-based guidelines is an important step for standardizing care bundles and preventing the occurrence

of adverse events. In the case of hip and knee replacements, it is likely that availability of evidence-based guidelines for VTE prevention (Geerts et al. 2008) may have facilitated improvements in care. Finally, the consistent Program effect across MUR quartiles 2 to 4 in the hip replacement cohort, as compared to a significant effect only in MUR quartile 2 in the knee replacement cohort is likely to be driven by the profile of patients in the respective cohorts. The hip replacement cohort had a significantly higher proportion of patients receiving emergent/urgent care, and hospitals may have optimized their VTE prevention programs to reduce the variation in VTE incidence among these patients. Importantly, the HAC-POA Program was motivated by the need to address the perverse incentive that existed in the Medical Severity—Diagnosis-Related Groups-based method for reimbursing hospitals (Rosenthal 2007). Prior to the onset of the Program, hospitals were likely to use higher-paying MS-DRG codes for patient stays that developed VTEs, thereby increasing the hospital's chances of maintaining their profits despite the occurrence of these adverse events. Notably, hospitals could sustain these profits by increasing their volume of high-risk patients (Eappen et al. 2013). However, with the HAC-POA Program, hospitals stand to lose an average of \$7,600 per VTE occurrence, which can place a substantial financial burden on hospitals given their slender operating margins. So while a particular hospital may still find some patients with VTE profitable, the *incremental* effect is to reduce that profit by the amount of severity-related payment differential. Furthermore, given that the cost of treating VTEs is nearly four times the cost of preventing them (Fernandez et al. 2015) and that VTE prophylaxis has been found to be cost-effective as compared to no prophylaxis or case detection (Nicolaidis et al. 2013), it is in the financial interest of the hospital to take measures to prevent VTEs.

The identification of the differential response of hospitals to the HAC-POA Program highlights important areas for improvement. Our findings show that hospitals in MUR quartile 1, despite having higher VTE incidence at baseline, did not have the intended response to this Program in comparison with other hospitals. MUR quartile 1 hospitals are hospitals with higher disproportionate patient percent, indicative of patients with greater clinical and social risk. While fewer Medicare dollars at stake is likely to partially explain why the Program did not achieve its intended effects in these hospitals, policy interventions that invest quality and financial resources in these hospitals are likely to achieve meaningful reductions in VTE incidence in these hospitals (Joynt et al. 2017). Furthermore, initiatives that support the exchange of best practices and ideas between high- and low-performing hospitals are likely to yield considerable value.

By identifying a Program-associated decline in VTE incidence, our study findings are qualitatively in agreement with the only other study (Gidwani and Bhattacharya 2015) that has examined the impact of the Program on VTE. However, our study expands on previous work in important ways. First, our study is among the first to examine the dose–response relationship within pay-for-performance programs. Second, our findings are strengthened by the use of the State Inpatient Database because of the availability and validity of the present-on-admission indicator to discriminate between pre-existing conditions and postoperative complications. Third, instead of choosing within-hospital, patient-level control groups such as privately insured patients, we choose hospital-level control groups that are most directly influenced by the Program yet are unlikely to be subject to the spillover bias, thereby addressing a key limitation of the previous VTE study. This bias may result when a hospital adopts new processes for all patients and not only for those exposed to the Program (Dimick and Ryan 2014).

Furthermore, given the unique nature of the HAC-POA Program, our research findings inform the current debate on the optimal design of payment reforms. The HAC-POA Program and the more recent initiatives (including pay-for-performance programs such as the Hospital Readmissions Reduction Program, and bundled programs such as Bundled Payments for Care Improvement and Comprehensive Care for Joint Replacement) have comparable overarching goals of improving quality and safety, yet they have distinct approaches to achieving these. The HAC-POA Program is an exclusively disincentive-/penalty-based program, it focuses only on the hospital stay, and its VTE metric is explicitly stated. The more recent programs include a mix of bonuses and penalties, focus on both the inpatient stay and postoperative discharge period of varying lengths, and include VTE as a part of a larger composite metric (PSI 90) with different weighting priorities; thereby assessing losses from VTE events is a relatively involved process. Notably, the design of the HAC-POA Program is such that each hospital with even a single HAC/VTE sees a decrease in its reimbursement. In contrast, with the newer programs, the receipt of bonuses and penalties is relative to the performance of other hospitals on quality metrics. Thus, by providing an actionable and well-defined metric, the HAC-POA Program complements the recent and more influential programs in reducing VTE and thereby improving the quality and safety of care.

The study has several limitations. First, the study uses administrative datasets which are known to have limitations in their sensitivity for clinical

outcomes such as VTE (Zhan and Miller 2003; Zhan et al. 2007). However, the longitudinal and State-wide scope of our analysis can be best addressed with these datasets. Importantly, CMS uses similar datasets to assess hospital quality and Program disincentives. Second, experts have raised concerns about surveillance bias in the detection of VTE, with the potential for a hospital's screening practices to influence the detection of VTE (Haut and Pronovost 2011; Bilimoria et al. 2013). However, in the absence of information on these practices, this remains a limitation of the data that CMS uses for computing the financial disincentives, and consequently of our analysis. Third, in keeping with the Program definition, our analysis focused on outcomes. In doing so, we may have missed important advances that hospitals may have made in VTE prevention processes. While we do examine the impact of the Program on a relevant process measure in the sensitivity analysis, this process measure is not specific to hip and knee replacements and applies to all patients in the hospital. Fourth, as the study focuses on NY hospitals and given the well-established geographic variation in outcomes, the generalizability of our study findings to other states is limited. Finally, as the scope of the Program is limited to inpatient stays, our analysis does not account for VTEs that may develop and are detected after discharge from the hospital. Thus, our findings are likely to be conservative estimates of a larger Program effect.

In conclusion, our study demonstrates that Medicare's Nonpayment Program was associated with lower VTE incidence mainly among patients undergoing hip replacements and among hospitals at risk of higher financial losses from the Program. These findings suggest that withholding payments for the cost of adverse events may be a useful strategy for reducing complications in surgical patients.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the supporting information section at the end of the article:

Appendix SA1: Author Matrix.

Table S1: International Classification of Diseases, Ninth Revision, Clinical Modification Procedure Codes for Identifying Hospital-Acquired Conditions Relevant to the Cohort.

Table S2: Description of Present-on-Admission Indicator Codes.

Table S3: Covariate Definition and Specifications.

Table S4: Interaction/Program Effects from Sensitivity Analyses for Risk of Venous Thromboembolism in Hip Replacement Cohort.

Table S5: Interaction/Program Effects from Sensitivity Analyses for Risk of Venous Thromboembolism in Knee Replacement Cohort.

Table S6: Interaction/Program Effects from Sensitivity Analyses for Hospital Compliance with VTE Prophylaxis Process Measure.

Table S7: Program Effects from Sensitivity Analysis Examining the Impact of the Program on Hospitals with Higher Than Median VTE Rates in the Baseline Period.

Figure S1: Lowess Curves for Unadjusted Linear Trends in VTEs in the Hip Replacement Cohort.

Figure S2: Lowess Curves for Unadjusted Linear Trends in VTEs in the Knee Replacement Cohort.