Impact of Hospital Readmissions Reduction Program Penalties on Hip and Knee Replacement Readmissions

Comparison of Hospitals at Risk of Varying Penalty Amounts

Caroline P. Thirukumaran, MBBS, MHA, PhD, Brian E. McGarry, PhD, PT, Laurent G. Glance, MD, Meiling Ying, MA, Benjamin F. Ricciardi, MD, Xueya Cai, PhD, and Yue Li, PhD

Investigation performed at the University of Rochester, Rochester, New York

Background: Little is known about the impact of the U.S. Centers for Medicare & Medicaid Services' Hospital Readmissions Reduction Program (HRRP) expansion to include readmissions following elective primary total hip and knee replacements; the expansion was finalized in 2013 and was implemented in 2014. We examined whether hospitals at risk of relatively large penalties from this expansion experienced greater declines in joint replacement readmissions compared with hospitals at risk of smaller penalties.

Methods: We used Medicare's 2009 to 2016 Hospital Compare data sets to examine the impact of the HRRP's expansion in the July 2013 to June 2016 period (post-expansion) compared with the July 2009 to June 2012 period (pre-expansion). The primary outcome was the hospital-level, 30-day, risk-standardized readmission rate (hereafter called the readmission rate) following joint replacement surgical procedures. We used the percentage of a hospital's total inpatient revenue attributed to Medicare (categorized into quartiles) to represent the risk of penalties. We used hierarchical linear regression models to examine the adjusted impact of the HRRP's expansion.

Results: Our study cohort included 2,326 acute care hospitals. In the pre-HRRP expansion phase, the mean readmission rate was 5.36% among hospitals with the highest proportion of Medicare revenues (quartile 4) and 5.46% among hospitals with the lowest proportion of Medicare revenues (quartile 1). With the HRRP expansion, the readmission rate declined by 18.92% (1.01 percentage points) among quartile-4 hospitals and by 17.97% (0.98 percentage point) among quartile-1 hospitals ($p = 0.45$). This nonsignificant difference in readmission rate declines between quartiles persisted in multivariable analysis (a decline of 18.41% [0.98 percentage point] in quartile 4 and a decline of 17.35% [0.94 percentage point] in quartile 1; $p = 0.35$).

Conclusions: The HRRP's expansion to include joint replacements did not lead to greater reductions in postoperative readmissions among hospitals at risk of larger penalties in comparison with hospitals at risk of smaller penalties. Readmission rates were declining at similar rates among all hospitals, before and after the HRRP's expansion.

Clinical Relevance: Readmissions and complications following joint replacements are measures of the quality of surgical care. These events have important clinical and economic implications for patients and providers. This study is clinically relevant because it examines whether policy interventions, such as the HRRP, have the potential to reduce these unintended consequences of surgical care.

In 2012, the U.S. Centers for Medicare & Medicaid Systems implemented the Hospital Readmissions Reduction Program (HRRP) to encourage hospitals to reduce read-

missions for medical conditions. Under this initiative, hospitals with higher-than-expected readmission rates for Medicare fee-for-service patients receive penalties as high as 3% of their base

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Medicare inpatient payments¹. In August 2013, Medicare finalized the expansion of the HRRP to include elective primary total hip and knee replacements, and this expansion came into effect in October 2014. Two key factors contributed to the inclusion of total hip replacements and total knee replacements in the HRRP. First, total hip replacements and total knee replacements are the most frequently performed inpatient surgical procedures for Medicare beneficiaries and the largest surgical expenditure for Medicare². Second, considerable hospital variability in readmission rates exists, and many surgical readmissions are associated with postoperative complications^{3,4}, many of which may be preventable.

Previous work has shown that the HRRP expansion to total hip and knee replacements resulted in modest reductions in readmissions for these surgical procedures⁵. However, the causal interpretation of these results is clouded by evidence that these declines began before HRRP's expansion and were more substantial for non-targeted surgical procedures⁶⁻⁸. Moreover, with 1 recent exception⁸, no study, to our knowledge, has examined surgical readmissions beyond 2014, the first year that the HRRP penalties came into effect for total hip and knee replacements. As a result, there has been uncertainty about both the short-term and medium-term effects of the HRRP expansion.

The purpose of this study was to examine the impact of the HRRP's expansion on readmission rates for total hip and knee replacements. Specifically, we examined whether hospitals that risked receiving larger HRRP penalties achieved greater reductions in readmissions and complications compared with hospitals that risked receiving smaller penalties. We also examined whether the HRRP led to smaller reductions in readmissions among safety-net hospitals compared with non-safety-net hospitals and the extent to which reductions in readmissions and complications were correlated.

Materials and Methods

Data Sources and Study Cohort

We used publicly available data files from Hospital Compare (Medicare's web portal for reporting hospital performance and payment data)⁹ to obtain hospital-level readmission and complication rates for total hip and knee replacements from July 2009 to June 2016. We linked these data sets to hospital-level Medicare Cost Reports¹⁰, the American Hospital Association Annual Survey Database¹¹, and the Medicare Impact File¹² to obtain the key independent variables and hospital characteristics in the pre-HRRP expansion (baseline) period. We used the patient-level 2012 Medicare claims data file¹³ to generate hospital-level measures of inpatient revenue for Medicare beneficiaries (see the Appendix for data set details). We limited the cohort to 2,326 acute care hospitals that were reimbursed by the Inpatient Prospective Payment System¹⁴ and that reported readmission rates in both the pre-HRRP expansion phase and the post-HRRP expansion phase (see the Appendix for cohort details).

Variables

Outcomes

The primary outcome of interest was the hospital-level, 30-day, risk-standardized readmission rate (hereafter called the readmission rate)¹⁵, and the secondary outcome was the hospital-level, risk-standardized complication rate (hereafter called the complication rate)¹⁵ following primary elective total hip and knee replacements. These rates are reported on Hospital Compare as 3-year means and are endorsed by the National Quality Foundation (see the Appendix for outcome details)¹⁶. The measures are adjusted for age, sex, and clinical comorbidities to account for case-mix differences between hospitals and a hospital-specific effect.

Key Independent Variables

For the main analysis, the key independent variables were the HRRP expansion phase (pre-expansion or post-expansion), the percentage of the total inpatient revenue of a hospital that can be attributed to Medicare (hereafter called the Medicare percentage), and an interaction between the 2 terms (see the Appendix for variable details).

The HRRP expansion phase was specified as a binary indicator of whether the readmission or complication rate was for Medicare patients undergoing total hip and knee replacements in the pre-expansion period or the post-expansion period. Because Medicare finalized the expansion of the HRRP for total hip and knee replacements in August 2013 (with implementation begun in October 2014), we treated 2013 as the intervention year because hospitals may have initiated readmission reduction measures in anticipation of penalties in 2014. Hence, we used data from July 2009 to June 2012 as the pre-expansion phase and data from July 2013 to June 2016 as the post-expansion phase.

We used the Medicare percentage to represent the exposure of a hospital to the HRRP penalties. We derived the numerator for this variable from the 2012 Medicare claims file as a hospital-level sum of revenues for all short-stay Medicare beneficiaries who were ≥66 years of age. The denominator represented the total inpatient revenue for a hospital and was obtained from the 2012 Medicare Cost Report. Under the HRRP, hospitals with higher-than-expected readmissions are penalized by a reduction in reimbursements for all Medicare stays, not just for conditions that are included in the HRRP¹⁷. Hence, hospitals that received a higher proportion of their revenues from Medicare (that is, a higher Medicare percentage) were subject to relatively larger penalties and consequently faced greater incentives to reduce readmission rates compared with hospitals with lower reliance on Medicare revenue. We fixed the Medicare percentage at baseline for each hospital and specified it in quartiles for the main analysis. Quartile-4 hospitals were at risk of the largest financial penalties and quartile-1 hospitals faced the lowest penalties.

We used the interaction between the HRRP phase and the Medicare percentage to determine whether the association between the HRRP expansion and readmission and

TABLE I Characteristics of Hospitals in the Period (2009 to 2012) Prior to Expansion of the HRRP to Hip and Knee Replacement Readmissions

Characteristics	Medicare Percentage*				Total	P Value†
	Quartile 1	Quartile 2	Quartile 3	Quartile 4		
No. of hospitals	581	582	581	582	2,326	
Exposure: Medicare percentage						
Medicare percentage‡	3.73 ± 0.88	6.19 ± 0.64	8.92 ± 1.00	14.78 ± 4.11	8.41 ± 4.66	<0.001
Total inpatient revenue in \$100,000§	7,377 (3,778 to 12,312)	3,922 (1,885 to 7,752)	2,271 (1,066 to 4,525)	909 (461 to 2,072)	2,778 (1,041 to 6,578)	<0.001
Total Medicare inpatient revenue in \$100,000§	255 (139 to 438)	242 (115 to 459)	202 (95 to 388)	129 (69 to 271)	203 (95 to 394)	<0.001
Baseline characteristics						
Region#						<0.001
Northeast	81 (13.94)	77 (13.23)	100 (17.21)	126 (21.65)	384 (16.51)	
South	248 (42.69)	224 (38.49)	213 (36.66)	172 (29.55)	857 (36.84)	
Midwest	63 (10.84)	147 (25.26)	183 (31.50)	242 (41.58)	635 (27.30)	
West	183 (31.50)	134 (23.02)	84 (14.46)	42 (7.22)	443 (19.05)	
U.S. territory	6 (1.03)	0 (0.00)	1 (0.17)	0 (0.00)	7 (0.30)	
Urban#	564 (97.07)	528 (90.72)	450 (77.45)	267 (45.88)	1,809 (77.77)	<0.001
Medical school affiliation#	242 (41.65)	202 (34.71)	210 (36.14)	164 (28.18)	818 (35.17)	<0.001
Hospital ownership#						<0.001
For-profit	214 (36.83)	126 (21.65)	85 (14.63)	51 (8.76)	476 (20.46)	
Not-for-profit	308 (53.01)	398 (68.38)	419 (72.12)	412 (70.79)	1,537 (66.08)	
Government	59 (10.15)	58 (9.97)	77 (13.25)	119 (20.45)	313 (13.46)	
Hospital size#						<0.001
Small (<200 beds)	218 (37.52)	290 (49.83)	347 (59.72)	463 (79.55)	1,318 (56.66)	
Medium (200 to 399 beds)	219 (37.69)	175 (30.07)	168 (28.92)	95 (16.32)	657 (28.25)	
Large (≥400 beds)	144 (24.78)	117 (20.10)	66 (11.36)	24 (4.12)	351 (15.09)	
Volume of hip and knee replacements§	210 (102 to 399)	276 (136 to 515)	271 (127 to 513)	191 (95 to 364)	233 (111 to 447)	<0.001
Disproportionate Patient Percentage‡	29.66 ± 16.81	24.81 ± 14.39	22.85 ± 11.88	23.33 ± 10.66	25.16 ± 13.90	<0.001
Transfer-adjusted case-mix index‡	1.63 ± 0.25	1.59 ± 0.26	1.51 ± 0.24	1.40 ± 0.22	1.53 ± 0.26	<0.001
Outcomes‡						
Pre-HRRP rates (2009 to 2012) (%)						
Risk-standardized readmission rate	5.46 ± 0.73	5.38 ± 0.73	5.30 ± 0.68	5.36 ± 0.70	5.38 ± 0.71	0.01
Risk-standardized complication rate	3.52 ± 0.70	3.45 ± 0.71	3.43 ± 0.71	3.51 ± 0.71	3.48 ± 0.71	0.03
Change in rates with HRRP implementation (%)						
Risk-standardized readmission rate	-0.98 ± 0.80	-1.02 ± 0.76	-0.93 ± 0.71	-1.01 ± 0.71	-0.99 ± 0.75	0.18
Risk-standardized complication rate	-0.70 ± 0.72	-0.68 ± 0.75	-0.65 ± 0.76	-0.67 ± 0.76	-0.68 ± 0.75	0.65
Post-HRRP rates (2013 to 2016) (%)						
Risk-standardized readmission rate	4.48 ± 0.60	4.36 ± 0.55	4.37 ± 0.56	4.35 ± 0.54	4.39 ± 0.57	0.002
Risk-standardized complication rate	2.82 ± 0.52	2.76 ± 0.52	2.78 ± 0.57	2.84 ± 0.59	2.80 ± 0.55	0.16

*This is the percentage of total inpatient revenue of a hospital that is attributed to Medicare. †The p values were determined with chi-square tests for categorical variables and with Kruskal-Wallis tests for continuous variables comparing the distribution of characteristics and outcomes across the 4 Medicare percentage quartiles. ‡The values are given as the mean and the standard deviation. §The values are given as the median, with the interquartile range in parentheses. #The values are given as the number of hospitals, with the percentage in parentheses.

Fig. 1
Trends in risk-standardized readmission rates (left panel) and complication rates (right panel) for hip and knee replacements from 2009 to 2016. In the x axis, the year extract refers to the 3-year data extract from Hospital Compare data (e.g., 09-12 refers to the data extract from 2009 to 2012). In the y axis, quartiles refer to hospital-level quartiles of the percent of inpatient revenue attributed to Medicare. The vertical dashed line indicates the finalization and public announcement of the expansion of the HRRP for hip and knee replacements in 2013. The time periods of 2009 to 2012 and 2013 to 2016 were used as the pre-HRRP expansion time period and the post-expansion time period for the main analysis. For each quartile, there were no significant differences in the slopes before and after program implementation.

complication reductions varied across hospitals with differing reliance on Medicare revenue. A significant decline in rates for higher Medicare percentage quartiles relative to quartile 1 would be suggestive of the independent effect of the HRRP penalties in producing these declines.

Covariates

All multivariable models controlled for important hospital-level characteristics (see the Appendix for covariate details). These include hospital location¹⁸, geographic region¹⁹, hospital size (number of beds)²⁰, medical school affiliation²⁰, and

TABLE II Key Estimates from Multivariable Hierarchical Linear Regression Models Examining the Impact of the HRRP Expansion on 30-Day Readmissions and Complications Following Hip and Knee Replacements*

	Risk-Standardized Readmission Rate	Risk-Standardized Complication Rate
No. of observations	4,636	4,619
HRRP phase† (percentage points)		
Pre-phase (2009 to 2012)	Reference	Reference
Post-phase (2013 to 2016)	−0.94† (−1.00 to −0.88)	−0.68† (−0.74 to −0.62)
Medicare percentage§ quartile† (percentage points)		
Quartile 1	Reference	Reference
Quartile 2	−0.06 (−0.13 to 0.01)	−0.05 (−0.12 to 0.03)
Quartile 3	−0.13† (−0.21 to −0.06)	−0.06 (−0.13 to 0.02)
Quartile 4	−0.09# (−0.17 to −0.01)	−0.02 (−0.11 to 0.06)
HRRP phase × Medicare percentage quartile† (percentage points)		
Post × quartile 2	−0.04 (−0.12 to 0.05)	0.02 (−0.07 to 0.11)
Post × quartile 3	0.05 (−0.04 to 0.14)	0.06 (−0.03 to 0.14)
Post × quartile 4	−0.04 (−0.13 to 0.04)	0.02 (−0.06 to 0.11)

*The multivariable models also controlled for geographic region, urban location, hospital size, medical school affiliation, ownership status, volume of hip and knee replacements, Disproportionate Patient Percentage, and transfer-adjusted case-mix index and for the clustering of observations within hospitals. The full model estimates are presented in the Appendix Table 1. †The values are given as the beta estimate, with the 95% CI in parentheses. ‡P < 0.001. §This is the percentage of a hospital's inpatient revenue that is attributed to Medicare. #P < 0.05.

ownership²¹. We also controlled for the volume of total hip and knee replacements that qualified for the measures²², the Disproportionate Patient Percentage²³, and the transfer-adjusted case mix²⁴, all of which were specified as continuous variables.

Statistical Analysis

In a bivariate analysis, we examined the characteristics and outcomes of hospitals across Medicare percentage quartiles and tested for differences using the chi-square and Kruskal-Wallis tests. We estimated multivariable linear regression models with an interaction between the HRRP expansion indicator and the Medicare percentage. The use of the interaction term enables the specification of a treatment (Medicare percentage quartile 4) and a control group (Medicare percentage quartile 1), thereby providing a distinct advantage over using only a specification of pre- or post-intervention. The interaction also aids in the control of other non-HRRP temporal changes that may affect outcomes²⁵. The intuition behind this strategy is an advanced econometric method, the difference-in-differences estimation, which has been used to assess the impact of policy interventions^{26,27}. However, our approach differed from the classic difference-in-differences estimation by using a control group that was exposed to the policy, but to the least possible extent. Such a setup was important because the HRRP was expanded to all acute care hospitals at the same time point. All multivariable models controlled for hospital-level confounders and hospital random effects to account for the clustering of observations within hospitals.

We examined the differential effect of the HRRP on safety-net and non-safety-net hospitals using the Disproportionate Patient Percentage to test concerns that safety-net hospitals that care for high proportions of vulnerable patients have smaller reductions in the readmission and complication rates in the HRRP compared with non-safety-net hospitals^{20,28}.

We also used Spearman correlation coefficients to examine the extent to which hospital-level changes in readmission and complication rates are correlated.

Sensitivity Analysis

We conducted additional analyses to check the robustness of the main findings. First, we used alternative specifications for the Medicare percentage variable, such as continuous, tertile groups, and quintiles. Second, we used alternative definitions of the exposure variable such as the percentage of the total inpatient revenues (from the Medicare Cost Report) of a hospital that could be attributed to total hip and knee replacements for older Medicare beneficiaries (from the Medicare claims file), and the percentage of inpatient volume that could be attributed to Medicare (from the American Hospital Association Annual Survey database). Third, we reestimated the main models by limiting the cohorts to hospitals with surgical volume greater than the median, thereby reducing bias due to random fluctuations of outcome rates in smaller hospitals²⁹. Finally, we specified a pre-HRRP expansion phase extending from 2010 to 2013 to account for the start of the HRRP expansion in October 2014. We also used the 2014 to 2017 Hospital Compare data as a new post-period to determine if there may have been a lag in the initiation of quality improvement efforts by hospitals.

Results

Descriptive Results

The overall mean Medicare percentage (and standard deviation) was $8.41\% \pm 4.66\%$, with a mean of $14.78\% \pm 4.11\%$ among quartile-4 hospitals and a mean of $3.73\% \pm 0.88\%$ among quartile-1 hospitals (Table I). Quartile-4 hospitals had 88% lower total inpatient revenue and 49% lower Medicare inpatient revenue than quartile-1 hospitals. In comparison with quartile 1,

TABLE III Multivariable Estimates from Hierarchical Linear Regression Models Examining the Differential Impact of the HRRP Expansion on Safety-Net and Non-Safety-Net Hospitals*

	Risk-Standardized Readmission Rate	Risk-Standardized Complication Rate
No. of observations	4,650	4,631
HRRP phase†		
Pre-phase (2009 to 2012)	Reference	Reference
Post-phase (2013 to 2016)	-0.96‡ (-1.03 to -0.89)	-0.63‡ (-0.70 to -0.56)
Hospitals†		
Non-safety-net hospitals	Reference	Reference
Safety-net hospitals	0.06 (-0.01 to 0.12)	0.14‡ (0.08 to 0.21)
HRRP phase × safety-net hospitals†		
Post-phase × safety-net hospitals	-0.02 (-0.10 to 0.06)	-0.04 (-0.12 to 0.04)

*These models examine the differential effects of the HRRP across safety-net and non-safety hospitals. Hospitals were categorized on the basis of whether the Disproportionate Patient Percentage for a hospital was $\geq 15\%$ (safety-net hospitals) or $< 15\%$ (non-safety-net hospitals). The multivariable models also controlled for geographic region, urban location, hospital size, medical school affiliation, ownership status, volume of hip and knee replacements, and transfer-adjusted case-mix index and for the clustering of observations within hospitals. †The values are given as the beta estimate, with the 95% CI in parentheses. ‡P < 0.001.

TABLE IV Hospital-Level Adjusted Correlations Between the Risk-Standardized Readmission and Complication Rates During Various Phases of the HRRP Expansion to Hip and Knee Replacement Readmissions

	Medicare Percentage*†			
	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Pre-HRRP phase‡	0.62	0.59	0.70	0.60
Post-HRRP phase§	0.65	0.63	0.75	0.65
Change in rates with HRRP	0.87	0.84	0.82	0.83

*This is the percentage of a hospital's inpatient revenue that is attributed to Medicare. †The values are given as the Spearman correlation coefficient between hospital-level predicted readmission and complication rates. All values were significant at $p < 0.001$. ‡The pre-HRRP phase extends from 2009 to 2012. §The post-HRRP phase extends from 2013 to 2016.

quartile 4 had a higher proportion of hospitals located in the Midwest, rural hospitals, hospitals not affiliated with medical schools, not-for-profit hospitals, and small hospitals.

Prior to the HRRP expansion (2009 to 2012), the overall mean readmission rate was $5.38\% \pm 0.71\%$ and the overall mean complication rate was $3.48\% \pm 0.71\%$ (Table I). With the HRRP expansion, the readmission rate declined by 18.92% (1.01 percentage points) among quartile-4 hospitals and by 17.97% (0.98 percentage point) among quartile-1 hospitals ($p = 0.45$ for the comparison between quartiles 1 and 4) (Fig. 1, Appendix Figure 1).

Adjusted Results Examining the Impact of HRRP Expansion

In multivariable analysis, we did not find evidence of significant differences between Medicare percentage quartiles in the readmission rate declines; the quartile-4 interaction term estimate was -0.04 percentage point (95% confidence interval [CI], -0.13 to 0.04 percentage point; $p = 0.35$) (Table II, Appendix Table 1). The adjusted readmission rate declined by 18.41% (0.98 percentage point) among quartile-4 hospitals and by 17.35% (0.94 percentage point) among quartile-1 hospitals ($p = 0.35$), and the complication rate declined by 18.88% (0.66 percentage point) among quartile-4 hospitals and by 19.39% (0.68 percentage point) among quartile-1 hospitals ($p = 0.61$) (see Appendix Figure 2). The findings from the sensitivity analysis were similar to those from the main analysis (see Appendix Tables 3, 4, and 5).

We did not find evidence that the HRRP's impact varied across safety-net and non-safety-net hospitals (Table III); the estimate was -0.02 percentage point (95% CI, -0.10 to 0.06 percentage point; $p = 0.62$). There was a strong within-hospital correlation between the changes in the 2 rates (correlation coefficients ranging from 0.82 for quartile 3 to 0.87 for quartile 1; $p < 0.001$) (Table IV, Appendix Figure 3).

Discussion

We found that following the expansion of Medicare's HRRP to total hip and knee replacements, the rates of readmissions and complications for these surgical procedures continued to decline for all hospitals, regardless of the proportion of total hospital revenue at risk for penalties. Safety-net hospitals, which may have limited resources to improve quality, exhibited similar reductions in readmission rates compared with non-safety-net hospitals. Hospitals achieving the greatest reductions in complication rates also achieved the greatest reductions in readmission rates, which suggests that many complications may be preventable. Importantly, we did not find evidence that the HRRP worsened the quality of care (as measured by the readmission and complication rates).

Our main findings are consistent with those from previous studies that used patient-level data to examine the impact of the HRRP expansion on total hip and knee replacement readmissions⁵⁻⁸. These studies demonstrated declines in surgical readmission rates since at least 2008; however, much of these declines occurred prior to the actual implementation of the HRRP penalties for total hip and knee replacement readmissions. Furthermore, the use of patient-level control groups from the same hospital in these studies makes it difficult to rule out HRRP-associated spillover effects^{30,31} and thus determine the direct effect of the HRRP penalties. Our study addressed this concern by exploiting hospital-level variation in the relative size of potential HRRP penalties.

The lack of differential responses between hospitals facing proportionally high compared with low financial penalties suggests that the improvements in post-discharge outcomes are universal and may not be the result of incentives specifically created by the HRRP. However, the precise mechanisms underlying this trend are unclear. Although this pattern could be consistent with anticipatory and spillover effects of the HRRP on all patients treated within the same HRRP-eligible hospitals^{30,31}, it may also be consistent with the mounting evidence that broad declines in readmissions since the passage of the U.S. Affordable Care Act may be attributable to factors beyond the threat of HRRP penalties³²⁻³⁷. The public reporting of readmission rates since 2009, the implementation of the HRRP for medical conditions in 2012, and the announcement of its expansion to surgical conditions in 2013 may have played a role in raising global awareness of the need to improve patient care at and around the time of hospital discharge³⁸. These explanations coupled with the fact that readmission reductions may be experiencing a floor effect support our findings⁸.

It does not appear that delayed responses on the part of hospitals explain our findings, as our sensitivity analysis that used the 2014 to 2017 data shows consistent findings. Moreover, recent studies have shown that the HRRP has not been associated with increases in stays at alternative locations such as observation-unit stays³⁹, thereby addressing concerns that hospitals may game the system by diverting readmissions to emergency rooms or classifying them as observation-unit stays⁴⁰. Given that the HRRP-related payment reductions

increased from 1% in fiscal year 2013 to 3% in fiscal year 2015, our findings should prompt policymakers to carefully consider whether the limited benefits of increasing payment penalties justify their potential costs. The loss of Medicare revenue may have important negative consequences for those facilities with higher readmission rates, particularly those with already-low profit margins²³.

We did not find evidence to support the differential impact of the HRRP on safety-net and non-safety-net hospitals, although patients seeking care at safety-net hospitals often lack reliable social support systems⁴¹, are less likely to comply with treatment plans⁴², and have limited access to primary care networks⁴³, all of which may increase their likelihood for readmissions. Recent research has shown that safety-net hospitals have taken measures to achieve reductions in readmissions following medical conditions⁴⁴. To our knowledge, our study is the first to examine the HRRP expansion impact on safety-net hospitals for surgical patients and demonstrates similar declines to non-safety net hospitals. We also found that hospitals that decreased their rates of postoperative complications also experienced reductions in readmission rates. The strong relationship is consistent with previous research demonstrating that postoperative complications are a direct cause of hospital readmissions^{3,4}. The correlation between the 2 rates may also be explained by the complication rate being primarily calculated for patients who were admitted or readmitted to hospitals. However, there are differences in the measurement of the 2 metrics; for example, readmissions may occur for reasons other than complications and the follow-up period is 30 days for readmissions and up to 90 days for complications, making it important to examine the correlation.

Our study had several limitations. First, because the unit of analysis was a hospital, the findings of this study could only be used to draw inferences about hospitals and not about their patients. However, because the HRRP has direct implications for hospitals, we believe that the concern of ecological fallacy in which inferences about patients are drawn from hospital-level data does not apply to this study⁴⁵. Second, the outcomes of our study were measured as 3-year means, which increases the precision of the estimates, and not as single-year rates, which could have enabled a yearly analysis. Importantly, the 3-year pre-expansion and post-expansion periods that we defined align with the public announcement of the HRRP in 2013. Third, we noted that all of the hospitals included in our analyses were at risk for some amount of penalty due to the HRRP. Nevertheless, our findings of a lack of a dose-response rela-

tionship have important implications for the HRRP penalty amounts that are designed to increase over time and may include additional conditions in the future. Furthermore, our identification strategy has the important benefit of eliminating potential within-hospital spillover effects that could bias effect estimates obtained by comparing patient populations treated within the same facilities.

In conclusion, we did not find evidence that the HRRP's expansion to total hip and knee replacements led to greater reductions in joint replacement readmissions among hospitals at risk of larger penalties in comparison with hospitals at risk of smaller penalties. Readmission rates were declining at similar rates across all hospitals, before and after the HRRP's expansion. Our findings suggest that planned increases in the HRRP penalties are unlikely to produce the intended effects. Evaluating the HRRP to determine the nature of readmissions that persist despite the penalties may yield further improvements.

Appendix

Supporting material provided by the authors is posted with the online version of this article as a data supplement at [jbjs.org \(http://links.lww.com/JBJS/F585\)](http://links.lww.com/JBJS/F585). ■

Caroline P. Thirukumaran, MBBS, MHA, PhD¹
Brian E. McGarry, PhD, PT²
Laurent G. Glance, MD¹
Meiling Ying, MA¹
Benjamin F. Ricciardi, MD¹
Xueya Cai, PhD¹
Yue Li, PhD¹

¹University of Rochester, Rochester, New York

²Harvard Medical School, Boston, Massachusetts

Email address for C.P. Thirukumaran:
caroline_thirukumaran@urmc.rochester.edu

ORCID iD for C.P. Thirukumaran: [0000-0003-3316-0951](https://orcid.org/0000-0003-3316-0951)
ORCID iD for B.E. McGarry: [0000-0001-5342-6548](https://orcid.org/0000-0001-5342-6548)
ORCID iD for L.G. Glance: [0000-0003-3381-699X](https://orcid.org/0000-0003-3381-699X)
ORCID iD for M. Ying: [0000-0002-3012-9791](https://orcid.org/0000-0002-3012-9791)
ORCID iD for B.F. Ricciardi: [0000-0001-9384-4840](https://orcid.org/0000-0001-9384-4840)
ORCID iD for X. Cai: [0000-0001-7922-2703](https://orcid.org/0000-0001-7922-2703)
ORCID iD for Y. Li: [0000-0001-7592-0299](https://orcid.org/0000-0001-7592-0299)

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