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Reductions in Readmission Rates Are Associated With Modest Improvements in Patient-reported Health Gains Following Hip and Knee Replacement in England

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Background: Although many hospital readmission reduction initiatives have been introduced globally, health care systems ultimately aim to improve patients' health and well-being. We examined whether the hospitals that report greater success in reducing readmissions also see greater improvements in patient-reported outcomes.

Research Design: We examined hospital groups (Trusts) that provided hip replacement or knee replacement surgery in England between April 2010 and February 2013. For each Trust, we calculated risk-adjusted 30-day readmission rates from administrative datasets. We also obtained changes in patient-reported health between presurgical assessment and 6-month follow-up, using general health EuroQuol five dimensions questionaire (EQ-5D) and EuroQuol visual analogue scales (EQ-VAS) and procedure-specific (Oxford Hip and Knee Scores) measures. Panel models were used to assess whether changes over time in risk-adjusted readmission rates were associated with changes over time in risk-adjusted health gains.

Results: Each percentage point reduction in the risk-adjusted readmission rate for hip replacement was associated with an additional health gain of 0.004 for EQ-5D [95% confidence interval (CI), 0.002–0.006], 0.39 for EQ-VAS (95% CI, 0.26–0.52), and 0.32 for Oxford Hip Score (95% CI, 0.15–0.27). Corresponding figures for knee replacement were 0.003 for EQ-5D (95% CI, 0.001–0.004), 0.21 for EQ-VAS (95% CI, 0.12–0.30), and 0.14 in the Oxford Knee Score (95% CI, 0.09–0.20).

Conclusions: Reductions in readmission rates were associated with modest improvements in patients' sense of their health and well-being at the hospital group level. In particular, fears that efforts to reduce readmission rates have had unintended consequences for patients appear to be unfounded.

Key Words: readmission rates, patient-reported outcome measures, hip and knee replacement surgery, quality of care

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England and the United States have incorporated financial penalties for hospitals with high readmission rates into their payment systems.[1] The English changes were introduced in 2011 as part of a substantial reform package to reduce avoidable unplanned readmissions.[2] In the first year, hospitals providing care for National Health Service (NHS) patients received no reimbursement for readmissions that occurred within 30 days of discharge where the index admission was planned (such for elective surgeries). For unplanned indexed admission (eg, via emergency departments), reimbursement occurred up to a threshold that was designed to reflect the readmission rate expected to occur even with high-quality care. From April 2012, this threshold was applied to determine reimbursement for all readmissions, regardless of the nature of the indexed admission, with monies accumulated from penalties largely being reinvested into postdischarge rehabilitation services. The US program [Hospital Readmission Reduction Program (HRRP)] was introduced in 2012, originally for acute myocardial infarction, heart failure and pneumonia, and in financial year 2015 was extended to cover hip and knee replacement and chronic obstructive pulmonary disease. Following HRRP's introduction, readmission rates for the targeted conditions have fallen in the United States, from 21.5% in 2007 to 17.8% in 2015,[3,4] possibly as a consequence of enhanced efforts stemming from HRRP.[5]

The focus on readmission rates has arisen partly because of their link to the quality and safety of the initial hospital stay,[6,7] transitional care services,[8–10] and postdischarge support.[11,12] However, while those associations have helped to establish the evidence base for using readmissions as a quality

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measure, it has been unclear how they relate to other domains of health care quality and in particular, patients' own sense of health and well-being.[13] Answering this question has proven difficult due to the lack of a systematic approach to collecting patient-reported outcome measures (PROMs) in many health care systems but, in this paper, we use a novel dataset from the English NHS, which contains PROMs for over 270,000 patients undergoing hip or knee replacement surgery since 2009.[14] We focus on hip and knee replacements, as these are both common elective surgeries meant to improve patients' functional outcomes though have substantial 30-day readmission rates (8.5% and 5.5%, respectively),[15,16] relevant to the HRRP expansion and the readmission penalties in England.

Various initiatives have been introduced to reduce readmissions following hip and knee replacement in England. These include "enhanced recovery programs" consisting of preoperative education, new anesthetic techniques, and postoperative rehabilitation plans[17]; nurse-led telephone helplines that offer advice following hospital discharge[18]; and orthopedic outreach services offering follow-up care outside of hospital settings.[19] Each intervention may have affected both readmission rates (eg, by strengthening the patients' ability to self-care, including managing pain or dressing wounds) and patient-reported health outcomes such as mobility or pain (eg, through exercise management). However, even though specific interventions have been evaluated individually,[20] it is still unclear whether, at a system level, reductions in readmission rates have coincided with improvements in broader patient outcomes. Assessing the association between these 2 is critical because of concerns that, by incentivizing hospitals to reduce readmission rates, there may have been unintended consequences for other aspects of care quality,[21–24] for example, if the penalties displaced follow-up activity from inpatient settings to other care settings (such as observation units) that are not included in the readmission metrics yet might have implications for patient care[4]; or had disproportionate impacts on some hospitals groups.[25,26]

Clearly, if a focus on readmission rates is having detrimental impacts on other patient outcomes, then the implications will warrant careful attention, and some corrective action may be needed for national policy or local implementation.[27] If, however, changes in readmission rates and PROMs are independent, then this might suggest that incentives to lower readmission rates cannot be relied upon to improve these aspects of care, and that (even though readmission penalties bring benefits) they might need to be supplemented with other approaches to improve patient-reported health gains. As no studies have been able to examine associations between readmissions and patient-reported outcomes at the institutional-level, we use the novel data from the English NHS to examine whether those hospitals that showed larger improvements in readmission rates also showed larger improvements in patients' long-term self-assessments of health gain following surgery.

METHODS

Study Sample

We focused on the period beginning with the publication of the 2010 Government white paper that introduced many readmission reduction initiatives in England,[28] and ending with a major reorganization of the NHS in 2013. We studied all NHS Trusts (health care providers that can combine a number of hospital sites, with on an average 3 orthopedic units each)[29] that conducted hip and knee surgeries during this period, regardless of procedure volume.

We used the Hospital Episode Statistics (HES) database to identify patients who underwent hip or knee replacement surgery at NHS Trusts. HES is a national administrative database, containing information on patient characteristics, diagnoses, and treatments for all admissions to NHS Trusts in England. We included both primary and revision surgeries for the hip and knee surgeries, defined using the Classification of Intervention and Procedure Codes (OPCS-4) given in Appendix A (Supplemental Digital Content 1, http://links.lww.com/MLR/B446 and Supplemental Digital Content 2, http://links.lww.com/MLR/B447).[30]

We studied all patients aged 18 or over undergoing a planned hip and knee replacement between April 1, 2010 and February 28, 2013. Patients undergoing hip or knee surgery in March 2013 were excluded to allow for sufficient follow-up to calculate 30-day readmission rates within the constraints of the available data. We also excluded patients for whom we were lacking the requisite data for risk-adjustment (see below). Patients experiencing multiple admissions for a hip or knee replacement were treated as separate observations in the analysis, provided both admission episodes were separated by >30 days.

Readmission Rates

We calculated readmissions rates using HES data in a way that is consistent with national readmission reduction policies in England, namely as all-cause, unplanned admissions occurring within 30 days of discharge following an index admission for hip or knee replacement. We risk-adjusted the readmission rates by conducting logistic regression at the patient level, adjusting for age, sex, ethnicity, comorbidities based on the Charlson Index, socioeconomic deprivation score (Index of Multiple Deprivation based on small geographic areas, each containing on an average 1500 residents),[31] and length of stay. Consistent with the risk-adjustment methodology for PROMs (see below), we calculated risk-adjusted readmission rates at the Trust level, for each financial year, by taking the ratio of observed to predicted readmissions for the Trust, and multiplying this ratio by the average readmission rate across all Trusts.

PROMs

Unlike many other health care systems, the NHS has collected information on patient-reported outcome measures since 2009. Intended to encourage transparent reporting of variations in care and to promote increases in efficiency,[32] the PROMs program covers the treatment of varicose veins, hip and knee replacements, and hernia repair.[33] Patients are asked to complete 1 questionnaire at preoperative assessment or on admission. Respondents to that first questionnaire are then mailed a postoperative survey 6 months after their procedure, including 1 reminder for nonresponders.

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We assessed changes in health gain following hip and knee replacement surgery using both general EuroQuol five dimensions questionaire (EQ-5D) and EuroQuol visual analogue scales (EQ-VAS) and procedure-specific (Oxford Hip Score and Oxford Knee Score) instruments. EQ-5D is a general measure of quality-of-life, and consists of 5 dimensions, namely patient mobility, self-care, activity status, pain/discomfort, and anxiety/depression. Patient assessments were converted into quality-of-life scores using utilities derived from trade-offs within a representative population (UK), and range from −0.59 (worse than death), through 0.00 (dead) to 1.00 (perfect health). EQ-VAS measures subjective health status using a single graphical scale, which ranges between 0 and 100. The Oxford Hip and Knee Scores were developed to measure health outcomes following these specific procedures,[34] such as functional status, including limping when walking due to the hip or knee. Both questionnaires include 12 items with 4 dimensions, and produce scores that range between 0 (severe symptoms and disability) and 48 (no problems). Previous research has assumed that, to be clinically significant, a minimal difference is required equal to 0.14 for EQ-5D, 8.4 for the Oxford Hip Score, and 3.8 for the Oxford Knee Score.[35] However, these differences are for individual patients and may not be appropriate for judging the means of populations.

Risk-adjustment of PROMs

We used publicly available summaries of PROMs data, reported for each Trust and financial year by the NHS Digital.[36] These data relate to average, risk-adjusted changes in health gain among the patients who returned both preoperative and postoperative questionnaires. The risk-adjustment was based on applying ordinary least squares regression models to the postquestionnaire score, adjusting for patient age, sex, comorbidities (self-reported), socioeconomic deprivation score, patient self-reported health status (from the preoperative questionnaire), discharge destination, length of stay, and timing of questionnaire completion.[37] For each Trust and financial year, the observed mean postoperative score was divided by the predicted mean postoperative score to indicate the extent to which the provider over or underperformed relative to the level expected. That ratio was then multiplied by the national average postoperative score to estimate the postoperative score that would have been achieved by the Trust had they treated a national average case-mix of patients. Finally, the risk-adjusted health gain for a given Trust was calculated by subtracting the national average preoperative PROMs score from the Trust-specific risk-adjusted postoperative PROMs score.

We linked the readmissions and PROMs data, separately for each operation (hip and knee replacement), Trust, and financial year (2010/2011, 2011/2012, and 2012/2013). We also assembled data on response rates for each Trust for use in the statistical analysis.

Statistical Analysis

Our analysis was conducted at the Trust level, and separately for each procedure (hip and knee replacement) and for the 3 corresponding PROMs. We used panel data models[38] that make use of PROMs information across multiple Trusts and time periods. In effect, these assessed whether changes over time in risk-adjusted readmission rates were related to changes over time in risk-adjusted health gains in the same Trusts. This approach deals with confounding due to differences in the characteristics of Trusts (whether observed and unobserved) provided the relationship between these characteristics and the outcome is constant over time. We used generalized least squares regression estimators with the risk-adjusted health gain as the dependent variable, and the risk-adjusted readmission rate as the explanatory variable.

We used the Hausman model specification test to determine whether Trusts should be entered as fixed or random effects in the panel data models, and as a result preferred random effects for all knee replacement models. For hip replacement, we preferred fixed effects when modeling EQ-5D and EQ-VAS, and random effects for the Oxford Hip Scores (see Appendix B, Supplemental Digital Content 3, http://links.lww.com/MLR/B448). We report the goodness of model fit using the R^2 statistics.

We tested several approaches to handling nonresponse to the PROMs data. First, we constructed regression models without controlling for response rates. Second, we entered the time-varying, Trust-level response rate into the regressions as an additional adjustment variable. Third, we repeated our modeling for Trusts reporting a minimum response rate of 60%. We also tested the impact of controlling for the Trust's mortality rate, which we calculated using data on deaths that occurred in hospital within 6 months of discharge.

Approach to Missing Data and Sensitivity Analysis

In some cases, data were missing for entire Trusts, either because PROMs data were unreported or because the Trusts had not been in existence for the entire period. In our main analysis, we included Trusts without PROMs data for 1 year, and thus required only that Trusts reported data for ≥ 2 years (thus, we had an unbalanced panel). As a sensitivity analysis, we constructed a strictly balanced panel, which was limited to those Trusts with data for all 3 years (see Appendix C, Supplemental Digital Content 4, http://links.lww.com/MLR/B449).

RESULTS

Index Discharges

Between April 2010 and February 2013, 158 Trusts conducted hip replacement surgery and 158 Trusts conducted knee replacement surgery. Of these, 26 of the hip replacement Trusts and 33 of the knee replacement Trusts did not report PROMs data for at least 2 of the 3 years, leaving us with 132 and 125 Trusts for the 2 surgeries, respectively.

We excluded only a small number of patients due to missing data for case-mix adjustment (6589 and 7256 for hip and knee replacement patients, respectively). Our analysis included 135,066 patients discharged alive following hip replacement (corresponding to 347.2 procedures per Trust per year, with a range from 70 to 1174), and 138,042 patients discharged following knee replacement (371.0 procedures per Trust per year, range 62–1148). The characteristics of

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both groups of patients changed only slightly between 2010 and 2013 (Table 1). For example, for both procedures the average length of hospital stay decreased across the study period, from 6.05 days in 2010 to 5.39 days in 2013 for hip replacements, and from 6.05 days in 2010 to 5.38 days in 2013 for knee replacements.

Across the 3 years, 71,168 hip replacement patients returned both preoperative and postoperative PROMs questionnaires and 70,329 did so for knee replacement, equating to response rates of 52.7% and 50.9%, respectively. There was substantial variation in response rates among Trusts, ranging from 12.1% to 84.9% for hip replacement and from 8.6% to 100% for knee replacement. Mean response rates improved slightly across the 3 financial years (50.1%, 51.7%, and 53.5% for hip replacement, and 47.8%, 52.5%, and 57.1% for knee replacement, in 2010/2011, 2011/2012, and 2012/2013, respectively). Among the patients receiving hip replacements between April 2010 and February 2013, 0.99% died in hospital within 6 months of discharge, and for knee replacement the equivalent figure was 0.88%.

Trends in Readmissions and Health Gain

For hip replacement, risk-adjusted readmission rates decreased by 1.6% from 6.5% in 2010 to 4.9% in 2013. Similarly, for knee replacement risk-adjusted readmission rates fell by 1.5% from 6.3% in 2010 to 4.8% in 2013 (Fig. 1). In total, 84.1% of Trusts showed a reduction in risk-adjusted readmission rate following hip replacement during this period, whereas 75.8% did so for knee replacement (Appendix D, Supplemental Digital Content 5, http://links.lww.com/MLR/B450).

For both procedures, patients tended to report higher quality-of-life 6 months after the surgery than before, and these health gains tended to increase over time (Table 1 and Fig. 2). For example, the risk-adjusted gain in EQ-5D following hip replacement increased by 0.03 from 0.39 in April 2010 to 0.42 in March 2013. Likewise, gain in EQ-5D following knee replacement increased by 0.02 over the same time period, from 0.29 to 0.31. Improvements in these measures were reported by 83.8% and 81.4% of Trusts, respectively.

Panel Data Models

Reductions in risk-adjusted readmission rates were associated with improvements in health gain for both groups of patients and all metrics. For example, an absolute 1 percentage point decline in the risk-adjusted readmission rate following hip replacement was associated with a 0.004 (95% confidence interval, 0.002–0.006) unit increase in health gain measured by EQ-5D for those patients (Table 2).

When we controlled for response rates (Appendix E, Supplemental Digital Content 6, http://links.lww.com/MLR/B451), our results showed no substantial difference in comparison with the findings from the main model. Restricting the sample to Trusts with a minimum response rate of 60% (N = 53 for hip replacement, and N = 61 for knee replacement) showed small reductions in coefficient sizes for EQ-VAS and Oxford Hip Score in comparison with the main model (Appendix G, Supplemental Digital Content 8, http://links.lww.com/MLR/B453). Changes in health gain remained statistically significant for all PROMs. When restricting our study sample to Trusts with complete data, we found an increase in coefficient size for

TABLE 1. Summary Statistics for NHS Trusts

	Hip Replacement						Knee Replacement					
	FY 2010/2011		FY 2011/2012		FY 2012/2013		FY 2010/2011		FY 2011/2012		FY 2012/2013	
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
No. operations	350.65	184.09	361.66	192.12	329.67	178.86	384.18	207.38	381.51	200.15	347.56	186.29
Patient age (y)	68.15	1.97	68.10	1.97	68.12	2.01	67.08	2.06	67.20	2.17	67.20	2.24
Female (%)	60.66	4.06	60.65	3.35	60.37	3.77	57.67	4.36	58.24	3.63	57.84	3.93
White (%)	96.27	6.31	96.17	6.80	95.71	7.65	95.53	7.08	95.18	7.48	95.35	7.63
Black (%)	0.90	2.52	0.87	2.32	1.08	3.07	1.20	3.46	1.29	3.76	1.14	3.11
Asian (%)	0.68	1.18	0.58	0.83	0.63	0.98	1.20	1.97	1.10	1.64	1.02	1.50
Living in rural areas (%)	13.40	11.37	13.68	11.66	13.33	11.14	12.61	10.75	12.99	11.23	12.86	10.62
Length of hospital stay (d)	6.05	0.95	5.58	1.14	5.39	1.00	6.05	1.15	5.60	1.22	5.38	1.09
No. admissions from least socioeconomically deprived areas	292.75	156.41	316.29	164.88	270.33	145.55	335.90	205.80	335.20	191.47	298.41	169.54
No. admissions from medium socioeconomically deprived areas	372.41	192.67	389.13	180.59	361.04	180.63	412.95	217.93	409.62	200.65	381.17	194.37
No. admissions from highest socioeconomically deprived areas	389.27	191.42	375.53	222.47	359.64	196.46	405.58	194.19	394.70	204.72	366.66	188.88
Charlson comorbidity index	0.28	0.07	0.29	0.08	0.33	0.07	0.27	0.06	0.27	0.06	0.33	0.06
Adjusted 30-day readmission rate (%)	6.51	2.37	5.97	2.07	4.92	1.74	6.26	2.24	6.16	2.00	4.87	1.62
Change in risk-adjusted EQ-5D (Δ)	0.39	0.03	0.41	0.03	0.42	0.03	0.29	0.03	0.30	0.03	0.31	0.03
Change in risk-adjusted EQ-VAS (Δ)	8.66	1.99	9.66	1.64	11.02	1.83	2.87	1.73	4.09	1.62	4.90	1.44
Change in risk-adjusted Oxford Knee Score (Δ)	19.34	1.28	19.78	1.30	20.61	1.23	—	—	—	—	—	—
Change in risk-adjusted Oxford Hip Score (Δ)	—	—	—	—	—	—	14.57	1.30	14.86	1.18	15.59	1.19
No. NHS Trusts	127	—	130	—	132	—	123	—	125	—	124	

Summary statistics are calculated across Trusts by financial year and procedure separately.
EQ-5D indicates EuroQuol five dimensions questionaire; EQ-VAS, EuroQuol visual analogue scales; FY, Financial year; NHS, National Health Service.

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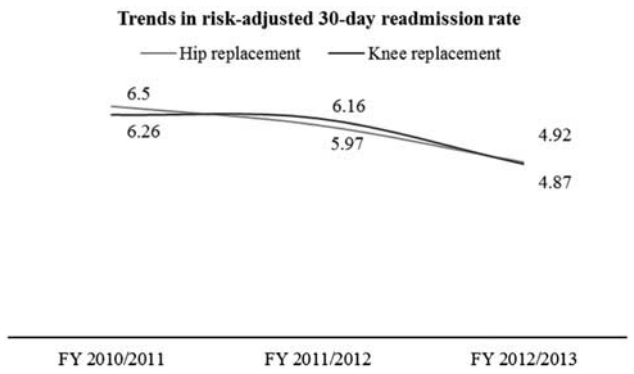

FIGURE 1. Trends in risk-adjusted, 30-day readmission rates across all Trusts. FY indicates Financial year.

EQ-VAS in hip and knee replacements, but no change in coefficients sizes for all other PROMs measures (Appendix C, Supplemental Digital Content 4, http://links.lww.com/MLR/B449). We found no significant associations between health gain and mortality rates.

DISCUSSION

We studied a period that was marked by a sustained focus on readmission reduction in England (2010–2013), over which time risk-adjusted hospital readmission rates fell from 6.5% to 4.9% for patients admitted for hip replacement, and from 6.2% to 4.8% for knee replacement. We found that those hospital Trusts that experienced greater reductions in risk-adjusted readmission rates during this period also tended to show greater improvements in risk-adjusted health gain. For hip replacement, each percentage point reduction in risk-adjusted readmission rates was associated with an additional improvement in general health gain of 0.004 according to EQ-5D and an additional improvement of 0.21 in procedure-specific quality-of-life, over and above what would otherwise be expected. Corresponding improvements for knee replacement were 0.003 and 0.14. These associations were modest, and lower than those that are usually considered to be clinically significant (ie, 0.14 for EQ-5D, 8.4 for Oxford Hip Score, and 3.8 for Oxford Knee Score),[35] though their significance for patients will depend on how the incremental health gains are distributed across the populations concerned. Importantly, we did not find evidence that reductions in readmissions were associated with deteriorations in patient-reported outcomes. Rather, readmission reductions were associated with modest benefits.

To our knowledge, this is the first study to explore the relationship between readmissions and patient-reported outcomes at the hospital level and over time. Previous research has explored the links between readmissions and other measures of care quality, for example, the existence of a climate of patient safety during the initial hospital stay,[6] and the approach to discharge coordination during a patients' transitional care period.[8] One study examined whether patient-reported outcomes following hip and knee replacement correlated with readmission rates, but in that study readmission rates were calculated over 6 months and relied upon self-reported data.[39]

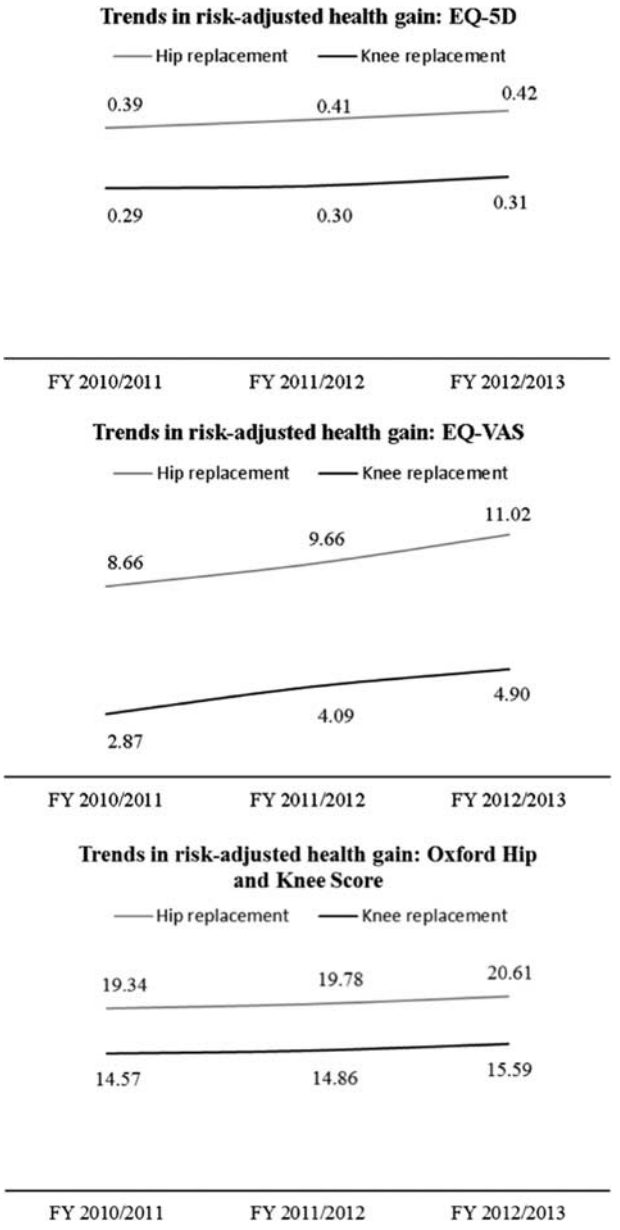

FIGURE 2. Trends in patient-reported outcome measures (average EQ-5D; EQ-VAS; Oxford Hip and Knee Score across all Trusts). EQ-5D indicates EuroQuol five dimensions questionaire; EQ-VAS, EuroQuol visual analogue scales; FY, Financial year.

Strengths and Limitations

We compared readmission rates with health gain at 6 months, to examine whether readmission reductions are associated with longer-term "spillover" effects for patient health. Six months was selected by the PROMs program in England as the earliest time for assessment of benefit postsurgery,[39] following a pilot study that concluded that clinical benefits would be observable to the patient by this point.[40] However, outcomes may continue to improve,[41] and other joint registries use longer time horizons for assessing patient outcomes.[42] One concern for our study was that, although the readmission metric reflected every

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TABLE 2. Unbalanced Panel Data Analysis

Variables	EQ-5D	EQ-VAS	Oxford Hip Score	Oxford Knee Score
30-day readmission rate following hip replacement	0.004***	0.39***	0.21***	—
Coefficient (95% CI)	(0.002–0.006)	(0.26–0.52)	(0.15–0.27)	—
Average no. Trusts per year	130	130	130	—
30-day readmission rate following knee replacement	0.003***	0.21***	—	0.14***
Coefficient (95% CI)	(0.001–0.004)	(0.12–0.30)	—	(0.09–0.20)
Average no. Trusts per year	124	124	—	124

***Variable has robust impact on dependent variable at 1% significance level.
**Variable has robust impact on dependent variable at 5% significance level.
*Variable has robust impact on dependent variable at 10% significance level.
The Hausman test was used to determine the preferred model effect.
Direction of coefficients has been inverted to represent effect of a 1% reduction in the readmission rate on the dependent variable.
The R^2 statistics were 11%, 12%, and 10% for hip replacement, and 6%, 6% and 8% for knee replacement.
CI indicates confidence interval; EQ-5D, EuroQuol five dimensions questionaire; EQ-VAS, EuroQuol visual analogue scales.

patient who was discharged alive, our measurement of health gain was necessarily restricted to those who returned the PROMs questionnaires. Previous studies have indicated that respondents to PROMs questionnaires have fewer preoperative conditions than nonrespondents,[43] have higher rates of literacy,[44] and lower rates of cognitive impairment, including dementia.[45] To investigate this potential threat to the validity of our study, we conducted sensitivity analysis that in addition controlled for the Trust-level response rate for each year. This did not materially change our findings (Appendix E, Supplemental Digital Content 6, http://links.lww.com/MLR/B451), nor did controlling for the 6-month mortality rate (Appendix F, Supplemental Digital Content 7, http://links.lww.com/MLR/B452). We also explored the impacts of restricting the study sample to Trusts with a minimum response rate of 60%, and found only a small change in coefficient sizes compared with the main model (Appendix G, Supplemental Digital Content 8, http://links.lww.com/MLR/B453).

Other studies have examined specific interventions aiming to reduce readmission rates (such as telephone helplines) but we aimed to assess a wide set of initiatives reflective of routine practice. Our nonexperimental design allowed us to compare trends over time in risk-adjusted readmission rates with trends over time in health gain among a large and representative sample of hospitals. The study benefited from a large database that was established in 2009 and now contains patient-reported outcomes for over 270,000 patients before and after hip or knee replacement surgery. We risk-adjusted both the readmission rates and PROMs to account for systematic differences between Trusts in observed patient characteristics, and also adopted a panel data modeling method to minimize confounding caused by constant differences in Trust characteristics (observed or unobserved). However, like any observational study, it is unlikely to discount entirely the possibility that other factors explained the associations seen. Our findings are susceptible to changes in case-mix over time and between Trusts, which cannot fully be reflected within risk-adjustment models applied to existing data, and to time-varying confounders, such as the establishment of specialist hip and knee centers, for example, the opening of the Orthopaedic Unit at The Mid Yorkshire Hospitals NHS Trust in 2013.[46]

Further studies could examine the mechanism of effect, for example, whether our findings reflect the impact of interventions aimed at reducing readmission rates on health gain (such as improved discharge support for patients), or efforts to improve both metrics simultaneously (such as perioperative rehabilitation programs).[47] These studies might benefit from collecting PROMs data on a more frequent basis, to test for deviations in patient health at around the time of the readmission. Studies could also explore whether our findings will generalize to other patient groups (eg, medical as well as surgical admissions), settings, and health care systems.

CONCLUSIONS

Declines in readmission rates after hip and knee replacement in England were accompanied by modest improvements in patient-reported health gain. These results persisted across different measures of patient-reported health status, thereby suggesting that readmission reductions have not resulted in unintended harm to patients, as previously feared. It is possible that readmission rates and patient-reported outcome measures relate to different dimensions of quality, and that although improvements in each are reflective of gains for patients, these gains materialize through different mechanisms.

Our findings underscore the need for more systematic approaches to collect patient-reported outcomes data across health care systems,[48] so that health gains can be studied more directly than is currently possible. Indeed, this study is an example of how large databases of patient-reported outcomes can be analyzed to produce insights about health care quality.

REFERENCES

1. Kristensen SR, Bech M, Quentin W. A roadmap for comparing readmission policies with application to Denmark, England, Germany and the United States. *Health Policy*. 2015;119:264–273.
2. Department of Health. Payment by results guidance for 2011-12. 2011. Available at: http://webarchive.nationalarchives.gov.uk/20130507170152/https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/151911/dh_126157.pdf.pdf. Accessed July 12, 2017.
3. Barrett ML, Wier LM, Jiang J, et al. *All-Cause Readmissions by Payer and Age, 2009-2013*. Rockville, MD: Agency for Healthcare research and quality; 2015.
4. Zuckerman RB, Sheingold SH, Orav EJ, et al. Readmissions, observation, and the hospital readmissions reduction program. *N Engl J Med*. 2016;374:1543–1551.
5. Joynt KE, Figueroa JF, Orav EJ, et al. Opinions on the Hospital Readmission Reduction Program: results of a national. *Am J Manag Care*. 2016;22:287–294.
6. Hansen LO, Williams MV, Singer SJ. Perceptions of hospital safety climate and incidence of readmission. *Health Serv Res*. 2011;46:596–616.

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7. Ashton CM, Del Junco DJ, Souchek J, et al. The association between the quality of inpatient care and early readmission: a meta-analysis of the evidence. *Med Care*. 1997;35:1044–1059.
8. Feltner C, Jones CD, Cene CW, et al. *Transitional Care Interventions To Prevent Readmissions for People With Heart Failure*. Rockville, MD: Agency for Healthcare research and quality; 2014.
9. Rennke S, Ranji SR. Transitional care strategies from hospital to home: a review for the neurohospitalist. *Neurohospitalist*. 2015;5:35–42.
10. Lee KH, Low LL, Allen J, et al. Transitional care for the highest risk patients: findings of a randomised control study. *Int J Integr Care*. 2015; 15:1–19.
11. Harrison JD, Auerbach AD, Quinn K, et al. Assessing the impact of nurse post-discharge telephone calls on 30-day hospital readmission rates. *J Gen Intern Med*. 2014;29:1519–1525.
12. Phillips CO, Wright SM, Kern DE, et al. Postdischarge support for older patients. *JAMA*. 2004;291:1358–1367.
13. Hostetter M, Klein S. Using patient-reported outcomes to improve health care quality. *The Commonwealth Fund*. 2011. Available at: www.commonwealthfund.org/publications/newsletters/quality-matters/2011/december-january-2012/in-focus. Accessed July 19, 2016.
14. Digital N. Time-series Analysis: PROMs from 2009-10 to 2014-15. 2015. Available at: http://digital.nhs.uk/catalogue/PUB18819. Accessed December 15, 2016.
15. Cram P, Lu X, Kaboli PJ, et al. Clinical characteristics and outcomes of Medicare patients undergoing total hip arthroplasty, 1991-2008. *JAMA*. 2011;305:1560–1567.
16. Huddleston JI, Maloney WJ, Wang Y, et al. Adverse events after total knee arthroplasty. *J Arthroplasty*. 2009;24:95–100.
17. Wright J, Cullinger B, Bacarese-hamilton I. Postoperative analgesia for enhanced recovery in joint replacement: audit of a new electronic prescribing order set. *BMJ Qual Improv Rep*. 2015;4:1–4.
18. Northumbria Healthcare National Health Service (NHS) Foundation Trust. New orthopaedic helpline reduces unnecessary hospital readmissions. 2012. Available at: www.northumbria.nhs.uk/news/new-orthopaedic-helpline-reduces-unnecessary-hospital-readmissions. Accessed April 24, 2017.
19. Guy's and St Thomas' National Health Service (NHS) Foundation Trust. Hip and knee replacement patients helped to recover at home. 2013. Available at: www.guysandstthomas.nhs.uk/news-and-events/2013-news/20130129-knee-replacement.aspx. Accessed April 27, 2017.
20. Alnaib M, Agni NR, Shaw N. Approaches to delivery of care at home following elective hip and knee joint replacement surgery. *Open J Ther Rehabil*. 2015;3:97–100.
21. Naylor MD, Kurtzman ET, Grabowski DC, et al. The care span unintended consequences of steps to cut readmissions and reform payment may threaten care of vulnerable older adults. *Health Aff*. 2012;31:1623–1632.
22. Mason D. The unintended consequences of the "Observation Status" policy. *JAMA*. 2014;312:1959–1960.
23. Carey K, Lin M-Y. Readmissions to New York hospitals fell for three target conditions from 2008 to 2012, consistent with Medicare goals. *Health Aff (Millwood)*. 2015;34:978–985.
24. Gu Q, Koenig L, Faerberg J, et al. The medicare hospital readmissions reduction program: potential unintended consequences for hospitals serving vulnerable populations. *Health Serv Res*. 2014;49:818–837.
25. Figueroa JF, Wang DE, Jha AK. Characteristics of hospitals receiving the largest penalties by US pay-for-performance programmes. *BMJ Qual Saf*. 2016;25:898–900.
26. Bernheim SM, Parzynski CS, Horwitz L, et al. Accounting for patients socioeconomic status does not change hospital readmission rates. *Health Aff*. 2016;35:1461–1470.
27. Friebel R, Steventon A. The multiple aims of pay-for-performance and the risk of unintended consequences. *BMJ Qual Saf*. 2016;25:827–831.
28. Department of Health Payment by Results Team. Payment by results guidance for 2010-11. Department of Health. 2010.
29. National Joint Registry. A-Z of hospitals. Available at: www.njrsurgeonhospitalprofile.org.uk/HospitalListing. Accessed April 24, 2017.
30. Health and Social Care Information Centre. Monthly patient reported outcome measures (PROMs) in England. 2015.
31. Department for Communities and Local Government. English indices of deprivation 2010. 2011. Available at: www.gov.uk/government/statistics/english-indices-of-deprivation-2010. Accessed May 13, 2015.
32. Department of Health. Equity and excellence: liberating the NHS (white paper). 2010:61.
33. Devlin NJ, Appleby J. *Getting the Most Out of PROMs: Putting Health Outcomes at the Heart of NHS Decision-Making*. London, England: The King's Fund; 2010.
34. Dawson J, Fitzpatrick R, Carr A, et al. Questionnaire on the perceptions of patients about total hip replacement. *J Bone Joint Surg Br*. 1996;78: 185–190.
35. Browne JP, van der Meulen JH, Lewsey JD, et al. Mathematical coupling may account for the association between baseline severity and minimally important difference values. *J Clin Epidemiol*. 2010;63: 865–874.
36. National Health Service (NHS) Digital. Patient reported outcome measures (PROMs). Available at: http://content.digital.nhs.uk/proms. Accessed October 17, 2016.
37. Coles J. *PROMs Risk Adjustment Methodology Guide for General Surgery and Orthopaedic Procedures*. Hemel Hempstead: Northgate Information Solutions Limited; 2010.
38. Wooldridge JM. *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA/London, England: The MIT Press; 2002:752.
39. Grosse Frie K, Van Der Meulen J, Black N. Relationship between patients' reports of complications and symptoms, disability and quality of life after surgery. *Br J Surg*. 2012;99:1156–1163.
40. Browne J, Jamieson L, Lewsey J, et al. Patient reported outcome measures (PROMs) in elective surgery. *Rep to Dep Heal*. 2007. Available at: www.lshtm.ac.uk/php/departmentofhealthservicesresearchandpolicy/assets/proms_report_12_dec_07.pdf. Accessed December 12, 2016.
41. Browne JP, Bastaki H, Dawson J. What is the optimal time point to assess patient-reported recovery after hip and knee replacement? A systematic review and analysis of routinely reported outcome data from the English patient-reported outcome measures programme. *Health Qual Life Outcomes*. 2013;11:128.
42. Rolfson O, Bohm E, Franklin P, et al. Patient-reported outcome measures in arthroplasty registries Report of the Patient-Reported Outcome Measures Working Group of the International Society of Arthroplasty Registries Part II. Recommendations for selection, administration, and analysis. *Acta Orthop*. 2016;87(suppl 1):9–23.
43. Hutchings A, Grosse Frie K, Neuburger J, et al. Late response to patient-reported outcome questionnaires after surgery was associated with worse outcome. *J Clin Epidemiol*. 2013;66:218–225.
44. Jahagirdar D, Kroll T, Ritchie K, et al. Patient-Reported Outcome Measures for chronic obstructive pulmonary disease. *Patient*. 2013;6: 11–21.
45. Gibbons E, Black N, Fallowfield L, et al. Patient-reported outcome measures and the evaluation of services. *Health Serv Deliv Res*. 2016;4: 55–68.
46. The Mid Yorkshire Hospitals NHS Trust. Yvette Cooper MP opens new orthopaedic unit at Pontefract Hospital. 2013. Available at: www.midyorks.nhs.uk/-yvette-cooper-mp-opens-new-orthopaedic-unit-at-pontefract-hospital. Accessed February 12, 2017.
47. Ibrahim MS, Khan Ma, Nizam I, et al. Peri-operative interventions producing better functional outcomes and enhanced recovery following total hip and knee arthroplasty: an evidence-based review. *BMC Med*. 2013;11:37.
48. Rolfson O, Eresian Chenok K, Bohm E, et al. Patient-reported outcome measures in arthroplasty registries. *Acta Orthop*. 2016;87(suppl 1):3–8.

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