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Association of the Hospital Readmissions Reduction Program Implementation With Readmission and Mortality Outcomes in Heart Failure

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IMPORTANCE Public reporting of hospitals' 30-day risk-standardized readmission rates following heart failure hospitalization and the financial penalization of hospitals with higher rates have been associated with a reduction in 30-day readmissions but have raised concerns regarding the potential for unintended consequences.

OBJECTIVE To examine the association of the Hospital Readmissions Reduction Program (HRRP) with readmission and mortality outcomes among patients hospitalized with heart failure within a prospective clinical registry that allows for detailed risk adjustment.

DESIGN, SETTING, AND PARTICIPANTS Interrupted time-series and survival analyses of index heart failure hospitalizations were conducted from January 1, 2006, to December 31, 2014. This study included 115 245 fee-for-service Medicare beneficiaries across 416 US hospital sites participating in the American Heart Association Get With The Guidelines-Heart Failure registry. Data analysis took place from January 1, 2017, to June 8, 2017.

EXPOSURES Time intervals related to the HRRP were before the HRRP implementation (January 1, 2006, to March 31, 2010), during the HRRP implementation (April 1, 2010, to September 30, 2012), and after the HRRP penalties went into effect (October 1, 2012, to December 31, 2014).

MAIN OUTCOMES AND MEASURES Risk-adjusted 30-day and 1-year all-cause readmission and mortality rates.

RESULTS The mean (SD) age of the study population (n = 115 245) was 80.5 (8.4) years, 62 927 (54.6%) were women, and 91 996 (81.3%) were white and 11 037 (9.7%) were black. The 30-day risk-adjusted readmission rate declined from 20.0% before the HRRP implementation to 18.4% in the HRRP penalties phase (hazard ratio (HR) after vs before the HRRP implementation, 0.91; 95% CI, 0.87-0.95; $P < .001$). In contrast, the 30-day risk-adjusted mortality rate increased from 7.2% before the HRRP implementation to 8.6% in the HRRP penalties phase (HR after vs before the HRRP implementation, 1.18; 95% CI, 1.10-1.27; $P < .001$). The 1-year risk-adjusted readmission and mortality rates followed a similar pattern as the 30-day outcomes. The 1-year risk-adjusted readmission rate declined from 57.2% to 56.3% (HR, 0.92; 95% CI, 0.89-0.96; $P < .001$), and the 1-year risk-adjusted mortality rate increased from 31.3% to 36.3% (HR, 1.10; 95% CI, 1.06-1.14; $P < .001$) after vs before the HRRP implementation.

CONCLUSIONS AND RELEVANCE Among fee-for-service Medicare beneficiaries discharged after heart failure hospitalizations, implementation of the HRRP was temporally associated with a reduction in 30-day and 1-year readmissions but an increase in 30-day and 1-year mortality. If confirmed, this finding may require reconsideration of the HRRP in heart failure.

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Supplemental content

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Heart failure (HF) is the leading cause of readmissions among Medicare beneficiaries.[1] The Patient Protection and Affordable Care Act of 2010 established the Hospital Readmissions Reduction Program (HRRP), which initially targeted readmissions from HF, acute myocardial infarction, and pneumonia. The HRRP involved public reporting of hospitals' 30-day risk-standardized readmission rates and created financial penalties for hospitals with higher readmissions. The penalties went into effect in fiscal year 2013 (October 2012) following a penalty-free implementation phase of public reporting of risk-standardized mortality rates from the time of passage of the law in March 2010 to September 2012. Excess HF readmissions have been the dominant driver of penalties in the HRRP.[2]

The establishment of statutory financial penalties for readmissions were intended to incentivize hospitals to improve care quality, including care transitions, to reduce readmission rates.[3] However, incentives to reduce readmissions can potentially encourage inappropriate care strategies, such as discouraging appropriate triage for emergency care, delaying hospital readmissions beyond discharge day 30, or increasing observation stays without admitting patients.[4] This potential has prompted concern that a policy emphasizing 30-day readmissions reduction may adversely affect patient outcomes. Previous cross-sectional and temporal studies have found an inverse association between hospitals' readmission and mortality rates following hospitalization for HF, although such associations have been modest, using claims data and the HRRP statistical methods.[5-7]

Recent publications have analyzed 30-day readmissions after the implementation of the HRRP and found that the implementation has been associated with a reduction in 30-day readmissions and thus suggest the program has been a success in improving care and outcomes.[8,9] However, the association between the HRRP implementation and mortality is not known, particularly after detailed clinical differences within the complex HF population are considered. In this study, we aimed to examine the association of the HRRP implementation with risk-adjusted readmissions and risk-adjusted mortality among fee-for-service Medicare beneficiaries discharged with HF in whom comprehensive, prospectively captured clinical information was available.

Key Points

Question What is the association of the Hospital Readmissions Reduction Program with the temporal trends in readmission and mortality rates among fee-for-service Medicare beneficiaries hospitalized with heart failure?

Findings In this observational study of 115 245 fee-for-service Medicare beneficiaries hospitalized with heart failure at 416 sites across the United States, implementation of the Hospital Readmissions Reduction Program was associated with a subsequent decrease in 30-day and 1-year risk-adjusted readmissions and an increase in 30-day and 1-year risk-adjusted mortality.

Meaning These findings support the possibility that the Hospital Readmissions Reduction Program has had the unintended consequence of increased mortality in patients hospitalized with heart failure.

Methods

Data Source

We used data from the American Heart Association's Get With The Guidelines-Heart Failure (GWTG-HF) registry and the linked Medicare Part A inpatient fee-for-service claims files. The GWTG-HF is an observational ongoing national voluntary quality improvement program initiated in 2005. The details of the design and objectives of the GWTG-HF registry have been described previously.[10,11] The registry includes patients admitted with HF as the primary diagnosis or those who developed significant HF symptoms during the hospitalization. It is representative of hospitals from all regions and various hospital types across the United States. Trained personnel at the participating hospital sites use an internet-based patient management tool (Quintiles Real-World & Late Phase Research) to collect patient-level information on consecutive HF admissions. Data collected include both patient-level characteristics (patient demographics, medical history, medications, laboratory data, and intra-hospital procedures) and hospital-level characteristics. The centers participating in the GWTG-HF are required to obtain institutional review board approval for the GWTG-HF protocol and are granted a waiver for informed consent under the common rule. Data were collected from January 1, 2006, to December 31, 2014. Data analysis took place from January 1, 2017, to June 8, 2017.

The aggregate deidentified data are analyzed at the Duke Clinical Research Institute, which serves as the data analysis center. Postdischarge outcomes were obtained from the linked Medicare inpatient claim files and the associated denominator files. The inpatient claims files contain the institutional claims related to the services provided during the inpatient stay. The associated denominator files contain the data on Medicare enrollment and mortality. The linkage between GWTG-HF registry patients and Medicare inpatient claim and denominator files was done using admission and discharge dates, hospital, date of birth, and sex.[12]

Study Cohort

The study cohort comprised fee-for-service Medicare beneficiaries aged 65 years or older who were discharged with HF from January 1, 2006, to December 31, 2014, at one of the GWTG-HF participating hospital sites and who had the Centers for Medicare & Medicaid Services-linked data available. If a patient had multiple hospitalizations during this time interval, the first hospitalization with HF was counted as the index hospitalization and any subsequent hospitalization was regarded as a readmission. Patients with index hospitalization length of stay greater than 30 days or who died in the hospital were excluded. In addition, patients who underwent placement of a left ventricular assist device or heart or heart-lung transplant within 30 days of index hospitalization were excluded. Patients who transferred into the GWTG-HF hospitals from other presenting hospitals for further management

were also excluded. Patients who transferred out of GWTG-HF hospitals were retained in the study cohort. The study cohort selection is detailed in eFigure 1 in the Supplement. The final study cohort consisted of 115 245 index hospitalizations in 115 245 unique patients from 416 hospital sites across the United States.

Exposure

The exposure of interest was the time intervals related to the implementation of the HRRP. The study period was divided into 3 phases: (1) pre-HRRP implementation phase—before the HRRP implementation from January 1, 2006, to March 31, 2010; (2) HRRP implementation phase—during the HRRP implementation from April 1, 2010, to September 30, 2012; and (3) HRRP penalties phase—after the HRRP implementation when the statutory financial penalties went into effect on October 1, 2012, to the end of the study period on December 31, 2014.

Readmissions and Mortality

The primary outcomes of interest were the 30-day and 1-year all-cause risk-adjusted readmissions as well as the 30-day and 1-year risk-adjusted mortality. The secondary outcomes of interest were the 30-day and 1-year HF-specific risk-adjusted readmissions. The day of discharge marked the start of the follow-up time for the outcomes. Risk adjustment was made for the patient-level and hospital-level characteristics. Patient-level characteristics included age, sex, race/ethnicity, diabetes, hypertension, hyperlipidemia, ischemic history (known coronary artery disease, history of myocardial infarction, previous percutaneous coronary intervention, or previous coronary artery bypass grafting), stroke or transient ischemic attack, peripheral arterial disease, chronic renal insufficiency (serum creatinine level >2.0 mg/dL), left ventricular ejection fraction group (reduced, borderline, or preserved), anemia, chronic obstructive pulmonary disease or asthma, systolic blood pressure at admission, and heart rate at admission. Hospital-level characteristics included teaching hospital status, transplant center, rural location, hospital size (number of beds), and geographic region. A secondary analysis of the readmission and mortality outcomes was carried out after excluding patients who were discharged to hospice. We also conducted sensitivity analyses of the primary readmission and mortality outcomes after including transferred patients (n = 8622) in the study cohort and in the subset of patients (n = 72 814) from hospital sites that continuously participated in GWTG-HF registry throughout the study period. For the primary and secondary outcomes, we tested interactions by race/ethnicity, teaching hospital status, and rural or urban hospital location.

Statistical Analysis

Patient and hospital characteristics across the HRRP periods were compared using standardized mean differences, with a standardized mean difference greater than 10 indicating an imbalance between groups.

The overall 30-day and 1-year risk-adjusted readmission and mortality rates for the HRRP periods were estimated using hierarchical Poisson models with random effects for the HRRP period and with an offset for follow-up times. The monthly 30-day and 1-year risk-adjusted readmission and mortality rates were estimated using hierarchical Poisson models with random effects for month and hospital and with an offset for follow-up times. Linear regression using generalized estimating equations to account for within-hospital clustering was used to examine trend. An interrupted time-series analysis was implemented using linear splines with knots at April 1, 2010, and at October 1, 2012, to allow for a change in trend slope with constant level at knots, as a change in policy is unlikely to lead to a sudden change in outcome level. The rates were weighted for number of index hospitalizations in each month. These models were further adjusted for seasonality.

Cox proportional hazards regression models were used to analyze the effect of the HRRP period on 30-day and 1-year risk-adjusted readmission and mortality rates. For readmission outcomes, death was assumed to be a competing risk in the models and the cause-specific hazards were modeled. The proportional hazards assumption was examined using Schoenfeld residuals, and there was no evidence that the proportional hazards assumption was violated.

Missing rates were as follows: age (0.0%), sex (0.0%), race/ethnicity (1.9%), medical history variables (6.2%), left ventricular ejection fraction group (3.9%), systolic blood pressure at admission (19.1%), heart rate at admission (19.2%), teaching hospital status (0.4%), transplant center (24.3%), rural location (0.2%), hospital size (0.3%), and geographic region (0.0%). Multiple imputation was used to handle missing data in the models. Hospital characteristics were not imputed. Variance inflation factors were less than 5 for all covariates, indicating the colinearity was not an issue between the variables in the models.

Data were analyzed using SAS, version 9.4 (SAS Institute Inc). All statistical tests were 2-sided with a $P < .05$ indicating statistical significance.

Results

Index Hospitalizations

Baseline patient demographics, comorbidities, and hospital characteristics were similar between the 3 HRRP periods (**Table 1**). The mean (SD) age of the study population (n = 115 245) was 80.5 (8.4) years, 62 927 (54.6%) were women, and 91 996 (81.3%) were white and 11 037 (9.7%) were black. The distribution of markers for the severity of HF admission, including systolic blood pressure, heart rate, serum sodium, blood urea nitrogen, serum creatinine, and hemoglobin values at admission or use of intra-aortic balloon pump, was balanced across the 3 HRRP periods (Table 1).

Readmissions and Mortality

The unadjusted 30-day all-cause readmission rate declined from 20.1% in the pre-HRRP implementation phase to 18.7% in the HRRP penalties phase. At the same time, unadjusted 30-day mortality rate increased from 7.6% in the pre-HRRP implementation phase to 9.3% in the HRRP penalties phase. The 30-day all-cause risk-adjusted readmission rate declined from 20.0% in the pre-HRRP implementation phase to 18.4% in the

Table 1. Baseline Patient and Hospital Characteristics[a]

Variable[b]	Overall, No. (%) (N = 115 245)	Pre-HRRP Implementation Phase, No. (%) (n = 39 226)	HRRP Implementation Phase, No. (%) (n = 35 222)	HRRP Penalties Phase, No. (%) (n = 40 797)	SMD1[c]	SMD2[d]
Demographics						
Age, mean (SD), y	80.5 (8.4)	80.1 (8.1)	80.6 (8.4)	80.9 (8.6)	6.0	8.9
Female sex	62 927 (54.6)	21 493 (54.8)	19 498 (55.4)	21 936 (53.8)	1.1	−2.1
Race/ethnicity						
White	91 996 (81.3)	31 230 (80.8)	27 385 (81.0)	33 381 (82.1)	−4.6	5.6
Black	11 037 (9.7)	4052 (10.5)	3306 (9.8)	3679 (9.1)	−3.2	−4.4
Hispanic	5521 (4.9)	1809 (4.7)	1755 (5.2)	1957 (4.8)	1.7	0.9
Comorbidities						
Diabetes	42 438 (39.2)	13 812 (38.6)	12 464 (39.1)	16 162 (40.0)	1.1	2.9
Hypertension	84 372 (78.0)	26 587 (74.2)	25 014 (78.4)	32 771 (81.0)	9.9	16.4
Hyperlipidemia	53 606 (49.6)	15 220 (42.5)	16 256 (51.0)	22 130 (54.7)	17.1	24.6
Ischemic history[e]	61 763 (57.1)	20 398 (57.0)	18 436 (57.8)	22 929 (56.7)	1.7	−0.5
Previous stroke/transient ischemic attack	17 733 (16.4)	5582 (15.6)	5199 (16.3)	6952 (17.2)	2.0	4.3
Peripheral vascular disease	14 074 (13.0)	4624 (12.9)	4086 (12.8)	5364 (13.3)	−0.3	1.1
Chronic renal insufficiency	22 496 (20.8)	6537 (18.3)	6740 (21.1)	9219 (22.8)	7.3	11.3
Chronic dialysis	3204 (3.0)	1043 (2.9)	977 (3.1)	1184 (2.9)	0.9	0.1
COPD or asthma	31 475 (29.1)	9888 (27.6)	9296 (29.2)	12 291 (30.4)	3.4	6.1
Anemia	21 347 (19.7)	6385 (17.8)	6429 (20.2)	8533 (21.1)	6.0	8.3
Depression	11 594 (10.7)	3468 (9.7)	3249 (10.2)	4877 (12.1)	1.7	7.6
Current smoking	9460 (8.3)	3459 (8.9)	2835 (8.2)	3166 (7.9)	−2.6	−3.7
Ejection fraction						
Preserved	55 181 (49.8)	17 354 (47.0)	17 198 (50.5)	20 629 (51.8)	9.2	12.7
Borderline	15 192 (13.7)	5060 (13.7)	4662 (13.7)	5470 (13.7)	1.0	1.5
Reduced	40 392 (36.5)	14 478 (39.2)	12 209 (35.8)	13 705 (34.4)	−4.7	−7.0
ICD implant						
ICD only	5324 (6.5)	661 (6.4)	2110 (6.6)	2553 (6.3)	0.7	−0.5
CRT-D only	3368 (4.1)	328 (3.2)	1280 (4.0)	1760 (4.4)	4.4	6.1
ICD or CRT-D	8447 (10.2)	974 (9.5)	3266 (10.2)	4207 (10.4)	6.0	6.6
Vital signs at admission						
SBP, mean (SD), mm Hg	142.2 (29.2)	141.5 (29.2)	142.9 (29.5)	142.3 (28.9)	4.6	2.6
Heart rate, mean (SD), bpm	83.7 (20.0)	83.5 (20.3)	83.6 (19.9)	84.0 (19.6)	0.6	2.8
Respiratory rate, mean (SD), rpm	21.4 (4.9)	21.6 (4.9)	21.4 (4.9)	21.2 (5.0)	−4.0	−8.3
Laboratory values at admission						
Hemoglobin, g/dL, mean (SD)	11.9 (6.1)	12.1 (7.6)	11.7 (3.4)	11.7 (5.2)	−7.5	−6.0
Serum sodium, mEq/L, mean (SD)	137.1 (8.9)	137.0 (10.1)	137.1 (7.3)	137.4 (8.4)	1.8	4.2
BUN, mg/dL, mean (SD)	30.3 (18.0)	30.3 (18.2)	30.2 (18.0)	30.3 (17.8)	4.6	−0.6
Serum creatinine, mg/dL, mean (SD)	1.8 (6.5)	1.7 (2.5)	2.1 (11.1)	1.7 (3.6)	2.0	1.8
In-hospital medications and procedures						
Parenteral inotrope therapy[f]	3226 (2.8)	1409 (3.6)	1128 (3.2)	689 (1.7)	−2.2	−11.9
Intra-aortic balloon pump	63 (0.1)	23 (0.1)	27 (0.1)	13 (0.1)	1.4	−0.2
Length of stay, mean (SD), d	5.1 (3.7)	5.4 (4.1)	5.0 (3.6)	4.8 (3.3)	−10.6	−18.1
Discharge destination						
Home	76 006 (66.0)	27 071 (69.0)	22 942 (65.1)	25 993 (63.7)	−8.3	−11.2
Skilled nursing facility	22 608 (19.6)	7374 (18.8)	6946 (19.7)	8288 (20.3)	2.3	3.8
Inpatient rehabilitation facility	4950 (4.3)	1279 (3.3)	1413 (4.0)	2258 (5.5)	4.0	11.1
Intermediate care facility	1757 (1.5)	1027 (2.6)	430 (1.2)	300 (0.7)	−10.2	−14.7
Long-term care facility	1415 (1.2)	304 (0.8)	470 (1.3)	641 (1.6)	5.5	7.4
Hospice, home	2163 (1.9)	532 (1.4)	658 (1.9)	973 (2.4)	4.1	7.6
Hospice, inpatient	1914 (1.7)	414 (1.1)	597 (1.7)	903 (2.2)	5.5	9.1

(continued)

Table 1. Baseline Patient and Hospital Characteristics[a] (continued)

Variable[b]	Overall, No. (%) (N = 115 245)	Pre-HRRP Implementation Phase, No. (%) (n = 39 226)	HRRP Implementation Phase, No. (%) (n = 35 222)	HRRP Penalties Phase, No. (%) (n = 40 797)	SMD1[c]	SMD2[d]
Hospital characteristics						
Teaching hospital	64 172 (55.9)	23 136 (59.0)	18 799 (53.6)	22 237 (54.9)	−10.8	−8.2
Transplant center	9968 (11.4)	3619 (11.0)	3146 (11.6)	3203 (11.9)	1.9	3.0
Rural location	8549 (7.4)	3095 (7.9)	2348 (6.7)	3106 (7.7)	−4.7	−0.9
Geographic region						
Northeast	38 148 (33.1)	11 870 (30.3)	12 863 (36.5)	13 415 (32.9)	13.3	5.6
Midwest	26 789 (23.3)	9281 (23.7)	7406 (21.0)	10 102 (24.8)	−6.3	2.6
South	38 353 (33.3)	13 887 (35.4)	11 292 (32.1)	13 174 (32.3)	−7.1	−6.6
West	11 955 (10.4)	4188 (10.7)	3661 (10.4)	4106 (10.1)	−0.9	−2.0
Hospital size (No. of beds), mean (SD)	373.8(197.9)	387.1 (200.4)	371.1 (202.4)	363.2 (190.7)	−7.9	−12.2

Abbreviations: BUN, blood urea nitrogen; COPD, chronic obstructive pulmonary disease; CRT-D, cardiac resynchronization therapy-defibrillator; HRRP, Hospital Readmissions Reduction Program; ICD, implantable cardioverter defibrillator; rpm, respirations per minute; SBP, systolic blood pressure; SMD, standardized mean difference.

SI conversion factors: To convert hemoglobin to millimoles per liter, multiply values by 0.6206; serum sodium to millimoles per liter, multiply values by 1.0; BUN to millimoles per liter, multiply values by 0.3571; serum creatinine to micromoles per liter, multiply values by 88.42.

[a] Pre-HRRP implementation phase: January 2006 to March 2010, HRRP implementation phase: April 2010 to September 2012, and HRRP penalties phase: October 2012 to December 2014.

[b] All values are number (percentage) unless specified with the variable. Percentages use denominator without missing data for individual variables.

[c] SMD represents differences in means or proportions divided by the SE and multiplied by 10. SMDs greater than 10 or less than −10 indicate imbalance between the groups. SMD1 compares the HRRP implementation phase with the pre-HRRP implementation phase as reference.

[d] SMD2 compares the HRRP penalties phase with the pre-HRRP implementation phase as reference.

[e] Ischemic history includes medical history of coronary artery disease, previous myocardial infarction, previous percutaneous coronary intervention, or previous coronary artery bypass grafting.

[f] In-hospital use of dopamine hydrochloride, dobutamine hydrochloride, or milrinone lactate.

HRRP penalties phase. At the same time, 30-day risk-adjusted mortality rate increased from 7.2% in the pre-HRRP implementation phase to 8.6% in the HRRP penalties phase. The time-series analysis of 30-day readmissions and mortality in the 3 HRRP periods are shown in **Table 2** and **Figure 1**. There was a significant decline in 30-day all-cause risk-adjusted readmissions in the HRRP penalties phase compared with the pre-HRRP implementation phase (change in slope, −0.039; 95% CI, −0.076 to −0.003). This was accompanied by a significant increase in 30-day risk-adjusted mortality (change in slope in the HRRP penalties phase compared with the pre-HRRP implementation phase, 0.039; 95% CI, 0.024-0.053). The results persisted in the survival analysis after accounting for censoring and competing risk of death for readmissions outcome (**Table 3** and **Figure 2**): the hazard ratio (HR) for the HRRP penalties phase vs pre-HRRP implementation phase was 0.91 (95% CI, 0.87-0.95; $P < .001$) for 30-day risk-adjusted readmissions and was 1.18 (95% CI, 1.10-1.27; $P < .001$) for 30-day risk-adjusted mortality.

The unadjusted 1-year all-cause readmission rate also declined from 61.0% in the pre-HRRP implementation phase to 57.9% in the HRRP penalties phase. At the same time, unadjusted 1-year mortality rate increased from 34.5% in the pre-HRRP implementation phase to 38.1% in the HRRP penalties phase. The 1-year all-cause risk-adjusted readmission rate also declined from 57.2% in the pre-HRRP implementation phase to 56.3% in the HRRP penalties phase. At the same time, 1-year risk-adjusted mortality rate increased from 31.3% in the pre-HRRP implementation phase to 36.3% in the HRRP penalties phase. The survival analysis showed hazard of 1-year risk-adjusted readmission rate declined significantly after the implementation of the HRRP (HRRP penalties phase vs pre-HRRP implementation phase, 0.92; 95% CI, 0.89-0.96; $P < .001$) (Table 3 and Figure 2). In contrast, the hazard of 1-year risk-adjusted mortality increased significantly after the HRRP implementation (HRRP penalties phase vs pre-HRRP implementation phase, 1.10; 95% CI, 1.06-1.14; $P < .001$) (Table 3 and Figure 2).

The 30-day and 1-year HF-specific readmission hazards also declined from the pre-HRRP implementation phase to the HRRP penalties phase similar to the decline in the all-cause readmission hazards (eTable 1 and eFigure 2 in the Supplement).

The findings of time-series and survival analyses for 30-day and 1-year risk-adjusted readmissions and mortality outcomes were robust in the sensitivity analysis after including transferred patients in the study cohort (eTable 2 in the Supplement) as well as in the subset of patients from hospital sites that continuously participated in GWTG-HF registry throughout the study period (eTable 3 in the Supplement).

In a secondary analysis of index hospitalizations after excluding patients discharged to hospice, the decline in hazards of 30-day and 1-year all-cause risk-adjusted readmissions was similar to the main analysis (eTable 4 in the Supplement). The 30-day and 1-year risk-adjusted mortality rate also increased with the implementation of the HRRP, but the increase was attenuated after excluding patients who were discharged to hospice (eTable 4 in the Supplement).

Interactions testing revealed no significant interactions by race/ethnicity, teaching hospital status, and rural or urban hos-

Table 2. Time Trends in 30-Day Risk-Adjusted Readmissions and Mortality

Period[a]	Readmissions (95% CI)	Mortality (95% CI)
Pre-HRRP implementation phase		
Slope[b]	0.005 (−0.008 to 0.018)	−0.017 (−0.024 to −0.010)
HRRP implementation phase		
Slope	−0.005 (−0.025 to 0.015)	0.006 (−0.004 to 0.016)
Change in slope from pre-HRRP phase	−0.009 (−0.033 to 0.014)	0.023 (0.011 to 0.035)
HRRP penalties phase		
Slope	−0.035 (−0.069 to −0.001)	0.022 (0.009 to 0.034)
Change in slope from pre-HRRP phase	−0.039 (−0.076 to −0.003)	0.039 (0.024 to 0.053)
Change in slope from implementation phase	−0.030 (−0.070 to 0.009)	0.016 (0.000 to 0.032)

Abbreviation: HRRP, Hospital Readmission Reduction Program.

[a] Pre-HRRP implementation phase: January 2006 to March 2010, HRRP implementation phase: April 2010 to September 2012, and HRRP penalties phase: October 2012 to December 2014.

[b] Slopes are scaled to represent yearly change in rate.

pital location for risk-adjusted 30-day all-cause or HF-specific readmissions (eTable 5 in the Supplement). However, there was a significant interaction by teaching status for 1-year risk-adjusted all-cause and HF-specific readmissions with a larger reduction present for the nonteaching hospitals compared with teaching hospitals in the HRRP penalties phase (eTable 6 in the Supplement). There was a significant interaction in 30-day risk-adjusted mortality rate by race/ethnicity, with the largest increase after the implementation of the HRRP in Hispanics (eTable 5 in the Supplement). The 1-year risk-adjusted mortality rate did not differ by race/ethnicity, teaching hospital status, and rural or urban hospital location (eTable 6 in the Supplement).

Discussion

Among fee-for-service Medicare beneficiaries aged 65 years or older who were discharged after an HF hospitalization, we found that implementation of the HRRP was associated with a reduction in 30-day and 1-year risk-adjusted readmissions. However, the HRRP was associated with an increase in both short-term (30-day) and long-term (1-year) mortality. The results persisted despite extensive risk adjustment with prospectively captured clinical data and consideration of hospice use. These findings raise concerns that the HRRP, while achieving desired reductions in readmissions, may have incentivized hospitals in a way that has compromised the survival of patients with HF.

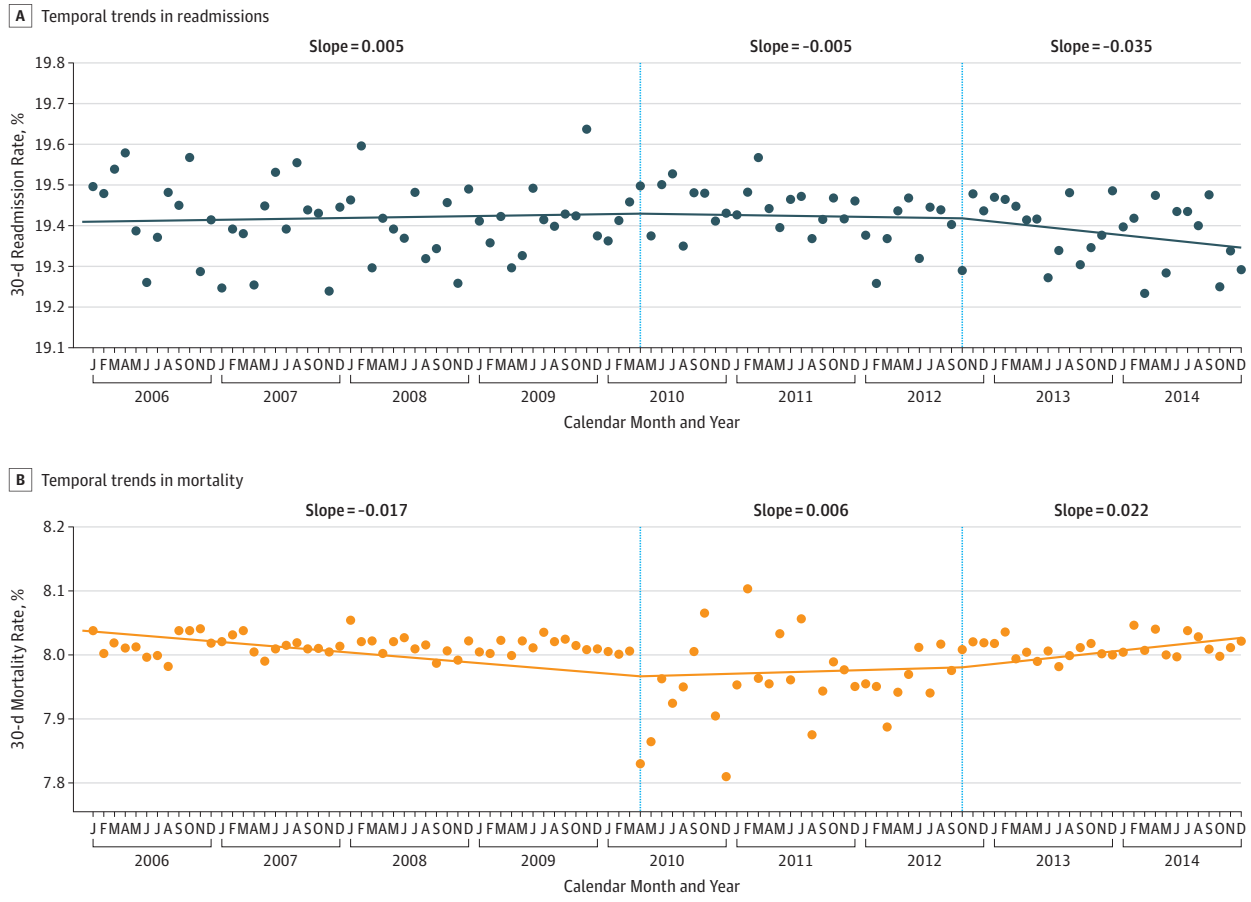
Recent studies have suggested that implementation of the HRRP has been successful in reducing readmission rates in fee-for-service Medicare beneficiaries.[8,9] Zuckerman et al[9] showed a temporal decline in readmissions following HF, pneumonia, or acute myocardial infarction hospitalizations from 21.5% to 17.8% with the implementation of the HRRP. Our study also found a decline in all-cause and HF-specific readmissions following HF hospitalizations after the implementation of the HRRP.

However, a key question is whether the HRRP implementation had unintended consequences for mortality. In this study, we found that the 30-day and 1-year mortality rates among patients with HF increased with the implementation of the HRRP. Previous studies examining the association between hospital 30-day readmission rates and mortality rates in patients with HF have raised concerns that those hospitals with lower 30-day risk-standardized readmission rates may have higher mortality rates.[5-7] In cross-sectional studies of fee-for-service Medicare beneficiaries, there was an inverse, although weak, association between 30-day readmission rates and both short-term (30-day)[5] and long-term (1-year)[6] mortality following discharge with HF. Similarly, a study within the Veterans Affairs health care system found divergent temporal trends in 30-day mortality and readmission rates following HF hospitalizations.[7] A recent analysis of Medicare beneficiaries hospitalized with HF along with other conditions covered by the HRRP from 2008 to 2014 reported on hospital 30-day readmission and 30-day mortality rates after discharge using claims data for risk adjustment.[13] With the HRRP implementation, 30-day risk-adjusted postdischarge mortality increased from 7.9% in 2008 to 9.2% in 2014 for patients with HF, a 1.3% absolute increase. These findings are consistent with the results of our study, and use of clinical data in our study helps diminish the possibility that temporal shifts in administrative coding are what account for these findings.

A slight decrease in mean (SD) length of stay was observed in our study from 5.4 (4.1) days in the pre-HRRP implementation phase to 4.8 (3.3) days in the post-HRRP implementation phase. A potential concern is that a reduction in length of stay may lead to a shift in inpatient mortality to postdischarge mortality, leading to a decline in inpatient mortality but a concomitant increase in postdischarge mortality. However, in our data set, there was no evidence of a decline in inpatient mortality from HF admissions over the study period: Inpatient mortality rates were 3.01% in the pre-HRRP implementation phase, 3.08% in the HRRP implementation phase, and 3.32% in the HRRP penalties phase.

There are several potential reasons that a policy incentivizing reductions in readmissions may be associated with an increase in mortality. First, there have been concerns that the statutory financial penalties established by the HRRP for higher readmission rates would incentivize hospitals to "game" the system, using strategies such as delaying admissions beyond day 30, increasing observation stays, or shifting inpatient-type care to emergency departments.[4] In a study of Medicare beneficiaries, there was a 3.1% reduction in within-hospital readmission rates with a concurrent 0.8% increase in within-hospital observation stays during the implementation phase of the HRRP, although their correlation was not statistically significant (Pearson correlation coefficient = -0.03; P = .07).[9] This study also found that the rate of observation stays grew significantly faster after the HRRP penalties went into effect for the HRRP-target conditions but not for the nontarget conditions.[9] Another analysis of Medicare data between 2011

Figure 1. Temporal Trends in 30-Day Risk-Adjusted Readmission and Mortality Rates by the Hospital Readmissions Reduction Program Periods



Each dot represents the mean rate for a calendar month weighted by the number of index hospitalizations in that month. The solid trend lines of the risk-adjusted rates are generated by linear splines from a linear regression model using generalized estimating equations and thus may not correspond exactly to the distribution of the points. Slope of the trend lines represents yearly change in predicted rates within each of the Hospital Readmissions Reduction Program (HRRP) periods. The vertical solid lines represent changes in the HRRP period (pre-HRRP implementation phase: January 1, 2006, to March 31, 2010; penalty-free HRRP implementation phase: April 1, 2010, to September 30, 2012; and the HRRP penalties phase: October 1, 2012, to December 31, 2014). A significant decline in 30-day risk-adjusted readmission rate was observed in the HRRP penalties phase, compared with the pre-HRRP implementation phase (change in slope: −0.039; 95% CI, −0.076 to −0.003) (A). In contrast, a significant increase in 30-day risk-adjusted mortality rate was observed in the HRRP penalties phase compared with the pre-HRRP implementation phase (change in slope, 0.039; 95% CI, 0.024-0.053) (B).

Table 3. Hazards of Risk-Adjusted Readmissions and Mortality by the Hospital Readmissions Reduction Program Periods[a]

Outcome	Pre-HRRP Implementation Phase	HRRP Implementation Phase (95% CI)	*P* Value[b]	HRRP Penalties Phase (95% CI)	*P* Value[c]
30 d					
Readmissions, HR	1 [Reference]	1.00 (0.95-1.06)	.88	0.91 (0.87-0.95)	<.001
Mortality, HR	1 [Reference]	1.15 (1.08-1.24)	<.001	1.18 (1.10-1.27)	<.001
1 y					
Readmissions, HR	1 [Reference]	1.01 (0.98-1.05)	.45	0.92 (0.89-0.96)	<.001
Mortality, HR	1 [Reference]	1.10 (1.07-1.14)	<.001	1.10 (1.06-1.14)	<.001

Abbreviations: HR, hazard ratio; HRRP, Hospital Readmissions Reduction Program.

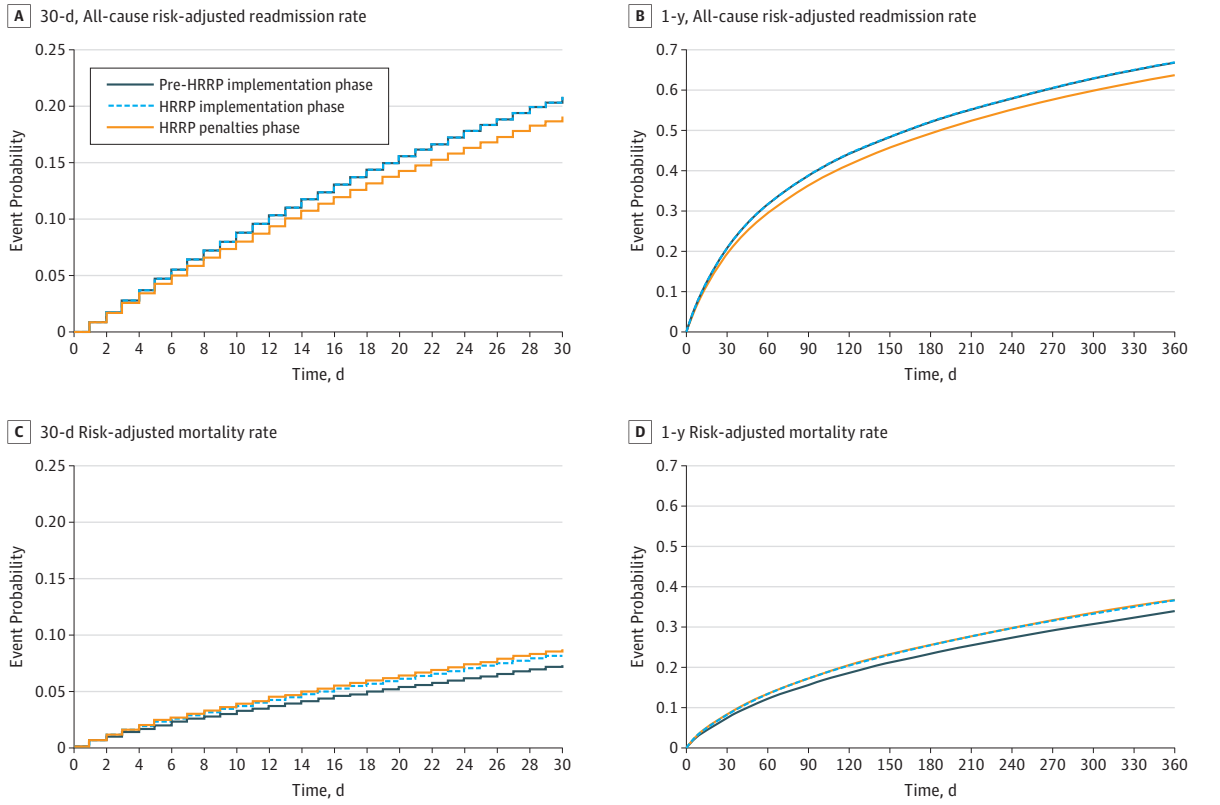
[a] Pre-HRRP implementation phase: January 2006 to March 2010, HRRP implementation phase: April 2010 to September 2012, and HRRP penalties phase: October 2012 to December 2014.

[b] *P* value for comparison of the HRRP implementation phase with the pre-HRRP implementation phase.

[c] *P* value for comparison of the HRRP penalties phase with the pre-HRRP implementation phase.

and 2012 showed that among the top decile of hospitals with the largest reduction in readmission rates, a mean drop of 15.7% in readmission rates was associated with a 25.4% increase in observation stays.[14] Further research is needed to examine the

Figure 2. Event Probability Curves for 30-Day and 1-Year Readmissions and Mortality by the Hospital Readmissions Reduction Program (HRRP) Periods



The event probability of all-cause 30-day (A) and 1-year (B) risk-adjusted readmission rates decreased and the 30-day (C) and 1-year (D) risk-adjusted mortality rates increased in the HRRP penalties phase (orange curve; October 1, 2012, to December 31, 2014), compared with the pre-HRRP implementation phase (blue curve; January 1, 2006, to March 31, 2010): hazard ratio (HR), 0.91; 95% CI, 0.87-0.95; $P < .001$ for 30-day readmission rates; HR, 0.92; 95% CI, 0.89-0.96; $P < .001$ for 1-year readmission rates; HR, 1.18; 95% CI, 1.10-1.27; $P < .001$ for 30-day mortality rates; and HR, 1.10; 95% CI, 1.06-1.14; $P < .001$ for 1-year mortality rates.

association of these "gaming" strategies for reducing readmission rates with mortality risk.

Second, the financial penalties from the HRRP have been shown to fall disproportionately on the academic medical centers and safety-net hospitals where higher readmission rates in these hospitals are associated with the higher case-mix complexity and lower socioeconomic status.[15-18] The HRRP-related financial penalties may hinder the ability of these hospitals to provide care for vulnerable and sicker populations. Whether penalties have resulted in adverse consequences for these hospitals is not known. In the present study, we found increased 30-day and 1-year mortality risk for both teaching and nonteaching hospitals, without any significant interaction by hospitals' teaching status.

Third, there is a competing risk between readmissions and mortality such that the hospitals with higher short-term mortality rate have fewer patients to readmit.[19] However, in our analysis, we excluded patients who suffered in-hospital mortality to avoid competing risk. Furthermore, to be conservative, for the analysis involving readmission rates, we modeled mortality as a competing risk. In addition, our study demonstrated an increase in not only short-term 30-day mortality, which is of main concern for competing risk, but also in long-term 1-year mortality. Therefore, it is unlikely that competing risk accounted for the divergent trends in readmissions and mortality rates in our study.

In a secondary analysis after excluding patients who were discharged to hospice, we found similar but attenuated temporal trends of decrease in readmissions and increase in mortality following the HRRP implementation. The attenuation was most prominent in the increased 30-day risk-adjusted mortality. We also observed a trend toward increasing use of home and inpatient hospice in the HRRP penalties phase, compared with the pre-HRRP implementation phase. Whether this trend reflects honoring of patients' wishes among those with otherwise poor quality of life or reflects an incentive for coercion toward hospice discharge to reduce any readmissions penalty is not known. Regardless, the 1-year risk-adjusted mortality was significantly increased even after excluding patients discharged to hospice. Thus, the policy directed at reducing readmissions was still associated with increased long-term mortality risk, even after accounting for hospice use.

Limitations

This study has several limitations. First, it is an analysis of index HF hospitalizations from hospitals participating volun-

tarily in the GWTG-HF clinical registry and may not be generalizable to other hospitals. However, participating hospital sites are from across the United States and comprise both small to large teaching and nonteaching hospitals in rural and urban locations. Previous studies have suggested that the Medicare beneficiaries in the registry are nationally representative.[20] Second, as an observational study, it cannot establish cause and effect among the HRRP implementation, readmissions reduction, and increased mortality risk. Because sociodemographic and care-of-transition factors strongly influence readmission risk, it is possible that interventions incentivized by the HRRP may have favorably influenced readmission trends, whereas trends in mortality could reflect secular trends for patients hospitalized with HF that placed them at higher risk for 30-day and 1-year mortality. Although we adjusted for clinical factors influencing mortality, patient severity of illness and intrinsic mortality risk may have increased in a way that was not adequately captured or adjusted for in this study. Factors other than the HRRP may also have influenced the findings. However, the temporal associations, even after extensive risk adjustment using prospectively captured clinical data and plausibility for increased risk raised previously, are suggestive. Third, this study is a patient-level analysis of readmissions and mortality and does not directly establish the association of change in readmission rate at a given hospital with change in its mortality rate.

Our findings have substantial public health and policy implications given that HF is the leading diagnosis associated with readmissions in Medicare beneficiaries with high associated costs. Public policies targeting readmissions after HF hospitalizations may be associated with a serious unintended consequence of higher mortality in both the short and long terms. Our study is also a reminder that, like drugs and devices, public health policies should be tested in a rigorous fashion—most preferably in randomized trials—before their widespread adoption.[21]

Conclusions

In fee-for-service Medicare beneficiaries discharged after HF hospitalizations, implementation of the HRRP was associated with a reduction in 30-day and 1-year readmissions yet an increase in 30-day and 1-year mortality. If further confirmed, these findings may require reconsideration of the HRRP in HF.

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REFERENCES

1. Hines AL, Barrett ML, Jiang HJ, Steiner CA. Conditions with the largest number of adult hospital readmissions by payer, 2011. Statistical Brief #172. Healthcare Cost and Utilization Project (HCUP) Statistical Briefs. https://www.hcup-us.ahrq.gov/reports/statbriefs/sb172-Conditions-Readmissions-Payer.jsp. Published April 2014. Accessed May 8, 2017.

2. Vidic A, Chibnall JT, Hauptman PJ. Heart failure is a major contributor to hospital readmission penalties. *J Card Fail*. 2015;21(2):134-137.

3. Bradley EH, Curry L, Horwitz LI, et al. Contemporary evidence about hospital strategies for reducing 30-day readmissions: a national study. *J Am Coll Cardiol*. 2012;60(7):607-614.

4. Woolhandler S, Himmelstein DU. The Hospital Readmissions Reduction Program. *N Engl J Med*. 2016;375(5):493.

5. Krumholz HM, Lin Z, Keenan PS, et al. Relationship between hospital readmission and mortality rates for patients hospitalized with acute myocardial infarction, heart failure, or pneumonia. *JAMA*. 2013;309(6):587-593.

6. Pandey A, Golwala H, Xu H, et al. Association of 30-day readmission metric for heart failure under the Hospital Readmissions Reduction Program with quality of care and outcomes. *JACC Heart Fail*. 2016;4(12):935-946.

7. Heidenreich PA, Sahay A, Kapoor JR, Pham MX, Massie B. Divergent trends in survival and readmission following a hospitalization for heart failure in the Veterans Affairs health care system 2002 to 2006. *J Am Coll Cardiol*. 2010;56(5):362-368.

8. Desai NR, Ross JS, Kwon JY, et al. Association between hospital penalty status under the Hospital Readmission Reduction Program and readmission rates for target and nontarget conditions. *JAMA*. 2016;316(24):2647-2656.

9. Zuckerman RB, Sheingold SH, Orav EJ, Ruhter J, Epstein AM. Readmissions, observation, and the Hospital Readmissions Reduction Program. *N Engl J Med*. 2016;374(16):1543-1551.

10. Smaha LA; American Heart Association. The American Heart Association Get With the Guidelines program. *Am Heart J*. 2004;148(5)(suppl):S46-S48.

11. Hong Y, LaBresh KA. Overview of the American Heart Association "Get with the Guidelines" programs: coronary heart disease, stroke, and heart failure. *Crit Pathw Cardiol*. 2006;5(4):179-186.

12. Hammill BG, Hernandez AF, Peterson ED, Fonarow GC, Schulman KA, Curtis LH. Linking inpatient clinical registry data to Medicare claims data using indirect identifiers. *Am Heart J*. 2009;157(6):995-1000.

13. Dharmarajan K, Wang Y, Lin Z, et al. Association of changing hospital readmission rates with mortality rates after hospital discharge. *JAMA*. 2017;318(3):270-278.

14. Noel-Miller C, Lind K. Is observation status substituting for hospital readmission? Health Affairs blog. http://healthaffairs.org/blog/2015/10/28/is-observation-status-substituting-for-hospital-readmission/. Published October 28, 2015. Accessed April 21, 2017.

15. Joynt KE, Orav EJ, Jha AK. Thirty-day readmission rates for Medicare beneficiaries by race and site of care. *JAMA*. 2011;305(7):675-681.

16. Jha AK, Orav EJ, Epstein AM. Public reporting of discharge planning and rates of readmissions. *N Engl J Med*. 2009;361(27):2637-2645.

17. Rathore SS, Foody JM, Wang Y, et al. Race, quality of care, and outcomes of elderly patients hospitalized with heart failure. *JAMA*. 2003;289(19):2517-2524.

18. Joynt KE, Jha AK. Characteristics of hospitals receiving penalties under the Hospital Readmissions Reduction Program. *JAMA*. 2013;309(4):342-343.

19. Gorodeski EZ, Starling RC, Blackstone EH. Are all readmissions bad readmissions? *N Engl J Med*. 2010;363(3):297-298.

20. Curtis LH, Greiner MA, Hammill BG, et al. Representativeness of a national heart failure quality-of-care registry: comparison of OPTIMIZE-HF and non-OPTIMIZE-HF Medicare patients. *Circ Cardiovasc Qual Outcomes*. 2009;2(4):377-384.

21. Newhouse JP, Normand ST. Health policy trials. *N Engl J Med*. 2017;376(22):2160-2167.