

Association Between Hospital Penalty Status Under the Hospital Readmission Reduction Program and Readmission Rates for Target and Nontarget Conditions

Nihar R. Desai, MD, MPH; Joseph S. Ross, MD, MHS; Ji Young Kwon, MPH; Jeph Herrin, PhD; Kumar Dharmarajan, MD, MBA; Susannah M. Bernheim, MD, MHS; Harlan M. Krumholz, MD, SM; Leora I. Horwitz, MD, MHS

 Supplemental content

IMPORTANCE Readmission rates declined after announcement of the Hospital Readmission Reduction Program (HRRP), which penalizes hospitals for excess readmissions for acute myocardial infarction (AMI), heart failure (HF), and pneumonia.

OBJECTIVE To compare trends in readmission rates for target and nontarget conditions, stratified by hospital penalty status.

DESIGN, SETTING, AND PARTICIPANTS Retrospective cohort study of Medicare fee-for-service beneficiaries older than 64 years discharged between January 1, 2008, and June 30, 2015, from 2214 penalty hospitals and 1283 nonpenalty hospitals. Difference-interrupted time-series models were used to compare trends in readmission rates by condition and penalty status.

EXPOSURE Hospital penalty status or target condition under the HRRP.

MAIN OUTCOMES AND MEASURES Thirty-day risk adjusted, all-cause unplanned readmission rates for target and nontarget conditions.

RESULTS The study included 48 137 102 hospitalizations of 20 351 161 Medicare beneficiaries. In January 2008, the mean readmission rates for AMI, HF, pneumonia, and nontarget conditions were 21.9%, 27.5%, 20.1%, and 18.4%, respectively, at hospitals later subject to financial penalties and 18.7%, 24.2%, 17.4%, and 15.7% at hospitals not subject to penalties. Between January 2008 and March 2010, prior to HRRP announcement, readmission rates were stable across hospitals (except AMI at nonpenalty hospitals). Following announcement of HRRP (March 2010), readmission rates for both target and nontarget conditions declined significantly faster for patients at hospitals later subject to financial penalties compared with those at nonpenalized hospitals (for AMI, additional decrease of -1.24 [95% CI, -1.84 to -0.65] percentage points per year relative to nonpenalty discharges; for HF, -1.25 [95% CI, -1.64 to -0.86]; for pneumonia, -1.37 [95% CI, -1.80 to -0.95]; and for nontarget conditions, -0.27 [95% CI, -0.38 to -0.17]; $P < .001$ for all). For penalty hospitals, readmission rates for target conditions declined significantly faster compared with nontarget conditions (for AMI, additional decline of -0.49 [95% CI, -0.81 to -0.16] percentage points per year relative to nontarget conditions [$P = .004$]; for HF, -0.90 [95% CI, -1.18 to -0.62 ; $P < .001$]; and for pneumonia, -0.57 [95% CI, -0.92 to -0.23 ; $P < .001$]). In contrast, among nonpenalty hospitals, readmissions for target conditions declined similarly or more slowly compared with nontarget conditions (for AMI, additional increase of 0.48 [95% CI, 0.01 - 0.95] percentage points per year [$P = .05$]; for HF, 0.08 [95% CI, -0.30 to 0.46 ; $P = .67$]; for pneumonia, 0.53 [95% CI, 0.13 - 0.93 ; $P = .01$]). After HRRP implementation in October 2012, the rate of change for readmission rates plateaued ($P < .05$ for all except pneumonia at nonpenalty hospitals), with the greatest relative change observed among hospitals subject to financial penalty.

CONCLUSIONS AND RELEVANCE Medicare fee-for-service patients at hospitals subject to penalties under the HRRP had greater reductions in readmission rates compared with those at nonpenalized hospitals. Changes were greater for target vs nontarget conditions for patients at the penalized hospitals but not at the other hospitals.

JAMA. 2016;316(24):2647-2656. doi:10.1001/jama.2016.18533

Author Affiliations: Author affiliations are listed at the end of this article.

Corresponding Author: Leora I. Horwitz, MD, MHS, NYU School of Medicine, 550 First Ave, TRB 607, New York, NY 10016 (leora.horwitz@nyumc.org).

The Hospital Readmission Reduction Program (HRRP) was enacted under Section 3025 of the Patient Protection and Affordable Care Act in March 2010 and imposed financial penalties beginning in October 2012 for hospitals with higher-than-expected readmissions for acute myocardial infarction (AMI), congestive heart failure (CHF), and pneumonia among their fee-for-service Medicare beneficiaries.¹ Since the program's inception, thousands of hospitals have been subjected to penalties now totaling nearly \$1 billion.^{2,3}

A recent examination of trends in readmission rates demonstrated that across all hospitals, readmission rates significantly declined for target conditions (AMI, CHF, pneumonia) and nontarget conditions, with a greater decline for the former, following announcement of the HRRP.⁴ It is not known whether trends in readmission rates overall, as well as specifically for target and nontarget conditions, differed based on whether a hospital was subject to penalties under the HRRP. Such information could offer insights into the mechanisms of the association of the HRRP with hospital performance. For example, reductions in readmission that are limited to hospitals later subject to financial penalty and/or that are larger in magnitude for target vs nontarget conditions would suggest either that hospitals responded to anticipated or actual penalties or that penalized hospitals with higher baseline readmission rates were more able to achieve reductions. In contrast, more widespread changes would suggest that all hospitals responded to the threat of potential penalties or were equally able to reduce readmissions. Similarly, comparable reductions in readmission rates among target and nontarget conditions would suggest that hospitals implemented broad, system-wide interventions to reduce readmissions, whereas selective reductions in readmissions for target conditions would suggest that hospitals implemented narrower, condition-specific strategies.

Accordingly, this study compared trends in readmission rates for target and nontarget conditions among patients hospitalized at hospitals that were and were not penalized under the HRRP.

Methods

Study Cohort

We used Medicare fee-for-service claims data for January 1, 2008, through June 30, 2015, to identify hospital admissions. Study cohorts were defined consistent with Centers for Medicare & Medicaid Services (CMS) methods for public reporting as well as the HRRP; details have been published previously.⁵⁻⁷ Briefly, for condition-specific measures, we used *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* codes to identify discharges of Medicare beneficiaries aged 65 years or older with a principal discharge diagnosis of acute AMI, CHF, and pneumonia. To define a cohort for nontarget conditions, we used methods for the hospital-wide readmission measure, which has also been described previously.^{8,9} This measure excludes admissions for medical treatment of cancer and uses ICD-9 codes to assign remaining hospitalizations to 1 of

Key Points

Question Was the Hospital Readmission Reduction Program (HRRP) associated with different changes in readmission rates for target and nontarget conditions among penalized and nonpenalized hospitals?

Findings In this longitudinal cohort study of 48 137 102 hospitalizations among 20 351 161 Medicare fee-for-service patients across 3497 hospitals, announcement of the HRRP was associated with significant reductions in readmissions at hospitals later subject to penalties, with significantly larger reductions for target conditions. Hospitals not subject to financial penalties experienced comparable reductions in readmissions for target and nontarget conditions. Readmission rates plateaued across all hospitals after implementation of the HRRP.

Meaning Hospitals subject to penalties under the HRRP had greater reductions in readmission rates compared with nonpenalized hospitals. Changes were greater for target vs nontarget conditions at the penalized hospitals, but not at nonpenalized hospitals.

5 cohorts: medicine, surgery/gynecology, cardiorespiratory, cardiovascular, or neurology. For this study, we removed hospitalizations for AMI, CHF, pneumonia, chronic obstructive pulmonary disease (COPD), and hip or knee arthroplasty surgery from the nontarget condition cohort. We excluded patients with COPD or hip or knee arthroplasty surgery because these conditions were added to the HRRP program during the study period. We also excluded patients discharged from hospitals that were not eligible for the HRRP (psychiatric, rehabilitation, long-term care, children's, cancer, and critical access hospitals, as well as all hospitals in Maryland). Patients who died during the hospitalization or did not have at least 30 days of postdischarge enrollment in Medicare fee for service were excluded, as were patients who left the hospital against medical advice or were enrolled in hospice at the time of admission or at any time in the previous 12 months.

The Yale University Human Investigation Committee accepted a waiver of consent and approved this analysis.

Hospital Penalty Status

We obtained data on which hospitals were subject to penalties at the time the HRRP was implemented in October 2012 from the CMS website.¹⁰ Hospitals were first privately provided by CMS data on their readmission rates along with national rates for CHF in August 2008 (calendar year 2006 data), then in April 2009, hospitals privately received readmission rate data for AMI, CHF, and pneumonia (July 2005–June 2008 data) prior to public reporting in July 2009. In April 2010, shortly after the HRRP was announced, hospitals received similar reports for July 2006 to June 2009, which included the first penalty year (initial penalty based on performance in July 2008 to June 2011). By this time, 2 of the 3 years used to determine HRRP penalties had already passed (eTable in the [Supplement](#)). Therefore, prior to actual implementation of the HRRP in October 2012, poorly performing hospitals were likely aware of their risk of impending financial penalties.

Outcome

The outcome was discharge-level, 30-day, risk-adjusted, all-cause unplanned readmission. For all calculations of readmission, we used a CMS algorithm to exclude planned readmissions for procedures or diagnoses that are typically elective or scheduled, such as maintenance chemotherapy and organ transplantation.^{11,12} If a patient experienced multiple readmissions within the postdischarge period of the index hospitalization, only the first readmission was counted.

Statistical Analysis

Characteristics of hospitals that were and were not subject to penalties under the HRRP were obtained from the American Hospital Association's 2013 annual survey and were compared using χ^2 testing. To examine time trends, we calculated a single risk-adjusted monthly readmission rate for each cohort: AMI, CHF, pneumonia, and nontarget conditions, stratifying by discharge from hospitals that did vs did not receive a penalty in fiscal year 2013. We used a single rate for each month to avoid the challenges of estimating and modeling hospital-level rates for monthly denominators that were often very low. We estimated the monthly rates for each cohort using a linear probability model, with readmission as the dependent variable, all risk factors from the corresponding publicly reported measure as independent variables, and an indicator for each calendar month. All independent variables except month were centered on their overall mean for the cohort, and the intercept was suppressed to allow all monthly indicators to remain in the model. The coefficients for each month were then used as the estimated adjusted monthly rate for that cohort.

To determine the association of the HRRP with readmission rates, we estimated a set of interrupted time-series models using the adjusted monthly rate as the dependent variable. Interrupted time-series models can incorporate both overall and trend effects of 1 or more events, or interruptions, in a long-term trend.^{13,14} Each model included a monthly time trend variable, indicators for the postannouncement and postimplementation periods, and terms for the interaction of announcement and implementation dates with the overall monthly trend during the period after that date. In this approach, the overall trend in readmission rate (time) was deconstructed into 3 components: the slope of readmission rates in the pre-HRRP period (January 2008 through March 2010), the change in slope in the post-HRRP announcement but pre-HRRP implementation period relative to the pre-HRRP period (April 2010 through September 2012), and the additional change in slope in the post-HRRP implementation period (October 2012 through June 2015) relative to the announcement period. In addition, the coefficient of the period indicators represents any overall effect independent of changes in the slopes.

We first examined the association of the HRRP announcement and implementation on trends in readmission rates by constructing 8 interrupted time-series models: 2 each for AMI, CHF, pneumonia, and nontarget conditions, stratifying discharges based on whether they were or were not from hospitals subjected to financial penalties. To determine whether there was a differential effect on discharges from penalty vs nonpenalty hospitals, we then estimated analogous models

using as the dependent variable the difference in monthly rates for each condition between penalty and nonpenalty hospitals ("difference models"). To assess whether there was a differential change in target vs nontarget conditions, we estimated another set of difference models using as the dependent variable the difference in monthly rates between each target condition and all nontarget conditions.

For non-difference-interrupted time-series models, we used linear regression models with autoregressive error terms. We first estimated a series of models with no independent variables and a range of autoregressive terms to identify the best error structure and then used that structure in the final models. For the difference-interrupted time-series models, we identified no autoregressive term and used ordinary linear regression. All analyses were conducted using SAS software, version 9.3.0 (SAS Institute Inc) and Stata version 14.1 (Stata Corp). All tests for statistical significance were 2-tailed and evaluated at a significance level of $P < .05$.

Results

The study cohort consisted of 48 137 102 hospitalizations and 7 964 608 readmissions among 20 351 161 Medicare fee-for-service beneficiaries discharged between January 1, 2008, and June 30, 2015, from 3497 hospitals. Characteristics of hospitals that were and were not subject to penalties under the HRRP are shown in **Table 1**. Compared with nonpenalty hospitals ($n = 1283$ [37%]), penalty hospitals ($n = 2214$ [63%]) were larger, were more likely to be teaching hospitals, and had higher proportions of Medicaid patients. The annual number of hospital discharges and readmissions for each target condition and for nontarget conditions, stratified by hospital penalty status, is shown in **Table 2**. The volume of hospitalizations for target conditions and nontarget conditions declined gradually over the course of the study period for both penalized and nonpenalized hospitals.

Association of the HRRP With Readmission Rates, Stratified by Hospital Penalty Status

Monthly, risk-adjusted, all-cause readmission rates for the 3 target conditions and the nontarget conditions for patients discharged from hospitals that were and that were not subject to the HRRP penalty are shown in the **Figure, A-D**, and in **Table 3**. In January 2008, the mean readmission rates for AMI, CHF, pneumonia, and nontarget conditions were 21.9%, 27.5%, 20.1%, and 18.4%, respectively, at hospitals later subject to financial penalties under the HRRP and 18.7%, 24.2%, 17.4%, and 15.7%, respectively, at hospitals not subject to HRRP penalties. Between January 2008 and March 2010, prior to HRRP announcement, readmission rates were stable for target and nontarget conditions regardless of penalty status except for AMI, for which readmission rates were declining at 0.78 percentage points per year (95% CI, -1.18 to -0.38) among hospitals that were not later subject to penalties. After announcement of the HRRP, trends in readmission rates differed significantly based on hospital penalty status. Specifically, readmission rates declined by 1.30 percentage points per year

Table 1. Characteristics of Hospitals That Were and Were Not Subject to Penalty Under the Hospital Readmission Reduction Program

Characteristics	Nonpenalty Hospitals (n=1283)	Penalty Hospitals (n=2214)	P Value ^a
Medicaid patients, %			
≤5	236 (18.4)	72 (3.3)	<.001
6-10	136 (10.6)	238 (10.8)	
11-15	181 (14.1)	384 (17.3)	
16-20	306 (23.9)	634 (28.6)	
21-25	175 (13.6)	360 (16.3)	
26-30	82 (6.4)	190 (8.6)	
>30	86 (6.7)	260 (11.7)	
Missing data	81 (6.3)	76 (3.4)	
Safety net			
No	947 (73.8)	1642 (74.2)	.19
Yes	255 (19.9)	496 (22.4)	
Missing data	81 (6.3)	76 (3.4)	
Teaching status			
Nonteaching	826 (64.4)	1406 (63.5)	<.001
Teaching	376 (29.3)	732 (33.1)	
Missing data	81 (6.3)	76 (3.4)	
Region			
West	297 (23.2)	332 (15.0)	<.001
Midwest	294 (22.9)	464 (21.0)	
Northeast	97 (7.6)	405 (18.3)	
South	467 (36.4)	937 (42.3)	
Associated areas	47 (3.7)	0	
Missing data	81 (6.3)	76 (3.4)	
Setting			
Urban	1103 (86.0)	1927 (87.0)	<.001
Rural	99 (7.7)	211 (9.5)	
Missing data	81 (6.3)	76 (3.4)	
Ownership			
Public	186 (14.5)	330 (14.9)	.16
Not for profit	708 (55.2)	1321 (59.7)	
For profit	308 (24.0)	487 (22.0)	
Missing data	81 (6.3)	76 (3.4)	
Beds			
6-99	546 (42.6)	571 (25.8)	<.001
100-199	278 (21.7)	633 (28.6)	
200-299	161 (12.6)	380 (17.2)	
300-399	97 (7.6)	222 (10.0)	
400-499	52 (4.1)	126 (5.7)	
≥500	68 (5.3)	206 (9.3)	
Missing data	81 (6.3)	76 (3.4)	

^a By χ^2 test of independence across penalty hospitals.

(95% CI, -1.88 to -0.72) for AMI compared with the preannouncement period, by 1.72 percentage points per year (95% CI, -2.36 to -1.08) for CHF, and by 1.36 percentage points per year (95% CI, -2.09 to -0.63) for pneumonia among patients discharged from hospitals later subject to penalties ($P < .001$ for all). In contrast, hospitals not subject to penalties had no significant change in readmission rates for any of the 3 target conditions after HRRP announcement (for AMI, -0.08 percentage points per year [95% CI, -0.66 to 0.50; $P = .79$]; for CHF,

-0.45 [95% CI, -1.10 to 0.20; $P = .18$]; and for pneumonia, -0.03 [95% CI, -1.15 to 1.10; $P = .96$]).

For nontarget conditions, we observed more modest but statistically significant declines in readmission rates after announcement of the HRRP regardless of whether patients were discharged from a hospital that was penalized (for penalty hospitals, -0.81 percentage points per year [95% CI, -1.23 to -0.39]; for nonpenalty hospitals: -0.54 [95% CI, -0.85 to -0.23]; $P < .001$). After HRRP implementation in October 2012, the rate

Table 2. Hospitalizations and Readmissions From 2008 to 2015 in Each Cohort by Year Stratified by Penalty Status

Cohort	No. of Hospitals	No. of Hospitalizations or Readmissions							
		2008	2009	2010	2011	2012	2013	2014	2015 ^a
Acute myocardial infarction hospitalizations									
Penalty	2209	133 483	126 890	125 658	124 379	115 804	121 660	118 236	60 415
Nonpenalty	1045	57 869	55 131	55 125	55 180	51 419	54 591	53 799	27 582
Total	3254	191 352	182 021	180 783	179 559	167 223	176 251	172 035	87 997
Acute myocardial infarction readmissions									
Penalty	2209	27 698	26 307	25 514	24 604	21 836	21 344	20 171	10 317
Nonpenalty	1045	9694	8812	8763	8890	7928	8020	7713	4098
Total	3254	37 392	35 119	34 277	33 494	29 764	29 364	27 884	14 415
Heart failure hospitalizations									
Penalty	2214	335 763	339 553	334 493	320 622	280 539	293 161	289 678	155 126
Nonpenalty	1108	119 039	122 125	120 523	117 305	104 812	112 545	114 485	62 040
Total	3322	454 802	461 678	455 016	437 927	385 351	405 706	404 163	217 166
Heart failure readmissions									
Penalty	2214	87 625	88 818	87 304	81 449	68 746	68 621	67 247	36 170
Nonpenalty	1108	26 246	26 431	25 973	25 022	22 287	23 145	23 553	12 829
Total	3322	113 871	115 249	113 277	106 471	91 033	91 766	90 800	48 999
Pneumonia hospitalizations									
Penalty	2214	260 675	243 812	242 873	250 316	218 394	228 120	201 725	119 459
Nonpenalty	1126	105 959	98 298	97 703	101 054	89 285	94 024	85 051	51 086
Total	3340	366 634	342 110	340 576	351 370	307 679	322 144	286 776	170 545
Pneumonia readmissions									
Penalty	2214	49 529	47 510	47 380	47 872	40 181	40 091	35 482	20 061
Nonpenalty	1126	16 977	15 652	15 406	15 948	14 321	14 561	13 321	7624
Total	3340	66 506	63 162	62 786	63 820	54 502	54 652	48 803	27 685
Nontarget condition hospitalizations ^b									
Penalty	2214	4 213 504	4 129 709	4 123 491	4 095 852	3 614 980	3 705 051	3 571 020	1 795 772
Nonpenalty	1283	1 690 022	1 637 626	1 627 903	1 628 501	1 464 849	1 533 120	1 498 431	760 407
Total	3497	5 903 526	5 767 335	5 751 394	5 724 353	5 079 829	5 238 171	5 069 451	2 556 179
Nontarget condition readmissions ^b									
Penalty	2214	709 504	693 997	694 795	688 267	591 673	589 432	571 710	286 030
Nonpenalty	1283	243 216	234 063	234 023	234 951	207 235	213 928	210 175	106 518
Total	3497	952 720	928 060	928 818	923 218	798 908	803 360	781 885	392 548

^a Includes January 1 through June 30, 2015.

^b Excludes acute myocardial infarction, heart failure, pneumonia, chronic obstructive pulmonary disease, and hip or knee arthroplasty surgery.

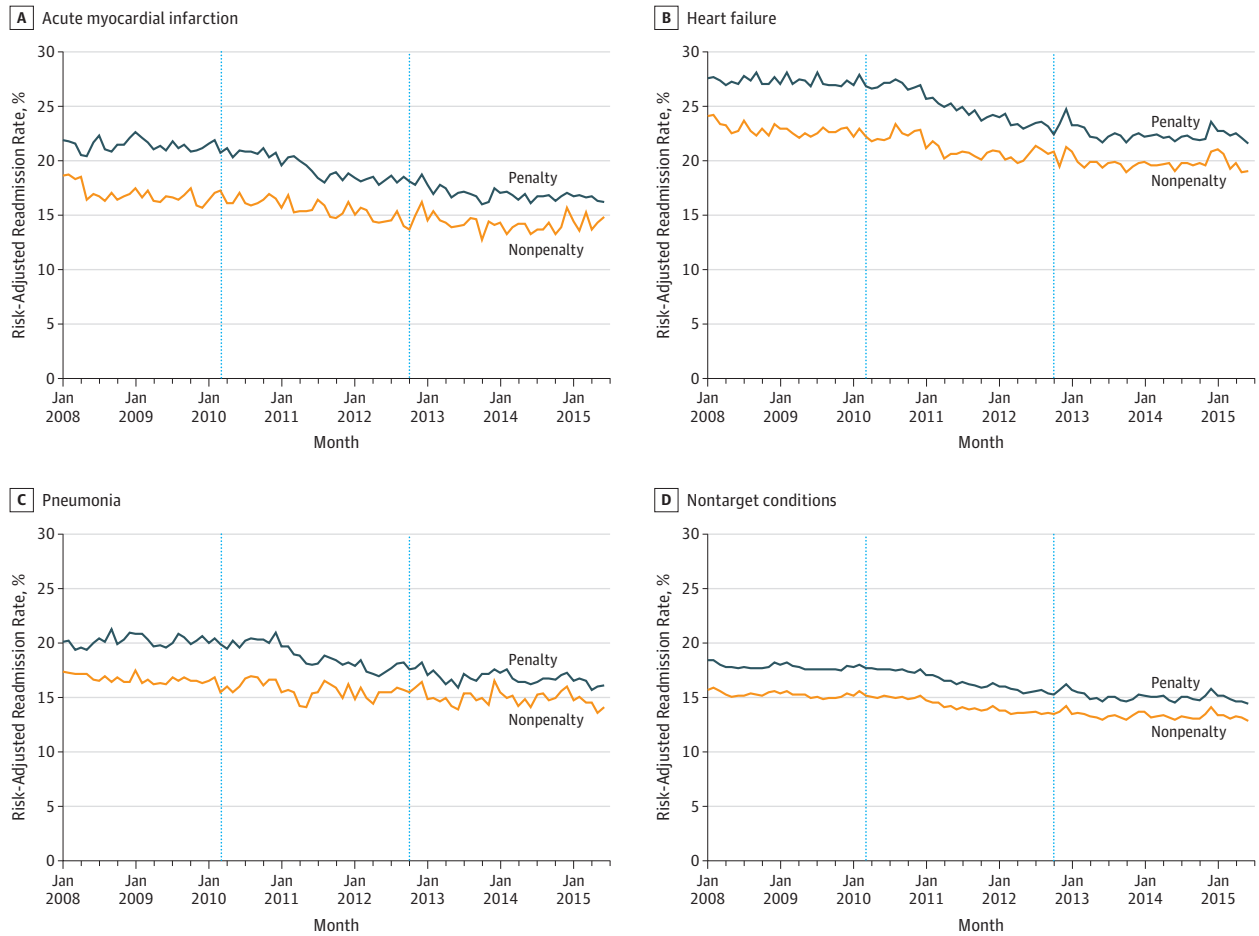
of change for readmission rates plateaued relative to the change observed after announcement but prior to implementation for both target and nontarget conditions among both penalty and nonpenalty discharges ($P < .05$ for all except pneumonia at nonpenalty hospitals), with the greatest relative change observed among hospitals subject to financial penalty. As a result, readmission rates for target and nontarget conditions have not significantly changed since October 2012 across hospitals regardless of penalty status.

The results of the difference interrupted time-series models, which determine the difference between readmission rates for penalty vs nonpenalty hospitals, stratified by condition, are shown in Table 4. Prior to the announcement of the HRRP, readmission rates for patients at hospitals later subject to a penalty were declining less rapidly than those for patients at hos-

pitals not later subject to financial penalties (for AMI, increase of 0.72 percentage points per year for penalty hospital discharges vs nonpenalty hospital discharges [95% CI, 0.26-1.19]; for CHF, 0.35 [95% CI, 0.04-0.65]; and for pneumonia, 0.48 [95% CI, 0.15-0.81]; $P < .05$ for all). However, between April 2010 and October 2012, after the announcement but prior to the actual implementation of the HRRP, readmission rates began to improve significantly faster for patients at hospitals later subject to financial penalties (for AMI, decrease of -1.24 percentage points per year for penalty hospital discharges vs nonpenalty hospital discharges [95% CI, -1.84 to -0.65]; for CHF, -1.25 [95% CI, -1.64 to -0.86]; and for pneumonia, -1.37 [95% CI, -1.80 to -0.95]; $P < .001$ for all).

For nontarget conditions, penalty and nonpenalty hospitals were improving at similar rates prior to HRRP announce-

Figure. Risk-Adjusted Readmission Rates Stratified by Hospital Penalty Status for Acute Myocardial Infarction, Heart Failure, Pneumonia, and Nontarget Condition Cohorts From January 2008 to June 2015



The vertical lines represent announcement of the Hospital Readmission Reduction Program (March 2010) and its subsequent implementation

(October 2012). Readmission rates are risk-adjusted for age, sex, comorbidity, and principal diagnosis (for the nontarget conditions group).

ment (difference of -0.01 percentage points per year; 95% CI, -0.09 to 0.07 ; $P = .83$). On announcement of the HRRP but prior to its implementation, readmission rates began to converge, but more modestly than observed for target conditions (relative decrease of -0.27 [95% CI, -0.38 to -0.17] percentage points per year for penalty hospital discharges vs nonpenalty hospital discharges; $P < .001$).

Comparison of the Association of the HRRP With Target and Nontarget Conditions, Stratified by Hospital Penalty Status

The results of the difference-interrupted time-series models, which determine the difference for target vs nontarget conditions, stratified by hospital penalty status, are shown in Table 5. At hospitals that were subject to financial penalties under the HRRP, in the period after announcement of the HRRP, the reductions in readmissions for AMI, CHF, and pneumonia were significantly greater than the reductions observed for nontarget conditions (for AMI, a relative decline of -0.49 percentage points per year [95% CI, -0.81 to -0.16 ; $P = .004$]; for CHF, -0.90 [95% CI, -1.18 to -0.62 ; $P < .001$]; and for pneumonia,

-0.57 [95% CI, -0.92 to -0.23 ; $P < .001$]). In contrast, at hospitals that were not subject to financial penalties under the HRRP, there was no differential improvement in readmission rates for target conditions. Reductions in readmissions were either comparable for the target and nontarget conditions or greater for the nontarget conditions (for AMI, a relative increase of 0.48 percentage points per year [95% CI, 0.01 - 0.95 ; $P = .05$]; for CHF, 0.08 [95% CI, -0.30 to 0.46 ; $P = .67$]; and for pneumonia, 0.53 [95% CI, 0.13 - 0.93]; $P = .01$).

Discussion

In this longitudinal examination of trends in readmission rates among Medicare beneficiaries, the significant reductions in readmission observed after announcement of financial penalties under the HRRP program occurred primarily at hospitals that were subject to financial penalties. Readmission rates for target conditions declined significantly more than rates for nontarget conditions at hospitals later subject to HRRP penalties,

Table 3. Interrupted Time-Series Analysis of Readmission Rates Stratified by Penalty Status

Cohort	No. of Hospitals	Pre-HRRP Announcement (January 2008–March 2010)		HRRP Announcement (March 2010)		Post-HRRP Announcement, Pre-HRRP Implementation (April 2010–September 2012)		HRRP Implementation (October 2012)		Post-HRRP Implementation (October 2012–June 2015)	
		Annualized Rate of Change, % (95% CI) ^a	P Value ^b	Additional Absolute Change, % (95% CI) ^a	P Value ^b	Annualized Rate of Change, % (95% CI) ^a	P Value ^b	Additional Absolute Change, % (95% CI) ^a	P Value ^b	Annualized Rate of Change, % (95% CI) ^a	P Value ^b
Acute myocardial infarction											
Penalty	2209	-0.01 (-0.47 to 0.44)	.95	-0.29 (-1.04 to 0.45)	.44	-1.30 (-1.88 to -0.72)	<.001	-0.16 (-0.82 to 0.49)	.63	0.84 (0.34 to 1.34)	.001
Nonpenalty	1045	-0.78 (-1.18 to -0.38)	<.001	0.65 (-0.20 to 1.50)	.14	-0.08 (-0.66 to 0.50)	.79	-0.10 (-0.80 to 0.59)	.77	0.70 (0.22 to 1.19)	.005
Heart failure											
Penalty	2214	-0.03 (-0.55 to 0.49)	.91	0.08 (-0.60 to 0.75)	.82	-1.72 (-2.36 to -1.08)	<.001	-0.07 (-0.72 to 0.58)	.83	1.46 (1.05 to 1.86)	<.001
Nonpenalty	1108	-0.43 (-0.96 to 0.09)	.11	-0.12 (-1.08 to 0.85)	.82	-0.45 (-1.10 to 0.20)	.18	0.04 (-0.63 to 0.70)	.91	0.67 (0.16 to 1.17)	.009
Pneumonia											
Penalty	2214	0.22 (-0.37 to 0.80)	.47	-0.09 (-0.93 to 0.75)	.83	-1.36 (-2.09 to -0.63)	<.001	-0.12 (-0.94 to 0.70)	.77	0.80 (0.24 to 1.36)	.005
Nonpenalty	1126	-0.27 (-1.26 to 0.73)	.60	-0.39 (-1.55 to 0.76)	.51	-0.03 (-1.15 to 1.10)	.96	-0.01 (-0.76 to 0.75)	.99	0.04 (-0.45 to 0.54)	.86
Nonpenalty	1283	-0.15 (-0.35 to 0.05)	.14	0.05 (-0.33 to 0.42)	.80	-0.54 (-0.85 to -0.23)	.001	0.09 (-0.31 to 0.49)	.66	0.57 (0.31 to 0.83)	<.001

Abbreviation: HRRP, Hospital Readmission Reduction Program. ^a Data are annualized percentage rates of change in readmission rates during each specified time interval or the additional absolute change, relative to previous trend, at specific time points. ^b P values represent the significance of the test for the change in the slope or the absolute change being equal to zero.

^c Excludes acute myocardial infarction, heart failure, pneumonia, chronic obstructive pulmonary disease, and hip and knee arthroplasty surgery.

Table 4. Interrupted Time-Series Analysis for the Difference in Readmission Rates Between Penalty and Nonpenalty Hospitals

Conditions	Pre-HRRP Announcement (January 2008–March 2010)		HRRP Announcement (March 2010)		Post-HRRP Announcement, Pre-HRRP Implementation (April 2010–September 2012)		HRRP Implementation (October 2012)		Post-HRRP Implementation (October 2012–June 2015)	
	Difference in Annualized Rate of Change, % (95% CI) ^a	P Value ^b	Difference in Additional Absolute Change, % (95% CI) ^a	P Value ^b	Difference in Annualized Rate of Change, % (95% CI) ^a	P Value ^b	Difference in Additional Absolute Change, % (95% CI) ^a	P Value ^b	Difference in Annualized Rate of Change, % (95% CI) ^a	P Value ^b
Acute myocardial infarction	0.72 (0.26 to 1.19)	.003	-0.79 (-1.58 to 0.00)	.05	-1.24 (-1.84 to -0.65)	<.001	0.01 (-0.75 to 0.77)	.97	0.21 (-0.29 to 0.70)	.41
Heart failure	0.35 (0.04 to 0.65)	.03	0.26 (-0.26 to 0.78)	.32	-1.25 (-1.64 to -0.86)	<.001	0.06 (-0.44 to 0.56)	.81	0.76 (0.43 to 1.08)	<.001
Pneumonia	0.48 (0.15 to 0.81)	.005	0.35 (-0.22 to 0.92)	.22	-1.37 (-1.80 to -0.95)	<.001	0.03 (-0.51 to 0.57)	.91	0.75 (0.40 to 1.11)	<.001
Nonpenalty conditions ^c	-0.01 (-0.09 to 0.07)	.83	0.12 (-0.02 to 0.26)	.09	-0.27 (-0.38 to -0.17)	<.001	-0.06 (-0.19 to 0.07)	.37	0.18 (0.10 to 0.27)	<.001

Abbreviation: HRRP, Hospital Readmission Reduction Program.

^a Data are the differences in annualized percentage rates of change in readmission rates during each specified time interval or the additional absolute change, relative to previous trend, at specific time points for penalty hospitals relative to nonpenalty hospitals.

^b P values represent the significance of the test for the change in the slope or the absolute change being equal to zero.

^c Excludes acute myocardial infarction, heart failure, pneumonia, chronic obstructive pulmonary disease, and hip and knee arthroplasty surgery.

Table 5. Interrupted Time-Series Analysis for the Difference in Readmission Rates Between Each Target Condition and Nontarget Conditions Stratified by Penalty Status

Cohort	Pre-HRRP Announcement (January 2008–March 2010)		HRRP Announcement (March 2010)		Post-HRRP Announcement, Pre-HRRP Implementation (April 2010–September 2012)		HRRP Implementation (October 2012)		Post-HRRP Implementation (October 2012–June 2015)	
	Difference in Annualized Rate of Change, % (95% CI) ^a	P Value ^b	Difference in Additional Absolute Change, % (95% CI) ^a	P Value ^b	Difference in Annualized Rate of Change, % (95% CI) ^a	P Value ^b	Difference in Additional Absolute Change, % (95% CI) ^a	P Value ^b	Difference in Annualized Rate of Change, % (95% CI) ^a	P Value ^b
Acute myocardial infarction										
Penalty	0.15 (-0.11 to 0.40)	.26	-0.45 (-0.89 to -0.02)	.04	-0.49 (-0.81 to -0.16)	.004	-0.19 (-0.61 to 0.22)	.36	0.09 (-0.18 to 0.35)	.53
Nonpenalty	-0.59 (-0.95 to -0.22)	<.002	0.45 (-0.17 to 1.08)	.15	0.48 (0.01 to 0.95)	.045	-0.26 (-0.87 to 0.34)	.38	0.06 (-0.33 to 0.45)	.75
Heart failure										
Penalty	0.10 (-0.12 to 0.32)	.37	-0.02 (-0.39 to 0.35)	.93	-0.90 (-1.18 to -0.62)	<.001	-0.04 (-0.39 to 0.32)	.84	0.72 (0.49 to 0.95)	<.001
Nonpenalty	-0.26 (-0.56 to 0.04)	.09	-0.16 (-0.67 to 0.35)	.53	0.08 (-0.30 to 0.46)	.67	-0.16 (-0.65 to 0.33)	.52	0.14 (-0.17 to 0.46)	.37
Pneumonia										
Penalty	0.37 (0.10 to 0.64)	.008	-0.20 (-0.66 to 0.25)	.38	-0.57 (-0.92 to -0.23)	.001	-0.03 (-0.47 to 0.41)	.90	0.05 (-0.24 to 0.33)	.74
Nonpenalty	-0.12 (-0.44 to 0.19)	.44	-0.44 (-0.97 to 0.10)	.11	0.53 (0.13 to 0.93)	.01	-0.12 (-0.63 to 0.40)	.65	-0.52 (-0.86 to -0.19)	.003

Abbreviation: HRRP, Hospital Readmission Reduction Program.

^a Data are the differences in the annualized percentage rates of change in readmission rates during each specified time interval or the additional absolute change, relative to previous trend, at specific time points for each target condition, relative to nontarget conditions, across hospitals that were and were not subject to penalties under the HRRP.

^b P values represent the significance of the test for the change in the slope or the absolute change being equal to zero.

which suggests that these hospitals specifically focused efforts to improve readmission outcomes for patients admitted for these target conditions. In contrast, at hospitals not subject to financial penalties, readmission rates for nontarget conditions had declines comparable with those for target conditions, which suggests that broader, system-wide readmission reduction strategies were more likely to have been used as opposed to strategies focusing solely on the target conditions. In addition, across all hospitals, readmission rates for target and nontarget conditions did not significantly change after October 2012. These findings may have implications for future policy programs aimed at reducing readmissions and may provide insight into the effect of external incentives.

This analysis may help elucidate the mechanism by which financial penalties in the HRRP were effective. Hospital readmission performance for AMI, CHF, and pneumonia for 2005–2008 was privately reported to hospitals beginning in April 2009 and publicly available in Hospital Compare beginning in July 2009. Yet, readmission rates were stable between January 2008 and March 2010, suggesting minimal effect of public reporting alone. Other studies have found similar results.¹⁵ Moreover, announcement of the HRRP in April 2010 was associated with a significant decrease in readmissions, particularly for target conditions and primarily among patients discharged from hospitals that had the highest readmission rates initially and were thus later subject to penalties. Specifically, it appears that the announcement of the policy was associated with improvement because it was coupled with the knowledge that some hospitals were likely to face financial penalties. Low-performing hospitals appear to have proactively responded to the threat of penalties, likely because they were aware of their performance; higher-performing hospitals did not respond in the same way, suggesting that they felt less urgency to specifically improve for the target conditions. These results are consistent with a recent survey of hospital leaders, which reported that 66% thought that the HRRP had a “major impact” on system efforts to reduce readmission rates.¹⁶ Policy makers considering payment penalty programs should thus consider whether the results on which they are based are available—ideally in advance of implementation—to the relevant stakeholders. In addition, plateauing of the rate of change for 30-day readmission rates for all conditions since October 2012 raises a number of important considerations. This may reflect that after initial realization of reductions in readmissions with modest investment and interventions, additional reductions in readmissions may be less feasible or may require larger-scale investment with smaller marginal benefit. Hospitals may have assessed the competing financial effect of readmissions on revenue and the potential penalty under the HRRP and determined that the net effect of additional reductions in readmission was not fiscally advantageous. The question of whether additional reductions in readmission rates can be realized and, if so, what policy and payment levers will be most effective in doing so remains an important priority for further study.

A recent study demonstrated that in the period after HRRP implementation, readmission rates for both target and nontarget conditions declined significantly, with larger reductions among the former, and that readmission rates did not appear

to decline as a consequence of increased use of observation services.⁴ The current analysis extends this work in a number of ways. First, it incorporates each hospital's penalty status and suggests important differences in the association of the HRRP with trends in readmission rates based on whether a hospital was subject to a financial penalty. An overall analysis without regard to penalty status masks the heterogeneity and the policy implications that follow. In addition, the present analysis used the publicly reported hospital-wide readmission measure cohort as the comparator population (nontarget conditions) and excluded patients with the target conditions as well as admissions for COPD and hip or knee replacement surgery, as these conditions are now included in HRRP.

There are several limitations to this analysis. First, while the interrupted time series is a valid approach to evaluating changes over time, by design it attributes observed changes to a single factor (the HRRP in this instance). Reducing readmissions had been an important priority for several years prior to the HRRP, and there were several national quality improvement programs focusing on readmission reduction over the period of this study. For instance, the CMS Partnership for Patients Hospital Engagement Networks (starting April 2011) and the CMS Community-based Care Transitions Program (starting February 2012) may have also contributed to the temporal trends.^{17–19} Nonetheless, those national quality improvement programs were unlikely to have been very effective so early after initiation, and even if they contributed, uptake was likely influenced by knowledge of the impending HRRP penalties. Moreover, most US hospitals participated in Hospital Engagement Networks, yet associations were observed only among penalty hospitals. Second, the disproportionate improvement among patients discharged from penalty hospitals may be a result of regression to the mean, in which random variation causing outlier performance is reduced in subsequent periods. If regression to the mean were a substantial influence, however, a similar regression to the mean would have been expected among high-performing outliers; that is, a worsening of readmission rates among nonpenalty hospitals. This was not present, reducing the likelihood that regression to the mean explains the results. Third, the precise mechanism for the observed differential improvements is unknown; hospitals with high readmission rates that were responding to the HRRP may have found it easier to reduce readmissions, invested more resources, prioritized readmission reduction interventions to a greater degree, or a combination thereof. Fourth, hospitals were stratified based on penalty status at the time of HRRP implementation in fiscal year 2013 even though Medicare reassessed hospitals' penalty status each fiscal year. However, 84.3% of hospitals retained the same penalty status in both years, and hospitals that changed status were subject to much smaller average penalties than those that did not.¹⁰ As additional longitudinal data become available, analyses of the effects of changing financial penalties over time to further define the association of the HRRP on readmission rates should be undertaken. Fifth, observation stays were not included in this analysis. However, prior work⁴ has suggested that reductions in readmission were not realized by increasing use of observation stays; therefore, it is unlikely that this

would have meaningfully affected the study results. Sixth, the analytic approach did not account for differential coding practices across hospitals or changes in documentation over time that could have affected the results. Seventh, whether the observed reductions in readmissions have been associated with changes in other quality measures, particularly 30-day risk-standardized mortality measures, remains an important question that warrants additional study.

Conclusions

Medicare fee-for-service patients at hospitals subject to penalties under the HRRP had greater reductions in readmission rates compared with those at nonpenalized hospitals. Changes were greater for target vs nontarget conditions for patients at the penalized hospitals but not at the other hospitals.

ARTICLE INFORMATION

Author Affiliations: Section of Cardiovascular Medicine, Yale University School of Medicine, New Haven, Connecticut (Desai, Herrin, Dharmarajan, Krumholz); Center for Outcomes Research and Evaluation, New Haven, Connecticut (Desai, Ross, Kwon, Dharmarajan, Bernheim, Krumholz); Section of General Medicine, Department of Internal Medicine, Yale University School of Medicine, New Haven, Connecticut (Ross); Robert Wood Johnson Foundation Clinical Scholars Program, Department of Internal Medicine, Yale University School of Medicine, New Haven, Connecticut (Ross, Krumholz); Department of Health Policy and Management, Yale University School of Public Health, New Haven, Connecticut (Ross, Krumholz); Health Research and Educational Trust, Chicago, Illinois (Herrin); Division of Healthcare Delivery Science, Department of Population Health, NYU School of Medicine, New York, New York (Horwitz); Center for Healthcare Innovation and Delivery Science, NYU Langone Medical Center, New York, New York (Horwitz); Department of Medicine, NYU School of Medicine, New York, New York (Horwitz).

Author Contributions: Drs Desai and Horwitz had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Desai, Ross, Herrin, Dharmarajan, Bernheim, Horwitz.
Acquisition, analysis, or interpretation of data: Desai, Ross, Kwon, Herrin, Dharmarajan, Krumholz, Horwitz.
Drafting of the manuscript: Desai, Horwitz.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Kwon, Herrin.
Obtained funding: Horwitz.
Administrative, technical, or material support: Desai, Kwon, Krumholz, Horwitz.
Study supervision: Horwitz.

Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. All authors work under contract with CMS to develop and maintain performance measures. Drs Desai, Ross, and Krumholz are recipients of a research agreement from Johnson & Johnson through Yale University to develop methods of clinical trial data sharing. Drs Ross and Krumholz receive research support from Medtronic through Yale University to develop methods of clinical trial data sharing and through a grant from the US Food and Drug Administration to develop methods for postmarket surveillance of medical devices. Dr Ross also receives research grant support from the Blue Cross Blue Shield Association. Dr Dharmarajan is a consultant for and member of a scientific advisory board for Clover Health. Dr Krumholz is the founder of Hugo, a personal health information platform, and chairs a cardiac scientific advisory board for UnitedHealth. No other disclosures were reported.

Funding/Support: This study was funded by the Agency for Healthcare Research and Quality (grant R01HS022882). Dr Desai is supported by grant K12 HS023000-01 from the Agency for Healthcare Research and Quality. Dr Dharmarajan is supported by grant K23AG048331 from the National Institute on Aging and the American Federation for Aging Research through the Paul B. Beeson Career Development Award Program. He is also supported by grant P30AG021342 via the Yale Claude D. Pepper Older Americans Independence Center.

Role of the Sponsors: The sponsors had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication.

Disclaimer: The content of this article is solely the responsibility of the authors and does not necessarily represent the official views or policies of the Department of Health and Human Services, the National Institutes of Health, the American Federation for Aging Research, or the Agency for Healthcare Research and Quality.

REFERENCES

- Hospital Readmission Reduction Program, Patient Protection and Affordable Care Act, §3025 (2010). Codified at 42 CFR §412.150-412.154.
- Rau J. Half of nation's hospitals fail again to escape Medicare's readmission penalties. *Kaiser Health News*. August 3, 2015. <http://khn.org/news/half-of-nations-hospitals-fail-again-to-escape-medicare-readmission-penalties/>. Accessed October 15, 2015.
- Boccuti C, Casillas G. Aiming for fewer hospital U-turns: the Medicare Hospital Readmission Reduction Program. September 30, 2015. <http://kff.org/medicare/issue-brief/aiming-for-fewer-hospital-u-turns-the-medicare-hospital-readmission-reduction-program/>. Accessed November 24, 2016.
- Zuckerman RB, Sheingold SH, Orav EJ, et al. Readmissions, observation, and the Hospital Readmissions Reduction Program. *N Engl J Med*. 2016;374(16):1543-1551.
- Lindenauer PK, Normand SL, Drye EE, et al. Development, validation, and results of a measure of 30-day readmission following hospitalization for pneumonia. *J Hosp Med*. 2011;6(3):142-150.
- Krumholz HM, Lin Z, Drye EE, et al. An administrative claims measure suitable for profiling hospital performance based on 30-day all-cause readmission rates among patients with acute myocardial infarction. *Circ Cardiovasc Qual Outcomes*. 2011;4(2):243-252.
- Keenan PS, Normand SL, Lin Z, et al. An administrative claims measure suitable for profiling hospital performance on the basis of 30-day all-cause readmission rates among patients with heart failure. *Circ Cardiovasc Qual Outcomes*. 2008;1(1):29-37.
- Horwitz L, Partovian C, Lin Z, et al. Hospital-wide all-cause unplanned readmission measure: final technical report. 2012. <http://www.qualitynet.org/dcs/ContentServer?c=Page&pagename=QnetPublic%2FPage%2FQnetTier4&cid=1219069855841>. Accessed November 10, 2016.
- Horwitz LI, Partovian C, Lin Z, et al. Development and use of an administrative claims measure for profiling hospital-wide performance on 30-day unplanned readmission. *Ann Intern Med*. 2014;161(10)(suppl):S66-S75.
- Centers for Medicare & Medicaid Services. FY 2013 and FY 2014 IPPS final rules: Hospital Readmission Reduction Program supplemental data files. <https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/Readmissions-Reduction-Program.html>. Accessed November 10, 2016.
- Horwitz LI, Partovian C, Lin Z, et al. Centers for Medicare & Medicaid Services Planned Readmission Algorithm—Version 2.1. March 2013. http://hscrc.maryland.gov/documents/HSCRC_Initiatives/readmissions/Version-2-1-Readmission-Planned-CMS-Readmission-Algorithm-Report-03-14-2013.pdf. Accessed June 3, 2015.
- Horwitz LI, Grady JN, Cohen DB, et al. Development and validation of an algorithm to identify planned readmissions from claims data. *J Hosp Med*. 2015;10(10):670-677.
- Penfold RB, Zhang F. Use of interrupted time series analysis in evaluating health care quality improvements. *Acad Pediatr*. 2013;13(6)(suppl):S38-S44.
- Wagner AK, Soumerai SB, Zhang F, Ross-Degnan D. Segmented regression analysis of interrupted time series studies in medication use research. *J Clin Pharm Ther*. 2002;27(4):299-309.
- DeVore AD, Hammill BG, Hardy NC, et al. Has public reporting of hospital readmission rates affected patient outcomes? *J Am Coll Cardiol*. 2016;67(8):963-972.
- Joynt KE, Figueroa JE, Oray J, Jha AK. Opinions on the Hospital Readmission Reduction Program. *Am J Manag Care*. 2016;22(8):e287-e294.
- Brock J, Mitchell J, Irby K, et al; Care Transitions Project Team. Association between quality improvement for care transitions in communities and rehospitalizations among Medicare beneficiaries. *JAMA*. 2013;309(4):381-391.
- Centers for Medicare & Medicaid Services. Community-based Care Transitions Program. <https://innovation.cms.gov/initiatives/CCTP/>. Accessed May 11, 2016.
- Centers for Medicare & Medicaid Services. Hospital Engagement Networks: connecting hospitals to improve care. December 14, 2011. <https://www.cms.gov/Newsroom/MediaReleaseDatabase/Fact-sheets/2011-Fact-sheets-items/2011-12-14.html>. Accessed May 11, 2016.