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ORIGINAL RESEARCH

Association Between Diagnosis Code Expansion and Changes in 30-Day Risk-Adjusted Outcomes for Cardiovascular Diseases

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BACKGROUND: In January 2011, Centers for Medicare and Medicaid Services expanded the number of inpatient diagnosis codes from 9 to 25, which may influence comorbidity counts and risk-adjusted outcome rates for studies spanning January 2011. This study examines the association between (1) limiting versus not limiting diagnosis codes after 2011, (2) using inpatient-only versus inpatient and outpatient data, and (3) using logistic regression versus the Centers for Medicare and Medicaid Services risk-standardized methodology and changes in risk-adjusted outcomes.

METHODS AND RESULTS: Using 100% Medicare inpatient and outpatient files between January 2009 and December 2013, we created 2 cohorts of fee-for-service beneficiaries aged ≥65 years. The acute myocardial infarction cohort and the heart failure cohort had 578 728 and 1 595 069 hospitalizations, respectively. We calculate comorbidities using (1) inpatient-only limited diagnoses, (2) inpatient-only unlimited diagnoses, (3) inpatient and outpatient limited diagnoses, and (4) inpatient and outpatient unlimited diagnoses. Across both cohorts, *International Classification of Diseases, Ninth Revision* (*ICD-9*) diagnoses and hierarchical condition categories increased after 2011. When outpatient data were included, there were no significant differences in risk-adjusted readmission rates using logistic regression or the Centers for Medicare and Medicaid Services risk standardization. A difference-in-differences analysis of risk-adjusted readmission trends before versus after 2011 found that no significant differences between limited and unlimited models for either cohort.

CONCLUSIONS: For studies that span 2011, researchers should consider limiting the number of inpatient diagnosis codes to 9 and/or including outpatient data to minimize the impact of the code expansion on comorbidity counts. However, the 2011 code expansion does not appear to significantly affect risk-adjusted readmission rate estimates using either logistic or risk-standardization models or when using or excluding outpatient data.

Key Words: acute myocardial infarction ■ heart failure ■ medicare ■ outcomes

In January 2011, the Centers for Medicare and Medicaid Services (CMS) expanded the number of available secondary diagnosis codes from 9 to 25 for inpatient hospitalizations.[1] Since then, 2 analyses have suggested that not accounting for this expansion in diagnosis codes may bias comorbidity counts and estimates of risk-adjusted readmission rates.[2,3] Another analysis found that this expansion was associated with a statistically significant increase in the measured severity of illness among diagnoses targeted by readmission-based incentive programs.[4] This has led some to advocate for limiting the number of diagnostic codes after January 2011 to 9,[3,5] whereas others have argued that there is no need to limit diagnosis codes if outpatient

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CLINICAL PERSPECTIVE

What Is New?

- In January 2011, the Centers for Medicare and Medicaid Services expanded the number of inpatient diagnosis codes from 9 to 25; this had led to concerns about the stability of comorbidity counts and risk-adjusted outcome rates for studies that span 2011.
- To address this, some have recommend limiting the number of inpatient diagnosis codes to 9 for studies that span 2011, whereas others have recommended including outpatient data as a way of mitigating the impact of the diagnosis code expansion.
- In this study, we found an increase in comorbidity counts after 2011 but no significant difference in risk-adjusted outcomes rates between models that limited the number of diagnosis codes to 9 versus those that did not or between models that used inpatient-only data versus inpatient and outpatient data.

What Are the Clinical Implications?

- For studies that span 2011, diagnosis codes may need to be limited for studies that use comorbidity counts, but the 2011 code expansion does not appear to significantly affect risk-adjusted readmission rate estimates using either logistic or risk-standardization models.

Nonstandard Abbreviations and Acronyms

CMS	Centers for Medicare and Medicaid Services
HCCs	hierarchical condition comorbidities

data are also included.[6–8] At present, little is known about the association between limiting versus not limiting diagnosis codes after 2011 and whether adding outpatient data influences this for acute myocardial infarction (AMI) and heart failure (HF). Understanding the associations between diagnosis code limits and data sources with comorbidity assessment and estimates of 30-day risk-adjusted readmission rates is important in comparing evaluations of policy interventions that span January 2011, most notably the Hospital Readmissions Reduction Program.[9–12]

Another factor to consider in comparing evaluations of policy interventions, such as the Hospital Readmissions Reduction Program, is the methodology used to risk adjust outcomes. Specifically, the 2 studies published to date that have questioned the reduction in readmission rates after the Hospital Readmissions Reduction Program used logistic regression models to risk adjust readmission rates for standard demographics, admission dates, and comorbidities.[2,3] In contrast, the CMS uses a complex hierarchical logistic regression to calculate a risk-standardized readmission rate as the ratio of "predicted" over "expected" readmissions/deaths and then multiplies each hospital's ratio by the national unadjusted rate. To date, whether the 2 methodologies produce different results and/or are affected differently by changes in diagnosis codes and the type of data used has not been explored.

The aim of this study is therefore 2-fold: (1) examine the association between limiting versus not limiting diagnosis codes and inpatient-only versus inpatient and outpatient data with changes in calculated risk-adjusted 30-day readmission rates and (2) determine the difference in risk-adjusted readmission rates calculated using standard logistic regression versus the CMS risk-standardized methodology and determine whether they are differentially sensitive to changes in diagnoses code counts or data sources.

METHODS

This project was reviewed and approved by the Dartmouth-Hitchcock Medical Center Institutional Review Board. This article is compliant with the Strengthening the Reporting of Observational Studies in Epidemiology reporting guideline for observational studies. The authors declare that all supporting data are available within this article and its online supplementary files. All analyses were performed between November 2019 and December 2020 using SAS 9.4.

Study Cohorts

We used 100% Medicare Parts A and B and 100% outpatient data to create 2 cohorts of beneficiaries aged ≥65 years with ≥1 admission for AMI or HF between 2009 and 2013. Using the CMS published methodologies, we created an AMI readmission and a HF readmission cohort (Figure S1).[13] Beneficiaries were required to have 12 months of fee-for-service coverage before their AMI or HF admission. Beneficiaries with unknown age or sex, those enrolled in Medicare for <12 months, those discharged against medical advice, those who died before discharge, and those who underwent implantation of a left ventricular assist device or heart transplant during admission or in the 12 months before admission were excluded.[14]

Calculating Hierarchical Condition Categories (Comorbidities) for Risk Adjustment

To determine the number of hierarchical condition comorbidities (HCCs)[15] per patient to include in the

readmission models, we used the following 4 different approaches/methods:

1. Inpatient-only data with diagnostic codes limited to 9 after 2011.
2. Inpatient-only data with diagnostic codes not limited after 2011.
3. Inpatient and outpatient data with diagnostic codes limited to 9 after 2011.
4. Inpatient and outpatient data with diagnostic codes not limited after 2011.

Risk-Adjusted Readmission Rates

We produced risk-adjusted readmission rates using a multivariable logistic regression model using all years of data between 2009 and 2013. The model(s) included age, sex, race, admission date, HCCs (determined using each of the 4 methods described previously) and a year-specific indicator.

Risk-Standardized Readmission Rates

To calculate the risk-standardized 30-day readmission rates, we used the CMS methodology. We used hierarchical logistic regression and all years of data between 2009 and 2013 with year-specific indicators to calculate the ratio of the number of "predicted" to the number of "expected" readmissions for each hospital and then multiplied that ratio by the national unadjusted readmission rate in that year. This approach is analogous to using a ratio of "observed" to "expected" such that a lower ratio indicates a lower than expected rate of readmissions/deaths, whereas a higher ratio indicates a higher than expected rate of deaths.[16] For each cohort, we then calculated the risk-standardized 30-day readmission rate using each of the 4 comorbidity ascertainment methods described previously.[17]

Statistical Analysis

We analyzed data from January 2009 through December 2013, 2 years before and 2 years after the diagnosis code expansion in January 2011. We calculated the mean *International Classification of Diseases, Ninth Revision* (*ICD-9*) counts and HCCs per patient in each year and report the means and standard deviations for both AMI and HF. We then determined the absolute difference in risk-adjusted/risk-standardized readmission rates depending on whether diagnosis codes were limited and whether outpatient data were included. We compared these differences using chi-square testing. We then used a difference-in-differences approach to examine changes in readmission rates from the baseline period (2009–2011) to the postperiod (2011–2013), depending on whether the *ICD-9* codes were limited to 9 and whether outpatient data were included.

RESULTS

Association Between Diagnosis Code Expansion and Changes in Comorbidity Burdens

As shown in Figure 1, when the number of diagnosis codes allowed for inpatient hospitalizations was expanded after 2011, the number of *ICD-9* and HCC conditions used for risk adjustment increased for both AMI and HF, regardless of whether inpatient-only or inpatient and outpatient data were used. The mean number of diagnosis codes used, at the hospital level, before and after 2011 show similar increases (Table S1), and the percentage of patients with 10 or more diagnosis codes on the index admission claim sharply increased after 2011, consistent with the abrupt step-up seen in Figure 1 (Table S2).

With the expansion in the number of allowed inpatient diagnosis codes, after 2011, the number of *ICD-9* and HCCs both increased significantly, although the magnitude of increase was larger for *ICD-9* diagnoses compared with HCCs (Figure 1). For example, in 2011 in the AMI cohort, when inpatient-only data were used, the average number of *ICD-9* diagnoses increased by 5.5 (from 14.1 to 19.6, +39%; $P<0.001$) and the average number of HCCs increased by 0.4 (from 4.0 to 4.4, +10%; $P<0.001$). For the HF cohort, when inpatient-only data were used, the average number of *ICD-9* diagnoses increased by 7.2 (from 18.8 to 26.0, +38%; $P<0.001$) and the average number of HCCs increased by 0.4 (from 4.7 to 5.1, +9%; $P<0.001$).

The inclusion of outpatient data mitigated the relative increase in both *ICD-9* and HCCs, but both increases remained statistically significant (Figure 1). When inpatient and outpatient data were used, for the AMI cohort, the average number of *ICD-9* diagnoses increased by 4.3 (from 47.8 to 51.1, +9%; $P<0.001$) and the average number of HCCs increased by 0.2 (from 6.2 to 6.4, +3%; $P<0.001$). For the HF cohort, the number of *ICD-9* diagnoses increased by 5.2 (from 62.2 to 67.4, +8%; $P<0.001$) and the average number of HCCs increased by 0.2 (from 7.4 to 7.6, +3%; $P<0.001$). Also notable, although the number of *ICD-9* and HCC conditions stayed relatively flat for AMI between 2009 and 2013, there was a general uptrend in both *ICD-9* and HCC conditions for the HF cohort across the same time period.

Inclusion of Diagnosis Code Expansion on Specific HCCs

Next, we determined which HCCs were most likely to be added to risk-adjustment models when the number of allowed diagnosis codes for inpatient hospitalizations was expanded. As seen in Table 1, when diagnosis codes were not limited, using inpatient-only data, dialysis was

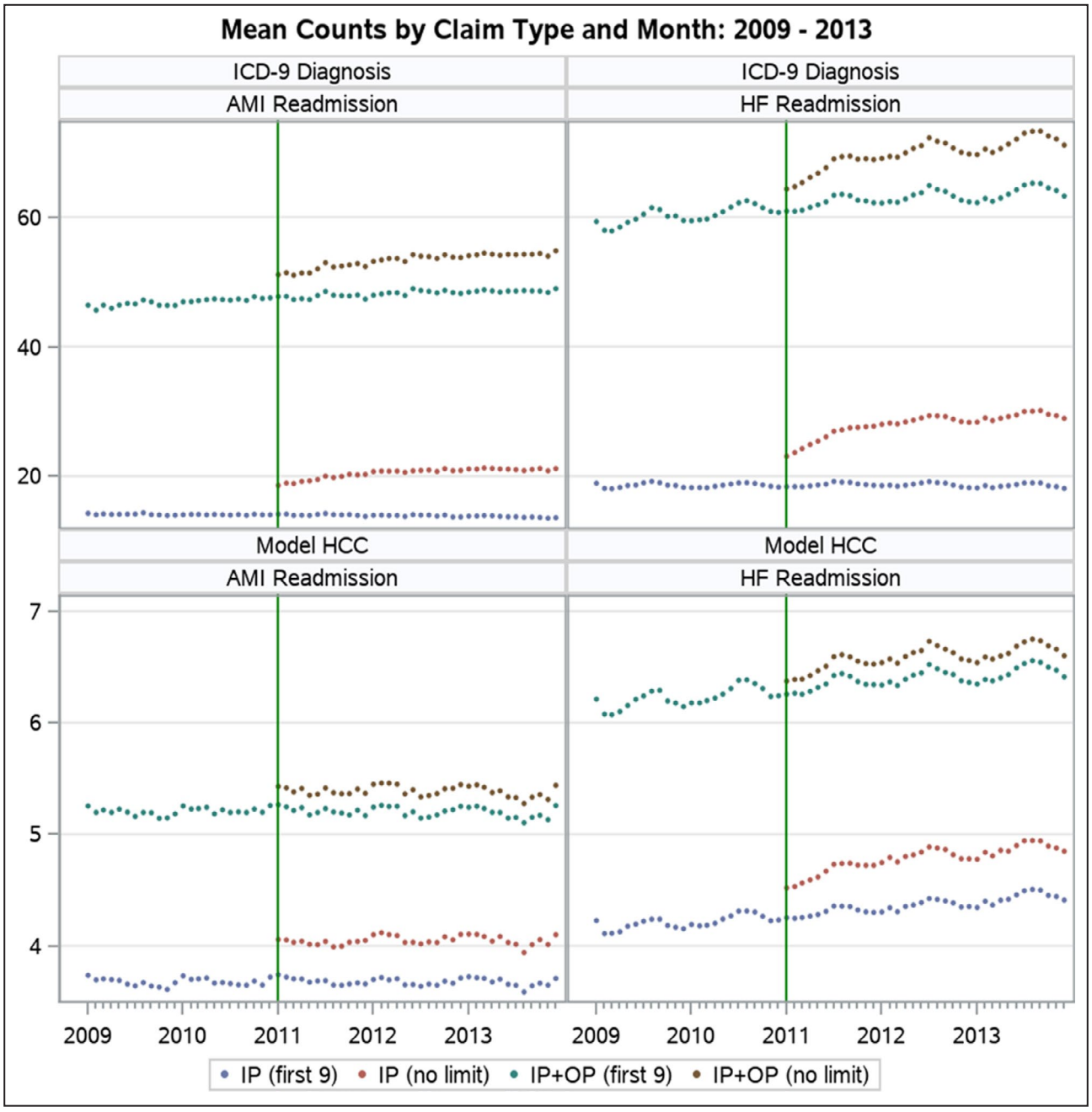

Figure 1. ***ICD-9*** **diagnoses and hierarchical condition categories by year, 2009 to 2013.**
Estimates and standard deviations are included in Table S2. Consistent with the Centers for Medicare and Medicaid Services methodology, both the index admission and the year before admission are considered in the calculation of the number if *ICD-9* codes and HCCs that should be included in risk adjustment. AMI indicates acute myocardial infarction; HCC, hierarchical condition comorbidity; HF, heart failure; *ICD-9*, *International Classification of Diseases, Ninth Revision*; IP, inpatient; and OP, outpatient.

95% more commonly coded for AMI readmissions and unspecified heart disease was 122% more commonly coded for HF readmissions. When inpatient and outpatient data were considered, dialysis was the most commonly added HCC in the AMI readmission cohort (20% more commonly coded) and nephritis was the most commonly added HCC in the HF readmission cohort (44% more commonly coded).

Association Between Diagnosis Code Expansion and Readmission Rates Calculated Using Logistic Regression for Risk Adjustment

Using logistic regression for risk adjustment, between 2009 and 2013, risk-adjusted readmission rates fell for both AMI and HF (Figure 2). Using inpatient-only data,

Table 1. Increase in Hierarchical Condition Category Diagnoses Observed When Diagnosis Codes Are Not Limited and When Outpatient Data Are Included

Inpatient-only data (percent difference)		Inpatient+outpatient data (percent difference)	
AMI readmission			
Dialysis	95.2	Dialysis	20.4
Urinary tract disease	81.8	History of CABG	17.5
Valvular/rheumatic disease	59.7	Valvular/rheumatic disease	15.3
HF readmission			
Unspecified heart disease	122.1	Nephritis	43.9
Nephritis	116.3	Drug, alcohol abuse	31.7
Psychiatric disease	115.0	Depression	30.8

AMI indicates acute myocardial infarction; CABG, coronary artery bypass grafting; and HF, heart failure.

in 2011, limiting diagnosis codes was not associated with a difference in 30-day AMI readmission rates (difference, −0.14%; P=0.37) or HF 30-day readmission rates (difference, −0.04%; P=0.70). By 2013, the difference was slightly larger (for AMI, 0.19% [P=0.20]; for HF, 0.10% [P=0.34]) but remained insignificant (Table 2).

Using inpatient and outpatient data, in 2011, for AMI, the difference between limited and unlimited models was 0.06% (P=0.70; compared with inpatient-only difference, 0.08%; P<0.001). Using inpatient and outpatient data, in 2011, for HF, the difference between limited and unlimited models was was 0.01% (P=0.92; compared with inpatient-only difference, 0.03%; P<0.001). In 2013, the difference between limited and unlimited models was 0.08% (P=0.59; compared with inpatient-only difference, 0.11%; P<0.001) and for HF was 0.02% (P=0.85; compared with inpatient-only difference, 0.08%; P<0.001).

Association Between Diagnosis Code Expansion and Readmission Rates Calculated Using the CMS Risk-Standardization Methodology

For both AMI and HF, the CMS risk-standardized readmission rates were approximately 1% higher than readmission rates calculated using logistic regression. Between 2009 and 2013, risk-standardized readmission rates fell for both AMI and HF (Figure 3).

Between 2011 and 2013, when inpatient-only data or inpatient and outpatient data were used, there were no significant differences between limited and unlimited model readmission rates for AMI. For HF, unlimited model estimates were 0.13% (P=0.04, in 2011) to 0.10% (P=0.04, in 2013) higher. When outpatient data were added, whereas unlimited model estimates remained higher for HF, the difference was no longer significant (2011 difference, 0.05% [P=0.42]; 2013 difference, 0.04% [P=0.44]). For both AMI and HF, the difference between limited and unlimited models was smaller (P<0.001) when outpatient data were included.

Comparison of Readmission Trends Before and After 2011 Diagnosis Code Expansion

Using a difference-in-differences approach, we compared risk-standardized readmission rates before versus after the 2011 code expansion using limited versus unlimited codes in the post-2011 period. For both AMI and HF, there were no significant differences in estimated readmission rates in the postperiod (2009 versus 2013) based on whether diagnoses codes were limited or not using both risk-standardized adjustment (Table 3) and logistic regression adjustment (Table S3).

DISCUSSION

Since 2011, when the CMS increased the number of diagnosis codes that could be submitted for an inpatient hospitalization, there has been controversy about how to accurately use claims data to ascertain comorbidities, longitudinally assess outcomes, and evaluate policies that span this time period. Consistent with prior work, this study confirms that to fairly compare the rates of specific comorbidities before and after 2011, researchers should consider limiting diagnosis codes after 2011.[3,4,18] This work also finds that when possible, outpatient data should be included to ensure completeness and consistency of comorbidity counts. Although there appear to be differences in readmission rates for AMI and HF, depending on whether logistic regression or the CMS risk-standardization methodology is used, longitudinal estimates of changes in risk-adjusted readmission rates are not affected by the 2011 code expansion, whether using CMS methods or logistic regression methods, or whether including or excluding outpatient data.

The first key finding of this work is that when possible, outpatient data should be included to ensure completeness of comorbidity assessment. For AMI, when diagnosis codes are expanded, “dialysis” was most

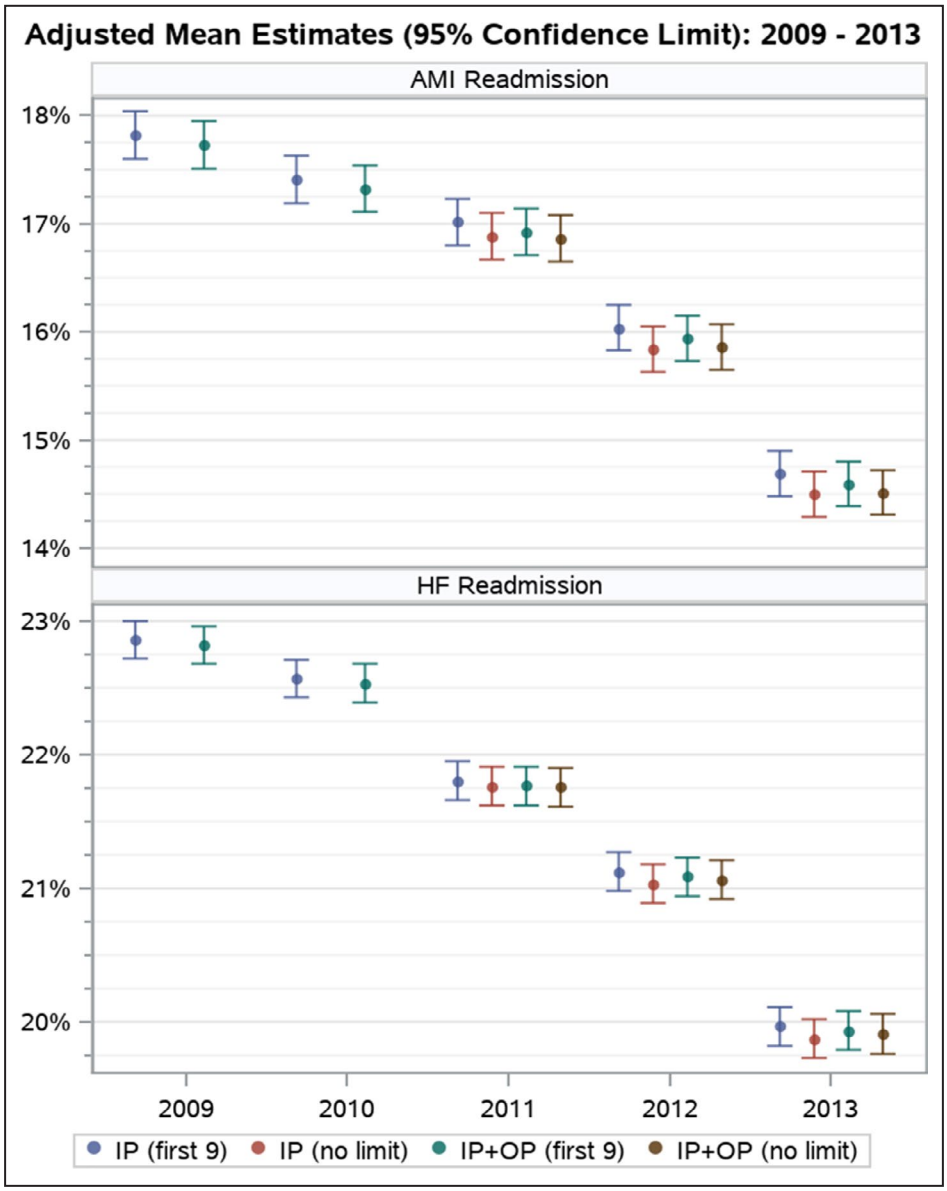

Figure 2. Risk-adjusted readmission rates calculated using logistic regression.
Models are adjusted for age, sex, race, year, and individual hierarchical condition comorbidities. AMI indicates acute myocardial infarction; HF, heart failure; IP, inpatient; and OP, outpatient.

commonly added and "unspecified heart disease" and "nephritis" were most commonly added for HF. Notably, the percentage increase in specific diagnoses was smaller when outpatient data were included, underscoring how including outpatient data minimizes the changes associated with diagnosis code limits.

The second key finding of this work is that when outpatient data are added, the difference between limited and unlimited models for AMI and HF is not significant for either logistic regression or risk-standardized models. Although prior work has suggested that logistic regression–based risk adjustment may be impacted by the 2011 diagnosis code expansion,[2,3] this work finds that including outpatient data minimizes any differences in readmission rates associated with changes in the number of diagnosis codes included.

The third key finding of this work is, when analyzed longitudinally and using a difference-in-differences analysis, there does not appear to be a significant difference in either logistic regression–adjusted or the CMS risk-standardized readmission rates trends before and after the 2011 diagnosis code expansion using either inpatient-only or inpatient and outpatient data.

Finally, because logistic regression and the CMS risk-standardization produce readmission rates that are ~1% different on average and because these 2 methods may be differentially affected by the 2011 diagnosis code expansion, researchers and policy

Table 2. Comparing the Association Between Diagnosis Code Expansion and Risk-Adjusted Logistic Regression Readmission Models Versus the Centers for Medicare and Medicaid Services Risk-Standardized Readmission Models

		Inpatient limited, percent (95% CI)	Inpatient unlimited, percent (95% CI)	Inpatient difference, percent (*P* Value)	Inpatient+Outpatient limited, percent (95% CI)	Inpatient+Outpatient unlimited, percent (95% CI)	Inpatient+Outpatient difference, percent (*P* Value)	Inpatient difference vs Inpatient+Outpatient difference, percent (*P* Value)
Risk-adjusted logistic regression models								
AMI readmissions	2011	17.02 (16.80–17.23)	16.88 (16.67–17.10)	0.14 (0.37)	16.92 (16.71–17.14)	16.86 (16.65–17.08)	0.06 (0.70)	0.08 (<0.001)
	2012	16.03 (15.83–16.25)	15.84 (15.63–16.05)	0.19 (0.21)	15.94 (15.73–16.15)	15.86 (15.65–16.07)	0.08 (0.60)	0.11 (<0.001)
	2013	14.69 (14.48–14.90)	14.50 (14.29–14.71)	0.19 (0.20)	14.59 (14.39–14.80)	14.51 (14.31–14.72)	0.08 (0.59)	0.11 (<0.001)
HF readmissions	2011	21.80 (21.66–21.80)	21.76 (21.62–21.91)	0.04 (0.70)	21.77 (21.62–21.91)	21.76 (21.61–21.90)	0.01 (0.92)	0.03 (<0.001)
	2012	21.12 (20.98–21.27)	21.03 (20.89–21.89)	0.09 (0.39)	21.09 (20.94–21.23)	21.06 (20.92–21.21)	0.03 (0.77)	0.06 (<0.001)
	2013	19.97 (19.82–20.11)	19.87 (19.73–20.02)	0.10 (0.34)	19.93 (19.79–20.08)	19.91 (19.76–20.06)	0.02 (0.85)	0.08 (<0.001)
Hospital risk-standardized readmission rate								
AMI readmissions	2011	18.16 (18.10–18.21)	18.17 (18.12–18.23)	0.01 (0.66)	18.14 (18.09–18.19)	18.15 (18.10–18.20)	0.01 (0.80)	0.01 (<0.001)
	2012	17.15 (17.10–17.20)	17.16 (17.11–17.21)	0.01 (0.67)	17.13 (17.09–17.18)	17.14 (17.09–17.19)	0.01 (0.81)	0.01 (<0.001)
	2013	15.77 (15.73–15.81)	15.78 (15.74–15.83)	0.01 (0.67)	15.75 (15.71–15.79)	15.76 (15.72–15.80)	0.01 (0.81)	0.01 (<0.001)
HF readmissions	2011	22.78 (22.70–22.86)	22.91 (22.82–22.99)	0.13 (0.04)	22.90 (22.82–22.99)	22.95 (22.87–23.03)	0.05 (0.42)	0.08 (<0.001)
	2012	22.10 (22.02–22.18)	22.22 (22.14–22.30)	0.12 (0.04)	22.21 (22.14–22.29)	22.26 (22.18–22.34)	0.05 (0.43)	0.07 (0.001)
	2013	20.93 (20.86,21.00)	21.03 (20.96,21.10)	0.10 (0.04)	21.03 (20.96–21.10)	21.07 (21.00–21.14)	0.04 (0.44)	0.07 (<0.001)

AMI indicates acute myocardial infarction; and HF, heart failure.

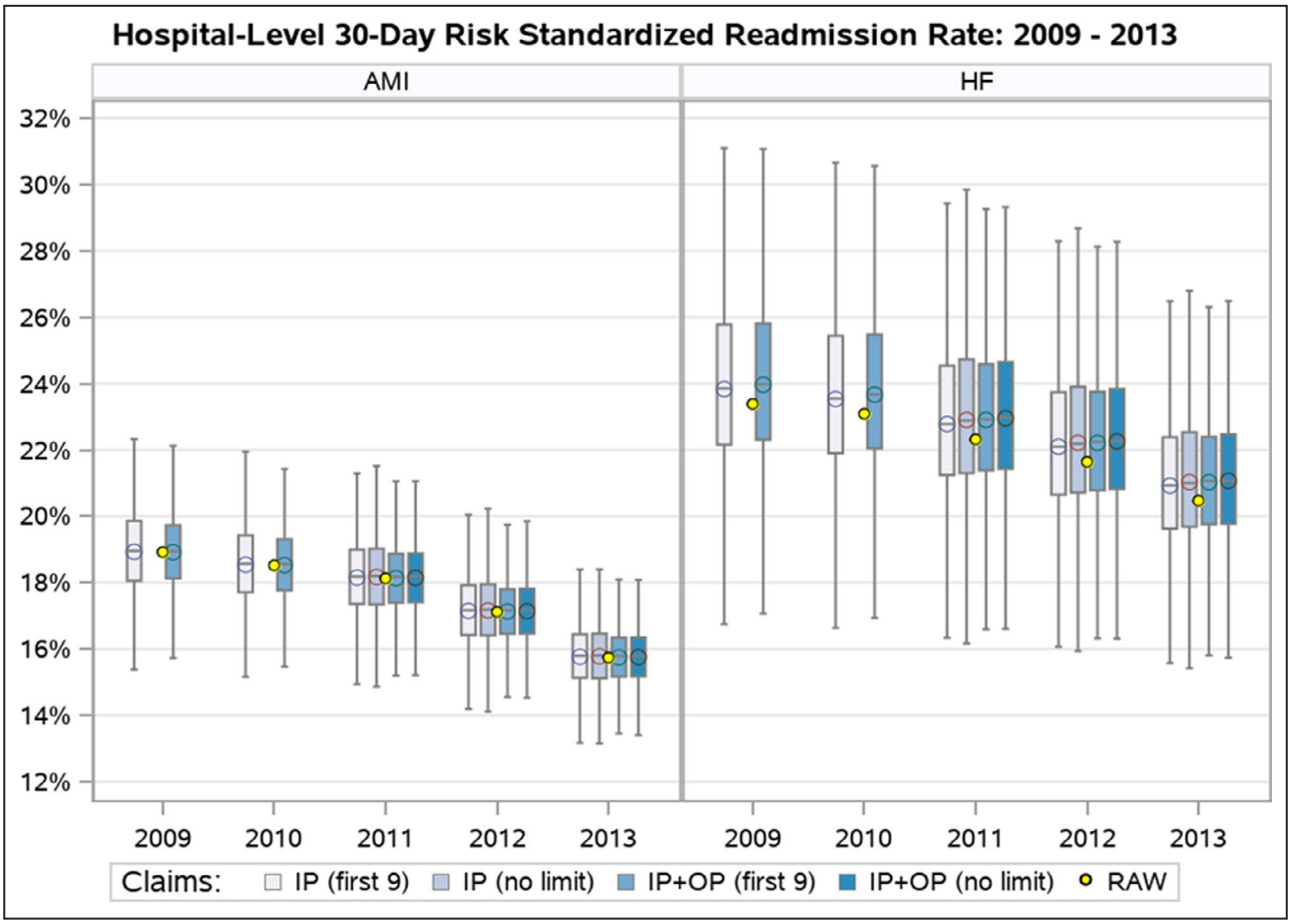

Figure 3. Risk-standardized readmission rates calculated using the Centers for Medicare and Medicaid Services published methodology.
AMI indicates acute myocardial infarction; HF, heart failure; IP, inpatient; and OP, outpatient.

makers should use caution when comparing the results of studies that use different analytic methods.

These results highlight important considerations for comparing the evaluations of policies that span 2011, specifically the following:

1. Researchers may want to consider limiting diagnosis codes to 9 to allow a fair comparison of comorbidity counts over time.
2. When outpatient data are included, diagnosis code limits do not appear to significantly affect readmission

Table 3. Difference in Differences Analysis Comparing Risk-Standardized Readmission Trends Before Versus After the 2011 Diagnosis Code Expansion Using 9 Versus 25 Codes in the Post-2011 Period

	2009 Risk-standardized readmission rate LS mean (95% CI)	2013 Risk-standardized readmission rate LS mean (95% CI)	LS mean *P* Value	*P* Value for interaction
Inpatient-only data				
AMI, limited	0.189 (−0.181 to 0.559)	0.157 (−0.151 to 0.465)	0.189	0.88
AMI, unlimited	0.189 (−0.182 to 0.560)	0.157 (−0.151 to 0.466)	0.189	
HF, limited	0.235 (−0.226 to 0.696)	0.206 (−0.197 to 0.609)	0.74	0.38
HF, unlimited	0.235 (−0.226 to 0.696)	0.206 (−0.198 to 0.610)	0.48	
Inpatient+outpatient data				
AMI, limited	0.189 (−0.181 to 0.559)	0.157 (−0.151 to 0.465)	0.94	0.38
AMI, unlimited	0.189 (−0.182 to 0.560)	0.157 (−0.151 to 0.466)	0.96	
HF, limited	0.235 (−0.226 to 0.696)	0.206 (−0.198 to 0.609)	0.90	0.77
HF, unlimited	0.235 (−0.226 to 0.697)	0.206 (−0.198 to 0.609)	0.81	

AMI indicates acute myocardial infarction; HF, heart failure; and LS, least squares.

rate estimates from either logistic regression or risk-standardized models.
3. When analyzed longitudinally, there does not appear to be a significant difference in either logistic regression–adjusted or the CMS risk-standardized readmission rates trends before and after the 2011 based on whether diagnosis codes are limited or whether inpatient-only or inpatient and outpatient data are used.
4. Caution should be used when comparing analyses that use logistic regression to studies that use risk standardization to compare risk-adjusted outcomes.

Limitations

This study is unique to the Medicare population of patients hospitalized with AMI or HF and the Medicare risk-adjustment algorithms used for these 2 conditions. Thus, caution should be used when extrapolating the findings to other patient groups and/or risk-adjustment algorithms. In addition, this study does not use a control group to formally evaluate longitudinal estimates using 9 versus 25 diagnosis codes nor does it formally compare estimates using inpatient-only versus inpatient and outpatient data. Although limiting to the first 9 diagnosis codes is a methodology demonstrated in previous studies, this does introduce potential arbitrariness because we have no knowledge about the ordering of the conditions listed. Typically, medical coders list comorbidities in order of priority based on likely reimbursement, but this may not always be the case.

CONCLUSIONS

For studies that span January 2011, researchers may want to consider limiting diagnosis codes to 9 to allow a fair comparison of comorbidity counts over time. In addition, outpatient data should be included when available to ensure completeness of comorbidity assessment. At the same time, researchers do not need to restrict to 9 codes or include outpatient data for analyses of risk-adjusted readmission rates before and after 2011.

Although the 2011 diagnosis code expansion and the inclusion of outpatient data do not appear to significantly impact risk-adjusted readmission rates for AMI or HF, when comparing studies that evaluate policies spanning 2011, is it important for readers, researchers, and policy makers to note the methodology used. Direct comparison of studies that use different risk-adjustment methodologies may be problematic.

ARTICLE INFORMATION

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Disclosures

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Supplementary Material

Tables S1–S3
Figures S1

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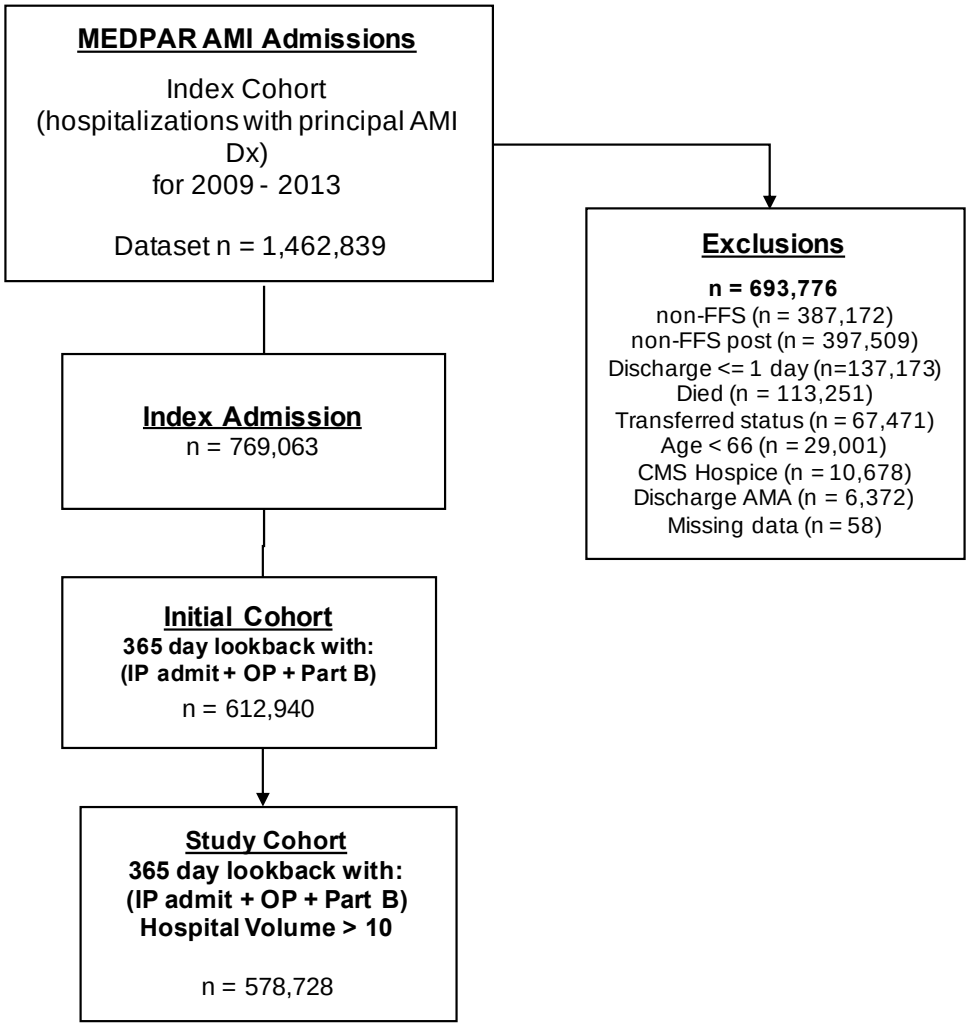
Supplemental Material

Figure S1. Consort Diagrams for 2 Cohorts.

AMI Risk Standardized Readmission Cohort Data Flow Diagram: 2009 - 2013



HF Risk Standardized Readmission Cohort Data Flow Diagram: 2009 - 2013

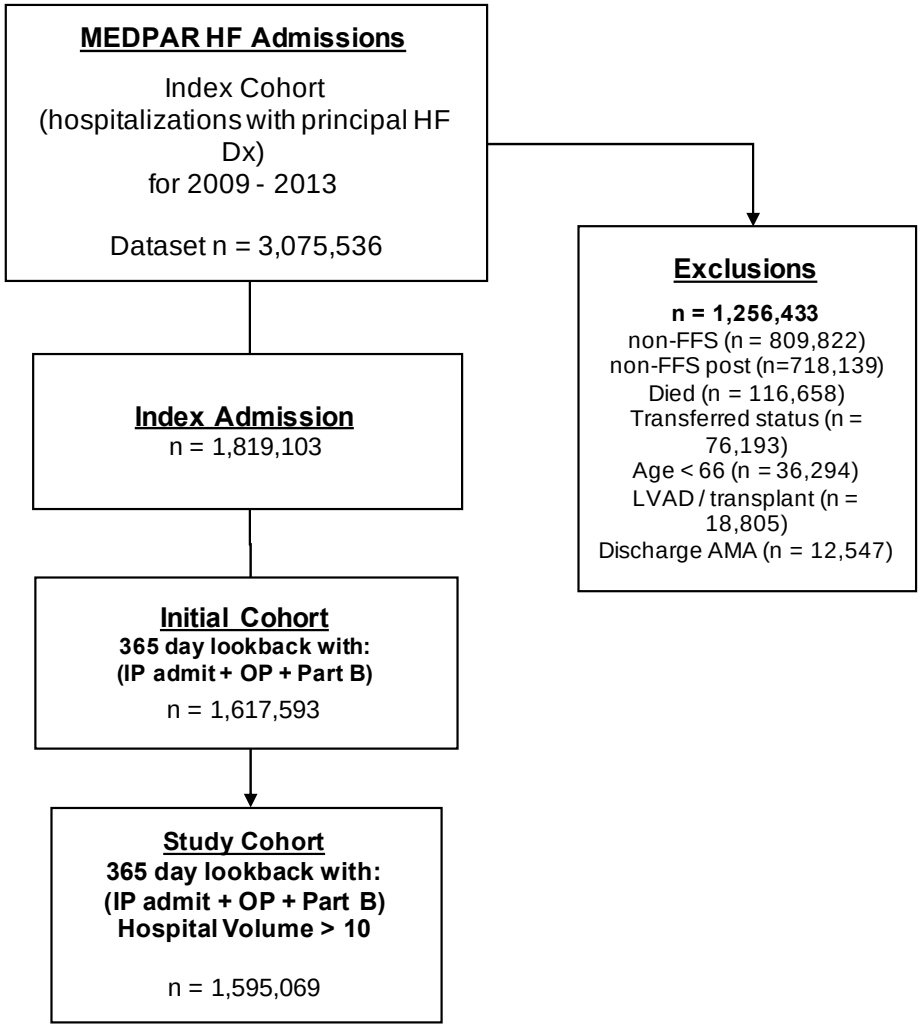


Table S1. Average Field Counts used to Count ICD-9 Before/After 2011.

		2009		2010		2011			
		IP (first 9)	IP+OP (first 9)	IP (first 9)	IP+OP (first 9)	IP (first 9)	IP (no limit)	IP+OP (first 9)	IP+OP (no limit)
AMI Readmissions	n (hospitals)	1998	1998	1998	1998	1982	1982	1982	1982
	n (patients)	116850	116850	116070	116070	115887	115887	115887	115887
	mean	14.2	46.5	14.1	47.4	14.1	19.6	47.8	52.1
	median	9.0	41.0	9.0	42.0	9.0	17.0	42.0	46.0
	std dev	8.8	25.5	8.8	26.0	8.8	12.4	26.2	28.1
	min	1.0	2.0	1.0	3.0	1.0	1.0	3.0	3.0
	max	98.0	265.0	96.0	239.0	94.0	137.0	237.0	248.0
HF Readmissions	n (hospitals)	3829	3829	3770	3770	3670	3670	3670	3670
	n (patients)	346730	346730	332725	332725	317961	317961	317961	317961
	mean	18.7	59.6	18.6	61.0	18.8	26.0	62.2	67.4
	median	16.0	55.0	16.0	56.0	16.0	23.0	58.0	63.0
	std dev	10.4	28.2	10.4	28.7	10.4	14.3	29.2	31.1
	min	1.0	3.0	1.0	4.0	1.0	1.0	3.0	3.0
	max	95.0	253.0	104.0	276.0	99.0	141.0	265.0	293.0

		2012				2013			
		IP (first 9)	IP (no limit)	IP+OP (first 9)	IP+OP (no limit)	IP (first 9)	IP (no limit)	IP+OP (first 9)	IP+OP (no limit)
AMI Readmissions	n (hospitals)	1954	1954	1954	1954	1910	1910	1910	1910
	n (patients)	117697	117697	117697	117697	112224	112224	112224	112224
	mean	14.0	20.9	48.4	53.8	13.8	21.2	48.7	54.4
	median	9.0	17.0	43.0	47.0	9.0	17.0	43.0	48.0
	std dev	8.7	14.1	26.6	29.6	8.6	14.3	26.6	29.8
	min	1.0	1.0	4.0	4.0	1.0	1.0	3.0	3.0
	max	100.0	149.0	252.0	281.0	84.0	145.0	235.0	281.0
HF Readmissions	n (hospitals)	3581	3581	3581	3581	3463	3463	3463	3463
	n (patients)	304913	304913	304913	304913	292740	292740	292740	292740
	mean	18.8	28.7	63.2	70.4	18.6	29.3	63.8	71.6
	median	16.0	25.0	59.0	65.0	16.0	25.0	59.0	66.0
	std dev	10.5	16.5	29.6	33.0	10.4	16.8	29.7	33.3
	min	1.0	1.0	4.0	4.0	1.0	1.0	4.0	4.0
	max	95.0	155.0	277.0	298.0	93.0	148.0	276.0	299.0

Table S2. Average Index Claim Counts Before/After 2011.

Year	AMI Index Claim n	9 or more diagnosis codes	10 or more diagnosis codes	HF Index Claim n	9 or more diagnosis codes	10 or more diagnosis codes
2009	116,850	79.5%	8.1%	346,730	85.3%	6.0%
2010	116,070	80.0%	4.6%	332,725	87.1%	4.7%
2011	115,887	81.0%	73.1%	317,961	89.2%	81.9%
2012	117,697	82.1%	75.1%	304,913	90.7%	85.0%
2013	112,224	83.0%	76.7%	292,740	92.2%	87.7%

Table S3. Difference in Differences Analysis Comparing Logistic Regression Adjusted Readmission Trends Before vs. After the 2011 Diagnosis Code Expansion using 9 vs 25 codes in the Post-2011 Period.

	2009 Risk-Standardized Readmission Rate LS Mean	2013 Risk-Standardized Readmission Rate LS Mean	Inpatient-Only, Limited Difference	Inpatient-Only, Unlimited Difference	P-Value for Interaction (Difference in Differences)
Inpatient-Only Data					
AMI (limited)	0.178	0.147	0.031	0.034	1.0
AMI (unlimited)	0.179	0.145			
HF (limited)	0.229	0.199	0.029	0.031	1.0
HF (unlimited)	0.229	0.200			
	2009 Risk-Standardized Readmission Rate LS Mean	**2013 Risk-Standardized Readmission Rate LS Mean**	**Inpatient+ Outpatient, Limited Difference**	**Inpatient+ Outpatient, Unlimited Difference**	**P-Value for Interaction (Difference in Differences)**
Inpatient+Outpatient Data					
AMI (limited)	0.177	0.1460	0.031	0.032	1.0
AMI (unlimited)	0.177	0.145			
HF (limited)	0.228	0.199	0.029	0.029	1.0
HF (unlimited)	0.228	0.199			