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Acute Myocardial Infarction Cohorts Defined by ICD-10 versus DRG: Analysis of Diagnostic Agreement and Quality Measures in an Integrated Health System

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Abstract

Background: Among Medicare value-based payment programs for acute myocardial infarction (AMI), the Hospital Readmissions Reduction Program (HRRP) uses ICD-10 codes to identify the program denominator, while the Bundled Payments for Care Improvement Advanced (BPCIA) program uses DRGs. The extent to which these programs target similar patients, whether they target the intended population (Type 1 myocardial infarction), and whether outcomes are comparable between cohorts is not known.

Methods: In a retrospective study of 2,176 patients hospitalized in an integrated health system, a cohort of patients assigned a principal ICD-10 diagnosis of AMI and a cohort of patients assigned an AMI DRG were compared according to patient-level agreement and outcomes such as mortality and readmission.

Results: 1,935 patients were included in the ICD-10 cohort compared to 662 patients in the DRG cohort. Only 421 patients were included in both AMI cohorts (19.3% agreement). DRG cohort patients were older (70 vs. 65 years, p<0.001), more often female (48% vs 30%, p<0.001), and had higher rates of heart failure (52% vs. 33%, p<0.001) and kidney disease (42% vs. 25%, p<0.001).

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Comparing outcomes, the DRG cohort had significantly higher unadjusted rates of 30-day mortality (6.6% vs. 2.5%, p<0.001), 1-year mortality (21% vs. 8%, p<0.001), and 90-day readmission (26% vs. 19%, p=0.006) than the ICD-10 cohort. Two observations help explain these differences: 61% of ICD-10 cohort patients were assigned procedural DRGs for revascularization instead of an AMI DRG, and Type 1 MI patients made up a smaller proportion of the DRG cohort (34%) than the ICD-10 cohort (78%).

Conclusions: The method used to identify denominators for value-based payment programs has important implications for the patient characteristics and outcomes of the populations. As national and local quality initiatives mature, an emphasis on ICD-10 codes to define AMI cohorts would better represent Type 1 MI patients.

Keywords

quality; outcome and process assessment; acute myocardial infarction; pay for performance; Medicare

Introduction

National efforts to improve inpatient cardiovascular care now include several value-based payment reforms initiated by the Center for Medicare and Medicaid Services (CMS): these include the Hospital Readmissions Reduction Program (HRRP), the Value-Based Purchasing program (VBP) and the voluntary Bundled Payments for Care Improvement Advanced (BPCIA). Because of its relatively high incidence and cost in the Medicare population and the availability of numerous evidence-based therapies that improve outcomes for Type 1 myocardial infarction (T1MI), acute myocardial infarction (AMI) is a condition targeted by all three programs.[1,2] These programs do not define AMI uniformly, however. While the BPCIA uses Medicare-severity diagnosis related groups (DRG) to define eligible AMI hospitalizations,[3] the HRRP and VBP programs use AMI codes from the international classification of diseases, 10th revision (ICD-10).[4,5]

Broadly, how AMI populations are defined is important to the work of hospitals, payers, researchers, and ratings agencies. Hospitals are continuously analyzing performance data to focus improvement efforts, but may not consider whether these data come from DRG or ICD-10 cohorts. Payers may dispense payments for inpatient care according to DRG diagnoses while at the same time measuring quality based on ICD-10 diagnoses. Researchers and ratings agencies, meanwhile, usually analyze AMI care based on a single population, either ICD-10 or DRG. In each of these cases, whether observations in one AMI population (e.g. DRG) are generalizable to another AMI population (e.g. ICD-10) is unknown. An assumption of equivalence between these populations, if untrue, has the potential to undermine efforts to improve AMI care.

With this in mind, we sought to characterize the extent to which DRG and ICD-10 diagnoses of AMI identify similar populations. We used data from a large integrated health system to determine patient-level agreement between AMI cohorts defined by ICD-10 codes versus AMI DRGs. We also compared cohorts according to outcome measures, such as 30-day mortality and readmission that are linked to value-based programs, as well as process measures of excellence in AMI care, such as cardiac rehabilitation referral rates.

Methods

The data that support the findings of this study are available from the corresponding author upon reasonable request. In a retrospective cohort analysis, we collected data for all patients who were admitted to a UCHealth hospital between January 1, 2017 and June 30, 2018 and were discharged alive with a diagnosis of AMI according to either the discharge DRG or principal ICD-10 code. UCHealth is a not-for-profit integrated health care system that included 8 Colorado hospitals, including the University of Colorado Hospital, during the timeframe of the study. Eligible AMI diagnoses were chosen to align with value-based payment programs (see “Exposure” section below). Patients with AMI who did not receive an eligible administrative AMI diagnosis were not included.

Exposure

Patients were divided into two cohorts – an ICD-10 cohort and a DRG cohort – though cohorts were not mutually exclusive. The DRG cohort was comprised of patients with a hospitalization during the study period that was assigned one of three DRGs for AMI described in the inclusion criteria for the BPCIA program.[3] Patients in the ICD-10 cohort were hospitalized during the study period with a primary discharge ICD-10 code included on a list of nine codes used by the HRRP and VBP programs.[4,5] A full list of DRGs and ICD-10 codes defining cohort inclusion can be found in Supplemental Table I. For patients with multiple AMI admissions, only their first AMI encounter during the study period was included in the analysis.

Outcomes

Outcome measures were selected for relevance to performance in value-based policy programs: these included rates of 30-day mortality, 1-year mortality, 30-day readmission and 90-day readmission. In order to understand rates of resource utilization in the two cohorts, we also compared cohorts according to process measures such as length of stay, inpatient medication use and utilization of cardiac testing and services. Among the medications analyzed were aspirin, beta blockers, oral P2Y12 inhibitors and high dose HMG-CoA reductase inhibitors (atorvastatin dose ≥ 40 mg, rosuvastatin dose ≥ 20 mg). Among the cardiac tests and services examined were cardiac rehabilitation referrals, cardiac catheterizations and cardiac imaging tests including echocardiography, computed tomography (Cardiac CT) and magnetic resonance imaging (Cardiac MRI). Finally, the ten most common principal ICD-10 diagnoses in the DRG cohort were enumerated, as were the ten most common DRG assignments in the ICD-10 cohort.

Statistical analysis

Patient-level agreement between the ICD-10 and DRG cohorts was assessed by percent agreement. Univariate logistic regression was used to determine the difference between groups for each categorized characteristic and outcome (e.g. medication rates and mortality rates), where the p-value associated with the Chi-Square test statistics was reported.

Univariate linear regression was used to compare non-categorized characteristics and outcomes (e.g. age, mean length of stay), where the p-value corresponded to a two-sample t-test assuming equal variances. Some patients were captured by both the ICD-10 and DRG cohorts. While summary statistics for each cohort include all patients in the cohort, including these overlap patients, statistical comparisons between groups reflect differences between patients included in only one of the cohorts. All statistical analysis and data manipulation was carried out in R, version 3.6.0 (R Core Team. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, 2014).

Subgroup Chart Review of UCH patients

All patients in the study who were admitted to the University of Colorado Hospital (UCH) were part of a subgroup analysis in which chart reviews were performed to establish a gold-standard diagnosis based on the Fourth Universal Definition of Myocardial Infarction (4-UDMI).[6] Five reviewers completed reviews (AEL, KSR, EWR, JDR, NMB) and uncertain or questionable cases were adjudicated by agreement between two reviewers (AEL, KSR). UCH was chosen for review because all five reviewers had access to medical records from this site. More details regarding the methods used for chart reviews are described in the Supplemental Methods.

Subgroup analysis

Baseline characteristics of UCH patients are compared to those of UCHealth patients in Supplemental Table II. Agreement between patients with chart-confirmed T1MI versus patients in the ICD-10 and DRG cohorts was assessed by percent agreement and dual-comparison Cohen’s kappa coefficients. T1MI patients were then used as the reference group for process and outcome measure comparisons to UCH patients in the ICD-10 and DRG cohorts. Statistical methods were identical to those described above in the “statistical analysis” section.

Sensitivity Analysis

Unadjusted analyses, as described above, were used for our main outcome measures because, while covariates are used by CMS and others for risk-adjusted comparisons between hospitals, our analysis was designed to compare cohorts within a single hospital system in order to highlight differences between cohorts that are directly relevant to local quality measurement and improvement. As a sensitivity analysis of the extent to which differences between cohorts are attributable to measured differences between cohorts, multivariate regression was performed using age, sex, and baseline rates of heart failure (HF), chronic kidney disease (CKD), and diabetes mellitus as covariates (Supplemental Table III).

Data acquisition and handling

With the exception of chart review data, all clinical data for the study were obtained from the Health Data Compass, an electronic data warehouse that integrates input from the UCHealth electronic health record (EHR) with outside sources such as the Colorado State Death

Registry and Colorado All Payer Claims Database.[7] This study was reviewed and approved by the Colorado Multiple Institutions Review Board (COMIRB 19–1877).

Results

Between January 1, 2017 and June 30, 2018, a total of 2,176 patients at UCHealth hospitals had an eligible DRG or primary ICD-10 diagnosis of AMI. Patient demographics and characteristics are described in Table 1. Baseline characteristics between DRG and ICD-10 cohort patients were different, most notably in terms of mean age (70 vs. 65 years, p<0.001) and gender (48% female vs 30%, p<0.001). Patients in the DRG cohort also had higher rates of comorbidities such as HF (52% vs. 33%, p<0.001), CKD (42% vs. 25%, p>0.001) and diabetes mellitus (41% vs. 37%, p=0.041) than the ICD-10 cohort. Further, patients in the DRG cohort were less often cared for by a Cardiologist (58% vs. 74%, p<0.001).

Out of the total cohort, 662 patients (30%) had an eligible DRG diagnosis of AMI and 1,935 patients (89%) had a primary ICD-10 diagnosis of AMI. 421 encounters had both an ICD-10 and a DRG diagnosis of AMI, corresponding to 19.3% concordance between the two cohorts (Figure 1). Among patients in the ICD-10 cohort who were not assigned a DRG for AMI, 61% were instead assigned a DRG for percutaneous coronary intervention (PCI) or coronary artery bypass graft surgery (CABG) (Figure 2). A complete listing of the ten most frequent ICD-10 assignments for the DRG cohort are provided in Supplemental Table IV and the ten most frequent DRG assignments for the ICD-10 cohort are provided in Supplemental Table V.

Significant differences in outcome and process measures were observed between the DRG and ICD-10 cohorts (Table 2). In terms of inpatient medication use, significantly fewer patients in the DRG group were prescribed P2Y12 inhibitors (44.6% vs. 81.6%, p<0.001) and high dose statins (80.2% vs. 92.5%, p<0.001) during their inpatient stay. Smaller, but still significant, differences were observed for inpatient aspirin and beta blocker use. Rates of cardiac catheterization (32.8% vs. 65.2%, p<0.001) and cardiac rehabilitation referral (22.4% vs. 57.8%, p<0.001) were also significantly lower in the DRG cohort. The only process measures that were not significantly different between the DRG and ICD-10 cohorts were hospital length of stay and rates of inpatient echocardiography. In terms of outcomes, rates of 30-day mortality (6.6 vs. 2.5%, p<0.001), 1-year mortality (20.8% vs. 8.0%, p<0.001), and 90-day readmission (26.4% vs. 18.9%, p=0.006) were all higher in the DRG cohort than the ICD-10 cohort. Differences in rates of 30-day readmission were not statistically significant (18.5% vs. 13.9%, p=0.065). These results were robust to sensitivity analysis using multivariate comparisons (Supplemental Table III) with the exception of differences in 90-day readmissions, which were no longer statistically significant, and length of stay, for which differences were shown to be significantly different after adjustment (3.9 days in DRG vs. 4.0 days in ICD-10, p=0.006).

A chart review subgroup analysis of all 645 AMI patients treated at UCH included 525 patients from the ICD-10 cohort and 258 from the DRG cohort. Baseline patient characteristics for the UCH subgroup compared to the UCHealth cohort are described in Supplemental Table II. Characteristics such as mean age and rates of diabetes, CKD, HF, and home medication use were different between the UCH cohort and the larger UCHealth cohort. Yet, agreement between ICD-10 and DRG subgroups from UCH was similar to the overall UCHealth cohort, with 138 patients being included in both subgroups (21.4% agreement).

Out of the 645 subgroup patients, gold-standard diagnosis based on chart review revealed that 425 (66%) were diagnosed with Type 1 MI (T1MI), 101 (16%) had Type 2 MI (T2MI) and 119 (18%) were diagnosed with non-ischemic myocardial injury (NIMI). Focusing on patients with T1MI, 78% (409/525) of patients in the ICD10-UCH subgroup were diagnosed with T1MI, compared to 34% (89/258) in the DRG-UCH subgroup (Figure 3). Patients that were only captured by the ICD10-UCH subgroup had the highest proportion of T1MI diagnoses 87% (336/387), compared with 53% (73/138) among patients in both subgroups and 13% (16/120) among patients only included in DRG-UCH subgroup (Supplemental Figure I). Most T1MI patients not assigned an AMI DRG were assigned a DRG for PCI (189/425, 44%) or CABG (47/425, 11%) (Supplemental Table VI). Overall patient-level agreement between T1MI and ICD-10 was fair (80% agreement, kappa 0.49 with 95% CI 0.42 to 0.56) while T1MI agreement with the DRG cohort was poor (22% agreement, kappa −0.47 with 95% CI −0.54 to −0.40) (Supplemental Table VII).

The baseline characteristics for T1MI patients were more similar to the ICD10-UCH subgroup than the DRG-UCH subgroup: while the ICD-10 cohort was not significantly different from the T1MI cohort in any of twenty baseline characteristics examined in this study, the DRG-UCH cohort was significantly different according to thirteen of twenty baseline characteristics including age, sex and rates heart failure and chronic kidney disease, among others (Table 1). T1MI patients were also more similar to ICD-10 patients in terms of process and outcomes measures in that there were no significant differences between T1MI patients and the ICD10-UCH subgroup. Patients in the DRG-UCH group, in contrast, were significantly different from T1MI patients in terms of 30-day mortality (5.0% vs. 1.7%, p=0.013), 1-year mortality (23.6% vs. 10.4%, p<0.001), rates of stress testing (11.6% vs. 2.1%, p<0.001), cardiac catheterization (31.4% vs. 66.4%, p<0.001), referral to cardiac rehabilitation (6.6% vs. 16.0%, p<0.001) and rates of inpatient use of aspirin (99% vs. 91%, p<0.001), P2Y12 inhibitors (38% vs. 80%, p<0.001), high-dose statins (85% vs. 96%, p<0.001) and beta blockers (76% vs. 94%, p<0.001) (Table 2). These findings were also robust to sensitivity analysis using multivariate comparisons (Supplemental Table II) with the exception of differences in 30-day mortality and inpatient aspirin use, which were no longer statistically significant, and length of stay, for which differences were shown to be significantly different after adjustment (4.9 days in DRG-UCH vs. 5.8 days in T1MI, p<0.001).

Discussion

In a retrospective cohort study of patients admitted to a large integrated health system in Colorado, only 19% of AMI patients were included in both the ICD-10 and DRG cohorts. The poor agreement between cohorts is partly explained by the observation that the majority of ICD-10 cohort patients (61%) were assigned a DRG for PCI or CABG. Perhaps more notably, patients in the DRG cohort were significantly less likely to receive medical therapy for AMI or undergo cardiac catheterization and had significantly higher rates of mortality and readmission. A subgroup analysis of patients admitted to the University of Colorado Hospital (UCH) suggests that these differences may, in part, be attributable to lower rates of true Type 1 MI in the DRG cohort (34%) compared to the ICD-10 cohort (78%). Similar to the ICD-10 cohort, the majority of Type 1 MI patients in the UCH subgroup were assigned a procedural DRG for PCI or CABG.

The simplest and most actionable conclusion to draw from these data is that hospitals must take considerable care when examining institutional outcomes and process measures for AMI patients. In particular, attention must be paid to how these patient populations are defined, as AMI populations defined by a DRG may be fundamentally different and receive different care than populations defined by ICD-10 codes. There are numerous practicing clinicians involved in the care of patients with AMI who likely have little, if any, understanding of the differences in these methodologies. Moreover, Chief Medical and Quality Officers, who contend with quality issues related to all the documented diagnoses in a hospital, typically think of AMI as one group of patients, not two. Extrapolating assumptions regarding performance (outcomes) and methods for improvement from one population (e.g. ICD-10) to a second dissimilar population (e.g. DRG) carries the risk of sub-optimizing patient care. That risk rises significantly when well-intentioned clinicians and leaders are not aware they are making this mental leap.

As it relates to national health policy, in addition to recent concerns raised about the equity[8–11], safety[12,13] and efficacy[14,15] of value-based payment programs, these findings raise concern regarding a lack of standardization in AMI inclusion criteria. Our findings are particularly relevant to hospitals participating in the BPCIA program for AMI, which uses an AMI DRG to define program inclusion and an ICD-10 based cohort for measuring the quality of AMI care. Our findings suggest that quality is measured in a group of patients (ICD-10 cohort) that is substantially different from the patients actually included in the program (DRG cohort). The program's use of two differing definitions for AMI – as opposed to holding the population definition constant – is akin to asking hospitals to do two things at once.

A central assumption of value-based payment programs – exemplified by the HRRP, VBP and BPCIA programs – is that there are *modifiable behaviors* that can be incentivized by restructuring hospital payments.[16] In the case of AMI, the evidentiary basis for "good" behaviors that improve readmission rates, such as cardiac rehabilitation, are primarily based on trials in Type 1 MI patients.[17] Performance measures endorsed by the American Heart Association and American College of Cardiology cater specifically to the care of patients with Type 1 MI.[2] This is in part because there are very few evidence-based therapies for patients with T2MI and NIMI.[18,19] Improving outcomes in the "non-Type 1 MI" population is an active area of research,[20] but in the meantime, care of these patients should not be lumped together with care of individuals with Type 1 MI.

If value-based programs are to more effectively target Type 1 MI, the subgroup analysis from our study strongly supports using an ICD-10 based definition for AMI over a DRG-based definition. The ICD-10 group was comprised by a higher percentage of Type 1 MI patients than the DRG group (78% vs. 34%) and, not surprisingly, the ICD-10 cohort was more representative of outcomes and patterns of care among Type 1 MI patients. Our data suggest that this is likely because the majority of Type 1 MI patients (55%) end up with a procedural DRG, either for PCI or CABG (Supplemental Table IV), a finding that is consistent with nationwide trends in revascularization.[21] The AMI DRG, therefore, includes only those "leftover" patients who were likely either too ill to undergo revascularization or for whom revascularization was not indicated. This is perhaps not surprising given that this group was composed primarily (66%) of T2MI and NIMI patients. With this in mind, patients included in DRGs for AMI may be suboptimal "targets" for payment reforms designed to improve AMI—specifically Type 1 MI—care.

It is important to note that ICD-10 based AMI cohorts are not perfect – over 20% of ICD-10 patients in our subgroup analysis had either T2MI or NIMI, which is similar to prior studies of ICD-9 codes.[22–24] While our results suggest that T1MI patients and ICD-10 patients have similar outcomes, our single center analysis is likely under-powered to detect small differences observed in other studies.[24] Further, while the ICD-10 system certainly has more diagnostic specificity than the DRG system, ICD-10 only recently implemented a code for Type 2 MI[25] and still does not have a code for NIMI. While this new T2MI code is omitted from the cohort definitions for HRRP and VBP programs,[4,5] T2MI and NIMI patients will continue to be misclassified in clinician documentation and, in some cases, included in these programs.[26,27] They may simply be included *less* than a similar program, like the BPCIA, using DRG-based cohorts.

A critical question is whether there is a better way to define and administer AMI cohorts for value-based programs. Given the existing infrastructure of clinical cardiovascular registries, it is appropriate to determine whether these registries more reliably track performance measures among AMI patients. Transcatheter aortic valve replacement (TAVR) could provide a blueprint for this path as registry participation is mandated under the national coverage decision and as TAVR is increasingly paid for under the BPCIA.[28,29] This provides an opportunity to use registry data to assess the quality of TAVR care within this value-based program.

This study has multiple limitations. First, it was conducted in a single integrated system of hospitals and, by design, only included patients with a coded diagnosis of AMI according to the discharge DRG or principal ICD-10 code. With this in mind, these findings must be applied with caution since they may be biased by institution-specific documentation and coding practices. Given the algorithmic nature of coding and secular trends in AMI care, we suspect that most hospitals would find that a majority of ICD-10 AMI patients are assigned a revascularization DRG (instead of an AMI DRG). Nevertheless, future studies should examine the extent to which there is hospital-level and system-level variation in this observation. Variation in MI types comprising ICD-10 versus DRG cohorts also merits further study since our findings are based on a single hospital and may not be representative of the whole UCHealth system. Rather than using our estimates of the proportion of MI types within each cohort, we would instead encourage institutions to sample their own AMI patients to better understand the breakdown of MI types within their ICD-10 and DRG cohorts. That we had 100% interrater agreement in terms of assessing T1MI based on chart review (see Supplemental Methods) suggests that such analyses are feasible, though we can never fully account for omitted or overlooked clinical information that may have changed a patient's AMI diagnosis. A final limitation of our study is that the electronic health record is less reliable than more traditional sources of outcomes data.[30] We wonder, for example, if rates of cardiac rehab referral would have been higher if we had been able to query a registry to answer our research question. We did our best to overcome this limitation by using a novel electronic data warehouse that integrates our EHR data with several local and regional healthcare databases.[7]

In conclusion, we found that a cohort defined by AMI DRGs differed significantly from a cohort derived using principal ICD-10 codes for AMI: there was little overlap between cohorts and DRG cohort patients had more comorbidities and higher rates of mortality and readmission. Likely contributing to these findings, we observed that many AMI patients in the ICD-10 cohort were assigned a procedural DRG for revascularization and that the DRG cohort contained a significantly higher proportion of T2MI and NIMI patients than the ICD-10 cohort. As national policy programs mature in defining patient populations and optimal measures of care, these findings suggest a need to revisit disparate and imperfect administrative definitions of AMI.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Non-standard Abbreviations and Acronyms:

AMI	Acute myocardial infarction
BPCIA	Bundled Payments for Care Improvement Advanced
CMS	Center for Medicare and Medicaid Services
CKD	Chronic kidney disease
CABG	Coronary artery bypass graft surgery
DRG	Diagnosis related groups
EHR	Electronic health record
4-UDMI	Fourth Universal Definition of Myocardial Infarction
HF	Heart failure
statin	HMG-CoA reductase inhibitors

HRRP	Hospital Readmissions Reduction Program
ICD-10	International classification of diseases, 10^{th} revision
NIMI	Non-ischemic myocardial injury
PCI	Percutaneous coronary intervention
TAVR	Transcatheter aortic valve replacement
T1MI	Type 1 myocardial infarction
T2MI	Type 2 myocardial infarction
UCH	University of Colorado Hospital

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What is known

- Medicare administers multiple value-based payment programs for AMI, some of which use ICD-10 codes to define AMI cohorts while others use AMI DRGs. The extent to which the AMI populations identified by these different mechanisms overlap is not known.

What the study adds

- In a large health system in Colorado, there was only 19% agreement between ICD-10 and DRG-based inclusion criteria for value-based programs targeting AMI.
- Compared to patients in the ICD-10 cohort, AMI patients in the DRG cohort had significantly higher rates of death both at 30 days and 1 year and readmission at 90 days.
- These differences may be attributable to the fact that only 34% of patients with an AMI DRG had a Type 1 MI, compared to 78% of patients identified by ICD-10 codes.
- Together, these findings suggest that divergent AMI cohorts in value-based programs have the potential to confuse efforts to improve AMI care.

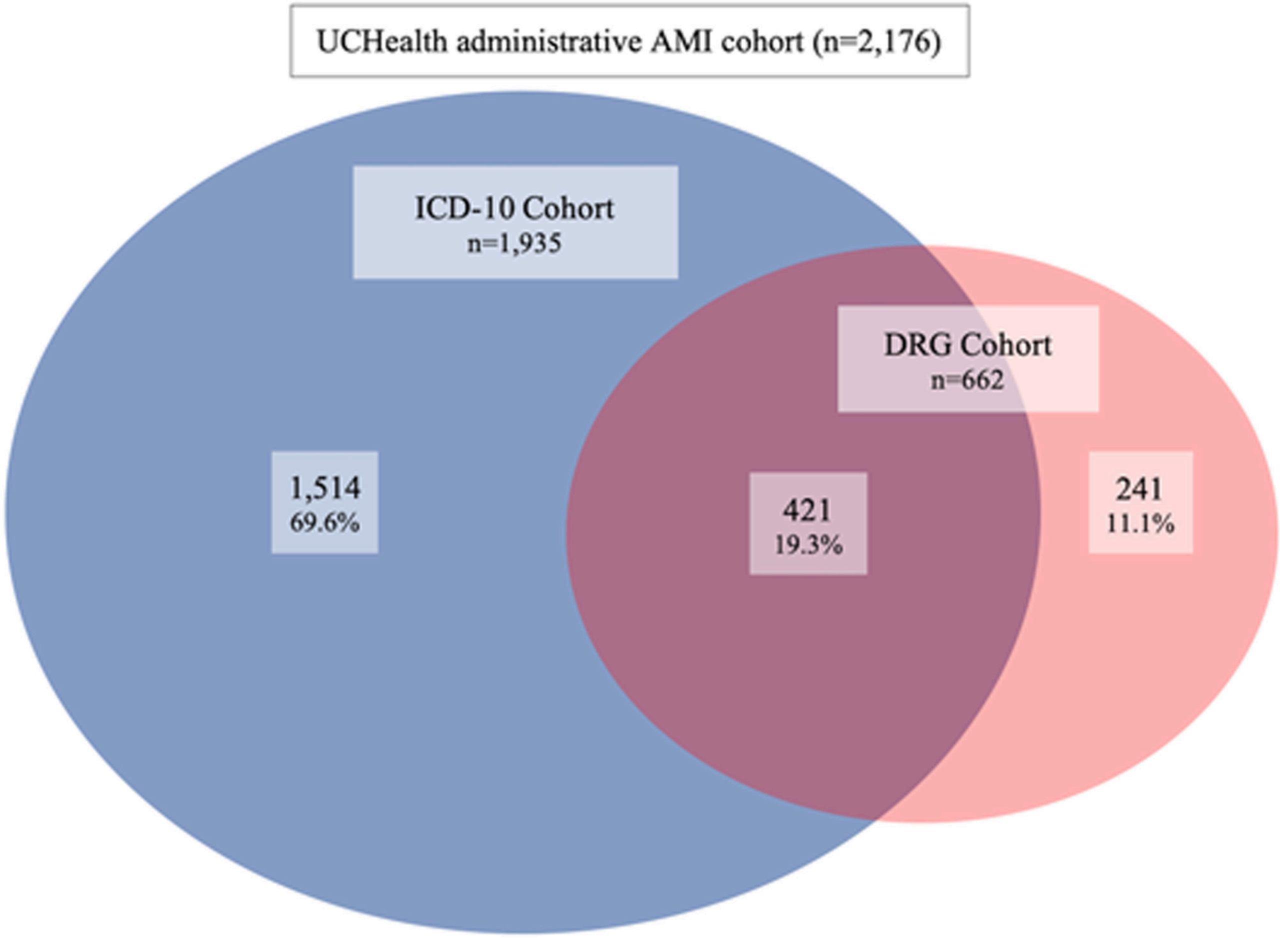

Figure 1.

AMI cohort agreement in an integrated health system

Abbreviations: AMI = acute myocardial infarction; DRG = diagnosis related group; ICD-10 = international classification of diseases, 10th revision.

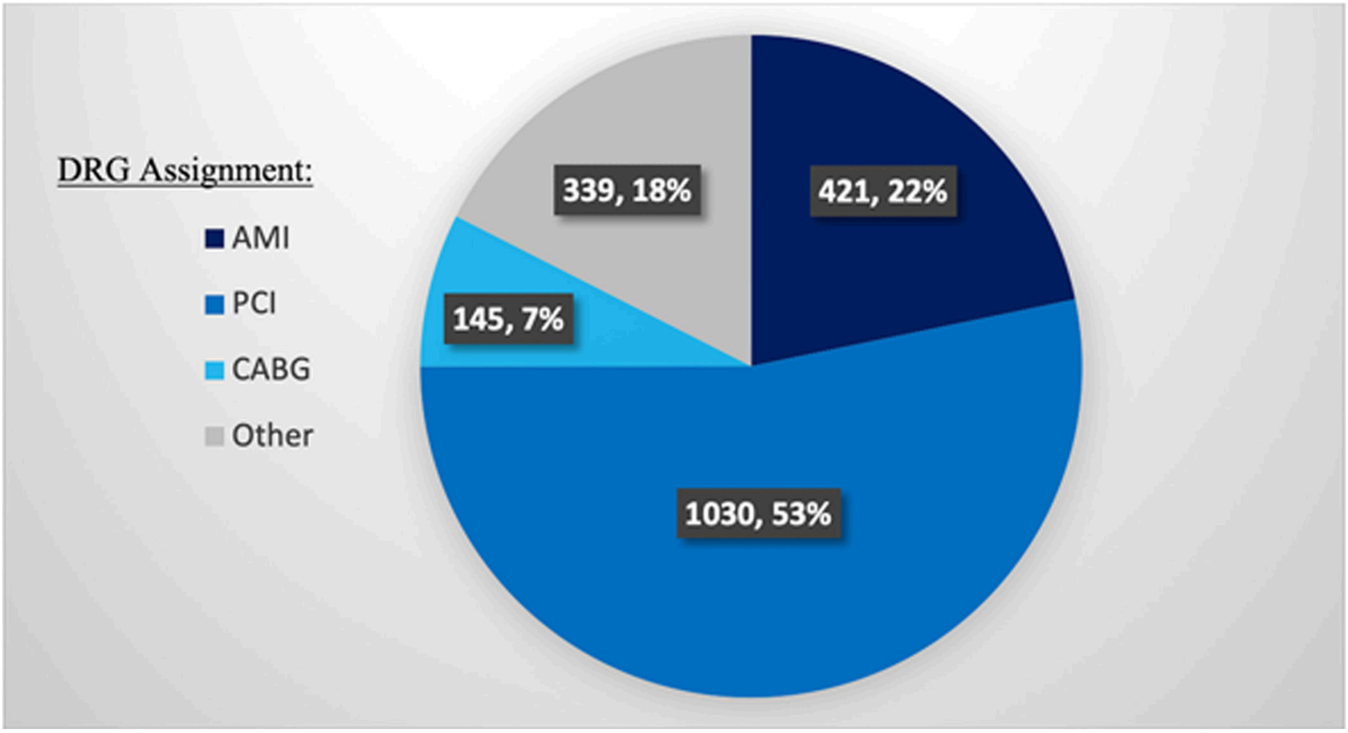

Figure 2.
DRG assignments in the ICD-10 cohort for AMI
Abbreviations: AMI = acute myocardial infarction; PCI = percutaneous coronary intervention, CABG = coronary artery bypass grafting.

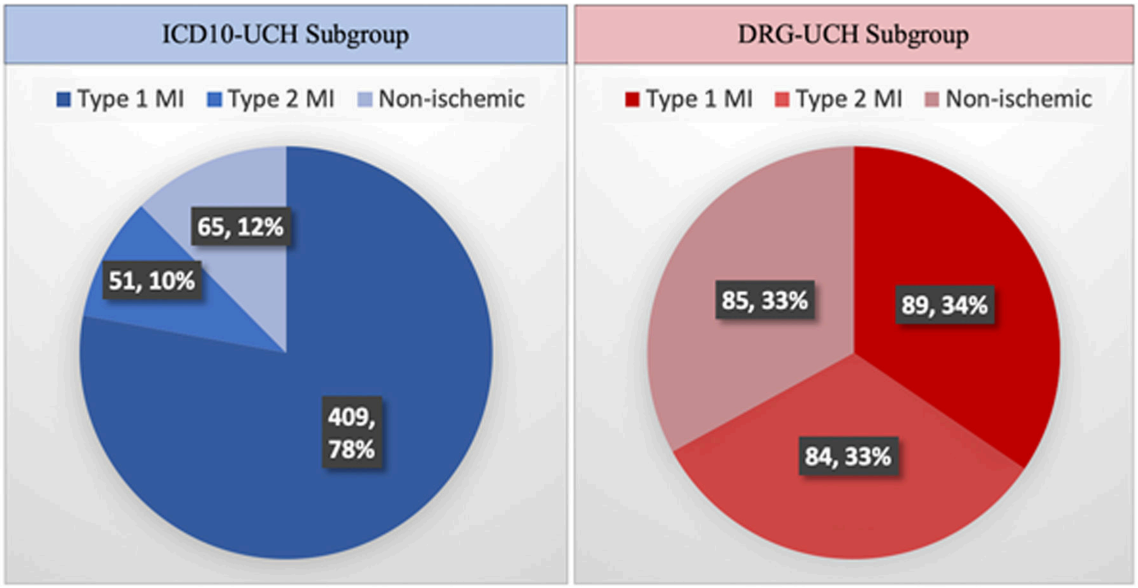

Figure 3.

ICD10-UCH and DRG-UCH subgroups stratified by chart review diagnosis*

*Part of a subgroup analysis of all patients cared for at the University of Colorado Hospital (UCH).

Abbreviations: UCH = University of Colorado Hospital, DRG = diagnosis related group; ICD-10 = international classification of diseases, 10^{th} revision; Type 1 MI = Type 1 myocardial infarction; Type 2 MI = Type 2 myocardial infarction; non-ischemic = non-ischemic myocardial injury

Table 1.

Baseline patient characteristics of AMI cohorts

	ICD-10	DRG	p† value	*T1MI-UCH	*ICD10-UCH	p† value	*DRG-UCH	p† value
Total n	**1935**	**662**		**425**	**525**		**258**	
Demographics								
Age (median)	65.2 (sd=13.4)	70.3 (sd=14.9)	<0.001	63.7 (sd=13.8)	63.3 (sd = 14.0)	0.192	68.3 (sd=15.1)	<0.001
Female	577 (29.8%)	321 (48.5%)	<0.001	128 (30.1%)	172 (32.8%)	0.758	126 (48.8%)	<0.001
White or Caucasian	1497 (77.4%)	492 (74.3%)	0.095	226 (53.2%)	278 (53.0%)	0.571	136 (52.7%)	0.649
Cardiology Team	1430 (73.9%)	385 (58.2%)	<0.001	218 (51.3%)	269 (51.2%)	0.607	107 (41.5%)	0.006
Medical History								
Diabetes Mellitus	713 (36.8%)	273 (41.2%)	0.041	185 (43.5%)	220 (41.9%)	0.405	103 (39.9%)	0.104
Hypertension	1510 (78.0%)	560 (84.6%)	0.002	324 (76.2%)	400 (76.2%)	0.963	213 (82.6%)	0.084
Hyperlipidemia	1333 (68.9%)	373 (56.3%)	<0.001	216 (50.8%)	259 (49.3%)	0.459	102 (39.5%)	0.004
Heart Failure	646 (33.4%)	347 (52.4%)	<0.001	169 (39.8%)	211 (40.2%)	0.242	136 (52.7%)	<0.001
Peripheral Artery Disease	78 (4.0%)	24 (3.6%)	0.305	15 (3.5%)	15 (2.9%)	0.311	1 (0.4%)	0.012
Prior Stroke	330 (17.05%)	167 (25.2%)	<0.001	81 (19.1%)	103 (19.6%)	0.325	58 (22.5%)	0.332
COPD	288 (14.9%)	138 (20.9%)	<0.001	68 (16.0%)	87 (16.6%)	0.818	61 (23.6%)	0.010
Chronic Kidney Disease	487 (25.2%)	279 (42.2%)	<0.001	118 (27.8%)	166 (31.6%)	0.189	122 (47.3%)	<0.001
Dementia	67 (3.5%)	65 (9.8%)	<0.001	11 (2.6%)	16 (3.1%)	0.603	26 (10.1%)	<0.001
Cancer	356 (18.4%)	137 (20.7%)	0.235	61 (14.4%)	81 (15.4%)	0.470	52 (20.2%)	0.009
Home Medications								
Aspirin	149 (7.7%)	100 (15.1%)	<0.001	42 (9.9%)	55 (10.5%)	0.999	48 (18.6%)	<0.001
P2Y12 Inhibitor	91 (4.7%)	52 (7.9%)	<0.001	30 (7.1%)	36 (6.9%)	0.279	23 (8.91%)	0.548
Beta Blocker	172 (8.9%)	112 (16.9%)	<0.001	58 (13.7%)	68 (13.0%)	0.116	54 (20.9%)	0.049
Any Statin	172 (8.9%)	99 (15.0%)	<0.001	53 (12.5%)	64 (12.2%)	0.715	47 (18.2%)	0.085
ACEi, ARB, ARNI	152 (7.9%)	81 (12.2%)	<0.001	51 (12.0%)	58 (11.1%)	0.159	43 (16.7%)	0.265
Oral Anticoagulation	34 (1.8%)	32 (4.8%)	<0.001	10 (2.4%)	14 (2.7%)	0.999	16 (6.2%)	0.003

*Subgroup analysis of all patients cared for at the University of Colorado Hospital (UCH).

†Reference group for the main study cohort was ICD-10; reference group for the UCH subgroup was T1MI (T1MI-UCH).

Abbreviations: ACEi=angiotensin-converting enzyme inhibitor; ARB=angiotensin-receptor blocker; ARNI = angiotensin-receptor neprilysin inhibitor; COPD = chronic obstructice pulmonary disease; DOAC = direct oral anticoagulant; DRG = Diagnosis Related Group; ICD-10 = international classification of diseases, 10th revision; T1MI = Type 1 myocardial infarction

Table 2.

Univariate comparison of quality measures and rates of resource utilization among different AMI cohorts

	ICD-10	DRG	*T1MI-UCH	*ICD10-UCH	*DRG-UCH
Total n	1935	662	425	525	258
Outcome measures					
1 year mortality	168 (8.7%) ref	147 (22.2%) p<0.001	44 (10.4%) ref	53 (10.1%) p=0.134	61 (23.6%) p<0.001
30 day mortality	51 (2.64%) ref	47 (7.1%) p<0.001	7 (1.7%) ref	8 (1.5%) p=0.078	13 (5.0%) p=0.013
90 day readmission	365 (18.9%) ref	171 (25.8%) p=0.016	93 (21.9%) ref	114 (21.7%) p=0.236	68 (26.4%) p=0.445
30 day readmission	269 (13.9%) ref	123 (18.6%) p=0.065	62 (14.6%) ref	76 (14.5%) p=0.454	45 (17.4%) p=0.719
Medications administered					
Aspirin	1916 (99.0%) ref	622 (94.0%) p<0.001	424 (99.8%) ref	519 (98.9%) p=0.992	235 (91.1%) p<0.001
P2Y12 inhibitors	1579 (81.6%) Ref	295 (44.6%) p<0.001	340 (80.0%) ref	393 (74.9%) p=0.846	98 (38.0%) p<0.001
High-dose Statin	1790 (92.5%) ref	531 (80.2%) p<0.001	407 (95.8%) ref	500 (95.2%) p=0.923	219 (84.9%) p<0.001
Beta Blocker	1804 (93.2%) ref	553 (82.5%) p<0.001	401 (94.4%) ref	477 (90.9%) p=0.940	197 (76.4%) p<0.001
Process measures					
Length of Stay	4.03 days ref	3.88 days p=0.059	5.81 days ref	5.79 days p=0.448	4.88 days p=0.054
Echocardiography	1294 (66.9%) ref	421 (63.6%) p=0.052	218 (51.3%) ref	271 (51.6%) p=0.551	122 (47.3%) p=0.209
Stress Test	24 (1.2%) ref	33 (5.0%) p<0.001	9 (2.1%) ref	20 (3.8%) p=0.879	30 (11.6%) p<0.001
Cardiac CT	7 (0.4%) ref	11 (1.7%) p<0.001	3 (0.7%) ref	4 (0.8%) p=0.288	8 (3.1%) p=0.991
Cardiac MRI	11 (0.6%) ref	8 (1.2%) p=0.016	8 (1.9%) ref	11 (2.1%) p=0.588	7 (2.7%) p=0.332
Cardiac Catheterization	1262 (65.2%) ref	217 (32.8%) p<0.001	282 (66.4%) ref	323 (61.5%) p=0.818	81 (31.4%) p<0.001
Cardiac rehabilitation referral	1118 (57.8%) ref	148 (22.4%) p<0.001	68 (16.0%) ref	79 (15.0%) p=0.981	17 (6.6%) P<0.001

*Part of a subgroup analysis of all patients cared for at the University of Colorado Hospital (UCH).

Abbreviations: CT = computed tomography; MRI = magnetic resonance imaging; DRG = diagnosis related group; ICD-10 = international classification of diseases, 10th revision; T1MI = Type 1 myocardial infarction