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Temporal Trends in Coronary Angiography and Percutaneous Coronary Intervention

Insights From the VA Clinical Assessment, Reporting, and Tracking Program

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ABSTRACT

OBJECTIVES The aim of this study was to evaluate temporal trends in characteristics and outcomes among patients referred for invasive coronary procedures within a national health care system for veterans.

BACKGROUND Coronary angiography and percutaneous coronary intervention remain instrumental diagnostic and therapeutic interventions for coronary artery disease.

METHODS All coronary angiographic studies and interventions performed in U.S. Department of Veterans Affairs cardiac catheterization laboratories for fiscal years 2009 through 2015 were identified. The demographic characteristics and management of these patients were stratified by time. Clinical outcomes including readmission (30-day) and mortality were assessed across years.

RESULTS From 2009 to 2015, 194,476 coronary angiographic examinations and 85,024 interventions were performed at Veterans Affairs facilities. The median numbers of angiographic studies ($p = 0.81$) and interventions ($p = 0.22$) remained constant over time. Patients undergoing these procedures were progressively older, with more comorbidities, as the proportion classified as having high Framingham risk significantly increased among those undergoing angiography (from 20% to 25%; $p < 0.001$) and intervention (from 24% to 32%; $p < 0.001$). Similarly, the median National Cardiovascular Data Registry CathPCI risk score increased for diagnostic (from 14 to 15; $p = 0.005$) and interventional (from 14 to 18; $p = 0.002$) procedures. Post-procedural medical management was unchanged over time, although there was increasing adoption of transradial access for diagnostic (from 6% to 36%; $p < 0.001$) and interventional (from 5% to 32%; $p < 0.001$) procedures. Complications and clinical outcomes also remained constant, with a trend toward a reduction in the adjusted hazard ratio for percutaneous coronary intervention mortality (hazard ratio: 0.983; 95% confidence interval: 0.967 to 1.000).

CONCLUSIONS Veterans undergoing invasive coronary procedures have had increasing medical complexity over time, without attendant increases in mortality among those receiving interventions. As the Department of Veterans Affairs moves toward a mix of integrated and community-based care, it will be important to account for these demographic shifts so that quality can be maintained. (J Am Coll Cardiol Intv 2018;11:879–88) Published by Elsevier on behalf of the American College of Cardiology Foundation.

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ABBREVIATIONS AND ACRONYMS

CI = confidence interval

HR = hazard ratio

NCDR = National Cardiovascular Data Registry

PCI = percutaneous coronary intervention

VA = U.S. Department of Veterans Affairs

Coronary angiography remains a fundamental diagnostic test for coronary artery disease. Similarly, percutaneous coronary intervention (PCI) plays a pivotal role in its management. Previous studies have attempted to characterize the use of these procedures at regional and national levels (1-3). Those studies have largely indicated a stable rate of diagnostic coronary angiography, with a decline in percutaneous revascularization over the past decade. These analyses are impressive in their scope, with the most recent publication including a large proportion of nonfederal facilities in the United States that provide diagnostic coronary angiography (70%) and percutaneous revascularization (90%). These national registries collect significant data regarding each episode of care, although the clinical outcomes recorded are largely limited to the inpatient setting (4).

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Integrated health systems include electronic medical records and quality improvement programs that are capable of capturing longitudinal health status. The U.S. Department of Veterans Affairs (VA) health care system is the largest integrated health system in the United States, affording a unique opportunity to study the use of invasive cardiac procedures on a national scale with the ability to simultaneously report longitudinal clinical outcomes. With this in mind, we sought to identify temporal trends in patient and procedural characteristics for patients evaluated and treated for coronary artery disease within the VA system. We then examined trends in medical management and long-term clinical outcomes for these patients.

METHODS

POPULATION. The VA Clinical Assessment, Reporting, and Tracking system is a national quality improvement program that includes all cardiac catheterization laboratories within the VA health care system. As described previously, this mandatory program captures and compiles standardized patient and procedural data elements for all coronary procedures performed in VA cardiac catheterization laboratories (5). The data elements surveyed are derived from previously established data definitions from the National Cardiovascular Data Registry (NCDR), and the dataset is independently assessed for accuracy and validity on a routine basis (6,7). The present analysis includes all patients included in the registry since the last report (October 2009), extending to the most recent data available with linked Medicare outcomes (September 2015). This analysis was approved by the Colorado Multiple Institution Review Board, which includes the VA Eastern Colorado Health Care System, with a waiver of informed consent.

DEFINITIONS. The population was separated into 2 groups on the basis of the invasive procedure performed: isolated coronary angiography or coronary angiography with percutaneous revascularization. PCI was defined as balloon angioplasty or stenting of any epicardial coronary artery. A patient who underwent both procedures on the same day was categorized as only having an intervention. The temporal trends were based on the number of procedures performed in a given fiscal year, such that a staged coronary intervention would be counted as a subsequent procedure. Evaluation of clinical outcomes including readmission or mortality was performed using a patient-level analysis, using the index procedure within each fiscal year in cases of recurrent procedures.

MEASUREMENTS. Patient and procedural characteristics were abstracted from the linked electronic medical record and cardiac catheterization report documentation. Medications prescribed at the time of the index procedure were ascertained from linked pharmacy data, including data on antiplatelet agents, angiotensin antagonists, beta-blockers, and statins. Information on aspirin were not collected, as the pharmacy data could not incorporate over-the-counter acquisition of the medication. Similarly, information regarding smoking cessation programs or referrals to cardiac rehabilitation are inconsistently reported across sites and are thus omitted. Procedural complications are voluntarily reported by individual sites and represent any complications that occurred within the cardiac catheterization laboratory. Major complications were defined as procedural death, stroke, or emergent cardiac surgery. Minor complications were defined as coronary complications (dissection, perforation), contrast reactions (anaphylaxis, respiratory distress, hives), or acute access-site injury (dissection, perforation, hematoma, retroperitoneal hemorrhage, limb ischemia, vascular complication requiring surgical repair). Post-procedural cardiac biomarkers were not routinely assessed across sites and time, making it impossible to accurately ascertain the rates of a post-procedural myocardial infarction. Readmission data were assessed from the

electronic medical record as well as using fee basis and Medicare billing data for patients readmitted to facilities outside the VA health care system. A primary diagnosis code for myocardial infarction (International Classification of Diseases-9th Revision codes 410.00, 410.01, 410.10, 410.11, 410.20, 410.21, 410.30, 410.31, 410.40, 410.41, 410.50, 410.51, 410.60, 410.61, 410.70, 410.71, 410.80, 410.81, 410.90, and 410.91; International Classification of Diseases-10th Revision codes I21.01, I21.02, I21.09, I21.11, I21.19, I21.21, I21.29, I21.3, I21.4, I22.0, I22.1, I22.2, I22.8, and I22.9) defined a readmission for recurrent myocardial infarction. Mortality was ascertained from the VA Information Resource Center Vital Status File, which includes data from the Beneficiary Identification Record Locator Subsystem Death File, VA Medicare Vital Status File, and Social Security Administration Death Master File (8).

ANALYSIS. Temporal trends were evaluated for a number of dichotomous variables, including clinical presentation (acute coronary syndromes vs. stable angina), procedural access (radial vs. femoral), and need for ventricular support. Additional investigations sought to characterize the clinical risk of patients undergoing invasive procedures. To do so, the Framingham risk score (9) and NCDR CathPCI mortality risk score (10) were calculated for every patient who underwent coronary angiography or percutaneous revascularization. To establish temporal trends across years for the dichotomous variables and the high-risk category of Framingham risk, a Cochran-Armitage test was applied on the annual percentage of each. The continuous measures of NCDR CathPCI mortality risk as well as catheterization and PCI volumes were analyzed using the nonparametric Theil-Sen estimator over the yearly median values. This method examines the slope between every pair of data points and retains the median of the rank-ordered slopes as the estimator (11). Duplicate median values were problematic for obtaining p values from the distribution of the Wilcoxon signed rank statistic and creating slopes of zero. To overcome this limitation, each analysis for Framingham risk and NCDR mortality risk was iterated 1,000 times with small $N(0,10^{-6})$ perturbations added to the fiscal year median values (12). From the 1,000 iterations, the median slope and p value were retained. In analyzing longitudinal medication prescriptions after procedures, patients who died within 90 days of the procedure or had documented allergies to a medication class were excluded from the analysis. Furthermore, patients who had not received any medications within the VA health care system for the prior year were also excluded, as it was not possible to accurately determine outside prescription rates.

Clinical outcomes were assessed for a subpopulation of patients with sufficient follow-up: those who presented from 2009 to 2014. Cox proportional hazards models were analyzed with adjustment covariates for Framingham risk score and the NCDR mortality risk score, as well as the year in which the procedure was performed. The outcomes for these models included readmission (30-day) and mortality (1-year). Fine and Gray competing risk subdistribution hazard ratios (HRs) were used to estimate rehospitalization for myocardial infarction in the presence of death. A small proportion of subjects did not have sufficient data to calculate the risk scores for these models (2% coronary angiography, 11% percutaneous revascularization) and thus were excluded from this portion of the analysis. Furthermore, exceptions were made for staged procedures, in which a patient had a second coronary intervention on the nonindex artery within 60 days of the index procedure. In these cases, the last of the staged procedures was used as the start date to prevent the procedure from being identified as an early rehospitalization of the earlier procedure. The follow-up period for capturing outcome events post-procedure was defined as a 365-day window.

All statistical analyses were performed with SAS 9.4 TS Level 1M3 (SAS Institute, Cary, North Carolina) and R version 3.3.1 (The R Foundation for Statistical Computing, Vienna, Austria). A p value <0.05 was considered to indicate statistical significance.

RESULTS

POPULATION. During the time period under investigation, 194,476 diagnostic coronary angiographic examinations and 85,024 percutaneous revascularization procedures were performed in 79 VA cardiac catheterization laboratories. The numbers of diagnostic angiographic studies ($p = 0.84$) and interventional ($p = 0.47$) coronary procedures remained relatively constant with time, starting at 24,420 and 10,280 procedures per year in 2009 and slightly increasing to 27,963 and 12,205 procedures, respectively, in 2015. The median numbers of coronary angiographic studies ($p = 0.81$) and interventions ($p = 0.22$) were also unchanged at each individual cardiac catheterization laboratory over the same period ($p = 0.22$) (Online Figure 1).

PATIENT CHARACTERISTICS. The demographics and medical comorbidities of patients undergoing

TABLE 1 Characteristics of Patients Undergoing Percutaneous Coronary Intervention, 2009 to 2015

	2009 (n = 10,280)	2010 (n = 12,468)	2011 (n = 12,909)	2012 (n = 12,964)	2013 (n = 12,156)	2014 (n = 12,042)	2015 (n = 12,205)
Age (yrs)	63 (59–71)	64 (60–70)	64 (60–70)	65 (61–70)	65 (61–71)	66 (62–71)	67 (62–71)
Male	10,125 (99)	12,263 (98)	12,717 (99)	12,742 (98)	11,962 (98)	11,830 (98)	12,006 (98)
Race							
African American	1,421 (14)	1,576 (13)	1,618 (13)	1,671 (13)	1,625 (13)	1,710 (14)	1,861 (15)
Caucasian	8,679 (84)	10,646 (85)	11,042 (86)	11,038 (85)	10,252 (84)	10,066 (84)	10,059 (82)
Other	180 (2)	246 (2)	249 (2)	255 (2)	279 (2)	266 (2)	285 (2)
Body mass index (kg/m^2)							
Underweight (<20)	69 (1)	67 (1)	76 (1)	82 (1)	63 (1)	71 (1)	87 (1)
Normal (20–25)	1,650 (16)	1,887 (15)	1,859 (15)	2,024 (16)	1,848 (15)	1,829 (15)	1,910 (16)
Overweight (30–35)	3,677 (36)	4,430 (36)	4,537 (36)	4,515 (35)	4,300 (36)	4,204 (35)	4,185 (34)
Obese (>35)	4,721 (47)	5,898 (48)	6,290 (49)	6,232 (48)	5,848 (48)	5,845 (49)	5,955 (49)
Missing	163 (2)	186 (1)	147 (1)	111 (1)	97 (1)	93 (1)	68 (1)
Medical comorbidities							
Cerebrovascular disease	1,688 (16)	2,176 (17)	2,353 (18)	2,446 (19)	2,378 (20)	2,446 (20)	2,591 (21)
Depression	3,030 (29)	3,635 (29)	4,028 (31)	3,971 (31)	4,002 (33)	4,042 (34)	3,970 (33)
Diabetes	4,798 (47)	5,962 (48)	6,373 (49)	6,491 (50)	6,252 (51)	6,313 (52)	6,522 (53)
Heart failure	2,492 (24)	3,057 (25)	3,158 (24)	3,409 (26)	3,340 (27)	3,495 (29)	3,629 (30)
Hyperlipidemia	9,009 (88)	11,212 (90)	11,733 (91)	11,873 (92)	11,158 (92)	11,074 (92)	11,265 (92)
Hypertension	9,204 (90)	11,253 (90)	11,746 (91)	11,848 (91)	11,152 (92)	11,070 (92)	11,255 (92)
Obstructive pulmonary disease	2,340 (23)	2,707 (22)	2,835 (22)	2,888 (22)	2,837 (23)	2,908 (24)	2,979 (24)
Peripheral vascular	328 (3)	399 (3)	405 (3)	376 (3)	411 (3)	421 (3)	456 (4)
Post-traumatic stress	1,483 (14)	1,884 (15)	2,178 (17)	2,230 (17)	2,267 (19)	2,297 (19)	2,264 (19)
Renal failure (dialysis)	2,064 (20)	2,584 (21)	2,645 (20)	2,718 (21)	2,719 (22)	2,921 (24)	2,975 (24)
Tobacco use (ever)	5,977 (58)	7,683 (62)	8,110 (63)	8,276 (64)	8,114 (67)	8,443 (70)	8,531 (70)
Laboratory data							
LDL cholesterol (mg/dl)	92 (73–118)	92 (73–116)	90 (70–114)	89 (69–114)	89 (69–114)	88 (68–114)	86 (65–113)
HDL cholesterol (mg/dl)	36 (31–43)	36 (31–43)	37 (32–44)	38 (32–45)	38 (32–45)	39 (33–46)	39 (33–46)
Glomerular filtration rate (ml/min/1.73 m^2)	78 (63–91)	77 (61–90)	77 (61–90)	77 (61–90)	76 (59–88)	77 (59–86)	77 (59–88)
Framingham risk score							
Low	2,040 (20)	2,315 (19)	2,496 (19)	2,336 (18)	1,994 (16)	1,845 (15)	1,842 (15)
Medium	5,792 (56)	7,061 (57)	7,333 (57)	7,346 (57)	6,850 (56)	6,624 (55)	6,514 (53)
High	2,443 (24)	3,091 (25)	3,079 (24)	3,277 (25)	3,310 (27)	3,572 (30)	3,848 (32)
Missing	5 (0)	1 (0)	1 (0)	5 (0)	2 (0)	1 (0)	1 (0)
NCDR mortality points	14 (10–22)	15 (10–23)	15 (10–22)	15 (10–23)	16 (10–23)	16 (10–24)	18 (10–24)

Values are median (interquartile range) or n (%).

HDL = high-density lipoprotein; LDL = low-density lipoprotein; NCDR = National Cardiovascular Data Registry.

coronary angiography (Online Table 1) and percutaneous revascularization (**Table 1**) were stratified by year. As shown, patients are becoming progressively older with greater body mass index values as time progresses. The prevalence rates of many medical comorbidities among patients undergoing coronary angiography and intervention have also increased with time, with the numeric proportion of patients experiencing every medical comorbidity investigated increasing from the beginning of the study period to the end. The composite assessment of medical comorbidities is consistent with this finding, as the proportion of patients classified as having high Framingham risk significantly increased among those undergoing angiography (from 20% to 25%; $p < 0.001$) and intervention (from 24% to 32%; $p < 0.001$) during the study period (**Figure 1**). Similarly, the median NCDR CathPCI mortality risk score also increased for diagnostic (from 14 to 15; $p = 0.005$) and interventional (from 14 to 18; $p = 0.002$) procedures over the time period under investigation.

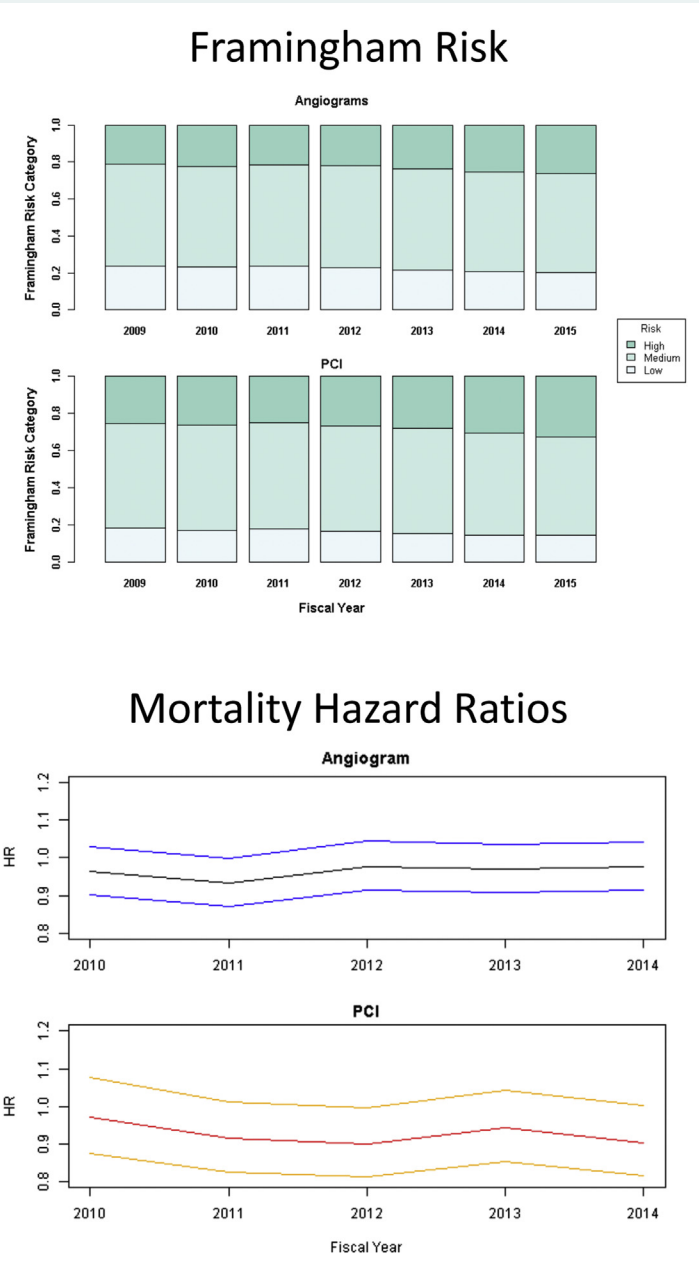
PROCEDURAL CHARACTERISTICS. The procedural characteristics of patients undergoing coronary angiography (Online Table 2) and intervention (**Table 2**) were also stratified by year. As shown, the indication for the procedure has changed over time, with an

increasing proportion of patients undergoing angiography or intervention for acute coronary syndromes ($p < 0.001$). The primary access site used to perform the procedure also changed, with a significant increase in the use of transradial access for both procedures ($p < 0.001$) (Online Figure 2). The number of diseased vessels remained similar among patients undergoing diagnostic angiography, with the largest proportion of interventions routinely performed on the left anterior descending coronary artery. The use of concomitant intra-aortic balloon pumps during percutaneous revascularization was constant with time ($p = 0.178$), with an increasing use of other mechanical support since tracking began in 2013 ($p < 0.001$).

MEDICAL MANAGEMENT. The temporal trends in medication prescriptions were analyzed among those who underwent coronary angiography and found to have non-normal coronary arteries (Online Table 3), as well as those who underwent percutaneous revascularization (**Table 3**). In both cases, the rates of medication prescriptions 90 days after the procedure remained relatively constant with respect to time. Approximately 73% of eligible patients undergoing intervention received prescriptions for all classes of medications that were evaluated, a value that remained similar across the time period under investigation.

CLINICAL OUTCOMES. The in-laboratory procedural complications and clinical outcomes among patients undergoing coronary angiography (Online Table 4) or intervention (**Table 4**) have been stratified by fiscal year. As shown, major and minor procedural complications were <1% across the period of investigation for both procedures. The proportion of patients readmitted within 30 days of the procedure remained constant over time, at approximately 17% for diagnostic angiography and 11% after intervention. The rates of recurrent myocardial infarction were also unchanged for both those undergoing angiography (subdistribution HR: 0.986; 95% confidence interval [CI]: 0.968 to 1.004) and percutaneous revascularization (subdistribution HR: 1.006; 95% CI: 0.983 to 1.029). Similarly, the raw mortality rates remained similar (7%) across all years. After adjustment for 2 contemporary composite risk scores (NCDR and Framingham), the adjusted HR for 30-day readmission actually declined across the years investigated (HR: 0.981; 95 CI: 0.974 to 0.988) without significant changes in the hazard for mortality (HR: 0.999; 95% CI: 0.988 to 1.010) among those undergoing coronary angiography alone. A similar analysis for patients undergoing percutaneous revascularization demonstrated that the adjusted HR for 30-day readmission (HR: 0.982; 95% CI: 0.969 to 0.995) decreased with time, with a nonsignificant trend toward a reduction

FIGURE 1 Temporal Trends in Patient Risk and Mortality



There was a significant increase in the proportion of patients undergoing coronary angiography ($p < 0.001$) and percutaneous coronary intervention (PCI) ($p < 0.001$) who were deemed to be at high Framingham risk over the period under investigation. The hazard ratio (HR) for mortality, however, remained constant over time, with a nonsignificant decrease among those undergoing intervention (HR: 0.983; 95% confidence interval: 0.967 to 1.000).

TABLE 2 Procedural Characteristics of Patients Undergoing Percutaneous Coronary Intervention, 2009 to 2015

	2009 (n = 10,280)	2010 (n = 12,468)	2011 (n = 12,909)	2012 (n = 12,964)	2013 (n = 12,156)	2014 (n = 12,042)	2015 (n = 12,205)
Inpatient	5,466 (53)	6,634 (53)	6,495 (50)	6,617 (51)	6,363 (52)	6,008 (50)	6,012 (49)
Outpatient	4,599 (45)	5,564 (45)	6,130 (48)	6,024 (47)	5,538 (46)	5,803 (48)	6,010 (49)
Missing inpatient or outpatient status	215 (2)	270 (2)	284 (2)	323 (2)	255 (2)	231 (2)	183 (2)
Status							
Elective	6,716 (65)	7,909 (63)	8,340 (65)	8,081 (62)	7,428 (61)	7,664 (64)	7,969 (65)
Urgent	2,719 (26)	3,526 (28)	3,563 (28)	3,791 (29)	3,737 (31)	3,478 (29)	3,384 (28)
Emergent	632 (6)	750 (6)	755 (6)	785 (6)	768 (6)	714 (6)	701 (6)
Salvage	26 (0)	30 (0)	18 (0)	20 (0)	20 (0)	26 (0)	25 (0)
Missing	187 (2)	253 (2)	233 (2)	287 (2)	203 (2)	160 (1)	126 (1)
Indication							
Stable angina	1,979 (19)	2,762 (22)	3,063 (24)	3,337 (26)	3,244 (27)	3,351 (28)	3,474 (29)
Unstable angina	1,374 (13)	1,907 (15)	2,074 (16)	2,225 (17)	2,364 (19)	2,317 (19)	2,232 (18)
Non-ST-segment elevation	1,064 (10)	1,478 (12)	1,718 (13)	2,036 (16)	2,177 (18)	2,262 (19)	2,254 (19)
ST-segment elevation	222 (2)	326 (3)	382 (3)	438 (3)	457 (4)	486 (4)	494 (4)
Other	1,392 (14)	2,187 (18)	2,380 (18)	2,431 (19)	2,492 (21)	2,431 (20)	2,579 (21)
Missing	4,249 (41)	3,808 (30)	3,292 (26)	2,497 (19)	1,422 (12)	1,195 (10)	1,172 (10)
Primary procedural access							
Femoral	9,546 (93)	11,020 (88)	10,909 (85)	10,730 (83)	9,571 (79)	8,899 (74)	8,086 (66)
Radial	507 (5)	1,043 (8)	1,733 (13)	1,995 (15)	2,366 (20)	2,957 (25)	3,897 (32)
Other	48 (0)	56 (0)	72 (1)	67 (0)	73 (1)	56 (0)	67 (0)
Missing	179 (2)	349 (3)	195 (2)	172 (1)	146 (1)	130 (1)	155 (1)
Coronary summary							
3-vessel disease	2,388 (23)	2,857 (23)	2,882 (22)	3,047 (24)	2,871 (24)	2,771 (23)	2,809 (23)
2-vessel disease	2,435 (24)	3,049 (25)	3,222 (25)	3,308 (26)	3,099 (26)	2,988 (25)	2,997 (25)
1-vessel disease	3,233 (31)	4,134 (33)	4,397 (34)	4,406 (34)	4,139 (34)	4,155 (35)	4,141 (34)
Nonobstructive	331 (3)	504 (4)	548 (4)	472 (4)	401 (3)	376 (3)	369 (3)
Normal	6 (0)	8 (0)	13 (0)	6 (0)	4 (0)	5 (0)	6 (0)
Missing	1,887 (18)	1,916 (15)	1,847 (14)	1,725 (13)	1,642 (14)	1,747 (14)	1,883 (15)
Vessel treated							
Left main coronary artery	184 (2)	297 (2)	294 (2)	314 (2)	319 (3)	260 (2)	277 (2)
Left anterior descending coronary artery	3,413 (33)	3,841 (31)	4,270 (33)	4,275 (33)	4,114 (34)	4,181 (35)	4,325 (35)
Left circumflex coronary artery	2,301 (22)	2,772 (22)	2,907 (23)	2,788 (22)	2,641 (22)	2,639 (22)	2,707 (22)
Right coronary artery	2,745 (27)	3,467 (28)	3,483 (27)	3,525 (27)	3,345 (28)	3,242 (27)	3,294 (27)
Other	225 (2)	277 (2)	234 (2)	293 (2)	259 (2)	247 (2)	231 (2)
Bypass graft	967 (9)	1,023 (8)	1,039 (9)	1,066 (8)	967 (8)	991 (8)	927 (8)
Missing	445 (5)	791 (6)	682 (5)	703 (5)	511 (4)	482 (4)	444 (4)
Ventricular support							
Intra-aortic balloon pump	141 (1)	162 (1)	166 (1)	169 (1)	165 (1)	137 (1)	147 (1)
Other	–	–	–	–	24 (0)	54 (0)	125 (1)

Values are n (%).

in mortality (HR: 0.983; 95% CI: 0.967 to 1.000) (Figure 1).

DISCUSSION

The present study evaluated the temporal trends in invasive coronary procedures using a national dataset collected at the point of care. As the data demonstrate, the number of coronary angiographic studies and coronary interventions remained relatively constant during the time period under investigation. The patient population undergoing these procedures has also grown older, with a higher degree of medical comorbidities, demonstrated by a significant increase in 2 contemporary composite risk scores calculated over time. Although medical management of these patients has remained constant, procedural management has changed with increasing adoption of transradial access and use of mechanical support for high-risk interventions. Despite the increases in baseline procedural risk, however, the procedural complications and clinical

outcomes among patients undergoing these procedures have remained constant. In fact, the adjusted HR for mortality showed a nonsignificant trend toward decreasing after considering the changes in medical comorbidities among those undergoing percutaneous revascularization. These data have important implications in the largest integrated health care system in the United States, as well as for the medical community as a whole.

The patient population undergoing invasive cardiac procedures is aging with a concomitant increase in their medical comorbidities. Previous research has demonstrated that Medicare patients undergoing PCI in the community have become progressively older, with a higher rate of heart failure and peripheral artery disease (13). Furthermore, a measure of composite risk among patients undergoing percutaneous revascularization has also increased with time among facilities enrolled in the NCDRs (14). The present study corroborates these findings in the largest integrated health care system in the United States, the VA health care system. The data demonstrate that patients undergoing coronary angiography and intervention are older, with a significant increase in every concomitant medical comorbidity measured. The prevalence of common psychosocial conditions in this population, such as post-traumatic stress disorder, has also increased with time. The sum of this medical complexity is reflected in a significant increase in the Framingham risk score, a composite measure used to calculate the risk for future coronary heart disease events. Additionally, the NCDR CathPCI score assessing the risk for periprocedural mortality during coronary intervention also increased with time. Interestingly, the median NCDR CathPCI mortality risk score among patients undergoing intervention at VA facilities (18; interquartile range: 10 to 24) exceeds the most recently reported value in the community by the NCDRs (16; interquartile range: 10 to 23) (14). It is important to note that fewer than one-half of the cardiac catheterization laboratories in the VA health care system provide 24-h coverage, which would presumably lower the measured acuity of the patient population treated. The finding of increased expected mortality within the VA system is thus even more surprising compared with the community, with a greater proportion of sites that provide around-the-clock invasive cardiology services. Additional data have suggested that the anatomic complexity of patients undergoing angiography and intervention has also increased with time, particularly among patients who are ineligible for surgical

TABLE 3 Medication Prescriptions 90 Days After Percutaneous Coronary Intervention, 2009 to 2014

	2009 (n = 10,280)	2010 (n = 12,468)	2011 (n = 12,909)	2012 (n = 12,964)	2013 (n = 12,156)	2014 (n = 12,042)
Angiotensin blockade						
Eligible	8,334	9,996	10,175	10,045	9,317	9,112
Prescription rate (%)	86	86	85	85	85	83
Beta-blocker						
Eligible	8,950	10,830	11,179	11,251	10,403	10,261
Prescription rate (%)	92	92	92	92	93	92
$P2Y_{12}$ inhibitor						
Eligible	9,601	11,637	12,050	12,092	11,298	11,315
Prescription rate (%)	97	97	97	98	98	98
Statin						
Eligible	9,096	10,988	11,313	11,315	10,581	10,583
Prescription rate (%)	94	94	94	94	95	95
All medications						
Eligible	7,162	8,640	8,756	8,600	7,978	7,796
Prescription rate (%)	74	74	73	74	75	73

Patients were deemed not eligible for a prescription if they met 1 of the following 3 criteria: died prior to 90 days after the procedure, had a documented allergy to the medication class, or received medications from outside the Veterans Affairs system.

TABLE 4 Procedural Complications and Clinical Outcomes Among Patients Undergoing Percutaneous Coronary Intervention, 2009 to 2015

	2009 (n = 10,280)	2010 (n = 12,468)	2011 (n = 12,909)	2012 (n = 12,964)	2013 (n = 12,156)	2014 (n = 12,042)	2015 (n = 12,205)
Procedural complications							
Major complications	5 (0.04)	19 (0.15)	15 (0.11)	16 (0.12)	9 (0.07)	17 (0.14)	5 (0.04)
Minor complications	147 (1)	181 (1)	189 (1)	160 (1)	143 (1)	128 (1)	116 (1)
Clinical outcomes							
Readmission (30-day)	1,167 (11)	1,337 (11)	1,391 (11)	1,434 (11)	1,334 (11)	1,295 (11)	–
Myocardial infarction (1-yr)	375 (4)	453 (4)	489 (4)	462 (4)	484 (4)	479 (4)	–
Mortality (1-yr)	679 (7)	785 (6)	803 (6)	795 (6)	840 (7)	815 (7)	–

Values are n (%) for proportions for longitudinal outcomes.

revascularization (15,16). The anatomic data within our dataset suggest that the number of diseased major coronary vessels has remained constant with time, although additional details regarding anatomic complexity such as the SYNTAX (Synergy Between Percutaneous Coronary Intervention With Taxus and Cardiac Surgery) score are not easily obtainable (17,18).

Management of these increasingly comorbid patients has evolved over time. Medical therapy for patients with coronary disease has remained constant, while new procedural techniques have been adopted over the past decade. Previous data have demonstrated that approximately one-half of patients undergoing interventions at private or community institutions were prescribed antiplatelet agents, angiotensin antagonists, beta-blockers, and statins in a contemporary cohort (19). In the present analysis, the prescription of these medications exceeded that prescribed in the community such that three-fourths of patients undergoing percutaneous revascularization in the VA system were treated with all 4 classes of medications at discharge. These rates of prescriptions were relatively constant with time, although there were significant changes in the procedural management. An increase in the use of radial access for coronary angiography and intervention is now recognized as a measure of improved quality of care (20,21). With this in mind, transradial access for both coronary angiography and PCI significantly increased over the time period studied, approaching 38% of diagnostic cases and 32% of interventional cases in the most recent year under investigation. These numbers exceed the most recent analysis from the NCDRs, which suggested that only 26% of patients underwent intervention via the radial approach at nonfederal facilities (4). It is important to note that even the superior adoption of transradial access within the VA system continues to lag well behind practice patterns in Europe, suggesting a potential opportunity for improvement (22,23). The adoption of mechanical support during high-risk interventions also increased in our cohort with time, although it constituted a small proportion of the total interventions. The continued use of guideline-directed medical therapy and advances in procedural technique may have contributed to an improvement in patient outcomes.

Clinical outcomes among patients undergoing invasive cardiac procedures have remained constant with time. After accounting for periprocedural risk, the readmission rate among those undergoing coronary angiography declined over time. Perhaps the tightly integrated nature of the health care system or the increased adoption of radial access contributed to this decline. Furthermore, the point estimates for HRs of readmission and mortality also declined with time among those undergoing percutaneous revascularization. Because of the episodic nature of data collection and lack of longitudinal follow-up, the HRs for readmission and mortality are not readily available in other datasets, making comparisons challenging. However, the overall rate of major complications occurring in the cardiac catheterization laboratory reported here, which includes emergent cardiac surgery, is consistently lower than that reported in the community (0.2%) according to the NCDRs (4). Taken together, the data suggest that the increasing medical complexity with time has not led to worsening of clinical outcomes for patients in the VA health care system. Furthermore, the complication rates observed in the largest integrated health care system in the United States compare very favorably with the voluntary reporting in similar community-based programs. These data highlight the potential benefits of an integrated health care system using a heart team approach as well as a central organization to monitor the overall quality and safety of invasive cardiac procedures. As such, careful consideration will need to be given to outsourcing the care of complex patients to ensure that interventional quality is maintained.

STUDY LIMITATIONS. The present project should be interpreted in the context of several limitations. The present analysis is derived from linked clinical and administrative databases used for clinical care. Data entry errors are thus possible, although several interventions have been deployed to increase the validity of the data. Temporal improvement in data capture or changes in coding practices may account for some of the trends in comorbidities noted in the present analysis. Procedural complication rates are voluntarily reported by the operators and may not reflect complications that occur after the patient leaves the cardiac catheterization laboratory. It is important to note that the primary outcomes, readmission for myocardial infarction or death, are not subject to this limitation. A small proportion of patients treated within the VA health care system receive additional care from outside providers. Fee-based data were used to capture readmissions to outside facilities, although this may remain

incomplete. Similarly, it is possible that some patients undergo repeat revascularization outside of the national health care system and are also not included in our outcomes. Finally, the current dataset includes predominantly male patients treated within the VA health care system. The results may thus not be generalizable to other populations with more diversity. Specifically, the risk scores used in this analysis were developed and validated for specific patient populations. The applicability of these models to patients undergoing isolated coronary angiography or in patients with high burdens of coronary artery disease is unknown. However, the potential uncertainty in precision of these models would likely be constant across years such that an assessment of temporal trends would not be significantly affected.

CONCLUSIONS

Invasive coronary procedures are being performed on progressively older patients with additional medical comorbidities. The medical and procedural management has undergone changes, with increasing adoption of transradial access. Clinical outcomes have remained constant, however, with a trend toward a declining HR for mortality among those undergoing percutaneous revascularization.

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PERSPECTIVES

WHAT IS KNOWN? Coronary angiography and PCI remain instrumental diagnostic and therapeutic interventions for coronary artery disease.

WHAT IS NEW? Using data from the largest integrated health care system in the United States, we demonstrate that veterans undergoing coronary angiography and PCI have had increasing medical complexity over time. Despite increasing medical complexity, however, longitudinal clinical outcomes have remained constant, with a trend toward a declining HR for mortality among those undergoing percutaneous revascularization.

WHAT IS NEXT? Further studies should evaluate similar trends in community-based practices, to ensure that the largest integrated health care system is providing the highest possible quality of care.

REFERENCES

1. Yeh RW, Sidney S, Chandra M, Sorel M, Selby JV, Go AS. Population trends in the incidence and outcomes of acute myocardial infarction. N Engl J Med 2010;362:2155–65.

2. Yeh RW, Mauri L, Wolf RE, et al. Population trends in rates of coronary revascularization. JAMA Intern Med 2015;175:454–6.

3. Dehmer GJ, Weaver D, Roe MT, et al. A contemporary view of diagnostic cardiac catheterization and percutaneous coronary intervention in the United States: a report from the CathPCI Registry of the National Cardiovascular Data Registry 2010 through June 2011. J. Am. Coll. Cardiol 2012;60:2017–31.

4. Masoudi FA, Ponirakis A, de Lemos JA, et al. Trends in U.S. cardiovascular care: 2016 report from 4 ACC National Cardiovascular Data Registries. J Am Coll Cardiol 2017;69:1427–50.

5. Maddox TM, Plomondon ME, Petrich M, et al. A national clinical quality program for Veterans Affairs catheterization laboratories (from the Veterans Affairs Clinical Assessment, Reporting, and Tracking program). Am J Cardiol 2014;114:1750–7.

6. Brindis RG, Fitzgerald S, Anderson HV, Shaw RE, Weintraub WS, Williams JF. The American College of Cardiology–National Cardiovascular Data Registry (ACC-NCDR): building a national clinical data repository. J Am Coll Cardiol 2001;37:2240–5.

7. Byrd JB, Vigen R, Plomondon ME, et al. Data quality of an electronic health record tool to support VA cardiac catheterization laboratory quality improvement: the VA Clinical Assessment, Reporting, and Tracking System for Cath Labs (CART) program. Am Heart J 2013;165:434–40.

8. US Department of Veterans Affairs. VIReC Home 2016. Available at: http://www.virec.research.va.gov/index.htm. Accessed July 27, 2016.

9. D'Agostino RB, Vasan RS, Pencina MJ, et al. General cardiovascular risk profile for use in primary care: the Framingham Heart Study. Circulation 2008;117:743–53.

10. Peterson ED, Dai D, DeLong ER, et al. Contemporary mortality risk prediction for percutaneous coronary intervention: results from 588,398 procedures in the National Cardiovascular Data Registry. J Am Coll Cardiol 2010;55:1923–32.

11. Sen P. Estimates of regression coefficient based om Kendall's tau. J Am Stat Assoc 1968;63:1379–89.

12. Shi X, Zhu H, Ibrahim JG. Local influence for generalized linear models with missing covariates. Biometrics 2009;65:1164–74.

13. Rao SV, Hess CN, Dai D, Green CL, Peterson ED, Douglas PS. Temporal trends in percutaneous coronary intervention outcomes among older patients in the United States. Am Heart J 2013;166:273–81.e4.

14. Vora AN, Dai D, Gurm H, et al. Temporal trends in the risk profile of patients undergoing outpatient percutaneous coronary intervention: a report from the National Cardiovascular Data Registry's CathPCI Registry. Circ Cardiovasc Interv 2016;9:e003070.

15. Huang HW, Brent BN, Shaw RE. Trends in percutaneous versus surgical revascularization of unprotected left main coronary stenosis in the drug-eluting stent era: a report from the American College of Cardiology-National Cardiovascular Data Registry (ACC-NCDR). Catheter Cardiovasc Interv 2006;68:867–72.

16. Waldo SW, Secemsky EA, O'Brien C, et al. Surgical ineligibility and mortality among patients with unprotected left main or multivessel coronary artery disease undergoing percutaneous coronary intervention. Circulation 2014;130:2295–301.

17. Sianos G, Morel M-A, Kappetein AP, et al. The SYNTAX score: an angiographic tool grading the complexity of coronary artery disease. EuroIntervention 2005;1:219–27.

18. Serruys PW, Morice M-C, Kappetein AP, et al. Percutaneous coronary intervention versus coronary-artery bypass grafting for severe coronary artery disease. N Engl J Med 2009;360:961–72.

19. Iqbal J, Zhang Y-J, Holmes DR, et al. Optimal medical therapy improves clinical outcomes in patients undergoing revascularization with percutaneous coronary intervention or coronary artery bypass grafting: insights from the Synergy Between Percutaneous Coronary Intervention with TAXUS and Cardiac Surgery (SYNTAX) trial at the 5-year follow-up. Circulation 2015;131:1269–77.

20. Naidu SS, Aronow HD, Box LC, et al. SCAI expert consensus statement: 2016 best practices in the cardiac catheterization laboratory: (endorsed by the Cardiological Society of India, and Sociedad Latino Americana de Cardiologia Intervencionista; affirmation of value by the Canadian Association of Interventional Cardiology-Association Canadienne de Cardiologie d'Intervention). Catheter Cardiovasc Interv 2016;88:407–23.

21. Roffi M, Patrono C, Collet J-P, et al. 2015 ESC guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation: Task Force for the Management of Acute Coronary Syndromes in Patients Presenting Without Persistent ST-Segment Elevation of the European Society of Cardiology (ESC). Eur Heart J 2016;37:267–315.

22. Johnman C, Pell JP, Mackay DF, et al. Clinical outcomes following radial versus femoral artery access in primary or rescue percutaneous coronary intervention in Scotland: retrospective cohort study of 4534 patients. Heart 2012;98:552–7.

23. Ratib K, Mamas MA, Anderson SG, et al. Access site practice and procedural outcomes in relation to clinical presentation in 439,947 patients undergoing percutaneous coronary intervention in the United Kingdom. J Am Coll Cardiol Intv 2015;8:20–9.

KEY WORDS coronary angiography, percutaneous coronary intervention, public reporting

APPENDIX For supplemental tables and figures, please see the online version of this paper.