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REVIEW

Performance Measures Have a Major Effect on Cardiovascular Outcomes: A Review

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ABSTRACT

Improved application of existing therapies, directed by evidence-based guidelines, may offer immediate savings of life and function to patients with cardiovascular disease. We sought to evaluate the evidence that use of performance measures derived from clinical practice guidelines is associated with better clinical outcomes in this context. We conducted a search of the MEDLINE database for published studies evaluating the relationship of evidence-based therapies and outcomes in patients with coronary artery disease or heart failure. Studies examined included single-center, regional, national, and international experiences, and varied considerably in design. Most studies linking guidelines-based care to outcomes focused on patients with coronary artery disease; relatively few addressed patients with heart failure. Few studies, all nonrandomized, examined the use of specific interventions to improve quality of care in the context of standardized care tools. Almost all studies showed a strong and "dose-response" association between adherence to guidelines and performance measures and outcomes. Higher quality of care, as documented by better performance based on measures derived from practice guidelines, is associated with improved outcomes in patients with cardiovascular disease.

KEYWORDS: Cardiovascular disease; Guidelines; Performance measures

Despite dramatic progress in the treatment of cardiovascular disease, it has remained the leading cause of death and disability in countries with developed economies because of the aging of the population combined with epidemics of obesity and diabetes mellitus.[1] Although new therapies are needed to meet this therapeutic challenge, better application of currently available therapies may offer more immediate savings of life and function.

Several decades ago, physicians treating cardiovascular disease developed a system that collected their combined knowledge into clinical practice guidelines, which were then regularly updated as new evidence became available. More recently, a relatively small number of therapeutic decisions have been distilled into performance measures. These measures can be used to estimate the quality of care provided by an individual, a practice, a hospital, or a health care system.[2,3] Widely available informatics platforms now allow for measured performance to be compared across practices, and results can be fed back to practitioners to stimulate improvement.

Although the conceptual framework for this practice has been described for some time, proof of its application has been lacking until recently. This report provides an overview of guidelines-based therapy in the clinical setting by examining current data on the application of evidence-based care in real-world practice and characterizes associations between measured performance and outcomes in patients with coronary artery disease and heart failure.

PERFORMANCE MEASURES AND OUTCOMES IN CURRENT LITERATURE

Database Search

We conducted an extensive search of English-language holdings catalogued in the Ovid MEDLINE database

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through December 2005 to identify all published studies evaluating relationships between use of evidence-based therapies and patient outcomes in cardiovascular disease. The search was performed using the "Advanced Search" function of the Ovid MEDLINE Database (Ovid Technologies Inc., version rel 10.3.1; SourceID 1.12052.1.95).

Through a relatively informal process, we established a list of search terms deemed likely to yield results that included published data on performance and quality-improvement measures in patient populations with coronary artery disease and/or heart failure. Search terms included the following: "quality," "quality of care," "quality indicators," "quality improvement," "performance measures," "evidence-based care," "evidence-based treatments," "evidence-based therapies," "guidelines-based treatments," "guidelines-based therapies," "acute coronary syndromes," "myocardial infarction," "unstable angina," "coronary artery disease," "coronary heart disease," "heart failure," "congestive heart failure," "outcomes," "death," and "mortality" in various combinations.

These searches yielded a total of 34 articles and 14 abstracts. The resulting journal references were reviewed and evaluated for relevance. For the purpose of this review, any journal article that addressed the use and/or assessment of American College of Cardiology/American Heart Association guidelines-based therapies in the clinical setting was initially deemed eligible for assessment, with guidelines-based therapies being defined as those implemented on the basis of Class I recommendations. We also examined the reference list of each identified study, as well as existing bibliographies of relevant studies and review articles. Finally, we examined scientific session abstracts in *Circulation*, the *Journal of the American College of Cardiology*, and the *European Heart Journal* through December 2005, using selection criteria noted above. Later an additional study meeting our criteria was noted and subsequently included in our review.

Categorization of Search Results

Reports were first categorized according to broad patient population (coronary artery disease or heart failure). Results were organized into the following categories: single-center studies, regional studies, national studies, and international studies. Results were categorized further on the basis of number of reporting institutions, number of subjects, patient population, study design, nature of performance measures, performance measure or quality improvement intervention (if any), and comparison groups (Tables 1 and 2, online).

Search results also were categorized to examine changes in performance measures, effects of specific interventions, and any resulting changes in mortality. Again, these results were examined using the broad categorizations of patient populations with coronary artery disease and populations with heart failure, and further categorized according to whether the study was local, regional, national, or international (Tables 3 and 4, online).

CLINICAL SIGNIFICANCE

- Mortality rates are lower among cardiovascular disease patients who receive evidence-based treatments at optimal doses when compared with patients who are not given evidence-based treatments or who do not take these drugs at target levels.
- The decrease in observed mortality is proportional to the number of appropriate therapies received (of all possible indicated therapies). Patients who receive all indicated treatments are likely to have a lower mortality than those who receive few or no such therapies.

RESULTS

Tables 1 and 2 (online) display studies that link guidelines-based care to outcomes. Most studies focused on examining this correlation in patients with coronary artery disease (ranging from stable disease to acute coronary syndromes),[4-18] but relatively few explored this association among patients with heart failure.[9,19-21] These investigations provide information regarding single-center experiences[4-8] and regional efforts,[9-12,19-21] or offer national[13-17] or international[18] perspectives. Study designs varied considerably and included pre- and postintervention use of performance measures and the association with outcomes (n = 4),[4,9,10,13] cohort studies (n = 4),[5,8,11,19] cross-sectional investigations associating care with outcomes (n = 6),[6,14-16,18,20] or evaluation of trends in care and outcomes (n = 3)[7,12,18] and case-control designs (n = 1).[21] Those studies that incorporated interventions did not perform them in randomized fashion, but depended rather on time-based measurements of performance measures and outcomes.

Tables 3 and 4 (online) display the relationship between performance measures and outcomes in studies listed in Tables 1 and 2 (online), respectively. Almost all published studies show a strong association between patient outcomes and adherence to clinical practice guidelines and performance measures and patient outcomes.

Studies evaluating multiple therapies demonstrate a "dose-response association" in which the observed decrease in mortality is proportional to the number of appropriate therapies (of all possible indicated therapies) received by an individual.[6,8,15] This dose-response association is further supported by the finding that among patients receiving an evidence-based therapy, those who receive the therapy at an optimal target dose are more likely to have lower mortality than those receiving suboptimal doses.[21]

Furthermore, change in compliance with guideline recommendations is associated inversely with change in mortality.[16] Two studies showed improved adherence to long-term treatment and lifestyle-modification goals for patients hospitalized for coronary artery disease or heart failure when these patients were targeted for appropriate treatments during hospitalization.[4,9]

Relatively few studies examined the use of interventions to improve quality of care in the context of standardized care tools. These interventions, performed in various combinations in nonrandomized fashion, included targeting increased use of indicators at discharge,[4] discharge medical programs,[9] standardized admission and discharge care tools,[9,21] and data feedback and peer review.[13,15,16]

DISCUSSION

As the importance of measuring and improving quality of care has received increased attention from the public, payers, and the government, process or performance measures rather than patient outcomes have been popularly adopted as intermediary quality indicators. This approval of process as a quality marker is based on demonstrated direct associations between performance measures and outcomes in randomized controlled clinical trials. However, there is still skepticism regarding the use of process as a means of measuring and improving health care outcomes, because the critical link between health care quality and outcomes in the "cycle of quality"[22] has remained an untested assumption when applied to unselected patient populations.

Our results provide evidence to complete this missing link in the treatment of cardiovascular disease.[22] These data indicate that the cycle of quality is likely to achieve reductions in death in excess of those seen for any individual new therapy or those observed in any clinical trial evaluating efficacy of a single treatment (the commonly observed treatment association is typically between 10% and 25% for major clinical outcomes). Fundamentally, by combining multiple effective therapies in a reliable delivery system, measurable outcomes can exceed those seen with any individual therapy.

As previously noted, the association of a close link between evidence-based treatments and mortality is further supported by additional findings from selected studies. Investigations that evaluated multiple therapies show a dose-response association—the decrease in observed mortality is proportional to the number of appropriate therapies received (of all possible indicated therapies).[6,8,14] Thus, a patient who receives all indicated treatments is likely to have a lower mortality than one who receives few or no such therapies. Even among patients receiving an evidence-based therapy, those receiving the optimal target dose are more likely to have lower rates of mortality than those receiving suboptimal doses.[19] In addition, changes in compliance with guideline recommendations are inversely associated with changes in mortality.[16] Thus, increased mortality is observed in institutions that show decreased use of evidence-based care, whereas in contrast, improvement in care is associated with decreased mortality proportional to the degree of change in the performance measure.

Implications

Although trends in evidence-based care continue to improve, several studies encompassing various cardiovascular conditions suggest that many Americans do not receive necessary care[13,18,22-25] despite evidence linking quality to outcomes (Tables 3 and 4). Previous investigations suggest that even modest improvements in delivery of guidelines-based care represent an opportunity to prevent 40,000 to 80,000 deaths related to cardiovascular disease, the most common cause of death globally.[26,27] These studies strongly suggest that embracing a culture of quality in the context of evidence-based practice will have a major effect on health and survival in patients with cardiovascular disease.

Why Is There an Association Between Performance Measures and Outcomes?

The definitive reason(s) for the association between performance measures and outcomes is difficult to ascertain from the studies reviewed in this article. Multiple factors may play a role, either separately or in conjunction with others. Although causality cannot be inferred, it is plausible that the proven efficacy of various therapies in the setting of randomized clinical trials is also observed in real-world practice.

Alternative explanations may also contribute to this association. Better adherence to guidelines-based treatments may be a marker of a better doctor or of an institution with an existing culture of quality care for individual patients, both of which are likely to be associated with better outcomes. Likewise, receipt of evidence-based treatment could be a marker of healthier patients with fewer confounding comorbid conditions. Few studies in our review accounted for patient-level differences in confounding baseline features or, for that matter, hospital characteristics. Studies that did examine associations between care and outcomes suggest that case mix and hospital characteristics significantly attenuate relationships between performance and outcomes.[6,7,12,14-18]

Achieving Better Performance in Hope of Better Outcomes

Many studies provide information on positive associations without addressing what works. Multiple modalities are aimed at improving care, yet evaluation is lacking. Most studies have no control groups, making it difficult to determine whether improvements in care are related to a universal trend favoring better guideline adoption or are related to a specific intervention, and the nonrandomized nature of studies evaluating interventions further confounds interpretation of this association.

Many potential barriers to improving adherence to guideline recommendations have been identified, including issues related to patients (age, gender, race, socioeconomic status, insurance status, comorbidities, risks, preferences); physicians (lack of knowledge of disease and of guidelines, preferences, lack of "buy-in" to the concept of improving outcomes through application of guidelines, lack of incentives, fear of complications or of penalty secondary to "scorecard medicine," lack of administrative support); and health care systems (lack of expertise, commitment, or dedicated resources).[28-32] Understanding these factors and incorporating approaches that take them into account would help to overcome them.

Physician involvement in the context of administrative support and acceptance of multidisciplinary teams is key to the success of such continuous quality improvement programs, and multiple strategies have been adopted to increase physician participation. Recently, public reporting of physician performance and quality of care and outcomes has gained momentum.[33] Proponents of this approach believe that peer pressure, competition, and fear of being reported as a poorly performing outlier is likely to motivate physicians to improve quality of care.

Another method to increase physician and institutional interest in quality improvement uses "pay for performance" programs pioneered by private insurance companies and health maintenance organizations in Michigan and Virginia. However, the cardinal example of such an initiative is the Centers for Medicare and Medicaid Services' Pay-for-Performance-Project.[34] This pilot program, involving approximately 300 hospitals and conducted in conjunction with Premier, Inc, began in March 2003 and is designed to test whether financial incentives will drive superior quality of patient care. The program's initial focus is on 5 health care areas: myocardial infarction, bypass surgery, heart failure, pneumonia, and hip and knee replacements. Participating hospitals are ranked according to specific quality metrics in each of these areas. The top 50% of performers in each area will be publicly acknowledged on the Internet, and the top 10% will receive a small financial bonus. This project is a prelude to efforts involving additional diseases and conditions, as well as more performance measures. In the near future, most acute-care hospitals in the US likely will participate in such programs. More in-depth investigations are needed to determine what works and what does *not* work, to achieve better outcomes.

Limitations

The number of relevant studies in this area remains small and is confounded by patients' levels of risk. As quality improvement methods continue to evolve, they will need to be evaluated by appropriately designed trials. Most of the studies reviewed reported positive results, indicating an association between use of evidence-based treatments and better outcomes. However, we note that a recent report by Bradley and colleagues,[35] linking use of performance measures to short-term outcomes among patients with acute myocardial infarction at 962 National Registry of Myocardial Infarction hospitals, found a hospital-level variation of only 6% in 30-day mortality attributable to differences in use of performance measures. These results, although not actually contradicting the findings of another recent study examining similar correlations,[15] suggest that development of additional measures may be warranted. More important, performance measures may act as markers of additional factors that have favorable effects on outcomes. Thus, caution must be exercised when attributing cause-and-effect relationships between performance and outcomes. We found no studies that failed to demonstrate an association between performance measures and outcomes; thus, publication bias cannot be excluded. Because most studies are observational rather than randomized evaluations of interventions to improve performance, association rather than causation of the effect of intervention should be inferred. However, the broad populations included in these studies provide strong evidence that the association applies to the span of patients seen in North American practice.

The relative efficacy of a specific intervention aimed at improving performance measures and outcomes has not been evaluated in any study.[36] The importance of such evaluation is highlighted by recent reports of failures of computerized physician order entry systems,[37,38] which serve to emphasize that methods of practice improvement can have a negative impact on outcomes if improperly implemented. Furthermore, the areas on which we have focused were developed over decades[2,3,22,39] in a field for which pragmatic randomized controlled trials form the underpinning for guidelines (and for resulting performance measures). When lower confidence levels of evidence are used, particularly in the absence of adequate measurement of the risk/benefit balance for a treatment, there is a potential for promoting regimented use of a suboptimal therapy.

CONCLUSIONS

This review offers evidence that higher quality of care, as documented by improvement in performance measures derived from clinical practice guidelines, improves survival in patients with cardiovascular disease. However, many patients still do not receive optimal care, and this in turn is responsible for many preventable deaths. Well-designed studies, capable of identifying those interventions most effective in generating new evidence and creating cultural changes necessary for promoting better quality of care, will be essential in closing this gap. Effective use of this cycle of quality promises to further reduce the major cause of death and disability in technologically developed societies.

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Table 1 Methods of Investigations Evaluating Evidence-Based Medicine and Outcomes in Patients with Coronary Artery Disease

Study	Patient Population	Study Design	Performance Measures	Intervention	Comparison Groups
Single-center					
Fonarow et al[4]	558 patients with AMI at tertiary hospital	Pre/post-intervention	Discharge rates of: ASA, β-blockers, ACEI, statins titrated to LDL ≤ 100 mg/dL	Yes: tools targeting increased use of indicators at discharge	Pre/post-intervention
Giugliano et al[5]	275 nonreferral UA patients	Retrospective cohort	IV thrombolytics; initial ASA, heparin, or β-blocker; Ca+ channel blockers; recommendation for cardiac catheterization or CABG; discharge ASA	No	Levels of concordance with AHCPR guidelines-recommended care
Mukherjee et al[6]	1358 patients with ACS at tertiary hospital	Cross-sectional	Discharge rates of ASA, β-blockers, ACEI, lipid-lowering agents	No	Levels of composite appropriate care based on no. of treatments received out of total indicated care
Newby et al[7]	31,750 patients undergoing cardiac procedure at Duke, 1995-2002	Cross-sectional trends in care and outcomes	Discharge ASA, β-blockers, statins, and ACEI in patients with/without heart failure	No	Patients with/without appropriate use of evidence-based medicine as noted
Jaber et al[8]	7745 patients undergoing successful PCI at tertiary care center	Retrospective cohort	Performance score based on discharge rates of ASA, β-blockers, ACEI, and lipid-lowering agents.	No	Patients grouped on scale of 0-4 based on no. of guidelines-based therapies received; patients receiving score of 0-1 used as reference group
Regional					
Lappe et al[9]	57,465 patients with CVD in 10 hospitals in Utah-based system	Pre- and post-intervention	Discharge rates of ASA, β-blockers, ACEI, statins, warfarin	Yes: discharge medical program	Pre/post-intervention
Eagle et al[10]	2857 Michigan Medicare patients with AMI in 33 hospitals	Pre- and post-intervention	Use of tools to promote admission and discharge ASA, β-blocker quality indicators	Yes: standardized admission and discharge care tools	Pre/post- intervention
Higashi et al[11]	372 high-risk vulnerable patients aged >65 y from 2 managed care plans; 1/3 with ischemic heart disease, 2 hospitals	Cohort study	Quality indicators of a total of 236 for 22 conditions further restricted to those for which at least 50 patients received it and 50 did not	No	Upper and lower half of quality score based on no. of appropriate quality-of-care procedures received out of total no. indicated
Watkins et al[12]	6379 patients with NSTE-ACS in 4 US communities	Cross-sectional	In-hospital ASA, β-blockers, revascularization	No	Trends 1987-2000

Table 1 Continued.

Study	Patient Population	Study Design	Performance Measures	Intervention	Comparison Groups
National					
Marciniak et al[13]	23,535 elderly Medicare patients with AMI in 390 hospitals	Pre-and post-intervention	Admission ASA, β-blockers, and reperfusion therapy; discharge ASA, β-blockers, ACEI, and smoking-cessation counseling	Yes: data feedback by peer review organizations	Four pilot states pre/post-intervention; post-intervention pilot states vs rest of nation
Chen et al[14]	149,177 elderly Medicare patients with AMI from CCP in 60 hospitals	Cross-sectional	Use of ASA, β-blockers, and reperfusion therapy in "America's Best Hospitals" vs others	No	"America's Best Hospitals" per *US News and World Report* vs others
Peterson et al[15]	64,775 high-risk NSTE-ACS at CRUSADE hospitals	Cross-sectional	Composite scores based on 4 admission (antiplatelet agent, heparin, β-blockers, GP IIb/IIIa) and 8 discharge indicators (ASA, clopidogrel, β-blockers, ACEI, statins, smoking cessation + dietary counseling, rehabilitation referral)	Yes: data feedback, standard care tools provided; use encouraged	Quartiles of composite quality scores
Peterson et al[16]	63,479 high-risk patients with NSTE-ACS at 301 CRUSADE hospitals	Cross-sectional	As above	Yes: data feedback, standard care tools provided; use encouraged	Quartiles based on change in composite adherence quality score between baseline and follow-up
Rogers et al[17]	1,514,292 patients with AMI in 2033 NRMI hospitals	Cross-sectional trends in care and outcomes	Reperfusion therapy and ASA, β-blockers and ACEI on admission and at discharge	No	Trends from 1990-1999
Bradley et al[35]	83,330* patients with AMI, aged >66 y, as reported to NRMI from 899 hospitals	Cross-sectional	Admission/discharge β-blockers and ASA; discharge ACEI; smoking cessation counseling; timely reperfusion; composite score†	No	Performance measures correlated with risk-adjusted 30-d mortality
International					
Granger et al[18]	20,140 patients with ACS at 94 participating GRACE hospitals	Cross-sectional	Admission ASA and β-blockers; discharge ASA, β-blockers, and ACEI	No	Quartiles based on composite adherence quality score for hospital

ACEI = angiotensin-converting enzyme inhibitor; ACS = acute coronary syndrome; AHCPR = Agency for Health Care Policy Research; AMI = acute myocardial infarction; ASA = acetylsalicylic acid; Ca^{+} = calcium (ion); CABG = coronary artery bypass graft; CCP = Cooperative Cardiovascular Project; CVD = cardiovascular disease; GP = glycoprotein; IV = intravenous; LDL = low-density lipoprotein; NRMI = National Registry of Myocardial Infarction; NSTE-ACS = non–ST-segment elevation acute coronary syndrome; PCI = percutaneous coronary intervention; UA = unstable angina.

*Subset of patients, aged ≥ 66 y, comprising sample in analysis of 30-d mortality rates.

†Composite score = performance on β-blocker and ASA at admission and at discharge plus ACEI performance at discharge.

Table 2 Study Design and Methods of Investigations Evaluating Evidence-Based Medicine and Outcomes in Patients with Heart Failure

Study	Patient Population	Study Design	Performance Measures	Intervention	Comparison Groups
Regional					
Lappe et al[9]	57,465 patients with CVD at 10 largest hospitals in Utah-based health system	Pre- and post-intervention	Discharge rates of ASA, β-blockers, ACEI, statins, warfarin	Yes: discharge medical program	Pre/post-intervention
Luthi et al[19]	621 Medicare patients with LVSD admitted to 64 hospitals in 5 US states	Retrospective cohort	ACEI	No	Patients receiving target dose of ACEI vs less than target dose vs none
Havranek et al[20]	1016 patients with HF admitted to 7 Colorado hospitals	Cross-sectional	ACEI	No	Patients receiving ACEI vs patients not receiving ACEI
Koelling et al[21]	2517 patients with HF admitted to hospitals in Michigan	Case-control	Participation in Quality Improvement Project	Yes: standardized admission and discharge care tools	8 intervention hospitals vs 6 control hospitals

ACEI = angiotensin-converting enzyme inhibitor; ASA = acetylsalicylic acid; CVD = cardiovascular disease; HF = heart failure; LVSD = left ventricular systolic dysfunction.

Table 3 Change in Performance Measures and the Association of this Change with Mortality in Patients with Coronary Artery Disease

Study	N	Change in Performance Measures	Effect Assessed	Mortality
Single-center				
Fonarow et al[4]	558	Discharge use of ASA, β-blockers, ACEI, statins increased by absolute of between 24% and 80%; high rate of adherence sustained at 1 y	No	Decreased from 7.0% to 3.3% at 1 y
Giuliano et al[5]	275	Compared with patients not receiving appropriate therapy, initial or discharge ASA, heparin, β-blocker use; avoidance of Ca+ channel blockers was between 8% and 16% higher; recommendation for cardiac catheterization or CABG was 1% to 26% higher	NA	1-y survival for guidelines-concordant patients vs non–guidelines-concordant: 95% vs 81%; $P = .001$
Mukherje et al[6]	1358	NA	NA	Adjusted OR vs 0 level: Level IV: OR 0.10 (CI 0.03-0.42) Level III: OR 0.17 (CI 0.04-0.75) Level II: OR 0.18 (CI 0.04-0.77) Level I: OR 0.36 (CI 0.08-1.75)
Newby et al[7]	31,750	Use of ASA, β-blockers, statins, ACEI in patients with and without HF increased between 7% and 22%	NA	Survival ASA + β-blockers + statins (vs those without these treatments) HR 0.67 (CI 0.59-0.77). ACEI in patients with HF, HR 0.75 (CI 0.67-0.84)
Jaber et al[8]	7745	NA	NA	0-1 guidelines meds: 13.0% (95% CI 16.2-9.8) 2 guidelines meds: 10.2% (95% CI 11.8-8.6) 3 guidelines meds: 7.5% (95% CI 8.6-6.4) 4 guidelines meds: 8.9 (95% CI 10.4-7.3) $P = .014$
Regional				
Lappe et al[9]	57,465	Discharge use of ASA, β-blocker, statin, ACEI, warfarin increased to $>$ 90%; high rate of adherence sustained at 1 y	No	Death at 1 y post-intervention HR 0.79 (CI 0.75-0.84)
Eagle et al[10]	2857	Use of admission and discharge standard orders increased by 26% and 29%; use of admission ASA and β-blockers and discharge ASA, β-blockers, ACEI, statins increased between 3% and 9%	No	1-y mortality post-intervention vs pre-intervention: 33.4% vs 38.3%. Adjusted OR 0.78 (0.64-0.95); adjusted OR for discharged standardized tool (vs no tool) 0.53 (0.36-0.86)
Higashi et al[11]	372	NA	NA	3-y mortality: upper vs lower half of quality score: 18% vs 28%. Adjusted HR for death after 500 d per 10% increase in score: 0.64 (CI 0.49-0.84)
Watkins et al[12]	6379	Use of ASA, β-blockers, coronary revascularization increased by absolute of between 26% and 44%	NA	30-d death decreased from 8.6% to 3.6%; adjusted OR (after adjusting baseline confounders) 0.75; $P = .0004$. When adjusted further for treatments OR 0.91; $P = .323$

Table 3 Continued.

Study	N	Change in Performance Measures	Effect Assessed	Mortality
National				
Marciniak et al[13]	23,535	Use of ASA during stay and ASA, β-blockers, ACEI at discharge increased by absolute of between 7% and 21% in pilot states from baseline to follow-up; use of ASA during stay and ASA, β-blockers, and ACEI at discharge was higher at follow-up in pilot states vs nonpilot states during same period	No	1-y mortality decreased from 32.9% to 30.4% between pre- and post-intervention period in pilot states. Follow-up 1-y mortality lower in pilot vs nonpilot states (30.4% vs 31.4%, $P = .0004$)
Chen et al[14]	149,177	Use of ASA and β-blockers higher in best hospitals vs others by an absolute of 8% to 27%	NA	Top-ranked hospital vs others adjusted OR 0.87 (CI 0.76-1.00); when adjusted further for ASA and β-blockers: OR 0.94 (CI 0.82-1.08)
Peterson et al[15]	64,775	NA	No	In-hospital mortality in 4-hospital composite quality quartile from lowest quality to highest 6.0%, 5.2%, 5.0%, and 4.2%, respectively. Adjusted OR for in-hospital mortality for every 10% increase in composite score: 0.89 (CI 0.81-0.98)
Peterson et al[16]	63,479	Difference in composite adherence score varied by absolute of between −5% in hospital with lowest change to +16% in hospitals with highest change	No	Change in the in-hospital mortality in 4-hospital quartiles from lowest to highest change in composite adherence score: +3.1%, −2.4%, −28%, and −37%, respectively
Rogers et al[17]	1,514,292	Use of ASA, β-blockers, ACEI in first 24 h, and at discharge increased by absolute of 10% to 23%. Door-to-needle time decreased from 62 to 38 min	NA	In-hospital mortality decreased from 11.2% to 9.4%
Bradley et al[35]	83,330*	NA	NA	Discharge β-blocker, discharge ASA, timely reperfusion, and composite score† had statistically significant correlations with risk-standardized 30-d mortality rate, but only 6% of hospital-level variance in short-term mortality rates was attributable to adherence to performance measures.
International				
Granger et al[18]	20,140	NA	NA	Adjusted in-hospital mortality among institutions in top performance quartile: 4.1% vs 5.6% in lowest quartile (27% relatively lower mortality [95% CI 11%-42%])

ACEI = angiotensin-converting enzyme inhibitor; ASA = acetylsalicylic acid; Ca^{+} = calcium (ion); CABG = coronary artery bypass graft; CI = confidence interval; HF = heart failure; HR = hazard ratio; NA = not applicable; OR = odds ratio.

*Subset of patients, aged ≥ 66 y, comprising sample in analysis of 30-d mortality rates.

†Composite score = performance on β-blocker and ASA at admission and at discharge plus ACEI performance at discharge.

Table 4 Change in Performance Measures and the Association of this Change with Mortality in Patients with Heart Failure

Study	N	Change in Performance Measures	Effect Assessed	Mortality
Regional				
Lappe et al[9]	57,465	Discharge use of ASA, β-blocker, statin, ACEI, warfarin increased to > 90%; high rate of adherence sustained at 1 y	No	Death at 1 y post-intervention: HR 0.77; $P < .0001$
Luthi et al[19]	621	NA	NA	Compared with target dose of ACEI, adjusted HR for suboptimal ACEI dose 1.30 (CI 0.86-1.70) and for no ACEI 1.63 (CI 1.02-2.60)
Havranek et al[20]	1016	NA	NA	1-y mortality in patients receiving ACEI vs those not receiving these drugs: 24% vs 36%; $P = .03$
Koelling et al[21]	2517	No data	No data	30-d mortality in intervention hospitals pre- and post-intervention: 9.4% vs 7.0%; adjusted OR 0.73 (CI 0.55-0.98); 30-d mortality in control hospitals pre- and post-intervention: 8.5% vs 10.7%; adjusted OR 1.30 (CI 0.87-1.95)

ACEI = angiotensin-converting enzyme inhibitor; ASA = acetylsalicylic acid; CI = confidence interval; HR = hazard ratio; NA = not applicable; OR = odds ratio.