Secondary Prevention After Coronary Artery Bypass Graft Surgery
Findings of a National Randomized Controlled Trial and Sustained Society-Led Incorporation Into Practice

Judson B. Williams, MD; Elizabeth R. DeLong, PhD; Eric D. Peterson, MD, MPH; Rachel S. Dokholyan, MPH; Fang-Shu Ou, MS; T. Bruce Ferguson, Jr, MD; for the Society of Thoracic Surgeons and the National Cardiac Database

Background—Despite evidence supporting the use of aspirin, β-blockers, angiotensin-converting enzyme inhibitors, and lipid-lowering therapies in eligible patients, adoption of these secondary prevention measures after coronary artery bypass grafting has been inconsistent. We sought to rigorously test on a national scale whether low-intensity continuous quality improvement interventions can be used to speed secondary prevention adherence after coronary artery bypass grafting.

Methods and Results—A total of 458 hospitals participating in the Society of Thoracic Surgeons National Cardiac Database and treating 361,328 patients undergoing isolated coronary artery bypass grafting were randomized to either a control or an intervention group. The intervention group received continuous quality improvement materials designed to influence the prescription of the secondary prevention medications at discharge. The primary outcome measure was discharge prescription rates of the targeted secondary prevention medications at intervention versus control sites, assessed by measuring preintervention and postintervention site differences. Prerandomization treatment patterns and baseline data were similar in the control (n = 234) and treatment (n = 224) groups. Individual medication use and composite adherence increased over 24 months in both groups, with a markedly more rapid rate of adherence uptake among the intervention hospitals and a statistically significant therapy hazard ratio in the intervention versus control group for all 4 secondary prevention medications.

Conclusions—Provider-led, low-intensity continuous quality improvement efforts can improve the adoption of care processes into national practice within the context of a medical specialty society infrastructure. The findings of the present trial have led to the incorporation of study outcome metrics into a medical society rating system for ongoing quality improvement. (Circulation. 2011;123:39-45.)

Key Words: coronary artery bypass grafting ■ coronary disease ■ prevention ■ revascularization ■ surgery

Continuous quality improvement (CQI) in its present form emerged in the early 1980s from the business theories of W. Edwards Deming,1 Joseph M. Juran,2 and Philip B. Crosby.3 Each stressed the importance of process measurement and feedback in any mechanism designed to measure and manage quality. Coronary artery bypass grafting (CABG) has been at the forefront of provider measurement and feedback systems. Specifically, the Society of Thoracic Surgeons’ (STS) National Cardiac Database (NCD) has been used as a platform for promoting better care and outcomes of CABG for 2 decades. A prior study has found that the STS infrastructure could be used to promote CQI in perioperative surgical issues.4 However, it is unclear whether this system could be used to also affect predischarge secondary medication choices on a national scale.

Editorial see p 8
Clinical Perspective on p 45

The benefits of secondary prevention in patients with coronary artery disease have been established, including after CABG.5 Unless contraindications exist, medications at discharge after CABG should include acetylsalicylic acid (ASA),6 β-blockers,7 lipid-lowering therapy,8 and angiotensin-converting enzyme inhibitors (ACEIs).9 The American Heart Association, American College of Cardiology (ACC), and STS have published guidelines directed specifically toward these and other secondary prevention...
measures for CABG patients. However, the implementation of secondary prevention therapies after CABG has lagged behind percutaneous catheter interventions.

The goal of this Agency for Healthcare Research and Quality grant was to evaluate whether we could successfully engage cardiac surgeons via an initiative to improve adherence to AHA/ACC/STS secondary prevention guidelines on a national scale. The design of this CQI intervention was a cluster randomized trial, randomizing sites to control or intervention.

**Methods**

The STS NCD

Begun in 1989, the STS NCD has since evolved into one of the largest specialty-specific clinical data registries in the world. The STS NCD currently houses data from >950 participants, representing just fewer than 90% of the cardiac surgery providers in the United States, with data on >3.6 million procedures. In collaboration with the Duke Clinical Research Institute’s outcomes research group, the STS has developed mortality, morbidity, and length-of-stay risk models for CABG and other major cardiac procedures for adults. Modifications aimed to expand the potential of the STS NCD to facilitate quality improvement efforts have been documented elsewhere.

Completeness of the NCD data has been compared with data from a Centers for Medicare and Medicaid Services diagnosis-related group data set for CABG, and no evidence for underreporting or misrepresenting of cases or events was found in the STS data. Quality of the data has been further assessed in a regional independent chart abstraction study, which documented a 96.2% correlation between submitted and reabstracted data elements.

**Intervention**

The intervention was a low-intensity educational effort, directed at a predetermined local opinion leader functioning as a quality champion at each individual site. Sites received educational information designed to influence the prescription of 4 medications at hospital discharge: ASA, β-blockers, lipid-lowering agents, and ACEIs (or angiotensin receptor blockers). Site-specific feedback reports highlighting the use of these 4 pharmacological agents at each site were generated every 6 months, along with standardized care orders, care reminders, a “call to action” letter on STS letterhead, and periodic newsletters. The site-specific performance data were illustrated against regional, national, and national “best practice” benchmarks. In addition, patient education materials, including patient educational materials that stress the importance of secondary prevention medications and other lifestyle modification interventions, were supplied for review before hospital discharge. Finally, patients and their physician were given a discharge “flight plan” checklist of evidence-based discharge medications to be considered. Each site documented whether the intervention material was received and by whom.

**Outcome Measures**

The primary end point of this trial was a composite measure of site performance rate for post-CABG prevention of cardiovascular disease by prescription at discharge of ASA, β-blockers, lipid-lowering agents, and ACEIs. Each patient contributed up to 4 records, each corresponding to an associated measure opportunity. The opportunity outcomes were coded as dichotomous responses indicating whether the patient was discharged with the particular secondary prevention medication. Each record included an indicator for the corresponding to an associated measure opportunity. Patient-specific, site-specific, and study-specific characteristics were incorporated, as well as the patient’s date of admission, enabling a time trend for uptake of secondary prevention to be derived.

Two additional outcomes were also identified. First, “overall adherence score” was defined as the number of therapies given (at both the patient and site levels) divided by the total number of eligible opportunities. Second, an “all versus not all” outcome (ie, “no missed opportunities”) took a value of 1 if a patient had every medication for which they were eligible and a value of 0 if the patient had fewer than every medication. The all versus not all performance score is the proportion of patients having every medication for which they were eligible.

**Randomization**

Before the trial, all NCD participant sites were surveyed on CABG care processes. All NCD sites were informed that they may periodically receive supplemental educational reports in addition to the standard site-specific semiannual reports. Participants were specifically not told of the current study design or that other NCD participants might be receiving interventions different from the ones they received. Hospitals in close geographic proximity or with shared surgeons were randomized as clusters. Participant sites were stratified by yearly CABG volume before randomization because CABG processes and outcomes may be influenced by procedural volumes at a given site. Clusters were then paired so that each pair was similar in terms of geography and CABG volume and randomized within pairs so that 1 cluster received the intervention and the other received the control assignment. The Duke University institutional review board served as the multiple projects assurance entity for this study for the STS and determined that informed consent was not required.

**Statistical Analyses**

Demographic patient-level and hospital-level characteristics were compared between the control and intervention arms to evaluate the adequacy of randomization. A weighted 2-sample t test was used to compare the overall difference in improvement in the usage rate of secondary prevention medications among control participants compared with among treatment participants. The usage rate was defined as the percentage of eligible patients who received the eligible medication.

Time trend analyses were performed with a conditional logistic model at the patient level, conditioning on the randomized pairs, to examine whether the rate of change in use of therapies differed between the intervention and control groups. The conditional logistic model accounts for the pairing of clusters and implicitly adjusts for differences in volume and geography. A significant interaction between period of time and treatment can be explained as the difference in slope between treatment and control participants.

A further subgroup analysis was performed on the change in the percentage of use of secondary prevention medications, examining the interaction between intervention group and site of CABG, academic versus nonacademic center site characteristic, use of process measure at baseline, and order for discharge by surgeon or nonsurgeon. For volume and measurement performance, sites were categorized as low, medium, or high according to whether they were in the first, second, or third tertile for the variable of interest. All analyses were performed with SAS version 9.1.3 (SAS Institute, Cary, NC).

**Sample Size**

The power for these analyses was conservatively calculated with sites used as the unit of analysis because sites were also the unit of randomization. The mean and SD percentage of discharge ACEI use in the year 2003 STS database retrieval of data were 39.9% and 18.6%, respectively, across all sites. A conservative estimate was made for a total of 450 sites entering the 2 study arms, and an increase of 5 percentage points in use of the secondary prevention measure ACEI over time in the control arm was assumed. Thus, the probability was 81% that the study would detect a treatment difference at a 2-sided 0.05 significance level.
if the true difference between treatment and control arms is 5 percentage points from baseline to end-of-study use of ACEI at discharge (ie, 45% use of ACEI in the intervention group versus 50% in the control arm at study end, a difference in improvement of 5 percentage points between groups). The SDs among sites for the use of ASA (7.30%), β-blockers (9.84%), and lipid-lowering agents (12.14%) were each considerably lower than for ACEI; hence, assuming the same level of difference, fewer sites were needed for these analyses to detect the same magnitude of difference as for the ACEI measure.

**Results**

As Figure 1 shows, a total of 491 sites with active cardiac surgery programs were considered for inclusion in this study on the basis of ongoing participation in the NCD. These sites had accrued 377 658 patients over the previous 7 NCD reporting intervals. The sites were distributed geographically within the continental United States. After excluding sites with >5% of patient records missing all discharge medications or >10% of patients missing any discharge medications, we randomized 234 control sites and 224 intervention sites in this trial. From these 458 sites, a total of 361 328 patients who underwent isolated CABG between July 1, 2002, and December 31, 2005, and were discharged alive to home from the hospital were included.

Table 1 shows demographic patient-level variables for the 2 trial arms, averaged first within sites and then across sites. As expected after randomization, baseline clinical characteristics at the site level were similar between the control and intervention groups. Baseline use of ASA, β-blockers, and lipid-lowering agents was slightly greater among the control hospitals, whereas baseline use of ACEIs was slightly greater among the intervention hospitals. The all versus not all adherence outcome was slightly higher at baseline in the control group (49.4% versus 46.3%). As demonstrated in Figure 2A and 2B, there was a wide variance in the hospitals’ baseline all versus not all performance scores (interquartile range, 39.2% to 56.1%), as well as in overall adherence scores (interquartile range, 71.3% to 81.6%).

Table 2 shows the improvements over the intervention period for each of the 4 secondary prevention medications by control and intervention hospitals. The positive change in adherence score for each of the measures was greater among the intervention hospitals. The difference between the mean change in adherence score between the 2 study groups reached statistical significance for β-blockers (9.7% versus 12.2%; \(P=0.032\), ACEIs (6.4% versus 13.1%; \(P<0.001\)), and lipid-lowering agents (13.1% versus 15.7%; \(P=0.017\)). The all versus not all outcome was also improved significantly more among the intervention hospitals (12.1% versus 16.7%; \(P<0.001\)).

Figure 3A and 3B shows the time trends for the all versus not all and adherence score outcomes over the study period. A conditional logistic model at the patient level examined whether the rate of change in the use of therapies differed between the control and intervention hospitals. Analysis of the composite treatment metric shows that the change in the all versus not all outcome was significant, as depicted in Figure 3A. The hazard ratio per one 6-month period increase was 1.1361 (for intervention hospitals) versus 1.1190 (for
control hospitals) \( P < 0.001 \) for different slopes. Similarly, the change in recommended adherence was significant over time (Figure 3B). The hazard ratio per one 6-month period increase was 1.0833 (for secondary prevention intervention) versus 1.0710 (for control) \( P < 0.001 \) for different slopes for the recommended population.

Table 3 shows the change in adherence score for subgroups based on baseline site volume, on whether the site was an academic center, and on whether the surgeon or another allied health provider was responsible for the discharge order. Low site volume at baseline was associated with a greater improvement in adherence score in the treatment group (mean change, 5.42% versus 9.60%; \( P = 0.019 \)). Overall, the nonacademic centers had a higher change in adherence (mean change, 6.69% versus 9.96%; \( P = 0.048 \)), and if the discharge order was made by nonsurgeons, the change in adherence was significantly greater in the treatment arm compared with the control arm (mean change, 5.06% versus 9.64%; \( P = 0.002 \)).

**Discussion**

The hospitalization after invasive procedures provides a valuable “teachable moment” during which secondary

---

**Table 2. Improvement in Secondary Prevention Medication Adherence Scores**

<table>
<thead>
<tr>
<th>Discharge medications</th>
<th>Control Mean Change (n=234), %</th>
<th>Intervention Mean Change (n=224), %</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASA</td>
<td>2.9</td>
<td>4.2</td>
<td>0.255</td>
</tr>
<tr>
<td>( \beta )-blockers</td>
<td>9.7</td>
<td>12.2</td>
<td>0.032</td>
</tr>
<tr>
<td>ACEIs</td>
<td>6.4</td>
<td>13.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lipid lowering</td>
<td>13.1</td>
<td>15.7</td>
<td>0.017</td>
</tr>
<tr>
<td>All vs not all</td>
<td>12.1</td>
<td>16.7</td>
<td>0.001</td>
</tr>
</tbody>
</table>

\( P \) values refer to between-group changes.

**Table 3. Change in Overall Adherence Score by Randomized Group**

<table>
<thead>
<tr>
<th></th>
<th>Control Mean Change (n=234), %</th>
<th>Intervention Mean Change (n=224), %</th>
<th>( P ) for Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>6.84</td>
<td>9.78</td>
<td>0.165</td>
</tr>
<tr>
<td>Order for discharge</td>
<td></td>
<td></td>
<td>0.079</td>
</tr>
<tr>
<td>Surgeon</td>
<td>7.96</td>
<td>10.10</td>
<td>0.835</td>
</tr>
<tr>
<td>Other</td>
<td>5.06</td>
<td>9.64</td>
<td>0.002</td>
</tr>
<tr>
<td>Site volume</td>
<td></td>
<td></td>
<td>0.093</td>
</tr>
<tr>
<td>Low</td>
<td>5.42</td>
<td>9.60</td>
<td>0.019</td>
</tr>
<tr>
<td>Medium</td>
<td>7.76</td>
<td>10.44</td>
<td>0.240</td>
</tr>
<tr>
<td>High</td>
<td>7.42</td>
<td>8.86</td>
<td>0.718</td>
</tr>
<tr>
<td>Academic center</td>
<td></td>
<td></td>
<td>0.017</td>
</tr>
<tr>
<td>No</td>
<td>6.69</td>
<td>9.96</td>
<td>0.048</td>
</tr>
<tr>
<td>Yes</td>
<td>8.42</td>
<td>7.19</td>
<td>0.060</td>
</tr>
</tbody>
</table>

All values are percentages except where noted.
prevention measures can be effectively implemented.\textsuperscript{17} The present trial demonstrates the ability of a low-level CQI intervention to engage surgeons and other providers in the use of secondary prevention measures at this crucial time for the coronary artery disease patient. This report documents a significant impact of the STS NCD CQI program on important secondary prevention measures on a national scale over a rapid time frame. In fact, local CQI teams embraced the concept and execution of secondary prevention after CABG to a degree that has changed national practice of care.\textsuperscript{18}

This trial validates the provider-led CQI model developed by the STS and the Duke Clinical Research Institute. The results, with $P<0.001$ for a difference in rate of adoption of secondary prevention between the intervention and control groups, were achieved against a background of ongoing baseline improvement in adherence to the chosen secondary prevention measures. Moreover, the present trial demonstrates that a surgical society CQI program can successfully accelerate the real-world application of best-practice measures directed beyond the surgical procedure itself. The application by surgeons of measures for secondary prevention of atherosclerotic progression was a relatively complicated CQI measure, requiring thought and coordination at multiple levels of care. This CQI effort focused not on more traditional short-term surgical processes or outcomes but on an effect to potentially impact the long-term benefit of the revascularization procedure. Importantly, this focus on care processes surrounding preventive medications supports the potential applicability of the present CQI model to other provider networks, societies, or the like.

The secondary prevention metrics used in this trial have since been incorporated into the STS quality score system for rating performance of participating hospitals. Participants may be awarded 1, 2, or 3 stars on the basis of a composite measure of 4 quality domains: avoidance of mortality, avoidance of morbidity, use of the internal thoracic artery, and adherence to recommended secondary prevention measures. STS NCD participants receive their quality scores with semiannual reports detailing their performance compared with national aggregate data for each of the quality domains. This incorporation of secondary prevention metrics with continuous feedback to clinical centers underscores the importance of the STS NCD in providing a sustainable structure and straightforward mechanism for incorporating effective CQI interventions into general practice. Adherence to recommended discharge medications among 144 526 CABG patients from 733 STS hospitals from January 1 through December 31, 2007, was 95.7%, 90.3%, and 88.7% for discharge ASA/antiplatelets, $\beta$-blockers, and lipid-lowering agents, respectively.\textsuperscript{19} These findings are suggestive of sustained quality improvement after completion of the trial.

The present findings are consistent with other studies indicating that adoption of best practices may largely be locally driven\textsuperscript{4,20} and that local providers respond to contemporary benchmarks.\textsuperscript{21} In this trial, individual sites and local leaders were allowed to determine how best to implement changes in their practices without specifically required CQI tools. This allowed active, as opposed to passive, involvement in the CQI process by the local providers. Many previously reported successes with CQI in medicine have involved high-intensity and/or site-specific interventions.\textsuperscript{22,23} However, the present study used a low-intensity CQI effort, which resulted in significant and rapid improvements relative to other CQI efforts.\textsuperscript{24} The present CQI effort hinged on the local leaders and on empowerment of individual sites to implement their own changes. Site-specific feedback with aggregated benchmark data from peer facilities provided motivation for goal-oriented improvements. Thus, through garnering the support of local quality champions, encouraging active individualized CQI changes, and adding a measure of “peer pressure,” the ingredients were in place for a marked increase in secondary prevention adherence among the intervention group hospitals in the trial.

Success of the low-intensity CQI intervention is likely referable in part to baseline CQI expertise already in place at individual sites, expertise gained from previous internal or external quality improvement initiatives. Other CQI studies have encountered difficulty deciphering intervention effects against baseline changes in quality measures.\textsuperscript{25} A key methodological consideration in this study is that without randomization and a group of control hospitals, the effect of the CQI interventions may have been grossly overestimated and trial results confounded by both nationwide improvements in secondary prevention adherence and regression toward the mean among poor performers. The observed improvements among control arm sites in the present trial are significant. These improvements may be attributed to cross-talk between sites about information contained in the intervention group materials if clinicians compared clinical practices and results at regional and national meetings, because all were blinded to the trial design. Control arm improvements may also reflect use by these hospitals of site-specific data included in routine ongoing STS NCD reports.

All contributing members of the STS NCD are voluntary, and whether a general focus on process improvement is greater at participating sites compared with nonparticipating centers is unknown. The present study validates an established platform for achieving meaningful and sustained improvements in quality of care processes, but it remains for government and third-party organizations to capitalize on the success of this type of effort to expand the approach to other areas of medicine. Importantly, the form of low-intensity intervention discussed here represents an approach that may be easily replicated by other provider groups.

**Limitations**

First, longer-term adherence measures evaluating discharge medications were not available; thus, we were unable to assess longer-term outcome differences. Furthermore, the outcomes assessed were processes of care and not direct metrics of morbidity and mortality, although the association between secondary prevention and improved outcomes has been shown.\textsuperscript{5} Second, this was a single intervention, and it remains unclear whether a more or less intensive intervention
would have been equally effective. Furthermore, differences in baseline CQI expertise between sites were not assessed, and despite randomization, confounding cannot be excluded. Finally, we did not assess the CQI infrastructure costs, prohibiting a cost-effectiveness analysis. However, the modest trial costs combined with the individual site cost of STS NCD participation compare favorably with prior regional quality improvement efforts in CABG.26

Conclusions
This national randomized controlled trial demonstrates that a professional society CQI program can incrementally speed adoption of secondary prevention therapies. Surgeons and other providers were successfully engaged in the CQI process with reproducible, low-intensity interventions. The findings of the present trial have led to the incorporation of study outcome metrics into a medical society rating system for ongoing quality improvement. Further investigation is needed to determine whether these interventions result in continued quality measure adherence and ultimately improved patient outcomes.

Sources of Funding
This work was funded by the Agency for Healthcare Research and Quality. Dr Williams is supported by National Institutes of Health training grant T32-HL069749 and the National Heart, Lung, and Blood Institute–sponsored Cardiothoracic Surgical Trials Network, grant U01-HL088953.

Disclosures
None.

References


**CLINICAL PERSPECTIVE**

This randomized controlled trial rigorously tests, on a national scale, whether low-intensity continuous quality improvement interventions can be used to speed secondary prevention adherence after coronary artery bypass graft surgery. A total of 458 hospitals participating in the Society of Thoracic Surgeons National Cardiac Database and treating 361,328 patients undergoing isolated coronary artery bypass graft surgery were randomized to either a control or an intervention group. The intervention group received continuous quality improvement materials designed to influence the prescription of the secondary prevention medications at discharge. The primary outcome measure of the study was discharge prescription rates of the targeted secondary prevention medications at intervention versus control sites, assessed by measuring preintervention and postintervention site differences. Prerandomization treatment patterns and baseline data were similar in the control (n=234) and treatment (n=224) groups. Individual medication use and composite adherence increased over 24 months in both groups, with a markedly more rapid rate of adherence uptake among the intervention hospitals and a statistically significant therapy hazard ratio in the intervention versus control group for all recommended secondary prevention medications. Thus, we conclude that provider-led, low-intensity continuous quality improvement efforts can improve the adoption of clinical care processes into national practice within the context of a medical specialty society infrastructure. The findings of the present trial have led to the incorporation of study outcome metrics into a medical society rating system for ongoing quality improvement.
Secondary Prevention After Coronary Artery Bypass Graft Surgery: Findings of a National Randomized Controlled Trial and Sustained Society-Led Incorporation Into Practice
Judson B. Williams, Elizabeth R. DeLong, Eric D. Peterson, Rachel S. Dokholyan, Fang-Shu Ou and T. Bruce Ferguson, Jr

Circulation. 2011;123:39-45; originally published online December 20, 2010; doi: 10.1161/CIRCULATIONAHA.110.981068
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2010 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/123/1/39

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/