Increasing Healthcare Resource Utilization After Coronary Artery Bypass Graft Surgery in the United States

Madhav Swaminathan, MD; Barbara G. Phillips-Bute, PhD; Uptal D. Patel, MD; Andrew D. Shaw, FRCA; Mark Stafford-Smith, MD; Pamela S. Douglas, MD; Laura E. Archer, MS; Peter K. Smith, MD; Joseph P. Mathew, MD

Background—Despite declining lengths of stay, postdischarge healthcare resource utilization may be increasing because of shifts to nonacute care settings. Although changes in hospital stay after coronary artery bypass graft (CABG) surgery have been described, patterns of discharge remain unclear. Our objective was to determine patterns of discharge disposition after CABG surgery in the United States.

Methods and Results—We examined discharge disposition after CABG procedures from 1988 to 2005 using the Nationwide Inpatient Sample. Discharges with a “nonroutine” disposition defined patients discharged with continued healthcare needs. Multivariable regression models were constructed to assess trends and factors associated with nonroutine discharge. Median length of stay among 8,398,554 discharges decreased from 11 to 8 days between 1988 and 2005 (P<0.0001). There was a simultaneous increase in nonroutine discharges from 12% in 1988 to 45% in 2005 (P<0.0001), primarily comprising home healthcare and long-term facility use. Multivariable regression models showed age, female gender, comorbidities, concurrent valve surgery, and lower-volume hospitals more likely to be associated with nonroutine discharge.

Conclusions—We found a significant increase in nonroutine discharges after CABG surgery across the United States from 1988 to 2005. The significant shortening of length of stay during CABG may be counterbalanced by the increased requirement for additional postoperative healthcare services. Nonacute care institutions are playing an increasingly significant role in providing CABG patients with postdischarge healthcare and should be considered in investigations of postoperative healthcare resource utilization. The impact of these changes on long-term outcomes and net resource utilization remain unknown. (Circ Cardiovasc Qual Outcomes. 2009;2:00-00.)

Key Words: coronary disease ■ surgery ■ bypass ■ epidemiology ■ mortality

Approximately 500,000 coronary artery bypass graft (CABG) procedures are performed annually in the United States at a substantial cost to the healthcare system. Several quality improvement initiatives have sought to improve process measures and outcomes. In the 1990s, in an effort to improve efficiency and potentially reduce cost, postoperative length of stay (LOS) was decreased through enthusiastic adoption of “fast-track” protocols. Several studies documented successful implementation of these initiatives with subsequent reductions in perioperative resource utilization. The impact of reduction in LOS has also been examined with regard to both costs and effect on readmission and postoperative morbidity. Despite shorter LOS, concurrent quality improvement programs have reported simultaneous reductions in postoperative mortality after CABG surgery. However, few studies have examined postoperative discharge disposition in this setting.

In New York State, postoperative LOS was found to have decreased after CABG surgery with a concurrent increase in transfer to nonacute care settings. Although decreases in LOS and in-hospital mortality may reflect improvements in management, shifts in postoperative care with continued healthcare requirements after discharge need to be considered. Whether recent trends are similar across the country remains unclear. Using a nationwide inpatient database, we hypothesized that LOS after CABG surgery has decreased over time, whereas nonroutine discharges have simultaneously increased throughout the United States. Additionally, we examined patterns of nonroutine discharges and determined factors associated with greater likelihood of a nonroutine discharge in this setting.

Methods

Data Sources
We used the Nationwide Inpatient Sample (NIS) to test our hypothesis. The NIS is a unique database of hospital inpatient stays dating back to 1988 that was developed by the Agency for Healthcare

Received October 28, 2008; accepted March 9, 2009.
From the Division of Cardiothoracic Anesthesiology and Critical Care Medicine, Department of Anesthesiology (M.S., B.G.P.-B., A.D.S., M.S.-S., J.P.M.); the Duke Clinical Research Institute (U.D.P., P.S.D.); Division of Thoracic Surgery; the Department of Surgery (P.K.S.); and the Division of Biostatistics, Duke Comprehensive Cancer Center (L.E.A.), Duke University Medical Center, Durham, NC.
Correspondence to Madhav Swaminathan, MD, Associate Professor of Anesthesiology, Department of Anesthesiology, Box 3094, DUMC, Duke University Medical Center, Durham, NC 27710. E-mail swami001@mc.duke.edu
© 2009 American Heart Association, Inc.
Circ Cardiovasc Qual Outcomes is available at http://circoutcomes.ahajournals.org DOI: 10.1161/CIRCOUTCOMES.108.831016

1
Research and Quality (Bethesda, Md; more information on the Nationwide Inpatient Sample, a database of the Healthcare Cost and Utilization Project, is available at http://www.hcup-us.ahrq.gov/nisoverview.jsp) and is used to analyze national trends in healthcare utilization, quality, and outcomes. The NIS database contains information relating to diagnosis and procedure codes, demographics, payer-independent charges, and hospital-based variables on all inpatients obtained from a 20% stratified sample of all nonfederal hospitals across the United States. Data from all available years (1988 to 2005) at the time of writing was used for this study. The database does not contain any unique patient identifiers and was therefore considered exempt from review by the Duke University Institutional Review Board.

Study Design and Selection Criteria

Inpatient data files were obtained for each year from 1988 to 2005. Data were merged with hospital-level files for each year to obtain the total discharges with hospital data (Figure 1). Cases with a discharge procedure code pertaining to CABG surgery in any of the 15 procedure fields were identified. The Clinical Classification Software (CCS) system was used to identify CABG procedures. Briefly, the CCS system was developed by the Healthcare Cost and Utilization Project and is a diagnosis and procedure categorization scheme. It simplifies the 17,300 diagnosis and procedure codes contained in the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) into a smaller number of clinically relevant categories. The CCS procedure code for CABG surgery (code 44) was used where applicable. This comprised the total CABG dataset from 1988 to 2005. Patients less than 18 years of age were excluded, as were discharges missing mortality information, leaving the CABG study population of interest. Discharges without in-hospital death were examined for LOS and discharge disposition. Finally, cases with nonroutine discharge codes were identified as a distinct subset by eliminating those with a routine discharge disposition code.

In the NIS database, discharge disposition is categorized as (1) to home or routine; (2) to a short term hospital; (3) to “other facility” (including skilled nursing facility and intermediate care facility); (4) to home healthcare; or (5) “against medical advice.” For analytic purposes, “other facility” was termed “long-term facility” to distinguish this group from the short-term hospital discharges. Discharges with missing and invalid data for discharge type were excluded (n = 9656). Nonroutine discharges were defined as those that were to a short-term hospital, long-term facility, home healthcare, or against medical advice. These discharges represented CABG survivors that required extended healthcare beyond index hospitalization.

Patient demographic and admission covariables were also extracted from the core files. Additional comorbidities were identified using the ICD-9-CM diagnosis codes. We also separately identified patients who had both CABG and concurrent valve surgery (CCS procedure code 43).

The primary outcome variables identified in the core files were length of hospital stay, in-hospital mortality and discharge disposition. Other variables included year of discharge and 3 hospital-level characteristics: (1) hospital teaching status (based on the presence of an American Medical Association–approved residency program or affiliation with the Council of Teaching Hospitals), (2) hospital CABG case volume, and (3) hospital location (rural or urban).

Statistical Analyses

To simplify assessment of trends in demographic and comorbid conditions within the CABG population, data were divided into 3 equal 6-year periods from 1988 to 2005. Values for these variables were tabulated for each period for descriptive purposes only.

Annual mortality rates were first computed for the CABG study population (Figure 1, box C) as a percentage of total CABG discharges. Next, LOS analyses were performed on all survivors of index hospitalization. Finally, discharge disposition analyses for patients with nonroutine discharges were performed. For each multivariable analysis, risk adjustment was performed including age, gender, concurrent valve surgery, elective surgical status, and 30 comorbidities in the regression model using the analytic approach suggested by Elixhauser. In addition to these patient-level variables, adjustment was also made for 3 hospital-level covariates—teaching status, case volume, and hospital location. This method is based on the identification of comorbidities distinct from the primary
reason for hospitalization, which results in a set of comorbidities that may be applied to administrative data for a variety of disease groups. The methodology was developed in a subset of the NIS and overcomes some of the disadvantages of prior comorbidity indices, such as the Charlson index. For purposes of graphing, adjusted probabilities were computed for mean values of covariates.

Primary outcomes were analyzed using hierarchical multivariable regression techniques. Continuous outcomes (LOS) were investigated with mixed models analysis of variance. Because of the potential for correlation among patients treated at the same hospital, dichotomous outcomes (mortality and nonroutine discharge) were analyzed with generalized estimating equations, using hospital identification number as a clustering variable, and specifying an exchangeable correlation matrix.

Within the nonroutine discharge group (Figure 1, box E), proportional distribution of discharges to short-term hospitals, long-term facilities, and home healthcare were assessed throughout the study period. Discharges coded as “against medical advice” (n=5164; 0.06% of all nonroutine discharges) were excluded from this model because these were considered to have an indeterminate health status.

Secondary analyses were performed on the subset of the principal CABG population excluding those who were admitted from another hospital or facility which included long-term care, because a non-

<table>
<thead>
<tr>
<th>Table 1. Baseline Characteristics, LOS, and In-Hospital Mortality Data for All Discharges After CABG From 1988 to 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variable</strong></td>
</tr>
<tr>
<td>Age (mean±SD), y</td>
</tr>
<tr>
<td>Female gender, %</td>
</tr>
<tr>
<td>Nonelective status, %*</td>
</tr>
<tr>
<td>Concurrent valve surgery, %</td>
</tr>
<tr>
<td>Comorbidities</td>
</tr>
<tr>
<td>Congestive heart failure, %</td>
</tr>
<tr>
<td>Valve disease, %</td>
</tr>
<tr>
<td>Peripheral vascular disease, %</td>
</tr>
<tr>
<td>Hypertension, %</td>
</tr>
<tr>
<td>Chronic pulmonary disease, %</td>
</tr>
<tr>
<td>Diabetes, %</td>
</tr>
<tr>
<td>Renal failure, %</td>
</tr>
<tr>
<td>Obesity, %</td>
</tr>
<tr>
<td>Pulmonary circulation disease, %</td>
</tr>
<tr>
<td>Paralysis, %</td>
</tr>
<tr>
<td>Neurological disorder, %</td>
</tr>
<tr>
<td>Hypothyroidism, %</td>
</tr>
<tr>
<td>Liver disease, %</td>
</tr>
<tr>
<td>Peptic ulcer disease, %</td>
</tr>
<tr>
<td>AIDS, %</td>
</tr>
<tr>
<td>Lymphoma, %</td>
</tr>
<tr>
<td>Metastatic cancer, %</td>
</tr>
<tr>
<td>Tumor without metastasis, %</td>
</tr>
<tr>
<td>Rheumatoid arthritis, %</td>
</tr>
<tr>
<td>Coagulopathy, %</td>
</tr>
<tr>
<td>Weight loss, %</td>
</tr>
<tr>
<td>Fluid and electrolytes disorder, %</td>
</tr>
<tr>
<td>Chronic blood loss anemia, %</td>
</tr>
<tr>
<td>Deficiency anemias, %</td>
</tr>
<tr>
<td>Alcohol abuse, %</td>
</tr>
<tr>
<td>Drug abuse, %</td>
</tr>
<tr>
<td>Psychoses, %</td>
</tr>
<tr>
<td>Depression, %</td>
</tr>
<tr>
<td>Outcomes</td>
</tr>
<tr>
<td>In-hospital mortality, %</td>
</tr>
<tr>
<td>Median length of stay among survivors, d</td>
</tr>
</tbody>
</table>

Sample sizes are estimated using discharge weights provided by the NIS.

*Nonelective status refers to “emergent” or “urgent” admission to the hospitalization during which a CABG was performed.
routine discharge in these patients does not constitute a change in discharge disposition.

Discharge weights provided by the NIS were applied uniformly to all analyses to obtain nationally representative discharge-level data (more information on NIS discharge weights available at http://www.hcup-us.ahrq.gov/databases.jsp). Significance was assessed at an α level less than 0.001 in all models. Statistical analyses were conducted using the SAS software program, version 9.1 (SAS Institute).

The authors had full access to the data and take responsibility for its integrity. All authors have read and agree to the manuscript as written.

Results
A total of 8,398,554 estimated CABG discharges were identified during the study period. After exclusions (age less than 18 years, missing mortality data), 8,394,913 discharges remained in the analysis. Figure 1 shows the sample size and exclusions for each analysis subset.

Table 1 shows demographic and comorbidity data for the entire CABG cohort from 1988 to 2005 (divided into 3 equal 6-year periods). Most comorbid conditions showed a rising incidence. Both in-hospital mortality and LOS showed a decline in each period. Risk-adjusted annual mortality rate decreased from 3.7% in 1988 to 1.3% in 2005, representing a 65% decline (Figure 2). Median LOS similarly declined from 11 days in 1988 to 8 in 2005. However, the decrease in mean LOS plateaued in 1998 (Figure 3).

There was an increase in the proportion of nonroutine discharges among survivors of the index hospitalization (Table 2 and Figure 4) from 12% in 1988 to 45% in 2005 (risk-adjusted values). The distribution of nonroutine discharges showed that a substantial proportion of this increase was attributed to an increase in discharges to long-term facilities and the use of home health services (Table 2 and Figure 5). In contrast, discharges to short-term hospitals comprised a declining percentage of total nonroutine discharges over time.

Multivariable logistic regression modeling of factors associated with nonroutine discharge showed that patients who were older, underwent concurrent valve surgery, and had greater comorbid conditions were more likely to have non-
routine discharges (Table 3). In terms of hospital characteristics, patients discharged from hospitals with larger case volumes were more likely to discharge patients in a routine manner, whereas the presence of a teaching program did not have a significant effect. The magnitude of effect with respect to the odds of nonroutine discharge from larger case volume hospitals was small. In contrast, the effect of geographical location was larger, with rural hospitals being less likely to have a nonroutine discharge than those in an urban location. The C-index of this model, despite including year and 36 other covariates, was 0.735, indicating moderate predictive ability.

In the secondary analysis, we identified 22.4% discharges in the CABG dataset that were admitted from “another hospital” or “other facility including long-term care.” Results from this subanalysis, excluding these patients, indicate similar results from the principal analyses of the whole sample. Table 3 was recreated with the reduced sample (data not shown). There was a high degree of similarity between both analyses with a linear effect for “year” (odds ratio 1.07 compared with 1.11 for overall sample), indicating increased nonroutine discharge over time. Similarly, the findings for mortality and length of hospital stay were supported in the secondary analysis.

Table 2. Distribution of Nonroutine Discharges Among Survivors of Index Hospitalization

<table>
<thead>
<tr>
<th>Variable</th>
<th>1988 to 1993 (n=1 715 780)</th>
<th>1994 to 1999 (n=2 745 760)</th>
<th>2000 to 2005 (n=3 635 996)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-term facility, %</td>
<td>1.3</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Long-term facility, %</td>
<td>4.2</td>
<td>10.7</td>
<td>14.5</td>
</tr>
<tr>
<td>Home health care, %</td>
<td>13.1</td>
<td>23.9</td>
<td>26.9</td>
</tr>
<tr>
<td>Against medical advice, %</td>
<td>0.08</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>Total non-routine discharge, %</td>
<td>18.7</td>
<td>35.6</td>
<td>42.2</td>
</tr>
</tbody>
</table>

Sample sizes are estimated using discharge weights provided by the NIS.

We found that the proportion of discharges with continued healthcare requirements after CABG surgery increased significantly from 1988 to 2005 throughout the United States. Declines in both in-hospital mortality and LOS may be partly related to a shift in healthcare to other specialized facilities postdischarge, which bear an increasing burden of the continuing morbidity and costs of CABG surgery.

Myocardial revascularization by both percutaneous and surgical approaches costs an estimated $12 to $20 billion in the United States each year.16 CABG surgery is an expensive procedure that consumes a significant amount of resources both during hospitalization and after discharge. Cumulative costs of a high-risk CABG surgery are estimated at $84 000 after 3 years and exceed $100 000 after 5 years.16 As a result of high costs, several efforts have focused on cost containment and quality improvement in cardiac surgery over the past 2 decades. Although studies have shown improvements in processes of care and reductions in adverse outcomes, including in-hospital mortality, little emphasis has been placed on postdischarge healthcare utilization.2,17 Our study highlights 2 significant issues that any assessments of outcomes after CABG surgery must consider: the temporal decrease in LOS over the past 2 decades, and the 4-fold increase in proportion of nonroutine discharges that continues to climb. Taken together, these issues suggest that the current paradigm of quality improvement efforts focusing only on acute hospitalization may limit the opportunity to address overall costs and outcomes.

**Decrease in LOS**

The trend toward decrease in LOS in cardiac surgery has been reported in several studies. However, most have focused on the subset of patients who were discharged early or eligible for fast-track protocols.11,18,19 Cowper et al investigated the characteristics and impact of early discharge on short-term morbidity among CABG patients in New York State11 and a large Medicare population.18 They reported that although early discharge did not result in increased adverse events or

---

**Discussion**

Figure 4.

Trend of nonroutine discharges among survivors of index hospitalization. Adjustment performed for age, female gender, concurrent valve surgery, nonelective status, and 30 other comorbidities as defined in the text.
postdischarge costs, there was wide variability in rates of early discharge among hospitals. The same group also found significant variability among institutions across the United States with regard to LOS and resource utilization. In our study, we found that LOS started to decline around 1992 from a median value of 11 to 8 days in 1995 with limited subsequent variability and further decline, supporting the earlier findings of Cowper et al. The observed timing of decrease in LOS may reflect the shift toward early extubation and shorter hospital stays in the mid 1990s. The plateau in LOS from 1995 onwards suggests that in the current US CABG population with an increasing prevalence of comorbid conditions, discharge may not be feasible any earlier without potential compromises to quality of care.

Increase in Nonroutine Discharges
We had previously reported a decrease in LOS and mortality with a simultaneous increase in nonroutine discharges among a subset of the CABG population that was discharged with a diagnosis of acute renal failure. In the current study, we observed the same trend across the entire CABG population. The increase in nonroutine discharges raises the concern that the observed decrease in in-hospital mortality and LOS may actually reflect a shift in care to other facilities rather than solely attributable to improvement in care. The trend toward shorter hospital stays and concern about greater postdischarge medical needs has been known since the 1980s. Lazar and colleagues found that a significantly higher percentage of CABG cases were discharged to extended care facilities in 1998 compared to 1990 (43.3% versus 2.9%). Their study, although important in highlighting discharge disposition, was limited to 786 patients in a single center in an urban setting. Hannan et al reported that discharge to a skilled nursing facility or rehabilitation hospital was significantly associated with hospital readmission within 30 days of the index CABG procedure. This study suggests that discharge to an institution may be associated with the development of delayed complications that require hospital readmission. A more recent study by Cowper et al showed a trend toward shorter LOS with concurrent increase in discharge to nonacute care settings, especially in patients with LOS exceeding 5 days. This study examined the New York State CABG population and was limited to the period between 1992 and 1998. Our study extends these findings by revealing that the temporal increase in nonroutine discharge has been consistent throughout the United States over a period of 18 years and continues unabated.

One explanation of the increase in nonroutine discharges could be the increased recognition of need for medical assistance in the postoperative period in a surgical population with significant comorbidities and increasing acceptance of specialized placement by patients and families. Indeed, an earlier study of elderly hospitalized patients indicated that the degree of postdischarge assistance was strongly associated with activity limitations at the time of discharge and suggested the need for hospitals to improve discharge planning. Thus, our findings may reflect the favorable impact of improvements in discharge planning by hospitals throughout the United States.

Another reason for the increasing trend in nonroutine discharges could be the greater availability of specialized facilities for nonacute postoperative care in recent years, stimulating a shift in care. In fact, there has been extensive growth in the availability of specialized nonacute care facilities since the 1980s. Medicare payments for long-term care hospitals increased by an average of 31% annually from 1988 to 1996. The number of such facilities almost doubled from 1993 to 1997, with a majority of admissions sourced from acute care hospitals. Our observation that a larger proportion of nonroutine discharges were to long-term facilities during the study period could partly reflect the increased availability of these centers. The increase in nonroutine discharges despite a plateau in LOS after 1995 also supports this hypothesis. The finding that rural hospitals were less likely to discharge patients in a nonroutine manner may reflect the same phenomenon.

We also noted an abrupt change in distribution of nonroutine discharges from 1997 to 1998 (Figure 5), which persisted.
until 2005. The proportion of discharges to home healthcare declined substantially, whereas discharges to long-term facilities increased. The sudden decline in home healthcare at that time has been previously reported and attributed to the implementation of the Balanced Budget Act of 1997.

Changes in reimbursement may have resulted in the effect we observed on discharge disposition.

The principal strengths of our study include the use of a large sample size across a long time frame and generalizability across institutions throughout the United States. Another strength of our study is the extensive adjustment for relevant variables, providing robust data across many patient groups. Although the lack of detailed clinical, laboratory, and follow-up data are a significant limitation of administrative databases precluding detailed investigation into mechanisms of observed trends, the US Healthcare Cost and Utilization Project explicitly developed the NIS database to identify, track, and analyze national trends in health care utilization, access, charges, quality, and outcomes. Our study was designed with some of these objectives as applicable to CABG surgery. The NIS is a validated database that undergoes extensive quality control procedures, making it an invaluable resource for analyzing trends at a national level.

A potential limitation is that survivors in later years may have been censored in earlier years, given the increase in post-CABG survival rates. Our analyses, however, have accounted for all patients, those that survive index hospitalization (and are included in LOS and discharge disposition analyses) and those that are included in mortality analysis. Each of these analyses includes a large amount of discharge data across a long time-frame that permits adequate interpretation of trends in these outcome variables.

### Summary and Implications

In summary, using a large national database, we found that there was a decrease in hospital stay after CABG surgery with a concurrent increase in discharges with extended healthcare facility requirements. This trend was consistent across the entire period of our study, from 1988 to 2005. Despite improving in-hospital indicators of morbidity and mortality, postdischarge resource utilization continues to increase after CABG surgery. Because nonroutine discharges are now common after CABG surgery, our study highlights the need to consider discharge disposition in any investigation of resource utilization after CABG surgery.

### Acknowledgments

We acknowledge Eugene Z. Oddone, MD, MHS, Vice Dean for Research, Duke University School of Medicine, for his critical review and analysis of this manuscript.

### Sources of Funding

This work was supported by intramural funds from the Department of Anesthesiology, Division of Cardiothoracic Anesthesiology, and Critical Care Medicine.

### Disclosures

None.

### References


Increasing Healthcare Resource Utilization After Coronary Artery Bypass Graft Surgery in the United States

Madhav Swaminathan, Barbara G. Phillips-Bute, Uptal D. Patel, Andrew D. Shaw, Mark Stafford-Smith, Pamela S. Douglas, Laura E. Archer, Peter K. Smith and Joseph P. Mathew

Circ Cardiovasc Qual Outcomes. published online June 16, 2009;
Circulation: Cardiovascular Quality and Outcomes is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2009 American Heart Association, Inc. All rights reserved.
Print ISSN: 1941-7705. Online ISSN: 1941-7713

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circoutcomes.ahajournals.org/content/early/2009/06/16/CIRCOUTCOMES.108.831016

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation: Cardiovascular Quality and Outcomes 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: Cardiovascular Quality and Outcomes is online at:
http://circoutcomes.ahajournals.org//subscriptions/