

Trends in use of off-pump coronary artery bypass grafting: Results from the Society of Thoracic Surgeons Adult Cardiac Surgery Database

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Objectives: Recent national trends in off-pump versus on-pump coronary artery bypass grafting have not been reported.

Methods: We analyzed data from the Society of Thoracic Surgeons Adult Cardiac Surgery Database regarding isolated primary coronary artery bypass grafting operations (N = 2,137,841; 1997-2012). The off-pump percentages were calculated in aggregate, by center, and by surgeon. On the basis of the 2007/2008 yearly off-pump volume, the analysis subgroups were "high" (center n > 200, surgeon n > 100), "intermediate" (center n = 50-200, surgeon n = 20-100), and "low" (center n = 1-49, surgeon n = 1-19).

Results: The use of off-pump procedures peaked in 2002 (23%) and again in 2008 (21%), followed by a progressive decline in off-pump frequency to 17% by 2012. After 2008, off-pump rates declined among both high-volume and intermediate-volume centers and surgeons; little change was observed for low-volume centers or surgeons (off-pump rates = 10% since 2008). By the end of the study period, 84% of centers performed fewer than 50 off-pump cases per year, 34% of surgeons performed no off-pump operations, and 86% of surgeons performed fewer than 20 off-pump cases per year. Except for a higher (7.8%) conversion rate in 2003, the rate for conversions fluctuated approximately 6%.

Conclusions: Enthusiasm for off-pump coronary artery bypass grafting has been tempered. The percentage of coronary artery bypass grafting operations performed off-pump has steadily declined over the last 5 years, and currently this technique is used in fewer than 1 in 5 patients who undergo surgical coronary revascularization. A minority of surgeons and centers continue to perform off-pump coronary artery bypass grafting in most of their patients. (J Thorac Cardiovasc Surg 2014;148:856-64)

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Off-pump (OFF) coronary artery bypass grafting (CABG) was introduced in the early 1990s and gained popularity over the next decade as a potential means of avoiding several of the complications and adverse effects of cardiopulmonary bypass (CPB), such as thrombocytopenia, activation of complement factors and inflammatory responses, and immunosuppression.¹ The avoidance of aortic cannulation with the OFF approach was likewise predicted to decrease the incidence of stroke and other embolic phenomena compared with procedures performed with CPB. However, although some studies have associated OFF CABG with favorable outcomes,²⁻⁶ others have not found a significant benefit to OFF CABG.⁷⁻¹²

In 2007, an intent-to-treat comparison of risk-adjusted outcomes was made between patients undergoing OFF CABG and patients undergoing on-pump (ON) CABG who were treated at experienced centers that contribute to the Society of Thoracic Surgeons Adult Cardiac Surgery Database (STS ACSD).¹³ This comparison showed a significant advantage for OFF CABG with regard to mortality and numerous morbidity end points. The relative benefit of OFF was greatest in patients with the most preoperative risk factors. Shortly after those findings were reported, results of the VA Outcomes Following Myocardial Revascularization:

Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
CPB	= cardiopulmonary bypass
OFF	= off-pump
ON	= on-pump
STS ACSD	= Society of Thoracic Surgeons Adult Cardiac Surgery Database

On and Off Cardiopulmonary Bypass trial were published, showing no significant difference between treatment groups in the rate of the 30-day composite outcome of death or complications.¹⁴ However, of notable concern was a lower patency rate of bypass grafts and less effective revascularization in the OFF cohort in the first postoperative year.

Given the inconsistency in the literature as to the relative benefits of OFF and ON CABG, it would be of interest to know the extent to which OFF CABG has been widely accepted by cardiac surgery practices nationwide and the degree to which the use of OFF CABG has changed over time. In addition, the difference in the risk profiles of patients who undergo surgical revascularization by either of these 2 approaches has not been well characterized.

The specific objective of this STS ACSD research project was to use time-dependent analyses to test for national trends in the use rates of OFF versus ON CABG, and for volume-specific trends among centers and surgeons. In addition, we examined the differences in the risk profiles of patients who undergo OFF versus ON CABG.

MATERIALS AND METHODS**Patient Population**

The study cohort consisted of all patients aged more than 18 years who underwent primary isolated CABG between January 1, 1997, and September 30, 2012, at any hospital that participated in the STS ACSD. Patients who underwent emergency CABG, robotic-assisted procedures, reoperative CABG, or any concomitant cardiac operation were excluded. [Figure 1](#) summarizes the study design, including the time-based cohorts and the volume subgroups for centers and surgeons analyzed.

Data Elements

The STS ACSD is a clinical registry widely used to assess changes in patient risk characteristics, clinical practice patterns, and outcome rates. During the study period, STS data definitions and elements changed. For the present study, 5 versions of the STS data-collection form were used: version 2.35 for 1997 to 2002, version 2.41 for 2002 to 2004, version 2.52 for 2004 to 2007, version 2.61 for 2008 to 2011, and version 2.73 for 2011 to 2012. Two versions were in use simultaneously during parts of 2002, 2004, 2007, and 2011. Information about these versions of the STS database can be found on the STS Web site (available at: <http://www.sts.org/quality-research-patient-safety/national-database/database-managers/adult-cardiac-surgery-database/d>). All definitions were reviewed to determine whether the study variables had comparable definitions over time. Variables that changed substantially were excluded from the analysis. Variables that had minor definitional changes or for which data were collected during only part of the study period (ie, at least 8 years during which the definitions were consistent) were included in this analysis.

Outcome Measures

The study's primary outcome measure was the percentage of OFF versus ON procedures as a function of time. Because some of the rate changes may have been due to the changing population (the number of sites participating in the database more than doubled from 1997 to 2012), a sensitivity analysis of the overall trends was performed on data from the subgroup of sites (n = 193) that submitted data for the whole 1997-2012 time period.

To specifically focus on recent trends in OFF use, the monthly percentage of OFF procedures was calculated from January 2008 to September 2012. In addition, for that period, we looked at the impact of volume on use trends by stratifying centers and surgeons according to their 2007/2008 yearly OFF caseload: (1) "high" volume centers (n > 200) or surgeons (n > 100), (2) "intermediate" volume centers (n = 50-200) or surgeons (n = 20-100), and "low" volume centers (n = 1-49) or surgeons (n = 1-19). For the volume-stratified analysis, we included only the 967 sites that submitted data for the full time period from 2007/2008 onward and the 2480 surgeons who submitted data for the full study period.

Data regarding intraoperative conversion from OFF to ON were captured starting in 2002, and unplanned conversions were captured starting in 2004. A planned conversion was defined as any scenario in which the surgeon's intention was to use or possibly use CPB for at least part of the procedure, whereas an unplanned conversion was defined as the use of CPB in cases in which the surgeon had originally intended not to. "As-treated" analysis was used for use trends analyses that spanned the entire study period, and "intention-to-treat" analysis was used for surgeon- and center-level trend analyses of data collected after 2008 ([Figure 1](#)).

For the comparison of patient characteristics, the STS ACSD data collected from 2002 onward were used for an intention-to-treat analysis, in which conversion-related adjustments were performed.

Statistical Analysis

This research study's analyses were coordinated by the STS Access and Publications Work Group; all statistical analyses were performed by the Duke Clinical Research Institute and STS National Research Office team members. Descriptive statistics were used to report patient characteristics in aggregate and by center and surgeon. Differences in OFF versus ON patient characteristics were assessed with the chi-square test for categorical variables and the Wilcoxon rank-sum test for continuous variables. Time-dependent trends were evaluated by using a 1-sided Cochran–Armitage test for a decreasing trend against the null hypothesis that the proportion of OFF CABG cases is the same for all years. Given the large sample size used, almost all comparisons documented a statistically significant finding; thus, clinically relevant differences also were evaluated.

RESULTS**Relative Use of ON Versus OFF Coronary Artery Bypass Grafting for Entire Cohort (1997-2012)**

The relative use of OFF CABG peaked at 23% in 2002. This peak was followed by a slow decline to 19% in 2006, a secondary peak of 21% in 2008, and then a decline to 17% in 2012 ([Figure 2](#)).

Subgroup A, Centers That Submitted Data for the Entire Study Period (1997-2012)

The ON and OFF rates among the subset of sites (n = 193) that reported for the entire study period were similar to those of the overall cohort, although these sites had a slightly greater decline in OFF procedures between 2002 and 2006 and between 2008 and 2012 ([Figure E1](#)).

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