Why Is Off-Pump Coronary Surgery Uncommon in Canada? Results of a Population-Based Survey of Canadian Heart Surgeons

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Background—Off-pump coronary artery bypass (OPCAB) is proposed to improve clinical outcomes and decrease resource use. However, off-pump surgery is not widely used in Canada. The purpose of this study was to determine the current use of OPCAB in Canada and determine why surgeons have not adopted this technique.

Methods and Results—The study was a population-based survey of all adult Canadian cardiac surgeons in practice >1 year. Eligible division heads and surgeons were contacted by mail. Of 19,806 isolated coronary bypass surgeries performed by respondents in Canada last year, 3164 (16.0%) were performed off-pump. More than 50% of Canadian surgeons performed OPCAB in <5% of coronary cases, and only 17% of surgeons performed OPCAB in >25% of coronary cases. Only 4 responding centers performed OPCAB in >25% of cases. Respondents were divided into those who performed <5% of cases off-pump (nonadopters), 5% to 25% off-pump (intermediate users), or >25% off-pump (enthusiasts). Mean number of distal anastomoses in off-pump cases were 1.7±0.6, 1.6±0.6, and 3.3±0.5 for nonadopters, intermediate users, and enthusiasts, respectively (P<0.001). Eleven percent of nonadopters, 55% of intermediate users, and 81% of enthusiasts believed OPCAB improved clinical outcomes (P<0.0001). Only 23% of all respondents felt OPCAB use would increase in the next 5 years.

Conclusions—Concerns regarding incomplete revascularization and lack of proven clinical benefit have limited OPCAB to being performed routinely by only a small number of surgeons in Canada. (Circulation. 2004;110[suppl II]:II-7–II-12.)

Key Words: cardiopulmonary bypass • surgery • coronary disease • off-pump • health professional survey

Coronary bypass surgery is an effective treatment for severe coronary heart disease. In the past 2 decades, despite a dramatic increase in the risk factor profile of coronary bypass patients, operative mortality and morbidity have declined significantly.1 These improvements have been ascribed to systematic advances in surgical technique and strategies of myocardial protection that prevent injury to the arrested heart.2 Until recently, it has been standard practice to perform coronary bypass on the arrested heart, which provides a still-operating field for the construction of fine anastomoses. Despite the tremendous success of coronary artery bypass grafting (CABG) with this technique, significant concern remains regarding the deleterious systemic effects of cardiopulmonary bypass. In particular, concerns regarding neurologic injury, renal dysfunction, and systemic inflammatory response have led surgeons to attempt coronary bypass surgery without cardiopulmonary bypass.3–7

New enabling technologies such as epicardial stabilizers have made it possible to perform coronary bypass surgery on the beating heart without cardiopulmonary bypass (ie, off-pump). Off-pump coronary artery bypass (OPCAB) has been shown in several small nonrandomized trials to decrease renal dysfunction, neurologic injury, overall morbidity, resource use, and costs in certain patients compared with on-pump CABG.8–10 Several other studies, including 2 small randomized trials, have been equivocal with regard to these variables.11,12 Two recently published randomized controlled trials designed to assess graft patency have provided contradictory information regarding patency outcomes after OPCAB.13,14

Despite the lack of strong evidence to support the use of one technique over the other, significant attention has been provided by the lay press to promote the use of off-pump surgery, and this has led to demand for this technique by referring cardiologists and patients.15 The primary objective of this investigation was to determine the current use of off-pump surgery in Canada. Secondary objectives included identifying factors leading to patient selection for off-pump surgery.
surgery, assessing the perceived completeness of revascularization with off-pump surgery, and assessing surgeon attitudes toward the clinical benefits and future of off-pump surgery.

Methods
The study consisted of a population-based survey of Canadian cardiac surgeons. Eligible cardiac surgeon names and addresses were derived from the Canadian Medical Directory, the Canadian Cardiovascular Society (www.ccs.ca) and the Canadian Society of Cardiac Surgeons, and verified against 2 industry-sponsored databases. Every cardiac surgeon performing any adult surgery and in active practice in Canada for >1 year was considered eligible. All Canadian cardiac surgeons were contacted by regular postal mail with a letter from the study authors and a 3-page survey form. The Division Head of cardiac surgery at each hospital was also identified and received an expanded questionnaire that assessed more specific institutional-level data. Surgeons involved in the study design were excluded. A total of 141 surgeons were initially contacted to participate in the survey. Each surgeon was allotted a unique identifier code for tracking purposes. The survey assessed use and surgeon attitudes toward beating heart surgery according to 60 unique domains. The expanded Division Head questionnaire assessed another 17 domains at the institutional level and was administered to 33 hospital Division Heads. The survey requested information regarding the period between January 1, 2002 and December 31, 2002. A predetermined response rate of 80% for this survey was determined to provide an adequate sample of the study population for the primary endpoint of OPCAB use. Data from the division head questionnaire, of which there were 29 responses (88% response rate). Thirty-three surgeons were sent the expanded division surgeon survey. Each surgeon was allotted a unique identifier code for individual respondents. Surgeons were divided into 3 groups: nonadopter, surgeons who performed off-pump surgery in <5% of their cases; intermediate user, surgeons, who performed off-pump surgery in 5% to 25% of their cases; and enthusiast, surgeons who performed off-pump surgery in >25% of their cases. Fifty-five percent of respondents were nonadopter, surgeons who performed off-pump surgery in <5% of their cases; intermediate user, surgeons, who performed off-pump surgery in 5% to 25% of their cases; and enthusiast, surgeons who performed off-pump surgery in >25% of their cases. Fifty-five percent of respondents were nonadopters, 28% of respondents were intermediate users, and 17% were enthusiasts (Figure 1). Nineteen percent of respondents reported they never perform beating heart surgery. Respondents were separated according to whether they have been in practice >10 years or <10 years to determine if there were surgeon seniority-related differences in practice pattern (Figure 1). No significant differences according to surgeon seniority were observed (P = 0.9). Ninety-six percent of respondents felt that exposure to off-pump surgery training was an important part of a resident’s training experience. Among 13 surgeons formally trained in OPCAB techniques, 8 were nonadopters (62%), 4 were intermediate users (31%), and only 1 was an OPCAB enthusiast (6%).

Figure 1. Use of off-pump coronary bypass in Canada. Solid bars represent total use percentages, open bars represent OPCAB use among surgeons in practice <10 years, and bars with diagonal lines represent OPCAB use among surgeons in practice >10 years. Surgeons were separated by practice pattern into nonadopters (<5% of isolated CABG cases off-pump), intermediate users (5% to 25% of isolated CABG cases performed off-pump), and enthusiasts (>25% of isolated CABG cases performed off-pump). No difference in off-pump use was seen between surgeons in practice >10 years versus those in practice <10 years (P = 0.9 by ANOVA).

Off-Pump Surgery Use
Responding centers performed a total of 19,806 isolated coronary bypass operations during the study period. Off-pump surgery was performed in 3164 (16.0%) of these cases. Among OPCAB cases, only 41 were performed through a mini-thoracotomy incision. At the institutional level, 4 of 29 responding centers (13.8%) performed >25% of their CABG procedures on the beating heart. These 4 centers accounted for >50% of all off-pump cases performed in Canada. The mean percent (± SD) of procedures performed on the beating heart was 57.1 ± 6.9% at these 4 institutions, versus 81.1 ± 6.6% at the remaining 25 centers, P = 0.02. In total, 4 centers (13.8%) performed >25% of procedures off-pump, 16 centers (55.2%) performed 5% to 25% of procedures off-pump, and 9 centers (31.0%) performed <5% of procedures off-pump.

Use of off-pump surgery also varied widely among individual respondents. Surgeons were divided into 3 groups: nonadopter, surgeons who performed off-pump surgery in <5% of their cases; intermediate user, surgeons, who performed off-pump surgery in 5% to 25% of their cases; and enthusiast, surgeons who performed off-pump surgery in >25% of their cases. Fifty-five percent of respondents were nonadopters, 28% of respondents were intermediate users, and 17% were enthusiasts (Figure 1).

Results
Of the initial 141 study questionnaires initially sent, 15 surgeons were deemed ineligible because they were retired, in practice <1 year, or they did not practice any adult cardiac surgery. Hence, 126 questionnaires were sent to eligible surgeons and 98 were completed and returned (78% response rate). Thirty-three surgeons were sent the expanded division head questionnaire, of which there were 29 responses (88% response rate). Data from the division head questionnaire were used to determine the primary endpoint of OPCAB use. Two of 4 nonresponding institutions and 13 of 28 nonresponding surgeons were from the province of Quebec.

Surgeon Demographics, Training, and Referral Patterns
The median length of time in practice for responding Canadian cardiac surgeons was 13 years, with a range of 2 to 35 years. Fifty-nine percent, 40%, and 20% of Canadian surgeons had been in practice for at least 10, 15, and 20 years, respectively. Among respondents, 87% of practicing cardiac surgeons did not have any formal training in beating heart surgery during their residency or fellowship. Of 13 respondents who had formal OPCAB surgery training, 12 had been in practice <5 years. Ten percent of division heads (3/29) indicated that their hospital had a policy of referring patients selected for off-pump surgery to surgeons with an expertise in the technique. Seventy-eight percent of centers that performed any off-pump surgery used reusable footplate-type retractor systems for their off-pump cases, whereas 22% of centers used disposable suction-type retractors.
Selection of on-pump technique over off-pump

The mean number (SD) of distal anastomoses was 3.6 on-pump and off-pump isolated coronary bypass cases. The on average, the number of distal anastomoses performed in incomplete coronary revascularization. Surgeons were asked, on average, the number of distal anastomoses performed in incomplete coronary revascularization. Surgeons were separated by practice pattern into nonadopters (<5% of cases performed off-pump), intermediate users (5% to 25% of cases performed off-pump), and enthusiasts (>25% of cases performed off-pump). Mean values±SD are shown (overall P=0.008 by ANOVA).

Patient Selection

Surgeons were asked to choose which patient-related features they felt should lead to the selection of an off-pump surgical strategy over an on-pump strategy (Table 1). Seventy-two percent of respondents felt that patients with severe calcification of the ascending aorta should undergo off-pump surgery. In lesser proportions, the presence of chronic renal failure, cerebrovascular disease, and advanced age were also associated with the selection of an off-pump operation. Diffuse distal vessel disease was cited as a strong indication for selection of a conventional on-pump bypass operation over a beating heart operation. Other preoperative risk factors associated, to a lesser degree, with the selection of an on-pump procedure included emergent operation, severe left ventricular dysfunction, and left main coronary artery disease (Table 1).

Adequacy of Revascularization

Seventy percent of responding surgeons believed that off-pump surgery was associated with an increased incidence of incomplete coronary revascularization. Surgeons were asked, on average, the number of distal anastomoses performed in on-pump and off-pump isolated coronary bypass cases. The mean number (±SD) of distal anastomoses was 3.6±0.6 in on-pump cases and 2.2±0.7 for off-pump cases (P<0.0001). The mean number (±SD) of distal anastomoses for non-adopter surgeons was 3.6±0.5 for on-pump cases and versus 1.7±0.6 for off-pump cases (P<0.0001) (Figure 2). This discrepancy in number of distal anastomoses was also seen in the intermediate user group. However, the mean number (±SD) of distal anastomoses among enthusiast surgeons was 3.5±0.6 for on-pump cases versus 3.3±0.5 for off-pump cases (P=0.1). The overall probability value for this analysis by ANOVA was 0.008.

Approximately 80% of nonadopter and 78% of intermediate user surgeons felt that incomplete revascularization was more common in off-pump surgery than on-pump surgery (Figure 3). Conversely, only 28% of enthusiast surgeons felt that incomplete revascularization was more common with off-pump techniques (P=0.0001).

Intraoperative Decision-Making:

Surgeons were polled on several matters related to intraoperative decisions regarding surgical technique selection. Twenty-nine percent of surgeons who performed off-pump surgery stated that they intraoperatively converted from off-pump to on-pump coronary bypass in >5% of their off-pump cases. Reasons for intraoperative conversion from off-pump to on-pump coronary bypass are presented in Table 2. Among non-adopters and intermediate users, 35% and 27% of surgeons, respectively, stated their conversion rate was >5%, whereas among enthusiasts, only 6% of surgeons had a conversion rate >5% (P=0.05). Twenty-eight percent of all surgeons stated they have converted from on-pump to off-pump coronary bypass to avoid a severely calcified ascending aorta in at least one case. In total, 11% of surgeons stated they intraoperatively convert from on-pump to off-pump surgery in >5% of their on-pump cases.

Attitudes Toward Beating Heart Surgery:

Surgeon attitudes toward the clinical impact and future of beating heart surgery were assessed(Figures 4 and 5). When asked if surgeons felt off-pump CABG improved clinical outcomes, 64% of respondents did not believe that off-pump CABG improved clinical outcomes. By practice pattern, 78%

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| TABLE 1. Patient Risk Factors Identified by Surgeons for Selection of Off-Pump or On-Pump Surgery |
| --- | --- |
| Risk Factor | % of Respondents |
| Selection of Off-Pump Technique Over On-Pump | |
| Severe calcification of ascending aorta | 72 |
| Chronic renal failure | 33 |
| Advanced age | 30 |
| History of cerebrovascular disease | 22 |
| Diffuse coronary disease | 66 |
| Emergent patient status | 35 |
| Poor ventricular function | 27 |
| Left main disease | 21 |

*Survey respondents were allowed to choose >1 selection. Therefore, totals sum were >100%.

![Figure 2](image)

**Figure 2.** Mean number of distal coronary anastomoses performed by study participants in the past 12 months for off-pump and on-pump coronary bypass cases. Surgeons were separated by practice pattern into nonadopters (<5% of cases performed off-pump), intermediate users (5% to 25% of cases performed off-pump), and enthusiasts (>25% of cases performed off-pump). Mean values±SD are shown (overall P=0.008 by ANOVA).

![Figure 3](image)

**Figure 3.** Survey question: Is incomplete revascularization more common in off-pump coronary bypass surgery? Surgeons were separated by practice pattern into nonadopters, intermediate users, and enthusiasts (overall P=0.001).
of nonadopters, 52% of intermediate users, and 17% of enthusiasts did not feel off-pump surgery improved clinical outcomes ($P = 0.001$) (Figure 4). A similar pattern was observed in surgeon opinions regarding resource use, for which 90% of nonadopters, 44% of intermediate users, and 20% of enthusiasts did not feel that off-pump surgery decreased resource use ($P = 0.001$).

Surgeons were also asked whether they thought that the use of off-pump surgery would increase, decrease, or remain the same in the next 5 years. Twenty-three percent of respondents felt off-pump surgery use would increase, 25% felt it would decrease, and 52% felt that it would remain the same over the next 5 years (Figure 6). There were no major differences between nonadopters, intermediate users, and enthusiasts for this question ($P = 0.3$).

**Discussion**

Off-pump coronary bypass surgery has gained significant implementation in the United States. Industry groups have suggested that the true proportion of off-pump surgery in the United States is $>25%$. The results of the current study show that the proportion of off-pump cases in Canada is significantly lower. Off-pump coronary artery bypass was performed in only 16.0% of isolated coronary bypass cases in Canada in 2002. The causes for decreased use of off-pump coronary bypass in Canada versus the United States are multifactorial and may be partially related to structural differences between the health care systems of these countries. In the United States, a decentralized private health system marketing pressures to attract patients with newer techniques or technologies has been speculated to play a role in the current popularity of off-pump coronary surgery. In the publicly funded Canadian health care system, cardiac surgery referrals are generally regionalized to specific centers and there is rarely competition between institutions for patients.

The lack of competition in the Canadian system may decrease the willingness to adopt highly marketable but unproven technologies and techniques. However, funding constraints imposed by government in the Canadian system may also delay spending on new technology and innovation. In particular, operating room technology used for OPCAB in Canada appears to be lagging behind. The use of suction-type stabilizers, which have been purported to decrease the rate of conversion to on-pump CABG and enable more complete revascularization, were used by a minority (22%) of Canadian surgeons for their OPCAB cases. This may have been related to increased per-procedure costs for using such devices, which are generally disposable, versus reusable.

**Table 2. Causes of Intraoperative Conversions**

<table>
<thead>
<tr>
<th>Cause</th>
<th>% of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversion from Off-Pump to On-Pump</td>
<td></td>
</tr>
<tr>
<td>Hemodynamic instability before manipulation of the heart</td>
<td>9</td>
</tr>
<tr>
<td>Hemodynamic instability after manipulation of the heart</td>
<td>35</td>
</tr>
<tr>
<td>Intramyocardial target vessels</td>
<td>25</td>
</tr>
<tr>
<td>Diffusely diseased target vessels</td>
<td>20</td>
</tr>
<tr>
<td>Anesthetist preference despite stable hemodynamics</td>
<td>15</td>
</tr>
<tr>
<td>Conversion from On-Pump to Off-Pump</td>
<td></td>
</tr>
<tr>
<td>Severely calcified ascending aorta</td>
<td>28</td>
</tr>
</tbody>
</table>

*Survey respondents were allowed to choose >1 selection. Therefore, totals sum were $>100%$.

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**Figure 4. Survey question: Does off-pump coronary bypass improve clinical outcomes? Surgeons were separated by practice pattern into nonadopters ($<5%$ of cases performed off-pump), intermediate users ($5%$ to $25%$ of cases performed off-pump), and enthusiasts ($>25%$ of cases performed off-pump) (overall $P = 0.001$).**

**Figure 5. Survey question: Does off-pump coronary bypass decrease resource utilization? Surgeons were separated by practice pattern into nonadopters ($<5%$ of cases performed off-pump), intermediate users ($5%$ to $25%$ of cases performed off-pump), and enthusiasts ($>25%$ of cases performed off-pump) (overall $P = 0.001$).**

**Figure 6. Survey question: In the next 5 years, will off-pump surgery utilization increase, decrease, or stay the same? Surgeons were separated by practice pattern into nonadopters ($<5%$ of cases performed off-pump), intermediate users ($5%$ to $25%$ of cases performed off-pump), and enthusiasts ($>25%$ of cases performed off-pump) (overall $P = 0.3$).**
footplate-type stabilizers. Depending on costs of cardiopulmonary bypass pump, disposables, and method of pump-standby, OPCAB cases with disposable stabilizers may be more expensive in operating room costs but provide lower overall costs because of decreased blood use, intensive care unit stay, and hospital stay. Because most Canadian hospitals are generally funded on an annual global basis as opposed to per-patient reimbursement, these savings are often not appreciated by the institution and prohibitive costs of disposables may discourage the use of OPCAB.

In this survey, among Canadian surgeons who were not OPCAB enthusiasts (<25% of cases performed off-pump), the mean number of distal anastomoses performed per case was significantly lower in off-pump patients (Figure 2). Although these numbers were self-reported and should be interpreted with caution, several studies have previously reported that off-pump patients receive less bypass grafts than similar on-pump patients. Fewer distal anastomoses have been reported in OPCAB series for several reasons, including hemodynamic instability, particularly while revascularizing the lateral wall of the heart, during residual epicardial motion, or for severely diseased, small, or intramyocardial coronary vessels. In these situations, surgeons must decide whether to expose the patient to the risk of conversion to an on-pump procedure or the risk of incomplete revascularization.

Because “completeness” of revascularization is difficult to truly quantify, we sought to determine if surgeons in the 3 different utilization groups felt the incomplete revascularization was occurring more often in their own OPCAB cases versus their own on-pump cases. As expected, nonadopter surgeons felt that incomplete revascularization was more common in their patients undergoing OPCAB. Surprisingly, in the intermediate user group, who performed OPCAB in up to 25% of CABG cases, nearly 80% of surgeons felt they were achieving incomplete revascularization in their own OPCAB patients. Because several clinical studies have shown that incomplete revascularization in patients with 3-vessel disease leads to an elevated risk of long-term mortality, we attempted to determine why these surgeons would choose off-pump techniques. Surgeons stated that the most important factor for selecting off-pump surgery was severe aortic calcification, followed, to a lesser degree, by cerebrovascular disease, renal disease, and advanced patient age. Thus intermediate user surgeons appear to be attempting to balance the risk of operation in morbid patients with the potential harm of incomplete revascularization by choosing an off-pump strategy. Although several reports suggest that early outcomes of off-pump surgery in higher risk patients are superior, it is not known whether the long-term consequences of incomplete revascularization will be similar in on-pump and off-pump patients.

Incomplete revascularization appears to be more prevalent during the learning curve of OPCAB surgery. This learning curve applies not only to the operating surgeon but also to the entire operating room team. Among surgeons with low OPCAB volume, ie, the Canadian nonadopter majority, the learning curve may never be adequately overcome because of the lack of repetition needed to master OPCAB surgical and anesthetic techniques. In a setting in which market forces and short-term economics do not create an incentive to perform OPCAB regularly, many Canadian surgeons may be performing incomplete revascularization because of lack of experience among the whole operating room team. Because the rate of conversion from OPCAB to on-pump CABG was dramatically higher in both the nonadopter and intermediate user groups, there does appear to be a general level of discomfort among these surgeons in performing OPCAB.

The implementation of off-pump surgery in Canada was both surgeon-dependent and site-dependent and appeared to be related to how the surgeon perceives this technique will benefit the patient. At present, >50% of off-pump operations are being performed in only 4 centers and by a few enthusiast surgeons. In the hands of these surgeons, revascularization rates appear to be equivalent, and these surgeons believe that patient outcomes are improved by using OPCAB. In this survey, the majority of Canadian cardiac surgeons (55%) were nonadopters of off-pump technology. This nonadopter majority did not believe that off-pump surgery improved clinical outcomes or decreased resource use. These surgeons may be waiting for better supporting evidence before adopting off-pump surgery more routinely. Because there is still no clear clinical evidence from multicenter randomized trials that either technique is superior, it is appropriate that off-pump surgery remains predominantly performed in centers of excellence until such data are available.

A large majority Canadian cardiac surgeons also felt that off-pump surgery use would not change over the next 5 years. This sentiment was expressed by nonadopter, intermediate user, and enthusiast surgeons alike, suggesting that most surgeons were confident in the case mix with which they were currently practicing. Interestingly, only 1 of 13 surgeons in Canada with specific training OPCAB was an OPCAB enthusiast. Despite the high proportion of nonadopter surgeons in Canada, an overwhelming majority (96%) of respondents felt that off-pump surgery training was an important part of resident training. With only a few centers actively performing off-pump surgery, it is unlikely that all Canadian cardiac surgery residents will receive adequate exposure to this technique.

There are several limitations to this study. It was a voluntary, postal mail survey of all Canadian cardiac surgeons. A high proportion (88%) of division heads contributed responses to the survey, giving an accurate estimate of OPCAB use throughout Canada. Although the overall response rate for the surgeon questionnaire was 78%, there were substantially more individual nonresponders from the province of Quebec, and the presented data may not accurately reflect surgeon opinions within that region. Otherwise, it is not known if nonresponders were systematically different in their practice patterns or opinions from responders. The survey data regarding self-reported mean number of distal anastomoses and rates of incomplete revascularization were obviously prone to reporting biases that would tend to support a particular surgeon’s practice style. As such, these findings should be interpreted with some caution. Evidence from provincial and national registry data are likely more reliable than surgeons’ own estimates of their performance.
This survey provides insight into the practice of coronary revascularization in Canada. Currently, OPCAB use in Canada appears to be less than that in the United States, and only a minority of surgeons and centers routinely perform this technique. The majority of Canadian surgeons do not appear convinced that the current literature or their clinical experiences support increasing the use of OPCAB surgery. This survey will be repeated in 3 to 4 years to determine if surgeon attitudes change with new evidence.

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References
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