Bypassing the Pump*
Changing Practices in Coronary Artery Surgery

Tiarnan D.L. Keenan, BA, BMBCh; Yasir Abu-Omar, MBChB, MRCS; and David P. Taggart, MD (Hons), PhD

Improvements in techniques in coronary revascularization over the past decade have led to a revival of interest in off-pump coronary artery surgery. A fifth of coronary revascularization procedures are now performed off-pump. Randomized trials comparing off-pump surgery with conventional coronary artery bypass grafting using cardiopulmonary bypass (CPB) mainly included low-risk patients and were therefore underpowered to detect a difference in mortality. Current evidence, however, suggests a significant reduction in morbidity with off-pump surgery. The avoidance of CPB and the elimination of any aortic manipulation may significantly reduce the risk of stroke. Those benefits are likely to be most marked in older, sicker patients, who represent an increasing proportion of the surgical population.

Key words: coronary artery bypass grafting; cardiopulmonary bypass; off-pump

Abbreviations: BHACAS = Beating Heart Against Cardioplegic Arrest Studies; CABG = coronary artery bypass grafting; CPB = cardiopulmonary bypass; OFFCABG = off-pump coronary artery bypass grafting; ONCABG = on-pump coronary artery bypass grafting

Coronary artery bypass grafting (CABG) is the most common surgical procedure performed on the heart, with almost 1 million operations carried out worldwide every year. The traditional operation (on-pump CABG [ONCABG]) uses cardiopulmonary bypass (CPB) to provide an artificial circulation, so that surgery can be performed while the heart is stopped (called cardioplegic arrest). This provides the surgeon with a motionless and bloodless operating field, while largely protecting the heart from the effects of ischemia.

Kolessov2 reported the first experience with coronary artery surgery on the beating heart in 1967, but the technique was soon abandoned with the advent of CPB. However, off-pump CABG (OFFCABG) has experienced a revival, beginning in the early 1990s with the work of Benetti et al3 and Buffolo et al.4 Their work in South America was motivated by economic considerations but demonstrated that unexpected benefits were associated with the avoidance of CPB. Following the introduction of new surgical techniques and instruments, about a fifth of CABG procedures are now performed off-pump, and the proportion is likely to increase.5

The absence of recognized guidelines has meant that decisions on the use of CPB are left to individual surgeons.6 Advocates of OFFCABG claim that there is reduced morbidity with off-pump surgery, and point to the adverse effects of CPB, including an inflammatory response caused by the circulation of blood through the extracorporeal circuit and the formation of microemboli.1 In particular, neurologic complications such as impairment of higher intellectual function may occur, especially in elderly patients. Meanwhile, critics of OFFCABG express concerns over the potential for intraoperative myocardial ischemia, suboptimal graft anastomoses, and a protracted learning curve for surgeons.6

In this context, the advantages and disadvantages of ONCABG and OFFCABG have been considered, and a critical appraisal made of the evidence available. The validity of evidence has been assessed by means of several criteria, including study design, size of the surgical population, and quality of statistical analyses. Finally, further issues for debate have been examined in order to gauge the role that OFFCABG will have in the future of cardiac surgery.

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Evidence From Prospective Trials

Clinical outcomes following ONCABG vs OFFCABG have been compared in six main prospective randomized trials, as shown in Table 1. Van Dijk and colleagues' carried out a multicenter trial on a cohort of 281 patients, with 139 patients randomly assigned to ONCABG and 142 patients to OFFCABG with a tissue stabilization system (Octopus Tissue Stabilization System; Medtronic; Minneapolis, MN). No significant differences in perioperative mortality or morbidity were demonstrated. At 1 month of follow-up, no patient had died, and similar proportions in both groups had been free of a cardiovascular event (OFFCABG, 93%; ONCABG, 94%). However, the OFFCABG group did show a reduction in cardiac enzyme release, duration of mechanical ventilation, and hospital stay, relative to the ONCABG patients.

Angelini and colleagues' pooled the results of Beating Heart Against Cardioplegic Arrest Studies (BHACAS) 1 and 2, two single-center prospective trials, with 201 patients randomized to ONCABG and 200 patients randomized to OFFCABG. No significant difference in mortality was demonstrated. The perioperative mortality rate was 0% for OFFCABG and 1% for ONCABG, while the late mortality rates (at a follow-up of >2 years for BHACAS 1 and >1 year for BHACAS 2) were 2% and 3%, respectively. In terms of morbidity, 15% of patients in the OFFCABG group had a cardiac event compared with 18% in the ONCABG group. Further benefits associated with OFFCABG are shown in Table 1.

Four further prospective randomized trials have shown results that are consistent with those described above. Puskas and colleagues' randomized 200 unselected patients to ONCABG or OFFCABG. They reported similar in-hospital and 30-day outcomes, similar completeness of revascularization (mean No. of grafts for OFFCABG, 3.39; mean No. of grafts for ONCABG, 3.40), shorter length of stay, reduced transfusion requirements, and less myocardial injury with OFFCABG. Nathoe and colleagues' randomized 281 low-risk patients to ONCABG or OFFCABG. No difference in cardiac outcome was observed at 1 year of follow-up. However, there was a significant cost reduction with the avoidance of CPB. Khan and colleagues randomized 104 patients to OFFCABG or ONCABG and undertook postoperative coronary angiography at 3 months postoperatively. There were no deaths, and the OFFCABG group had lower transfusion rates. In addition, they reported inferior patency rates with OFFCABG, stating that the learning curve for this procedure is probably substantial and may be longer than anticipated. Most recently, Legare and coworkers' reported no significant benefits with OFFCABG in a randomized trial of 300 patients.

Interpretation

The prospective randomized trial is the preferred tool for comparing the benefits of ONCABG and OFFCABG. Its main advantage is the elimination of selection bias. However, advocates and critics of OFFCABG have interpreted the results from these trials differently. Critics have claimed that they show little benefit with OFFCABG, since none of the trials was able to demonstrate significant differences in more than a few chosen end points, such as blood loss and cardiac enzyme release. Bonchek' has argued that these end points are noncritical. The difference in cardiac enzyme release, for example, is understandable (since OFFCABG was performed with snaring of single coronary arteries, whereas ONCABG was done with crystalloid cardioplegia) and also unimportant (since ONCABG can also be done with single-vessel occlusion, or with intermittent global ischemia without cardioplegia).

Meanwhile, advocates have emphasized that the trials were designed only to show that OFFCABG is at least as safe as ONCABG. As such, their relatively small size and use of low-risk patients meant that they were statistically underpowered to detect differences in mortality. In the trial by Angelini and colleagues,' for example, there were two deaths in the ONCABG group and no deaths in the OFFCABG group, but this difference did not achieve significance. Larger trials would therefore be required to assess any potential survival benefit.

The implications of results from these trials are also limited by potential bias through incomplete randomization. In the van Dijk trial, for example, the patients and cardiologists were not blinded to the treatment group. The authors concede that this may have influenced the timing of hospital discharge, self-reported quality of life, and assessment of angina. Indeed, incomplete randomization might help explain the observed difference in hospital stay, since readiness for hospital discharge is known to be a highly subjective decision.

The inferior patency rates with OFFCABG reported by Khan and colleagues' illustrate the need to confirm intraoperative graft patency. CABG is one of the few interventional vascular procedures in which confirmation of a satisfactory result is not routine. Using an intraoperative fluorescent imaging system, we found that 2% of grafts are not patent and require revision before the conclusion of surgery, and this incidence would almost certainly be higher during the learning curve of OFFCABG. If the potential short-term and long-term benefits of OFFCABG and arterial grafts are to be fully realized, the confirmation of graft patency in the operating room should be mandatory.
Table 1—Clinical Outcomes Following ONCABG vs OFFCABG

<table>
<thead>
<tr>
<th>Variables</th>
<th>Van Dyk et al7</th>
<th>Angelini et al8</th>
<th>Puskas et al9</th>
<th>Nathoe et al10</th>
<th>Khan et al11</th>
<th>Legare et al12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On</td>
<td>Off</td>
<td>P</td>
<td>On</td>
<td>Off</td>
<td>P</td>
</tr>
<tr>
<td>Patients, No.</td>
<td>139</td>
<td>142</td>
<td></td>
<td>201</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>30-d mortality†</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
<td>2 (1)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Hematologic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Blood loss,‡ L</td>
<td>0.4</td>
<td>0.5</td>
<td>0.02</td>
<td>31%§</td>
<td>21%§</td>
<td>0.02</td>
</tr>
<tr>
<td>Postoperative use of blood</td>
<td>29</td>
<td>28</td>
<td>0.85</td>
<td>49</td>
<td>18</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>products, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Cardiac</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inotropic use, %</td>
<td>28</td>
<td>27</td>
<td>0.88</td>
<td>24</td>
<td>7</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Cardiac enzymes release</td>
<td></td>
<td></td>
<td>27%¶</td>
<td>164¶</td>
<td>&lt;0.01</td>
<td>31#</td>
</tr>
<tr>
<td>Myocardial infarction, %</td>
<td>4.3</td>
<td>4.9</td>
<td>0.14</td>
<td>2</td>
<td>1</td>
<td>0.99</td>
</tr>
<tr>
<td>Atrial fibrillation, %</td>
<td>21</td>
<td>20</td>
<td>0.70</td>
<td>37</td>
<td>13</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Respiratory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to extubation, h</td>
<td>9</td>
<td>3</td>
<td>&lt;0.01</td>
<td>40%**</td>
<td>25%**</td>
<td>0.001</td>
</tr>
<tr>
<td>Chest infection, %</td>
<td>20</td>
<td>8</td>
<td>0.001</td>
<td>0</td>
<td>2</td>
<td>0.246</td>
</tr>
<tr>
<td>Renal failure, %</td>
<td>1</td>
<td>0</td>
<td>0.31</td>
<td>0</td>
<td>2</td>
<td>0.246</td>
</tr>
<tr>
<td>Neurologic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke/TIA, %</td>
<td>1.4</td>
<td>0.7</td>
<td>1.5</td>
<td>1.5</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>ICU stay, h</td>
<td>22</td>
<td>22</td>
<td>0.88</td>
<td>20¶</td>
<td>71¶</td>
<td>0.0004</td>
</tr>
<tr>
<td>Hospital stay, d</td>
<td>7</td>
<td>6</td>
<td>&lt;0.01</td>
<td>28¶</td>
<td>15¶</td>
<td>0.002</td>
</tr>
<tr>
<td>Patient characteristics (exclusions)</td>
<td>Poor LV</td>
<td>LVEF &lt;30%</td>
<td>No exclusions</td>
<td>Poor LV</td>
<td>Poor LV</td>
<td>Poor LV</td>
</tr>
<tr>
<td>MI &lt;6 wk preoperatively</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>MI &lt;1 mo and disease in distal circumflex (includ ed in BHACAS) 2</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Previous stroke/TIA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Renal and/or respiratory impairment</td>
<td></td>
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<tr>
<td>**On = on-pump; Off = off-pump; MI = myocardial infarction; LV = left ventricle; LVEF = left ventricular ejection fraction; TIA = transient ischemic attack.</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>†Values given as No. (%). ‡Values given as the mean. §Percentage of patients with &gt; 1 L of blood loss. ¶Area under the curve for creatine kinase-MB values.</td>
<td></td>
<td>Values given as the median. **Area under the curve for troponin T values. #Area under the curve for troponin T values.</td>
<td></td>
<td></td>
<td>Values given as the median. ¶¶Area under the curve for troponin T values. **Percentage of patients intubated for &gt; 10 h. ††Percent of patients intubated for &gt; 4 h. †††Percentage of patients with an ICU stay of &gt; 1 day. ¶¶¶Percentage of patients with a hospital stay of &gt; 7 days.</td>
<td></td>
</tr>
</tbody>
</table>
Finally, the presence of exclusion criteria for potential subjects, such as poor left-ventricular function or recent myocardial infarction, limits the applicability of any conclusions to an entire surgical population. In the trial by van Dijk et al., the 281 patients were randomly allocated after they had been judged suitable for either technique. Additionally, all surgeons were experienced in both OFFCABG and ONCABG surgery. Hence, any benefits observed might apply only to a subgroup of patients in the hands of selected surgeons. For these reasons, it has been argued that large retrospective studies are also helpful, when supported by sophisticated statistical analysis.

Evidence From Retrospective Trials

Cleveland and colleagues conducted a multicenter retrospective study of 118,140 CABG procedures, as recorded in the National Adult Cardiac Surgery Database of The Society of Thoracic Surgeons. Of these, 11,717 were OFFCABG and 106,423 were ONCABG. The authors used a risk-adjusted analysis and demonstrated a significant reduction in the operative mortality rate with OFFCABG (2.3% vs 2.9%, respectively; p < 0.0001). In addition, they showed a reduction in major complications (eg, deep sternal infection, bleeding, renal failure, and prolonged ventilation) with OFFCABG compared with ONCABG (10.6% vs 14.1%, respectively; p < 0.0001). Similar results were reported by Calafiore and colleagues.17

Retrospective studies may also be helpful in assessing which patient groups are likely to benefit most from OFFCABG. The prospective randomized trials used exclusion criteria, as described above, and recruited younger patients with relatively low surgical risk profiles. However, it has been suggested that higher risk patients are likely to benefit more from the avoidance of CPB.

Plomondon and colleagues reported a significant reduction in mortality rates (2.7% vs 4.1%, respectively) and morbidity rates (8.8% vs 14%, respectively) with OFFCABG in a retrospective analysis of 680 patients undergoing OFFCABG and 1,733 patients undergoing ONCABG. Magee and colleagues conducted a retrospective study of 1,983 OFFCABG procedures and 6,466 ONCABG procedures from two US centers in a higher risk surgical population. Of these patients, the mean age was 64 years, 48% had impaired left ventricular function, 30% had diabetes, and about 20% had significant comorbidity (including 5% with renal failure and 5% undergoing repeat CABG). The authors used propensity score analysis, and included statistical compensation for the nonrandomization of patients. They showed that the OFFCABG group had a higher preoperative risk. Despite this, the ONCABG group had higher mortality than the OFFCABG group (odds ratio of CPB as a predictor for postoperative mortality, 1.9; 95% confidence interval, 1.2 to 3.1). In addition, the OFFCABG group showed a reduction in findings for morbidity that was consistent with the results of previous trials.

Similarly, Al-Ruzzeh and colleagues completed a retrospective analysis of CABG in 1,398 consecutive high-risk patients (OFFCABG, 286 patients; ONCABG, 1,112 patients). Again, the OFFCABG group had a higher preoperative risk but showed a lower 30-day mortality rate than the ONCABG group (3.5% vs 7%, respectively; p = 0.04) with a significant reduction in morbidity.

Interpretation

The major limitation in these retrospective studies is the potential for bias related to differences in patient selection, surgical technique, and surgical skill. The use of risk-adjustment models is problematic, since no model can identify all confounding variables. Indeed, it has been argued that current models of risk adjustment ignore some confounding variables (eg, the presence of intramyocardial coronary arteries or left ventricular hypertrophy) that are specific to OFFCABG, and could affect mortality, morbidity, and the selection of patients. The role of the surgeon’s experience and technical skill is very difficult to include in the analysis, because of the subjective nature of the assessment, and problems in comparisons between different institutions.

The initial application of off-pump coronary artery surgery in the early 1990s was mainly directed to highly selected and relatively low-risk surgical patients. But as shown above, an increasing body of evidence began to point toward high-risk patients as those most likely to benefit from this modality. Since then, much work has gone into identifying the theoretical and practical disadvantages of CPB and the accompanying cardioplegic arrest. These include cerebral, renal, and myocardial injury. This subsystem organ dysfunction is thought to arise from a systemic inflammatory response syndrome (as blood circulates through the extracorporeal circuit) and the formation of microemboli (from damaged blood constituents and lipids).

In this context, the increased use of OFFCABG would hold particular benefits for high-risk patients, in whom these organs are already compromised. Cardiac surgical practice and its referral pattern have therefore come full circle, so that OFFCABG is now more commonly used in those patients presenting with preoperative risk factors and comorbidities that make them more susceptible to the hazardous effects of CPB.
Inflammatory Response

Several studies\(^2^2\) have compared the inflammatory response in OFFCABG vs that in ONCABG by the measurement of cytokines and acute phase proteins before and after surgery in serum. These have demonstrated a significant attenuation of the inflammatory response with OFFCABG. In principle, this reduction in systemic inflammation should be accompanied by a reduction in organ dysfunction. The extent to which this is borne out in surgical practice will be assessed below.

Cerebral Injury

Cerebral injury is considered to be the most significant and disabling complication of CABG.\(^2^1\) Stroke occurs in roughly 3% of patients after CABG, although up to two thirds of patients show a cognitive decline of variable duration. It has been argued\(^2^1\) that stroke is due to an embolism caused by atheromatous debris during the manipulation of the diseased aorta, while cognitive dysfunction is caused by microembolism of particulate debris during CPB. Indeed, using transcranial Doppler ultrasound, we have demonstrated a substantial reduction in the total number of intraoperative microemboli, as well as a reduction in the proportion of solid microemboli, with OFFCABG.\(^2^3\) Despite this, initial trials failed to demonstrate any significant reduction in cognitive decline with OFFCABG. Van Dijk and colleagues,\(^2^4\) for example, observed no significant difference in cognitive decline between ONCABG and OFFCABG groups, in their randomized trial of 281 patients.

Several limitations in these studies may help to explain this discrepancy. First, the tests of cognitive function may not be sufficiently sensitive to detect subtle differences between the groups. Second, the size of the studies may have meant that they were statistically unable to detect any differences. Third, the studies used younger surgical populations; cognitive decline following CABG, however, is known to be strongly age-dependent.\(^2^1\) Finally, the surgical populations consisted of low-risk patients and contained a majority of patients with single-vessel or double-vessel disease. In contrast, a study by Zamvar and colleagues\(^2^5\) included only patients with triple-vessel disease. These authors reported a marked reduction in postoperative cognitive decline in patients undergoing OFFCABG in their randomized trial of 60 patients.

Recent developments may further reduce problems with cerebral dysfunction after surgery. The combination of OFFCABG with total arterial revascularization allows the avoidance of aortic manipulation (also called the “no-touch aortic technique”). In what some view as the ideal operation, total arterial revascularization offers longevity of grafts, while the no-touch technique may reduce neurologic sequelae by preventing embolism from the diseased aorta. Indeed, one study\(^2^6\) of 222 patients undergoing OFFCABG with no aortic manipulation reported no strokes in any patient, compared to a 4% stroke rate in an age-matched group undergoing conventional ONCABG. In addition, Sharyon and colleagues\(^2^7\) reported a significant reduction in the risk of stroke in patients with atheromatous aortas undergoing OFFCABG.

Renal Dysfunction

Renal dysfunction occurs after CABG, ranging from subclinical injury in most patients to renal failure requiring dialysis in 1 to 5% of patients. Evidence for a protective effect of OFFCABG on renal function has come from several studies. In a prospective randomized trial, Ascione and colleagues\(^2^8\) used biochemical evaluation to show that OFFCABG reduced the frequency of renal impairment. In addition, the retrospective study by Magee et al\(^2^9\) (described above) demonstrated a reduction in the frequency of renal failure after OFFCABG (2.1% vs 3.3%, respectively), despite significantly worse preoperative renal function in this group. These findings were consistent with results from other retrospective studies.

Myocardial Injury

Myocardial injury is thought to occur during ONCABG, due to the cardiac ischemia of cardioplegic arrest. OFFCABG should therefore reduce myocardial injury, since it allows continuous perfusion of the beating heart. Indeed, in the randomized trial conducted by Angelini and colleagues\(^8\) the frequency of myocardial infarction was reduced in the OFFCABG group (2%), relative to the ONCABG group (4%), at 2 years of follow-up. While the randomized trial by van Dijk and colleagues\(^7\) showed no significant difference between groups, the study was limited by its short period of follow-up (1 month). It did demonstrate a 41% reduction in the release of creatine kinase-MB in the OFFCABG group, but the functional significance of biochemical findings of this kind has been questioned.\(^7\) More recently, cardiovascular MRI has provided evidence in support of reduced myocardial injury with OFFCABG. In a randomized trial of 60 patients, Selvanyagam and colleagues\(^2^0\) reported significantly better postoperative left ventricular function in the OFFCABG group.
QUALITY OF ANASTOMOSES

The quality and adequacy of revascularization has been a major criticism of off-pump surgery, with initial concern about suboptimal anastomoses and poor long-term results. More recently, however, the results of BHACAS trials 1 and 2 showed no difference (at a mean follow-up of 29 months and 16 months, respectively) between OFFCABG and ONCABG groups in terms of late mortality, cardiac events, and the need for further coronary revascularization procedures.8 This evidence is supported by angiographic studies of OFFCABG procedures, which have demonstrated graft patency rates at least equivalent to those of ONCABG procedures. Khan and colleagues11 reported patency rates of 88% and 98%, respectively, in OFFCABG and ONCABG surgery. However, this may be explained by the fact that both surgeons in this trial performed only 13% of their coronary workload off-pump. This may indicate that the procedures were performed within the learning curve phase for these surgeons. Indeed, our own experience with an intraoperative device for the assessment of graft patency showed a similar incidence of graft failure in patients undergoing OFFCABG surgery vs those undergoing ONCABG surgery.15 Most of the trials described were limited by their period of study, since the loss of patency may be a late effect; longer-term follow-up is therefore essential.

ECONOMIC CONSIDERATIONS

Economic considerations are an extremely important issue in evaluating the role of OFFCABG in the future of cardiac surgery, as OFFCABG is expected to lower costs by reducing perioperative morbidity and recovery time. Calculation of the in-hospital costs of the first BHACAS trial showed a saving of about 25% per patient. In addition, the randomized trial of Nathoe and colleagues10 compared expenditures alongside cardiac outcomes in OFFCABG and ONCABG groups. OFFCABG was found to be less expensive ($13,100 vs $14,900 per operation, respectively) and more cost-effective than ONCABG. This has important implications for health policy and expenditure, although the findings are limited by the period of follow-up (1 year), and the variation in medical practices and costs between countries.

SURGICAL TRAINING

The integration of OFFCABG into surgical practice and training is a further issue for debate, as the adoption of OFFCABG by new surgeons and teams has been associated with a variable “learning curve.” Some surgeons have advocated the gradual adoption of OFFCABG into routine practice and recommend the selection of single-graft cases before progression to more complex cases. Nevertheless, natural differences in surgical expertise mean that the decision to adopt OFFCABG, and to what degree, must be left to the discretion of individual surgeons. This will pose vital questions for future training programs.

FUTURE DEVELOPMENTS

OFFCABG is compatible with total arterial grafting offering the advantages of longevity of arterial grafts in a younger population and a reduced risk of neurologic complications in the elderly by eliminating the need for aortic manipulation and CPB. The development of sutureless anastomotic devices eliminates the need for side-biting aortic clamps, and may reduce the risk of dislodgment of atheromatous material and stroke.30 The further development of anastomotic devices may facilitate distal coronary anastomoses, especially in the context of OFFCABG.

CONCLUSIONS

Cardiac surgery has witnessed a recent revival in the practice of OFFCABG. About one fifth of CABG procedures are now performed off-pump, and the proportion is likely to increase. However, in the context of evidence-based medicine, more data are now required before further the implementation of OFFCABG. Many clinical trials have been conducted to assess the benefits and harms of off-pump surgery, relative to conventional on-pump surgery. Prospective, randomized, controlled trials have compared on-pump and off-pump surgery. In general, these have demonstrated little difference in mortality between groups, but some benefit in morbidity with off-pump surgery. Retrospective studies have consistently shown some benefit with off-pump surgery, but are limited by bias in patient selection and surgical skill, and problems with risk-adjustment models. This has led some to argue that, as yet, off-pump surgery has only been proven to be better than on-pump surgery for noncritical end points, in a subgroup of patients, in the hands of selected surgeons.

However, the magnitude of the benefit with OFFCABG may depend on the clinical status of the patient, and these studies were carried out on low-risk surgical populations. Claims of increased benefit in elderly and high-risk patients have now been investigated, and many studies have suggested a reduction in morbidity and mortality with OFFCABG. In the context of an aging and ailing population, this has enormous implications and
might usher in a new paradigm in OFFCABG, with consideration of indications and contraindications. The absence of recognized guidelines has meant that decisions on the use of CPB have been left to individual surgeons, many of whom remain reluctant to adopt OFFCABG. As some have argued, this cautious approach is justified, since a technically more demanding procedure is being offered in place of a successful, well-studied, and reproducible operation. But if further evidence for the benefits of OFFCABG is conclusive, this would have great implications for the future of cardiac surgery in terms of quality of patient care and economic considerations. Future coordinated implementation of OFFCABG may necessitate specific guidelines, formal training programs, and dedicated audit systems.

References