Routine Intraoperative Angiography Improves the Early Patency of Coronary Grafts Performed on the Beating Heart*

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Objectives: The techniques of performing coronary revascularization without cardiopulmonary bypass are rapidly evolving. However, concern remains regarding the accuracy of coronary artery anastomoses performed on the beating heart. This report reviews the use of intraoperative angiography in the critical appraisal of “off-pump” coronary artery bypass graft (CABG) surgery.

Patients: Intraoperative angiography was performed in 24 consecutive patients undergoing CABG surgery without cardiopulmonary bypass. In all, 24 left internal mammary artery (LIMA) grafts and 18 saphenous vein bypass grafts were assessed for patency, anastomosis quality, distal and proximal runoff, and correct placement.

Results: All of the saphenous vein-to-coronary artery anastomoses were widely patent, although two patients (8%) required revision of their LIMA grafts on the basis of angiographic findings.

Conclusion: Intraoperative angiography permits the surgeon to immediately appraise the CABG and to revise, if necessary, any graft abnormality, thus potentially eliminating the need for early repeated surgery. The practice of routine intraoperative angiography is likely to improve the outcome of CABG surgery on the beating heart.

Key words: angiography; coronary artery; heart surgery; minimally invasive

Abbreviations: CABG = coronary artery bypass graft; LAD = left anterior descending coronary artery; LIMA = left internal mammary artery; MIDCABG = minimally invasive direct coronary artery bypass graft; SVG = saphenous vein grafts

The known morbidity associated with extracorporeal circulation has led to the recent surge of interest in performing coronary revascularization (using a median sternotomy or a minithoracotomy) without cardiopulmonary bypass.1–3 Indeed, there is already substantial experience with “off-pump” coronary artery bypass graft (CABG) surgery to indicate that this approach is becoming a permanent part of the cardiac surgeon’s armamentarium.

The principal challenge of CABG surgery on the beating heart is to accurately anastomose bypass conduits to targeted coronary vessels that are constantly moving. Despite the various refinements and the range of instruments that have been developed to facilitate this process,4 the accuracy of the anastomotic procedure on the beating heart remains a serious concern.5

Recently, we highlighted the importance of obtaining angiographic data for the critical appraisal of minimally invasive direct CABG (MIDCABG) surgery, as opposed to relying solely on clinical outcome measures.6,7 We report here our experience with utilizing routine intraoperative angiography in CABG on the beating heart.

Materials and Methods

Patients

Following our pilot studies,6,7 intraoperative angiography was performed in 24 consecutive patients undergoing CABG surgery without cardiopulmonary bypass. Ten of the patients underwent MIDCABG surgery, and 14 underwent surgery through a median sternotomy.

Surgical Technique

Our technique for performing MIDCABG has been described previously.8 Briefly stated, following anesthetic induction and
endotracheal intubation with a double-lumen tube, the patient is placed in a 30° right lateral decubitus position, and the left arm is flexed and suspended above the patient's head. After the left lung has collapsed, a 6- to 8-cm left anterior minithoracotomy is performed in the fourth intercostal space and the fourth costal cartilage is completely excised. A 10-mm thoracoscope with a 0° lens is inserted through a trocar placed in the fourth left intercostal space at the mid-axillary line. With video guidance, the left internal mammary artery (LIMA) is completely mobilized along the course of the phrenic nerve.6

When the surgery is performed through a median sternotomy, traction sutures are applied to the margins of the pericardium to stabilize the coronary artery. The coronary anastomoses are then performed in a manner similar to the MIDCABG process.

Angiographic Technique

In the first 18 patients, the angiographic assessments were performed after the closure of the wound using a standard C-arm fluoroscopy device (model BV300; Philips Medical Systems North America; Shelton, CT). For the six subsequent patients, we used a cardiac digital mobile imaging system with high-resolution digital imaging capability (Series 9600; OEC Medical Systems; Salt Lake City, UT).

Catheters (Super Torque Plus; Cordis; Miami, FL) were introduced through a right femoral artery sheath to inject left coronary grafts (6F LCB curve style), right coronary grafts (6F RCB curve style), or into the left subclavian artery to inject LIMA grafts (6F IM curve style). Iopamidol contrast medium (Iopamiro; Bracco; Milan, Italy) was used, and straight anterior, lateral, and oblique views of the coronary anastomoses were obtained. The angiographic assessments included evaluating the graft and the anastomosis for patency, noting the distal and proximal runoff, and verifying that the conduit was placed in the correct location. In addition, the obliteration of the intercostal branches of the LIMA grafts was investigated.

All of the angiographic studies were performed by the cardiac surgeon after the completion of several full coronary angiographic studies under the supervision of a cardiologist in the cardiac catheterization laboratory.

RESULTS

Ten patients underwent LIMA-to-LAD bypass graft surgery using a MIDCABG approach. Of the 14 patients who underwent surgery through a median sternotomy, 2 patients underwent isolated LIMA-to-LAD grafts and 12 patients received additional saphenous vein grafts (SVGs) to other coronary vessels (Table 1). In total, 24 LIMA-to-LAD anastomoses and 18 SVG-to-coronary artery anastomoses (6 to diagonal branches, 3 to obtuse marginal branches, and 9 to right coronary artery branches) were studied. The angiographic assessment confirmed that all 18 of the SVGs and all 22 of the LIMA grafts and anastomoses were widely patent and had a good runoff.

Two of the LIMA-to-LAD grafts required revision. One revision was due to an absent distal flow into the LAD, and the other revision was due to a narrow LIMA-to-SVG anastomosis in a patient requiring LIMA graft lengthening during a MIDCABG procedure (Fig 1). In both patients, a repeat angiography following the revision of the graft demonstrated satisfactory results. Neither of the patients had any ECG changes or hemodynamic instability, nor did they demonstrate any wall motion abnormality on transeosophageal echocardiography before revision of the graft. Therefore, in the absence of intraoperative angiography, there would not have been any clinical evidence to suggest the impairment of flow through the LIMA grafts.

Although the angiographic picture was satisfactory in the majority of cases when a standard fluoroscopy device was used, occasional minor abnormalities in the anastomoses could not be confidently ruled out. In comparison, when the cardiac digital imaging system was used, the image resolution was always of excellent quality.

The femoral sheath was removed immediately following the procedure, and there were no complications related to the technique.

DISCUSSION

Quality assurance is essential in the development of new surgical procedures, and evaluating the results of surgery using the off-pump modality is a pressing topic that must be kept in mind.5 Recently,

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<td>CABG</td>
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*D1 = first diagonal branch; OM1 = first obtuse marginal branch; RCA = right coronary artery.
we highlighted the importance of obtaining angiographic data as opposed to relying solely on clinical outcome measures for the critical appraisal of MIDCABG. As demonstrated in this study, the importance of obtaining angiographic data also applies to off-pump coronary surgery performed through a median sternotomy because poor coronary grafting may not manifest immediately with clinical signs of ischemia.

Although nonangiographic physiologic methods of graft assessment, such as Doppler velocity waveform, thermal imaging, and flow measurements, promise to document graft patency and function, these methods have not been substantiated in large prospective studies in comparison to the “gold standard” of angiography. Furthermore, even if one nonangiographic method was reliably shown to detect poor graft function, the method may still lack the ability to define the problem anatomically. Hence, at least for the foreseeable future, we believe that patency of graft anastomosis and pedicle is an anatomic characteristic that is best defined by angiography.

Performing the angiography intraoperatively has significant advantages over a postoperative cardiac catheterization, regardless of whether the catheterization is performed on the same day or later, before hospital discharge. With intraoperative angiography, graft patency is confirmed instantly. If an abnormality is detected, the graft can be revised immediately, and the patient leaves the operating room with adequate revascularization. Achieving the ideal 100% immediate patency rate, therefore, is possible and practical. The patients are spared the discomfort of additional cardiac catheterization and the possibility of repeated surgery that would be necessary if graft anomalies were encountered. Furthermore, performing a postoperative cardiac catheterization increases the expense of the surgical procedure, and this added cost may not be seen by third-party payers as “medically indicated.” We have not encountered any complications related to intraoperative angiography. Although the dissection of the LIMA is a potential concern, this is unlikely to occur with modern catheters that are small and soft-tipped.

The technique of intraoperative angiography, particularly when using the LIMA, is relatively straightforward and easy to learn. We have found that brief training in the cardiac catheterization laboratory by a keen cardiologist is sufficient for the surgeon to be able to confidently perform an angiographic assessment. We do not believe that the patients are exposed to an increased risk when the angiographic assessment is performed by a surgeon because most surgeons have experience in performing intraoperative angiography during peripheral vascular procedures. The time that is spent doing intraoperative angiography can be used to stabilize the patient and to wean the patient off the ventilator. When the surgeon is assured of good graft patency, most patients can be extubated immediately or within a few hours of the angiography.

Our experience with using two types of imaging systems suggests that even though the cardiac digital imaging system produces an ideal image resolution, using such a system is not absolutely necessary because the standard fluoroscopy device (available in most operating rooms) can provide a satisfactory angiographic picture in most patients.

In conclusion, this study indicates that intraoperative angiography can be performed satisfactorily by the surgeon, and it allows for an immediate appraisal of CABGs. Our preliminary experience with intraoperative angiography enabled us to explain certain angiographic abnormalities and, in turn, to prevent their repetition. By enabling the surgeon to revise any graft abnormality immediately, routine intraoperative angiography can potentially eliminate the need for repeated surgery. Such data also helps the surgeon in his or her own process of learning. We believe that the practice of routine intraoperative angiography is likely to improve the outcome of CABG surgery without cardiopulmonary bypass.
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