Aortocoronary Bypass Graft
Initial Blood Flow through the Graft, and Early Postoperative Patency

By Claude M. Grondin, M.D., Gilles Lepage, M.D., Yves R. Castonguay, M.D., Claude Meere, M.D., and Pierre Grondin, M.D.

SUMMARY
Intraoperative measurements of blood flow were made in 70 patients in whom a total of 103 venous bypass grafts had been inserted from the aorta to the right, the left anterior descending, or the circumflex coronary artery. Cineangiographic evaluation of graft patency was performed in all patients. Overall patency rate was 90.3%. Flow in all bypass grafts averaged 68 ml/min. All grafts with flow of 20 ml or less or which failed to respond to the injection of 20 mg of papaverine became occluded. All grafts with flow greater than 45 ml/min remained open.

Additional Indexing Words:
Surgery for acquired coronary artery disease Intraoperative blood flow measurements

Electromagnetic blood flowmeters have been utilized for several years in peripheral vascular surgery.1 Opinions are still divided on the quantitative correlation of blood flow and early or late postoperative patency in femoropopliteal venous bypass grafts.2-6

Recently, aortocoronary venous bypass grafts have gained widespread acceptance in the surgical treatment of atherosclerotic coronary artery disease,7-9 and early postoperative patency from 59 to 95% has been reported in various centers.8,9 Little information is available, however, concerning blood flow through aortocoronary venous bypass grafts.

The purpose of this communication is to report on the correlation of intraoperative blood flow through aortocoronary venous bypass grafts and early postoperative patency in a group of 70 patients who underwent this operation at the Montreal Heart Institute.

Methods
This study was carried out in 70 patients (10 females, 60 males) who received at operation a total of 103 grafts to the right, the left anterior descending, or the circumflex coronary artery, or to a combination of these arteries. Selective angiography of the graft was obtained in all patients from 10 to 21 days after surgery.

Blood flow in the grafts at operation was measured with various sizes of electromagnetic flow probes* with slight constriction of the vein. The accuracy of the precalibrated probes was established beforehand with saline solution and blood flowing through arterial segments taken from laboratory animals. Blood flow zero was obtained by clamping the graft 2 cm distal to the probe and adjusting the flowmeter, sensing needle, and chart accordingly.

Measurements were carried out in normothermia shortly following cessation of cardiopulmonary bypass once the patient's heart rate and blood pressure had stabilized. Twenty milligrams of papaverine hydrochloride were then injected in the graft itself and the blood flow response was recorded.

*Statham Instruments Inc., Flowmeter Model SP2200, Oxnard, California.

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Address for reprints: Dr. Claude Grondin, Department of Surgery, Montreal Heart Institute, 5000 Bélanger Street East, Montreal, 410, Quebec, Canada.
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Blood flow in all grafts (103) → 68 cc/min

Blood flow in occluded grafts (16) → 27 cc/min

Figure 1

Initial blood flow in the entire series of 103 grafts. Solid dots represent open grafts at reevaluation; open circles occluded grafts at that time. Mean flows, standard deviation, and probability values are indicated for both groups.

Results

Initial blood flow (fig. 1) in the 103 aortocoronary venous bypass grafts ranged from 5 to 180 ml/min and averaged 68 ml/min. In the grafts to the right coronary artery (42 grafts), flow averaged 62 ml, to the left anterior descending (57 grafts) 72 ml, and to the circumflex artery (four grafts) 75 ml/min (fig. 2).

Response to Papaverine

In the right coronary artery following injection of 20 mg of papaverine, blood flow rose to an average of 110 ml/min. In the left anterior descending artery this value reached 150 and in the circumflex artery, 152 ml/min.

No untoward effect was noted after injection of papaverine except in one patient in whom injections were repeatedly followed by episodes of ventricular tachycardia which were easily terminated by electrical counter-shock.

Blood pressure tended to drop (an average of 15 mm Hg) and heart rate to rise secondarily after injection of papaverine. The increase in coronary blood flow preceded these changes, however, and lasted less than 4 min. Injections could therefore be repeated and doses of 120 mg were used without apparent ill effects. In approximately 10% of the cases, flow following injection of papaverine stabilized at a level higher than the one initially recorded. This probably was secondary to the relief of preexisting vasospasm in the coronary vascular bed.

Blood Flow in Occluded Grafts

Sixteen of the 103 grafts were eventually found to be occluded at the time of reevaluation by selective cineangiography. Initial flow in these grafts had ranged from 5 to 45 ml and averaged 28 ml/min. All seven grafts with initial flow of 20 ml/min or less became occluded.

Figure 2

Blood flow in grafts to the right (RCA), the left anterior descending (LAD), and the circumflex (CIRC) coronary arteries. Open circles indicate occluded grafts at reevaluation and solid dots patent grafts at that time.

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![Graph showing blood flow response to papaverine injection in patent and occluded grafts.](image)

**Figure 3**

Blood flow in response to injection of papaverine into the grafts. Response in the group of patent grafts (solid dots) represents average response. In both groups, dots set off to the right of the others represent average flow of entire group and average response to papaverine.

**Response to Papaverine Injection in Grafts Found Occluded Later (Fig. 3)**

All grafts with initial flow greater than 25 ml/min showed a normal or near normal response to papaverine infusion. Eight of the 42 grafts to the right coronary artery were nonpatent at postoperative angiography. Blood flow in these grafts at operation averaged 21 ml/min and rose to 40 ml following papaverine. There was no response to papaverine injection in two cases.

Seven of the 57 grafts to the left anterior descending coronary artery became occluded; the average initial flow in these grafts was 30 ml with a rise to 63 ml/min following injection of papaverine. There was no response to papaverine in two instances.

One of the grafts to the circumflex artery that had an initial blood flow of 35 ml/min and a normal response to papaverine became occluded.

**Fate of the Patients with Occluded Grafts**

No patient had more than one graft occluded. Reoperation for occlusion of a graft was performed on 10 patients with single grafts. The graft was either replaced or lengthened. Postoperative patency was achieved in six patients (all but one with grafts to the anterior descending coronary artery) bringing the overall patency rate to 90.3% (93 of 103 grafts).

Reoperation was unsuccessful in three patients whose graft had low blood flow (of 20 ml/min or less). The fourth patient reoperated upon unsuccessfully had an initial blood flow of 45 ml/min in the right aortocoronary graft.

**Influence of Various Factors on Blood Flow**

There was no difference in blood flow when factors such as age, sex, weight, or the presence of cardiomegaly were analyzed. For example, blood flow in 27 grafts of 15 patients with electrocardiographic evidence of left ventricular hypertrophy averaged 66 ml/min and blood flow in 14 grafts of 18 overweight patients (weighing more than 175 pounds) was 61 ml/min.

**Discussion**

Coronary blood flow in patients with ischemic heart disease has been estimated to be approximately 225 ml/min when measured by indirect noninvasive methods. Using direct electromagnetic flow probes, Dart and associates measured blood flow in internal mammary arteries 2 to 5 years after implantation and reported that single implants delivered an average of 8.1 ml/min to the myocardium, with a range of 4 to 19 ml/min.

Barner and co-workers reported a range of 17 to 130 ml/min at rest in femoropopliteal venous bypass grafts. In similar studies other authors found no correlation between blood flow measurements and postoperative patency. Minimum flow necessary to maintain patency in these grafts has not been defined but patency with flow as low as 15 ml/min has been reported.

Johnson and associates reported flows of 63 ml/min in aortocoronary venous bypass grafts and in Kay’s series blood flow ranged from 8

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to 159 ml in 10 patients. Grafts with flow of 8 ml/min became occluded.

In the present series all seven grafts with flow of less than 25 ml became occluded. On the other hand all grafts with flow greater than 45 ml per minute remained patent.

Validity of blood flow measured at surgery has been questioned since general anesthesia, surgical manipulation, and local ischemia do not represent "normal" physiologic conditions. Opening of the chest may cause a decrease in cardiac output of up to 30%.

Response to papaverine injection may be a more reliable index of the potential flow or of the capacity of the vascular bed. In the present series the average flow in aortocoronary venous bypass graft was 68 ml/min "at rest" and rose to 134 ml/min following injection of papaverine into the graft. In one patient in whom a triple graft to the right coronary artery, the left anterior descending, and the circumflex artery was inserted, blood flow initially totalled 210 ml/min and rose to 465 ml/min following papaverine. Papaverine is said to mimic conditions of exercise and has been used for intraoperative hemodynamic evaluation of arterial stenoses seen angiographically. Its usefulness in aortocoronary venous bypass graft stems from its apparent unique effect on coronary blood flow. Contrary to nitroglycerin, papaverine increases flow despite a decrease in systemic pressure. Of interest in this series were the four patients who failed to respond to papaverine. None of their grafts remained patent. This we believe is indicative of a diseased distal coronary arterial tree.

Measurements of flow at the time of operation is also of importance since high flows may avoid unnecessary postoperative angiographic reevaluation. Hence in this series all grafts with flows greater than 45 ml remained open. Systematic angiographic reevaluation in the early postoperative period has not been abandoned. Occasional finding of isolated stenosis of the graft or of short grafts pulling distally on the coronary artery, especially the left anterior descending coronary artery may be better dealt with in the early postoperative period. Grafts with flow of 20 ml or less which failed to respond to papaverine injection need not be reevaluated since little can be done if the graft is occluded. Only time will tell whether late patency remains high as is the case in femoropopliteal bypass grafts. Angiographic reevaluation of patients with aortocoronary bypass grafts is presently being conducted 1 year after surgery in this institution and will form the basis of a subsequent communication.

Addendum

Seventy-seven patients with a total of 111 grafts have undergone a second angiographic study 1 year after surgery. Eight grafts were occluded in the initial study. Twenty-four of the remaining 103 grafts (23%) were occluded 1 year later.

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CLAUDE M. GRONDIN, GILLES LEPAGE, YVES R. CASTONGUAY, CLAUDE MEERE and PIERRE GRONDIN

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