Aortocoronary Saphenous Vein Bypass Grafts

Long-term Patency, Morphology and Blood Flow in Patients with Patent Grafts Early After Surgery

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SUMMARY Early and late (range 5–73 months, average 2.5 years) postoperative arteriographic studies were performed in 85 patients after saphenous vein aortocoronary bypass surgery. In a prior study (≤ 2 weeks postoperative) of 570 patients with 1197 grafts, arteriography revealed 89.6% early patency of grafts. Late follow-up in 85 patients discharged with all grafts patent revealed 92.2% still patent, an annual mean graft attrition rate (percent of grafts closed/year) of 3.2%/year. This mean graft attrition rate was only slightly affected by regrouping patients according to the interval between the two postoperative studies; however, recurrent angina pectoris was influenced by vein graft attrition. Thus, in 36 patients restudied because of recurrent angina pectoris, the attrition rate was 6.1%/year, compared with 1.1%/year in 49 patients without angina. Progressive coronary artery disease (41% vs 18%), graft closure (22% vs 4%) and incomplete revascularization (39% vs 16%) were significantly more frequent in those with recurrent angina. The frequency of progressive coronary disease was directly related to the duration of follow-up (i.e., the longer the follow-up the higher the frequency of progressive disease). The mean annual rate of progressive coronary disease in arteries not grafted was 11.8%/year. Kinking or graft stenosis was observed in 3.1% of grafts in the early study, while late localized graft narrowing was observed in 8%. At late follow-up, most patent grafts were uniformly narrowed and foreshortened. The mean graft diameter decreased by 17% at late follow-up, and 25% of grafts had at least 25% reduction in mean diameter; however, the mean graft diameter/mean recipient artery diameter ratio exceeded 1.0 in all but one graft. The graft/artery diameter ratio at late follow-up was over 1.5 in 71% of the grafts. The mean graft blood flow determined by cine densitometric methods revealed a 30% or more reduction in blood flow in 35% of grafts, compared with early postoperative measurements.

THE WIDESPREAD APPLICATION of aortocoronary bypass surgery in selected patients with coronary artery disease has required both short- and long-term studies to determine the fate of autogenous saphenous vein grafts. It is generally appreciated that coronary bypass surgery is followed by symptomatic improvement; however, it is uncertain whether the surgical procedure prolongs life. Information regarding the fate of these grafts in terms of patency, morphologic changes and functional state as a conduit for blood supply to ischemic areas is of paramount importance. Serial arteriographic studies describing both morphologic changes and closure rates in these grafts have been reported, while other studies have described in detail the histologic changes at various times after surgery. The purpose of this report is to describe 2-week postoperative and late arteriographic studies of the early and late patency rate, morphologic changes and bypass flows in saphenous vein grafts in 85 patients.

Material and Methods

We present serial observations on 85 patients who received one or more saphenous vein bypass grafts as an isolated procedure between 1971–1977. During this time, 937 patients had isolated aortocoronary bypass surgery, with 13 (1.4%) operative deaths. Just before discharge from the hospital and after giving informed consent, 570 patients (61.7%) had repeat arteriography to evaluate the patency and morphologic aspects of their saphenous vein grafts. All implanted vein grafts in the 85 patients were patent at their initial postoperative studies. This initial study is a routine procedure performed in this institution as part of the overall evaluation of the patient before discharge from the hospital. The long-term follow-up arteriographic procedure was done either because angina pectoris recurred or as part of a study to evaluate the late results of aortocoronary bypass surgery. The only criterion used in selection was willingness of the patient to participate in this late postoperative evaluation. Surgical methods and diagnostic techniques used in these patients have been previously described. To facilitate the postoperative study, a metal clip was sutured to the aortic wall at the origin of each saphenous vein graft. We considered a graft closed if we could not visualize the graft by selective and aortic root injections. In the majority of instances, graft closure was marked by a dimple on the aortic wall adjacent to the metal clip. Patients in whom saphenous vein bypass could not be performed in all major coronary arteries with significant...
occlusive disease were considered incompletely revascularized; in most instances, either the diseased vessel was completely blocked, without any evident run-off, or diffuse distal disease was present. We considered progressive disease of the native coronary circulation to be present when the coronary score of that artery increased when compared with the preoperative study. Progression of coronary artery disease was evaluated in the three major coronary arteries; we considered the obtuse marginal artery an extension of the circumflex artery. Smaller branches were not evaluated. Only ungrafted vessels were evaluated for progressive disease, because progression proximal to the graft was not systematically evaluated.

Arteriographic studies were performed in multiple projections, including 60° right anterior oblique, 45° left anterior oblique and left lateral projections. Hemiaxial projections were not performed in these studies. Early and late postoperative flow studies were done in 30 patients by means of a roentgen densitometric method based on the mean transit time of the radiopaque medium along the graft and the mean graft diameter. Only in these 30 patients could criteria be fulfilled as previously described to perform duplicate flow studies. Others have used and validated this method and we have described it in detail. Briefly, cinedensitometric flow measurement is based on the derivation of a pair of indicator dilution curves from two points along the bypass graft. From two such curves, the mean transit time between the two points can be derived. When both the mean diameter and the distance between the two points of the graft are known, the mean flow can be derived. The method used for these studies has been reported in detail. We were particularly careful to ensure that the patient obliquity and image intensifier-patient distance were the same at both the early and late study.

The variables used to determine the bypass flow were obtained from graft segments judged parallel to the plane of projection. For flow derived from the left anterior descending graft, the right anterior projection was used and for both the right coronary and left circumflex artery graft, the left anterior projection was used. In comparing flow determinations made in early and late postoperative studies, differences in flow ≤ 10 ml/min were not considered significant, while differences > 10 ml/min were considered significant. To evaluate changes in graft diameter between the two studies, we derived an overall mean graft diameter from the average of three graft segments, including 1-cm segments from proximal, mid- and distal portions of the graft. The mean diameter of the native coronary artery adjacent to the point of the distal anastomosis was also obtained from a 1-cm segment of the artery. From the latter measurement, the mean graft-mean artery diameter ratio was derived. This ratio has been previously used in evaluating the relationship of graft and artery diameters. A Quantimet 720 image-analyzing computer system (Imanco) incorporated with a Tagarno cine projector and a 9830 HP software system (Hewlett-Packard) were used to obtain both bypass flow and mean vascular diameters. Results were expressed as the mean ± sd, and statistical comparison between initial and follow-up studies was determined by means of the t and chi-square tests.

### Results

#### Early and Late Patency

The initial early study (8–12 days postoperatively) revealed that 89.6% of 1197 grafts in 570 patients were patent. The highest patency rates were in the left anterior descending artery (92.0%) and the lowest (85.3%) in the left circumflex artery (table 1). The late

<table>
<thead>
<tr>
<th>Number of patients studied</th>
<th>Interval after operation (yrs)</th>
<th>Number of grafts studied</th>
<th>Grafts patent %</th>
<th>*Attrition rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.94</td>
<td>32</td>
<td>31</td>
<td>96.9</td>
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<tr>
<td>27</td>
<td>2.10</td>
<td>53</td>
<td>50</td>
<td>94.3</td>
</tr>
<tr>
<td>22</td>
<td>3.22</td>
<td>39</td>
<td>34</td>
<td>87.2</td>
</tr>
<tr>
<td>16</td>
<td>3.90</td>
<td>29</td>
<td>26</td>
<td>89.7</td>
</tr>
<tr>
<td>Total</td>
<td>2.46</td>
<td>153</td>
<td>141</td>
<td>92.2</td>
</tr>
</tbody>
</table>

*Percent of grafts closed per year.
follow-up (average 2.5 years) study in 85 patients discharged with all 153 grafts patent on the initial study revealed 92.2% still patent, with the highest late patency rate in the left circumflex artery (96.6%) and the lowest (89.6%) in the left anterior descending artery (table 1). Comparing these 85 patients with the remaining patients who did not have a late postoperative study revealed no significant differences in age, sex, risk factors, prior myocardial infarction, number of vessels having significant disease or number of vessels grafted. The mean annual graft attrition rate (percent of grafts closed per year) in the 85 patients with all grafts patent at the early postoperative study was 3.2% per year. Dividing these 85 patients into four groups dependent on the interval of time between the two postoperative studies disclosed only slight variations in the graft attrition rates (table 2). Thus, 20 patients were studied 5–16 months (average 0.94 years) after the initial study. The percent of grafts patent and the attrition rate were, respectively, 96.9% and 3.3% per year. In 27 patients, the interval between the two studies was 19–28 months (average 2.1 years); the graft patency was 94.3% and the graft attrition rate 2.7% per year. Twenty-two patients were studied 31–41 months apart (average 3.2 years), and 87.2% of grafts were patent, resulting in an annual attrition rate of 4.0% per year. Finally, in 16 patients studied 42–73 months apart (average 3.9 years), 89.7% of the grafts were still patent and the attrition rate was 3.2% per year. Of the 85 patients restudied, eight had one graft closed; two had two grafts closed, and the remaining 75 patients (88%) had all grafts patent.

Functional Status Related to Angiographic Findings

In the 85 patients with both early and late follow-up studies, 36 were referred for the second postoperative study because of recurrent angina pectoris. Figure 1 shows a comparison of the arteriographic findings of these 36 patients with the remaining 49 patients. Progressive coronary disease was present in 42% of the patients with recurrent angina pectoris, compared with only 18% in patients without pain (p < 0.025). The frequency of patients with progressive disease was directly related to the interval between the two studies (fig. 2). Thus, at a 2-year interval, 19% of patients had progressive coronary artery disease, compared with
50% at 4 years. Evaluating the progression of coronary disease by the number of vessels involved revealed that of 102 vessels not grafted, 29.7% had progression or new, significant lesions. Thus, the mean annual rate of progression or development of new lesions was 11.8% per year.

Graft closure was present in 22% and 4% of patients (fig. 1) with and without angina pectoris, respectively (p < 0.05), and incomplete revascularization was present in 39% of patients referred with recurrent angina compared with 16% without angina (p < 0.025). At least one of these three factors — progressive disease, graft closure or incomplete revascularization — was found in 83% of patients with angina pectoris compared with 37% without angina (fig. 1). In the patients with angina pectoris, the mean annual graft attrition rate was 6.1% per year, compared with 1.1% per year in the 49 patients without angina pectoris. Neither graft closure nor progressive coronary artery disease could be related to the frequency of hypertension, diabetes mellitus, cigarette smoking, a family history of coronary artery disease or the incidence of abnormal serum level of cholesterol or triglyceride.

**Graft Morphology and Blood Flow**

In the early postoperative study performed in 570 patients, 3.1% of the grafts had either proximal kinking or stenosis adjacent to the distal or proximal

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**Figure 3.** Early and late postoperative selective saphenous vein graft angiograms of the left anterior descending artery. Arrow points to proximal portion of saphenous graft showing, at late study, a localized area of stenosis. The rest of the graft shows uniform narrowing and the graft appears foreshortened.

**Figure 4.** Early (left panel) and late (right panel, 2 years later) postoperative selective saphenous vein graft angiograms of the right coronary artery viewed in the left anterior oblique projection. Note proximal localized narrowing (arrow) and shortening of the graft on the late postoperative study.
anastomotic site. In 85% of such instances, there was distal stenosis. In five patients who were reevaluated, the stenosis progressed in two, the graft closed in one and diffuse graft narrowing was present in two patients with graft kinking. In the remaining 137 grafts that were patent when restudied, 11 (8%) had significant localized narrowing: in eight at the proximal portion of the graft and in three adjacent to the distal anastomotic site. In the majority of such instances, it seemed that the late localized narrowing of the graft could be related to the presence of a proximal bend together with foreshortening of the entire graft (figs. 3 and 4). In most patent grafts, late follow-up showed uniform narrowing accompanied by foreshortening of the graft (fig. 5). The diameter of the graft was less than that of the native coronary artery adjacent to the distal anastomotic site in only one instance.

In 30 patients with 52 grafts, the mean graft diameter was determined at the early and late postoperative study (fig. 6). The average interval between the two studies in these 30 patients was 1.6 years. The mean diameter of the graft to the left anterior descending artery was 3.4 ± 0.6 mm at the initial study compared with 2.8 ± 0.6 mm at late follow-up (p < 0.01). Similarly, the mean diameter of the grafts to the right coronary and left circumflex artery was 3.5 ± 0.6 mm, while at the late postoperative study the mean graft diameter was 2.9 ± 0.6 mm (p < 0.01). In 13 of 52 grafts (25%), the follow-up study showed at least 25% reduction in mean diameter. Table 3 shows the relationship of the

![Figure 5](image-url)  
**Figure 5.** Early (2 weeks postoperatively) and late (1 year postoperatively) postoperative selective saphenous vein graft angiograms of the obtuse marginal artery of the left circumflex artery viewed in the right anterior oblique projection. Note uniform narrowing and shortening of the saphenous vein graft.

![Figure 6](image-url)  
**Figure 6.** Mean graft diameter of the grafts to the left anterior descending (LAD), right coronary (RCA) and the left circumflex artery (Circ). A = early postoperative study; B = late postoperative study. Horizontal bar is mean value for each study. N = number of grafts restudied.
Table 3. Change in Mean Graft Diameter as Related to Interval Between Study

<table>
<thead>
<tr>
<th>Interval between study (yrs)</th>
<th>Number of patients studied</th>
<th>Number of grafts studied</th>
<th>Mean graft diameter (mm)</th>
<th>Percent change in mean graft diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Initial study</td>
<td>Follow-up study</td>
</tr>
<tr>
<td>0.5</td>
<td>5</td>
<td>5</td>
<td>3.4</td>
<td>2.8</td>
</tr>
<tr>
<td>1.0</td>
<td>7</td>
<td>9</td>
<td>3.6</td>
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</tr>
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<tr>
<td>2.1</td>
<td>8</td>
<td>16</td>
<td>3.4</td>
<td>3.0</td>
</tr>
<tr>
<td>2.9</td>
<td>4</td>
<td>9</td>
<td>3.3</td>
<td>2.8</td>
</tr>
</tbody>
</table>

interval between the two postoperative studies and the percent reduction in mean graft diameter. Initially, the ratio of graft diameter to the coronary artery diameter adjacent to the anastomotic site was 2.0 ± 0.5 for the left anterior descending artery; at follow-up study, it was 1.7 ± 0.5 (p < 0.001). Similarly, the initial graft/coronary artery ratios were 2.1 ± 0.5 and 2.6 ± 0.6, respectively, for the right coronary and left circumflex vessels; at late follow-up, the corresponding ratios were 1.7 ± 0.6 and 2.0 ± 0.4 (p < 0.01). Of the 52 grafts in these 30 patients, at follow-up, 15 (29%) had a ratio > 1.5, and one had a ratio < 1, while at the initial study, only six (11.5%) had a ratio ≤ 1.5.

In these 30 patients, the mean graft flow was determined in both the early and late postoperative study (fig. 7). There was no significant difference in heart rate or mean aortic pressure during the two postoperative studies. Mean graft flow to the left anterior descending artery was 79 ± 39 and 67 ± 31 ml/min in the early and late follow-up studies respectively (p < 0.01). Similarly, the graft flow in the initial study was 65 ± 17 and 68 ± 25 ml/min for grafts to the right and left circumflex arteries, respectively, whereas at late follow-up, the corresponding graft flows were 42 ± 17 (p < 0.025) and 60 ± 24 ml/min (p < 0.01). In 18 of 52 grafts (35%), the late follow-up study showed at least 30% (average 45%) reduction in flow compared with the early postoperative study. In 18 other grafts, there was either no significant change (n = 14) or an increase (n = 4) in the flow at late follow-up.

Discussion

The present study indicates that the majority of aortocoronary vein graft occlusions occur during the early postoperative period. In 570 patients, arteriographic study within 2 weeks after surgery revealed that 10.4% of 1197 grafts were closed. Selection of patients for this early postoperative study was based only on the willingness of the patient to undergo evaluation just before discharge. Late follow-up (average 2.5 years) showed that 7.8% of 153 grafts in 85 patients were closed. Others have reported early postoperative closure rates of 8-12%. Some studies in which the initial evaluation was performed within the first year after surgery, have implied that the majority of graft closures occur 3-6 months after surgery. Our findings and those of others indicate that the early postoperative period is more important for graft closure. In our experience, early graft closure has resulted from mechanical problems, including faulty surgical technique, inadequate size of the coronary vessels and poor run-off. Other studies and our own experience indicate that adequate run-off as reflected by intraoperative flow measurement is an important predictor of early graft patency. In our experience, early closure of a graft with a high (> 60 ml/min) intraoperative flow indicates technical problems with the graft or mechanical compression. In 10 such patients who were reoperated 2 weeks after initial surgery, early closure resulted from kinking of the graft or from mechanical compression of the graft by either a pericardial band or thymus. Kinking and stenosis of a graft, observed in 3.1% of grafts in the early postoperative study, is usually secondary to poor surgical technique. Improper length of a graft may lead to redundancy and kinking if the graft is too long; excessive tension on the graft may occur if it is too short.

![Figure 7. Mean graft flow to left anterior descending (LAD), right coronary (RCA) and left circumflex artery (Circ). A = early postoperative study; B = late postoperative study. N = number of grafts restudied. Horizontal bar is the mean value for each study.](http://circ.ahajournals.org/doi/abs/10.1161/01.CIR.60.4.906)
Such faulty technique is more likely to result in late
graft occlusion.\textsuperscript{1, 3, 4, 9, 25, 26} Campeau et al.\textsuperscript{26} reported
improved results when they compared an early series
of patients with a later group that underwent
modification of the surgical technique. Modifications
included different techniques for isolating the
saphenous vein and performing the anastomosis. The
2-week postoperative patency rate was 85.3\% vs 91.8\%
after modification of surgical technique with a reduc-
tion of localized stenosis from 15 to 5.5\% (p < 0.025).
Such a modification in technique was also accom-
panied by significant changes in late patency; the
1-year patency rate was 67\% in the early series, but
after modification of technique, 1-year patency was
85.5\% (p < 0.005). Differences in technique at the
distal anastomosis affect both early and late patency
rates.\textsuperscript{25, 26} High intraoperative flow is not only
associated with a higher early patency rate, but also
with a higher late patency rate.\textsuperscript{8, 9, 25} Differences in
early patency rate from series to series can best be ex-
plained by differences in surgical technique.

Complete revascularization has resulted in 87\% of
patients becoming asymptomatic, compared with 56\%
and 42\% of patients with partial or no revasculariza-
tion, respectively.\textsuperscript{23} Thus, long-term patency of
saphenous vein bypass grafts, which has been the sub-
ject of various studies,\textsuperscript{1, 4, 7, 10, 26, 27} should be accom-
panied by continuation of this improved clinical state.

The mean annual graft attrition rate (percent of grafts
closed per year) of grafts open after surgery has varied
from 0.9–8.4\%, with the majority of studies reporting
mean annual graft attrition rates <3\% per year. In the
present study, the mean annual graft attrition rate was
3.2\% per year. We evaluated our results on the basis of
the interval between the two postoperative arterio-
graphic studies (table 2), and found that attrition rates
for the various time intervals varied only slightly,
ranking from 2.6–4.1\% per year. Thus, within the time
intervals indicated in table 2, the attrition rates reflect
the anticipated annual frequency of graft closure.
However, patient selection influences the attrition rate
in any study. Thus, in the 36 patients referred for
restudy because of angina pectoris, the graft attrition
rate was 6.1\% per year, while in the 49 patients
restudied but without angina, the attrition rate was
only 1.1\% per year. Similarly, Campeau et al.\textsuperscript{3}
reported an annual attrition rate of 2.4\% per year;
however, in their patients restudied because of angina
pectoris, the attrition rate was 6.5\% per year. Lawrie
and associates\textsuperscript{40} observed a graft patency of 91\% in
asymptomatic patients studied more than 5 years after
surgery, compared with 81\% in symptomatic patients.
However, the most frequent finding associated with
recurrent angina pectoris after aortocoronary bypass
surgery was progressive disease in the native circula-
tion (fig. 1). Forty-two percent of the patients with
recurrent angina pectoris had evidence of progressive
coronary artery disease, compared with only 18\%
without recurrent symptoms, while graft closure was
observed in 22\% of patients with recurrent symptoms
compared with only 4\% of those without angina. In
83\% of patients with recurrent angina pectoris, there
was progressive coronary disease, graft closure or in-
complete revascularization, compared with only 37\% in
patients without recurrent symptoms. In a study by
Seides and co-workers\textsuperscript{2} encompassing a 5-year follow-
up, recurrent angina pectoris was observed in 11
patients, and nine had progressive coronary disease in
the ungrafted vessels. Similarly, Robert et al.\textsuperscript{27} in a 5-
year postoperative follow-up, observed progressive
coronary disease in 88\% of patients with symptomatic
deterioration, compared with 27\% whose clinical
status was unchanged. They concluded that symp-
tomatic deterioration related more to progressive coro-
nary disease than to graft failure. In the present
study, the mean annual rate of progression of disease
or development of new lesions in ungrafted coronary
vessels was 11.8\% per year compared with 6.7–11\%
per year reported by others.\textsuperscript{3, 27, 28} Progression of the
coronary artery disease was related to the time inter-
val between observations (fig. 2). Bemis et al.\textsuperscript{40}
observed that plasma lipid abnormalities were
associated with subsequent arteriographic evidence of
progressive coronary disease, but others\textsuperscript{27, 31, 32} have
not found any relationship between any risk factor and
progressive coronary disease.

Histologic\textsuperscript{5, 11-17} and angiographic\textsuperscript{1, 4, 7, 10, 24} studies
have described morphologic changes in saphenous vein
bypass grafts. Histologic changes in saphenous
Arterial coronary bypass grafts have also been observed when
autogenous vein grafts were used for femoropopliteal
bypass surgery.\textsuperscript{39} The histologic changes include en-
dothelial injury, fibrous overgrowth, especially in the
intimal layer, intimal lipid deposition and, rarely, aneurysmal
dilatation. The changes that occur in such
grafts eventually result in a "stiff, fibrous-tissue con-
duct."\textsuperscript{11} One month after surgery, intimal fibrous
proliferation is invariably present. Initially, this is un-
even in distribution, but eventually becomes circu-
mferential and diffuse to various degrees, and, in
some cases, becomes extensive enough to result in late
focal stenosis or occlusion with or without thrombosis.
In the majority of instances, the intimal fibrosis results in
an almost uniform reduction in the caliber of the
graft and only rarely results in a graft luminal
diameter < 1.5 times that of the recipient artery. The
changes observed in arterIALIZATION of the saphenous
vein are possibly related to elevated luminal pressure,
trauma and thrombosis resulting in intimal alteration
and medial and adventitial ischemia as a result of the
loss of vasa vasorum and increased transmural
pressure. In saphenous vein grafts, atherosclerotic
changes\textsuperscript{12-15} consisting of intimal fibrous plaque laden
with foam cells have been reported by Lie and
associates\textsuperscript{41} to be influenced by hyperlipemic states.
After 12 months, only three of 26 grafts from nor-
molipemic patients had atherosclerotic changes,
compared with 11 of 14 grafts from hyperlipemic cases.\textsuperscript{33}
However, in saphenous grafts used for femoropopliteal
grafts, atherosclerotic changes in 7.7\% of cases
could not be related to serum lipid levels, cigarette
smoking, diabetes mellitus or atherosclerosis in other
organs.\textsuperscript{33}

Usually, late angiographic studies have shown
structural alterations in the saphenous vein graft consisting of various degrees of reduction of the graft lumen, usually uniform but occasionally localized. 

The frequency of segmental stenosis has varied from 1.7–20% in these late studies. In the early series of Campeau et al., late, localized stenosis (≥40%) was observed in 16.5% of grafts, whereas in a later series, after modification of surgical technique, the frequency was only 6% (p < 0.025). This suggests that in some instances even late graft stenosis is related to surgical technique. In the present study, 11 grafts (8%) developed late segmental stenosis, which was adjacent to the proximal anastomosis in eight (figs. 3 and 4). Such proximal stenoses seemed to be related to a proximal bend in the graft, accentuated as a result of graft foreshortening (fig. 3). Restudy of saphenous vein grafts has almost invariably revealed uniform reduction in the caliber-angiographic correlate of intimal fibrous proliferation. The foreshortening of the graft is probably related to fibrotic replacement in the media and adventitia. Thus, the late angiographic morphology of a saphenous vein graft shows a fibrous rigid tissue arterial conduit.

In the 1-year postoperative study of 60 grafts reported by Lesperance and co-workers, compared with their early 2-week postoperative study, 17 (28%) had little or no change in internal diameter, 28 (47%) had a slight (20–40%) and 15 (26%) a moderate (40–60%) reduction in internal diameter. In a later study, only 12.7% of grafts had diffuse narrowing ≥40%. In the present study, the mean graft diameter for the entire study group was reduced by 17% on late study, and 25% of the grafts had a reduction in mean diameter ≥25%. There was no evident difference in reduction of graft diameter and the particular recipient coronary artery (fig. 6). The majority of grafts (71%) maintained a mean graft diameter/artery diameter ratio >1.5 on late follow-up, with only one graft ratio <1. Thus, despite the reduction in mean graft diameter, the saphenous graft maintained a cross-sectional luminal area greater than that of the recipient artery. In an earlier study, comparing internal mammary artery grafts with saphenous vein grafts to the left anterior descending artery, the mean graft diameter/artery diameter ratios were 1.2 and 1.9, respectively (p < 0.01). In the present study, the graft/artery ratio to the left anterior descending artery was 2.0 initially and 1.7 in the late study. Thus, despite the reduction in the mean graft diameter, the relationship to the recipient artery remains favorable when compared with internal mammary artery grafts. The reduction in mean graft diameter does not appear to be progressive in nature, as evidenced by the lack of progressive luminal reduction as the interval between studies increased (table 3). Neither Lesperance nor Lawrie and co-workers found evidence of any further reduction in graft caliber 12 months after surgery.

The change in the graft caliber was accompanied by a similar directional change in mean graft flow (fig. 7). In almost one-third of the grafts restudied, the reduction in mean graft flow was at least 30%. In an earlier study, the mean graft flow in 25 internal mammary artery grafts was 46 ml/min, significantly less than that observed in saphenous vein grafts to the left anterior descending artery (p < 0.01). However, the late morphologic alterations in the saphenous vein grafts at subsequent follow-up study might offset the differences in blood flow in these two types of grafts. In the present study, although there was a reduction in mean blood flow (79 ml/min to 67 ml/min) in saphenous vein grafts to the left anterior descending artery, the late study still showed a higher flow in saphenous vein grafts compared with the early flow studies in the internal mammary artery. Finally, late studies (>1 year) of luminal diameter changes in internal mammary arteries are not available, and such grafts are not immune to atherosclerotic changes.

Thus, in the present study, the majority of grafts studied were mildly to moderately reduced in luminal diameter, but not enough to cause an unfavorable graft/artery diameter ratio and adequate in 60% of instances to maintain a resting graft flow ≥50 ml/min.

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