Journal of the American College of Cardiology
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Published by Elsevier Inc.

Vol. 51, No. 2, 2008
ISSN 0735-1097/08/$34.00
doi:10.1016/j.jacc.2007.09.029

EDITORIAL COMMENT

Coronary Artery Bypass Graft Patency and Competitive Flow*

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Factors Influencing Bypass Graft Patency

Ever since the observation by Loop et al. (1) that internal thoracic arteries (ITA) are more effective coronary artery bypass grafts than saphenous veins in prolonging patient survival and preventing recurrent ischemic events, cardiothoracic surgeons have tried to improve the results of surgical revascularization by using other arteries as bypass conduits, such as the gastroepiploic, radial, and inferior epigastric arteries (2–4). The better patient outcomes observed with ITA grafts are related to their excellent long-term stable patency (5). Saphenous vein graft patency is not stable; it declines with time from development of vein graft arteriosclerosis. From 1 to 5 years after surgery, saphenous vein grafts occlude at a rate of 1% to 2% per year, accelerating to 4% to 5% per year by 6 to 10 years. By 10 years, only 50% to 60% of these grafts are patent, and only one-half of these are free of angiographic arteriosclerosis (6,7). Unlike saphenous veins, ITA grafts rarely develop arteriosclerosis (<4%), and only 1% develop important arteriosclerotic luminal narrowing (8). This resistance to arteriosclerosis results in 90% of ITA grafts being patent 10 years after surgery (5,6). Surgeons have hoped that other arterial grafts would behave similarly.

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However, factors other than arteriosclerosis influence graft patency. An important factor affecting *early* arterial graft patency is native coronary artery blood flow (5,6,9). When an arterial graft is used to bypass a coronary artery with only moderate proximal stenosis, the need for bypass blood flow is low, causing the graft to constrict and fail. This is consistent with the physiology of arteries. Unlike saphenous veins, arteries are muscular and can autoregulate their lumen in response to blood flow demand. This phenomenon influencing arterial graft patency is referred to as native coronary artery competitive blood flow, but because it is difficult to measure, maximum coronary artery stenosis (either in the native artery proximal to the graft or in the entire pathway between graft and aorta) is often used as its surrogate.

Choice of Conduit

These observations—that different factors influence arterial and vein graft patency and that they act at different times, arteriosclerosis decreasing late vein graft patency and competitive flow decreasing early arterial graft patency—influence surgeons' decisions about what conduit is most likely to be best (remain patent) for an individual coronary artery with a specific stenosis. Surgeons ask 2 questions when choosing between arterial and saphenous vein conduits: 1) is there a degree of coronary artery stenosis below which a saphenous vein graft will more likely remain patent and therefore be more effective than an arterial graft? and 2) how does this comparison change over time as vein grafts fail from development of vein graft arteriosclerosis?

Answers to these questions have been reported for ITA and saphenous vein grafts. For all left-sided coronary arteries and the posterior descending coronary artery, both early and late ITA graft patency is better than saphenous vein graft patency at all levels of clinically important (≥50%) coronary artery stenosis and at all points in time (6). Therefore, an ITA should always be a more effective graft than a saphenous vein for bypassing stenoses in these coronary arteries or their branches. However, this is not true for the right coronary artery (RCA). Early (<5 years) after surgery, saphenous vein grafts seem to have better patency than ITA grafts unless the RCA is severely (>80% to 90%) stenosed; late (≥10 years) after surgery, however, ITA grafts are more likely to be patent than saphenous vein grafts (6). Thus, early after surgical revascularization, ITA grafts are less effective than saphenous vein grafts when bypassing a moderately stenosed main RCA; late after surgery, ITA grafts are likely to be more effective. Therefore, ITA grafting of the main RCA should be reserved until it is at least 70% stenosed.

Gastroepiploic Artery Grafts

In this issue of the *Journal,* Glineur et al. (10) report an investigation on the first of the aforementioned 2 questions for gastroepiploic artery and saphenous vein grafts when used to bypass the RCA and its branches. They evaluate which pre-operative angiographic variables (surrogates for native coronary artery competitive flow) might influence gastroepiploic artery and saphenous vein graft patency 6 months after coronary artery bypass surgery. Consecutive patients were randomized to receive either a gastroepiploic artery (n = 90) or a saphenous vein graft (n = 82) to bypass the posterior descending artery or posterolateral branch of the RCA. Follow-up angiography was performed 6 to 8 months post-operatively. The angiographic surrogates for

*Editorials published in the *Journal of the American College of Cardiology* reflect the views of the authors and do not necessarily represent the views of *JACC* or the American College of Cardiology.

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native coronary artery competitive blood flow used in the analysis were: 1) pre-operative maximum coronary artery stenosis and 2) minimum lumen diameter. Other angiographic variables included in their analysis were RCA diameter, location of stenosis, run-off of RCA, and regional wall motion abnormality. At 6 months, there was a statistically significant difference in functioning gastroepiploic (62%) and saphenous vein (85%) grafts. Gastroepiploic patency increased as minimum lumen diameter decreased (surprisingly, coronary run-off was not associated with graft patency). When minimum lumen diameter of the RCA was 0 (100% stenosed), all gastroepiploic grafts were patent, whereas when it was >1.4 mm, only 5% were functioning. The authors identified a threshold of ≤1 mm for minimum lumen diameter where gastroepiploic artery patency was best. Not surprisingly, saphenous vein patency was much less influenced by competitive flow. The authors conclude that most saphenous vein grafts and only a minority of gastroepiploic grafts remain patent when RCA minimum lumen diameter is >1 mm and recommend that, in patients with RCA stenosis of intermediate severity, saphenous vein grafts are preferable to gastroepiploic artery grafts.

Comments

This is a well-done study that contributes important new knowledge to our understanding of graft patency. The study design had many strengths. First, it was a randomized trial; there are few randomized trials comparing conduits in coronary artery bypass surgery, and this is the first to compare saphenous vein and gastroepiploic artery grafts. Second, in addition to maximal percent stenosis, the authors for the first time use minimum lumen diameter as a surrogate for competitive flow. Maximum percent stenosis is not as good a measure of competitive flow as minimum lumen diameter. This makes physiologic sense: Competitive flow through a 50% stenosed, 5-mm RCA must be greater than that through a similarly stenosed 2-mm artery. Using only maximal coronary artery stenosis does not adjust for coronary artery size, whereas minimum lumen diameter does. In future studies of the effect of competitive flow on graft patency, minimum lumen diameter rather than maximal coronary artery stenosis should be used as a surrogate for competitive flow. The authors should be credited with this important contribution. Third, a validated quantitative angiographic analysis was used to determine severity of coronary artery stenosis. Although such methods are used routinely in interventional cardiology studies, visual inspection with stenosis estimates is the norm in the published surgical reports.

The principal findings of the article are valuable in that they will assist cardiothoracic surgeons in making conduit decisions for RCA revascularization. Surgeons should no longer use only maximal coronary artery stenosis but instead rely more on minimum lumen diameter. From the data in this report, it seems that for coronary minimum lumen diameters of ≤1 mm, gastroepiploic artery graft patency is at least equivalent if not better than that of saphenous vein grafts at 6 months. An important unanswered question is what happens to gastroepiploic artery graft patency in the long term, for little is known about this. Do they remain patent like an ITA graft or gradually occlude like a saphenous vein graft? Suma et al. (2) have reported that gastroepiploic patency declines over time, from 91% at 1 year to 80% at 5 years to 62% at 10 years. If these percentages are correct, there does not seem to be much benefit of gastroepiploic artery grafting. However, this would depend on the rate of decline in patency compared with that of vein grafts. These are important unknowns, and hopefully, the authors will follow their patients longitudinally to answer these questions.

A missed opportunity for the authors was analyzing how pre-operative conduit variables influenced arterial graft patency. For example, how do conduit lumen diameter and blood flow influence arterial graft patency? Such knowledge could assist surgeons in making conduit decisions. Although the authors measured gastroepiploic diameter, this did not seem to have been entered into the analysis. A larger arterial conduit with greater blood flow is more likely to remain patent, despite only moderate native coronary stenosis, than a smaller arterial conduit.

So, should an arterial graft ever be used to revascularize the RCA? We (11) as well as Gilneur et al. (10) believe that, besides using an ITA to graft the left anterior descending coronary artery (LAD), a second arterial graft is beneficial. However, this is not widely accepted, as demonstrated by data from the Society of Thoracic Surgeons' Adult Cardiac National Database: in 2003, only 3% to 4% of patients undergoing surgical coronary revascularization received bilateral ITA grafts. It is also important to note that surgeons who do believe that bilateral ITA grafting has clinical benefit preferentially use the second ITA to bypass the second most important (after the LAD) left-sided coronary artery, not the RCA. This preference is based on the observation that, owing to competitive flow, arterial grafts to the RCA have a lower patency than when used to bypass left-sided coronary arteries (6). There is also no evidence that using an arterial graft to the RCA or its branches confers patient benefit. However, logic would dictate that if a gastroepiploic artery graft is more likely to remain patent than a saphenous vein graft and therefore more effective, it should confer some patient benefit, such as angina relief. This requires further investigation.

In summary, the report by Glineur et al. (10) is well done and adds important information on 6-month gastroepiploic patency. It also sets the standard for how future studies of comparative bypass conduit patency studies should be performed: in a randomized manner with quantitative analysis of coronary stenosis. Although the study suggests that, for patients with *severe* stenosis of the RCA, gastroepiploic artery grafts are more likely to be patent early after surgery,

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January 15, 2008:126–8

the important question is whether they are more effective than saphenous vein grafting in the long term.

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