Clinical Investigation

Scoring System for Predicting Saphenous Vein Graft Patency

in Coronary Artery Bypass Grafting

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The initial and long-term benefits of coronary artery bypass grafting depend upon maintaining the coronary blood flow supplied by the graft. In order to devise a scoring system for predicting graft patency, we evaluated presumptive correlations between saphenous vein graft patency and the characteristics of saphenous veins that were used as conduits in coronary revascularization.

We prospectively evaluated 1,000 saphenous vein segments that were implanted in 403 consecutive patients who underwent on-pump coronary artery bypass grafting at our hospital from January 2006 through February 2009. Branches, varicosity, diameter, and wall thickness were evaluated, and a scoring system was created in order to obtain a value for each characteristic. The patients were postoperatively monitored for 1 year, and graft patency was then evaluated with the use of 64-slice multidetector computed tomography.

Lesions were found in 12.3% of the grafts. All of the evaluated characteristics of the grafts had a significant correlation with saphenous vein graft flow (P <0.0001). Using the venous characteristics in our statistical analysis, we devised a formula to obtain a score (range, 4–12) to predict the patency of each graft. A cutoff score of 7 yielded 87.8% sensitivity and 82.8% specificity.

Our scoring system has good prognostic value. We believe that it can assist surgeons in choosing the most appropriate conduit and target vessel for coronary artery bypass grafting, especially in high-risk patients who are particularly dependent on blood flow through saphenous vein grafts. ***(Tex Heart Inst J 2010;37(5):525-30)***

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Graft patency is known to have reliable prognostic value in the outcome of coronary artery bypass grafting (CABG). Although the internal mammary artery is commonly used by cardiac surgeons, more than 1 graft is usually required in CABG.

The use of saphenous veins as conduits in CABG has become an established method in treating intractable angina and improving the long-term prognosis in selected populations.[1] Saphenous vein graft (SVG) conduits typically last 10 years.[2-5] However, 15% of SVGs occlude within the 1st year.[6,7]

In order to formulate a scoring system for the prediction of graft patency, we prospectively evaluated presumptive associations between SVG patency and characteristics of saphenous veins that are used as conduits in CABG.

Patients and Methods

From January 2006 through February 2009, 1,000 SVGs were implanted by 2 surgeons in 403 consecutive patients who underwent elective on-pump CABG with no associated procedures. Emergent cases were excluded. Table I shows the characteristics of the patients.

This study was approved by our hospital's Institutional Human Research Committee. Informed written consent was obtained from each patient.

Source of Conduit Vessels. We recorded whether the saphenous veins that were used as conduits were harvested from the right or left calf or thigh. As Table II shows, 65.4% of the veins were harvested from calves and 34.6% from thighs. No thrombosed saphenous vein was used as a graft conduit.

TABLE I. Characteristics of the 403 Patients

Characteristic	Value
Age, yr	57.5 ± 9.1
Male	74.9
Left ventricular ejection fraction	0.42 ± 0.11
Hyperlipidemia	45.2
Hypertension	42.2
Diabetes mellitus	32.8
Smoking	31.8
Family history of ischemic heart disease	23.3
No. of grafts in each patient	2.5 ± 1.1

Data are presented as mean ± SD or as percentage.

TABLE II. Characteristics of the Saphenous Veins, the Target Vessels, and SVG Patency

Characteristic	Category	Percentage
SVG origin	Left calf	54.4
	Left thigh	25.1
	Right calf	11.0
	Right thigh	9.5
SVG branches	None*	36.6
	Few**	37.3
	Multiple***	26.1
SVG varicosity	Nonvaricose*	64.8
	Semivaricose**	27.9
	Varicose***	7.3
SVG diameter	Normal*	49.0
	Dilated**	34.7
	Small***	16.3
SVG wall thickness	Thin*	65.2
	Medium**	15.2
	Thick***	19.6
Target vessels for implantation	D	32.5
	LAD	4.6
	LCx	15.5
	OM	24.5
	PDA	10.5
	RCA	12.4
Target-vessel runoff	Good	66.6
	Relatively good	19.0
	Relatively poor	10.0
	Poor	4.4
SVG patency 1 year after surgery	Normal	87.7
	Localized stenosis	3.7
	Multiple stenoses	2.6
	Occluded	6.0

D = diagonal coronary artery; LAD = left anterior descending coronary artery; LCx = left circumflex coronary artery; OM = obtuse marginal coronary artery; PDA = posterior descending coronary artery; RCA = right coronary artery; SVG = saphenous vein graft

In accordance with our scoring system:
* 1 point
** 2 points
*** 3 points

Scoring System

We considered the characteristics of the harvested saphenous veins and created a scoring system that consisted of the following components (Table II).

Branches. The harvested veins were classified as follows with respect to number of branches: None, when there were no significant furcated branches from the lumen (score, 1 point); Few, when there were 3 or fewer furcated branches (2 points); or Multiple, when there were more than 3 branches (3 points).

Varicosity. At the surgeons' discretion, the quality of each vein was classified as Nonvaricose (1 point), Semivaricose (2 points), or Varicose (3 points).

Diameter. When a venous segment was continuous, had an internal diameter from 3 mm to 5 mm, and progressively increased in size proximally, it was classified as Normal (1 point). A venous segment with an internal diameter of more than 5 mm was classified as Dilated (2 points). A venous segment with an internal diameter of less than 3 mm was classified as Small (3 points). Veins that were not continuous or did not increase in size proximally were excluded from the study.

Wall Thickness. On the basis of touch, the surgeons classified venous walls as Thin (1 point), Medium (2 points), or Thick (3 points).

To arrive at a prognostic score for early graft patency after CABG, we tallied the points for each vein characteristic, as follows: Vein Score = Branches + Varicosity + Diameter + Wall Thickness (Table III). The best possible score was 4 (1 point in each category, indicating a good patency result), and the worst possible score was 12 (3 points in each category, indicating a poor result).

Characterization of the Target Vessels

Table II shows the coronary arteries and branches to which the saphenous veins were grafted. In accordance with preoperative angiographic findings, the runoff of the native coronary arteries was classified as Good (normal runoff), Relatively Good (when parietal irregularities were present), Relatively Poor (when distal runoff was very irregular), or Poor (when distal runoff was not seen).

Monitoring of the Patients

Each patient was started on aspirin postoperatively. Quarterly follow-up examinations were conducted. One year after surgery, all grafts were evaluated with the use of 64-slice multidetector computed tomography (MDCT). Two observers (blinded to the study) interpreted and reached consensus on the axial, multiplanar reconstruction, and 3-dimensional volume-rendered MDCT images.

Graft Patency. Grafts with no evidence of luminal stenosis were classified as Normal. Diseased conduits were classified as Localized, when there was a local lesion;

TABLE III. Correlation between Saphenous Vein Characteristics, the Target Vessels, and SVG Patency after 1 Year

Variable	Categories	Normal Flow (%)	Localized Stenosis (%)	Multiple Stenoses (%)	Occluded Flow
Origin of harvested saphenous vein	Left calf	92.3	1.7	3.7	2.4
	Left thigh	81.3	7.6	2.4	8.8
	Right calf	90.9	0	0	9.1
	Right thigh	74.7	9.5	0	15.8
Branches	None	94.3	3.8	0.5	1.4
	Few	86.3	6.2	2.7	4.8
	Multiple	80.5	0	5.4	14.2
Varicosity	Nonvaricose	95.5	2.9	0.3	1.2
	Semivaricose	77.1	3.9	4.7	14.3
	Varicose	58.9	9.6	15.1	16.4
Diameter	Normal	99.0	1.0	0	0.0
	Dilated	83.0	2.0	7.2	7.8
	Small	63.8	15.3	0.6	20.2
Wall thickness	Thin	99.5	0.2	0.2	0.2
	Medium	75.7	6.6	11.2	6.6
	Thick	57.7	13.3	4.1	25.0
Target vessels	D	92.0	3.1	2.2	2.8
	LAD	73.9	15.2	6.5	4.3
	LCx	94.8	1.9	1.3	1.9
	OM	87.8	3.3	3.7	5.3
	PDA	81.9	4.8	4.8	8.6
	RCA	77.4	3.2	0	19.4
Target-vessel runoff	Good	95.6	1.2	0	3.2
	Relatively good	78.9	9.5	10.5	1.1
	Relatively poor	65.0	9.0	5.0	21.0
	Poor	56.8	4.5	2.3	36.4

D = diagonal coronary artery; LAD = left anterior descending coronary artery; LCx = left circumflex coronary artery; OM = obtuse marginal coronary artery; PDA = posterior descending coronary artery; RCA = right coronary artery; SVG = saphenous vein graft

P <0.0001 for all evaluated vein characteristics in relation to SVG patency after 1 year. *P* <0.05 was considered statistically significant.

Multiple, when there was more than 1 lesion; or Occluded, when a lesion completely occluded the lumen.

Statistical Analysis

All results were expressed as mean ± SD for continuous variables and as percentage for categorical variables. The analytical software was SPSS version 15 (SPSS Inc., an IBM company; Chicago, Ill). The χ^2 test was used to define the association between SVG patency and the categorical variables. One-way analysis of variance was used to define the association between SVG patency and the continuous variables. The Bonferroni correction was used for post hoc comparisons. Receiver operating characteristic (ROC) curve analysis, positive predictive value, and negative predictive value, as well as specificity and sensitivity, were used to evaluate the validity of the predictive cutoff point. The binomial exact method[8] was used to calculate 95% confidence intervals (CIs) for sensitivity, specificity, positive predictive value, and negative predictive value. A logistic regression model was constructed to calculate the odds ratios for the variables that might have influenced graft patency. A *P* value of less than 0.05 was considered statistically significant. The data conformed to each test by which they were analyzed.

Results

In our study, all 403 patients underwent postoperative 64-slice MDCT. After 1 year, flow was normal in 87.7% of the grafted conduits. One or more nonocclusive lesions had developed in 6.3% of the conduits, and 6% were occluded (12.3%). Table III shows the correlation between the veins' characteristics, the target vessels, and SVG patency after 1 year. All evaluated characteristics of the veins had a statistically significant correlation with SVG flow (*P* <0.0001). For this analysis, the χ^2 test was used, and the distribution of each variable was examined; the *P* value was related to the difference in frequency distribution of all groups.

Vein Scores

The prognostic scores (mean ± SD) for the vessels were: Normal, 6.1 ± 1.5; Localized, 8.5 ± 1.4; Multiple, 9.1 ± 1.1; and Occluded, 10 ± 1 (Fig. 1). The mean of the prognostic score in the Normal and Localized groups differed from that of the Multiple and Occluded groups (*P* <0.0001) (Fig. 1). Our results showed that, after 1 year, 41.7% of SVGs that scored 7 or more points developed 1 or more lesions (a poor result), whereas 98% of SVGs with a score below 7 exhibited no marked lesion (a good result).

The ROC curve had an area under the curve of 92.7% (range, 90.6%–94%) at a 95% CI (Fig. 2). At 95% CIs, a cutoff score of 7 yielded an 87.8% sensitivity (range, 80.7%–93%), an 82.8% specificity (range, 80.1%–85.2%), a 41.7% positive predictive value (range, 35.6%–48%), and a 98% negative predictive value (range, 96.7%–98.9%).

The mean of the vessel scores was calculated for each patient, and a logistic regression model was constructed in order to analyze the vessels that were found to be occluded on MDCT imaging. Upon multivariate analysis, only the number of grafted vessels and the mean of the vessel scores had significant odds ratios (Table IV). At a 95% CI, a cutoff point of 7 yielded an odds ratio of 26.7 (range, 14.2–50.3) for scores above 7.

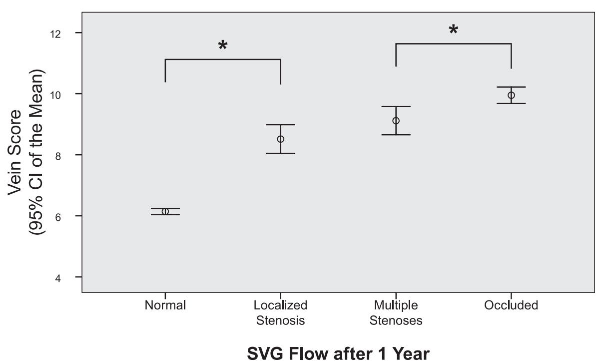

Fig. 1 *The mean scores in each group of vessels in accordance with the degree of stenosis after 1 year.*

CI = confidence interval; SVG = saphenous vein graft

**P <0.0001 between paired groups. P <0.05 was considered statistically significant.*

Discussion

Apart from the technical success or failure of proximal or distal anastomosis, the patency of SVGs can depend

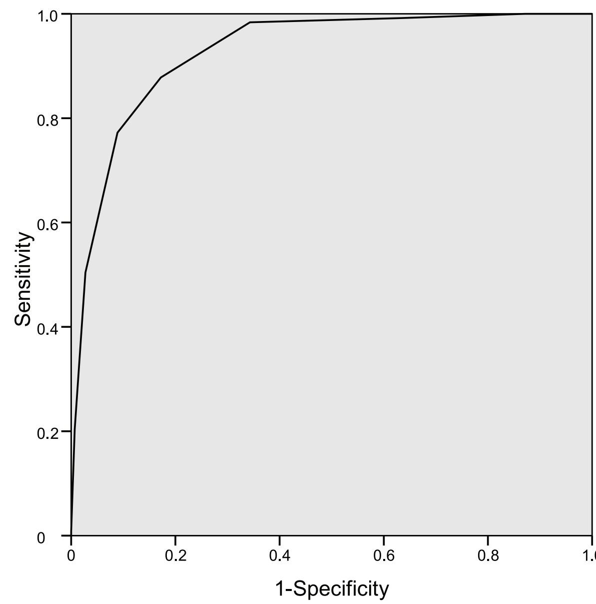

Fig. 2 *Receiver operating characteristic curve for obtaining the predictive cutoff point.*

TABLE IV. Odds Ratios of the Variables upon Univariate and Multivariate Analysis

	Univariate Analysis			Multivariate Analysis		
Characteristic	**B**	**OR**	***P* Value**	**B**	**OR**	***P* Value**
Male	–0.05	0.95	0.847	0.85	2.34	0.063
Age	0	1.00	0.811	0.01	1.01	0.788
Left ventricular ejection fraction	0	1.00	0.885	–0.01	0.99	0.748
No. of grafted vessels	0.37	1.45	0.001	0.79	2.19	0
Hypertension	0.44	1.55	0.071	0.09	1.09	0.935
Hyperlipidemia	0.39	1.48	0.102	–0.38	0.68	0.718
Diabetes mellitus	0.56	1.74	0.024	0.33	1.40	0.534
Family history of ischemic heart disease	–0.47	0.62	0.078	0.95	2.58	0.152
Smoking	0.56	1.74	0.025	1.09	2.97	0.066
Mean of vessel scores*	1.58	4.87	0	1.80	6.08	0

B = regression coefficient; OR = odds ratio

P <0.05 was considered statistically significant.

*Vessel score was the sum of Branches + Varicosity + Diameter + Wall Thickness.

upon disease processes, venous characteristics, and the magnitude of the vascular bed for runoff.[9]

Three well-described, distinct disease processes are known to influence the early or late failure of SVGs. During the first 30 postoperative days, up to 12% of grafts may become occluded; this is referred to as acute graft failure.[5] Between 1 month and 1 year, neointimal hyperplasia (the accumulation of smooth muscle cells and extracellular matrix in the intimal compartment) can occur. Although this condition rarely leads to a clinically significant stenosis,[10] it could provide the foundation for the development of graft atheroma. After the 1st postoperative year, late graft failure can occur in the form of graft vasculopathy (accelerated atherosclerosis), which is present in 17% of grafts after 6 years and in 46% of grafts after 11 years.[11] In our series, 87.7% of the grafts were patent after 1 year, which is in accord with rates reported in other studies.[6,7]

The influence of saphenous vein characteristics on SVG patency has been evaluated previously. Most investigators have used coronary angiography or MDCT to compare early results of graft patency after construction of arterial and venous conduits during CABG.[12-14] Traditional coronary artery angiography is invasive and can cause serious or even fatal complications.[15,16] Less invasive methods, such as MDCT, have resulted in considerably fewer complications and are economical.[17] Studies have shown that 64-slice MDCT can detect stenosis or occlusion in CABG with acceptable sensitivity and specificity.[14,18]

Poor runoff from the target vessel has an adverse impact on graft patency.[9,19] In our study, 36.4% of the SVGs implanted in coronary arteries with poor preoperative runoff were totally nonfunctional after 1 year; conversely, 95.6% of the SVGs implanted in arteries with good preoperative runoff were completely functional. This finding agrees with results of other studies and reinforces the point that a maximal stenosis of the graft on baseline angiography is most likely an independent prognostic factor for SVG failure. It can be concluded that high-quality veins (those of lower score, in our system) are more favorable for implantation in coronary arteries with poor runoff when a patient has multiple veins with higher scores. Applying this theory could decrease the likelihood of SVG failure.

In our study, fewer SVGs to the right coronary artery and its branches were patent (77.4%) than were SVGs to either the left anterior descending coronary artery and its branches (92%) or the circumflex coronary artery and its branches (94.8%). These findings, in conjunction with those reported in other studies, indicate that it is particularly advisable to graft higher-quality veins to the right coronary artery. (Of note, in most of our patients, the internal mammary artery was used as a conduit on the left anterior descending coronary artery, and, as a result, fewer SVGs were grafted to that vessel.)

Few reports have compared SVG failure in the presence versus the absence of diabetes mellitus, and there are discrepancies in regard to the reported impact of diabetes on SVG patency. Schwartz and colleagues[20] reported that treated diabetes did not appear to adversely affect the patency of bypass grafts. In contrast, in long-term follow-up, other investigators have found lower SVG patency rates in patients with diabetes than in patients without diabetes.[13] Our finding that diabetes had no impact on SVG patency 1 year after CABG may be the result of an insufficient follow-up period. The adverse effect of diabetes on our patients' grafts is probable in the long term.

Conclusion

As our study shows, the characteristics of harvested saphenous veins significantly influence graft patency. We conclude that our formula and system of scoring produce very reliable data on graft prognosis. Specifically, we believe that our methods can dependably guide surgeons in the selection of the most suitable target artery for each venous segment and meaningfully assist them in choosing the most appropriate venous segments—particularly for high-risk CABG patients who are especially dependent on blood flow through SVGs.

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