Long-term patency of sequential and individual saphenous vein coronary bypass grafts

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Abstract

Objectives: The long-term patency rates for individual and sequential saphenous vein grafts (SVG) as coronary bypass conduits are angiographically compared; the impact of native coronary vessel characteristics is investigated. **Methods**: A total of 875 distal coronary anastomoses on 500 SVGs were assessed in 430 patients at an average of 5.8 ± 3 years after a coronary revascularization procedure. **Results**: The patency rates of sequential *conduits* were markedly higher than those of individual ones (82 vs. 68%, $P = 0.0005$). Also, the *anastomoses* on the sequential conduits had better patency (75 vs. 68%, $P = 0.03$). This difference was even more pronounced in coronary arteries of poor quality and small (<1.5 mm) diameter (57 vs. 28% for the sequential grafts and individual grafts, respectively, $P = 0.001$). Also, when the most distally located coronary artery on a sequential graft was of poor run-off, the patency rate for the entire conduit was considerably low (42.5%). **Conclusions**: The patency of a sequential vein graft conduit is generally better than that of an individual one, especially for poor run-off coronary vessels, provided that the most distally located anastomosis is done on a good coronary artery in terms of quality and diameter. Using a minimal length of conduits is another advantage. However, failure of a single sequential conduit jeopardizes all the anastomoses along that graft segment. Besides, sequential grafting is technically more demanding, and the technical expertise in performing a sequential anastomosis is probably among the important determinants of short- and long-term patency. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

With the introduction of internal mammary arteries (IMAs) as bypass conduits, they rapidly became the standard grafts of choice for the major epicardial coronary vessels such as left anterior descending artery (LAD). Since the current coronary artery bypass grafting (CABG) candidates are usually the patients with multi-vessel disease, and only two mammary arteries are available, other bypass conduits are often necessary for complete revascularization purposes. In attempting total arterial revascularization, a variety of arterial grafts and even the sequential use of valuable IMAs have been proposed. This also caused a tendency toward sparing the saphenous veins for future peripheral vascular operations as advocated by many.

Despite the introduction and popularization of a variety of arterial grafts having supposedly superior long-term patency rates, and recent enthusiasm for arterial revascularization, saphenous vein grafts (SVGs) continue to be the backbone of daily coronary revascularization practice. Although these grafts are still widely in use, this is often limited to the revascularization of tribute coronary vessels, and to the situations in which a high starting flow is desirable immediately. Emergency procedures, poor left ventricular functions, and replacement of a stenotic tiny arterial graft previously anastomosed to a major coronary vessel are examples for such situations [1,2]. In some instances, the unavailability or inappropriateness of arterial conduits also mandates the use of saphenous veins.

Keeping in mind that SVGs are still needed in daily practice, factors determining their longevity must be thoroughly evaluated. One of the issues that may be of concern in regard to the long-term patency of these conduits is whether to use them as individual or sequential grafts [3]. The studies focusing on this subject are scarce and mostly go back to at least a decade ago. More importantly, it appears that the popularity of arterial revascularization has markedly suppressed such SVG studies. In this study, the influence of these two grafting techniques (individual versus sequential) on long-term graft patency is compared, and possible rela-

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tions to the native coronary vessel characteristics are investigated by means of angiographic evaluation.

2. Materials and methods

Four hundred thirty patients who had previously undergone CABG in Yüksek Ihtisas Hospital in Turkey between April 1975 and January 1992 were angiographically examined. A total of 875 distal coronary anastomoses on 500 SVGs (apart from 232 left IMA (LIMA) anastomoses) were assessed by contrast coronary angiography, at an average age of 5.8 ± 3 years after CABG. Forty-eight (11%) of the patients were female. The mean age of the patients was 49 ± 8 years (range 43–67 years). Postoperative angiographic examination was performed in patients who gave consent for routine postoperative angiographic control. This also includes evaluation for typical/atypical symptoms and newly developed ECG changes, or a major cardiac assessment before a major surgical procedure (abdominal, vascular, neurological, etc.). Two groups (for individual and sequential grafts) were formed. There were no statistically significant differences between the sequential and individual grafting groups with regard to age, sex, atherosclerotic risk factors, graft age (5.7 ± 4 years for individual grafts and 5.9 ± 3 years for sequential grafts, $P = 0.6$) and symptomatology.

2.1. Operative technique

Complete revascularization was the goal in all patients. In situ individual LIMA was the graft of choice for revascularization of the LAD. SVGs were generally used for revascularization of the remaining coronary vessels. The choice between the individual and sequential techniques was primarily based on the anatomical position and neighborhood of the vessels to be grafted. For this purpose, our current policy is to use one segment of vein (either individual or sequential, when technically appropriate) for each major coronary system. However, especially in the early era of our practice (1970s and early 1980s), only one snake graft circumflexing the heart or sequential grafts supplying more than one major coronary system had also been used. Using both visual and probe examination, the quality of the native coronary vessel was described as good, fair or poor, while the diameter was assessed using 1, 1.5 and 2 mm metal-tipped coronary probes. All coronary anastomoses were done using a double armed 7-0 polypropylene suture with a continuous suturing technique. The most distal anastomosis on a sequential graft was done in end-to-side fashion. Others were constructed side-to-side. Side-to-side anastomoses were done in a diamond-shape (graft axis perpendicular to coronary arteriotomy) and end-to side anastomoses were done parallel to the native coronary vessel axis. Proximal anastomoses were constructed on the ascending aorta with continuous double armed 6-0 polypropylene sutures using a side-biting clamp during the rewarming period.

2.2. Control angiograms

Preoperative and postoperative coronary angiograms were performed by the Judkins technique in four planes: antero-posterior, left lateral, right anterior-oblique and left anterior-oblique positions. Two physicians who were unaware of the aim of the study interpreted all angiograms. Grafts and native coronary arteries were categorized as follows: *patent*: no stenosis; *occluded*: non-opacified graft; *partially patent*: hemodynamically significant (>50%) stenosis, and/or newly developed plaques and/or at least one open anastomosis through a sequential graft. Graft patency rates included both patent and partially patent grafts. For the patients who underwent repetitive postoperative control catheterization, only the last examination was included in the study. Patency rates were separately calculated for each vessel quality category. All grafts were also put into one, three and five postoperative year groups according to their age, so a time-related patency trend could be demonstrated on a line-chart.

2.3. Statistical analysis

All statistics were performed using SPSS statistical software (release 6.0, SPSS Inc., Chicago, IL). Means $\pm$ standard deviation are presented. The unpaired t-test and the χ^2-test were used in statistical analysis and a P value equal to or smaller than 0.05 was considered statistically significant.

3. Results

3.1. General considerations

The mean duration between the operation and control angiography was 5.8 ± 3 years, ranging between 1 and 12.2 years (5.7 ± 4 years for individuals and 5.9 ± 3 years for sequentials, $P = 0.6$). Of the 1107 reviewed anastomoses, 232 had been done using IMA, 300 using individual SVG, and 575 using 200 sequential SVG segments; therefore, a total of 875 anastomoses on 500 SVGs were examined.

3.2. Overall comparison of individual and sequential grafts

The overall patency, including partially patent grafts, was 87% for IMA grafts, 82% for sequential vein grafts and 68% for individual vein grafts. The sequential SVGs have markedly superior patency than the individual ones ($P = 0.0005$). IMA grafts, as expected, were superior to either type of SVG grafts ($P = 0.03$ for IMA versus sequential SVG and $P = 0.001$ for IMA vs. individual SVG). Overall *graft* patency is compared between the individual and sequential grafting groups in Table 1. Patency rates for different type of grafts are also depicted in Fig. 1.

Table 1
Overall graft patency[a]

	Graft type (%)		
	Individual SVG	Sequential SVG	IMA
Patent	194 (64.7)	126 (63)	189 (81.5)
Partially patent	9 (3)	38 (19)	13 (5.6)
Occluded	97 (32.3)	36 (18)	30 (12.9)
Total	300	200	232

[a] IMA, internal mammary artery; SVG, saphenous vein graft.

Table 2
Sequential grafts[a]

	Number of grafts	Number of anastomoses
Double	77	154
Triple	75	225
Quadruple	44	176
Quintuple	4	20
Total	200	575

[a] There was an average of 2.9 anastomoses per sequential graft.

3.3. Overall comparison of individual and sequential anastomoses

Of the 575 anastomoses on 200 sequential SVGs, 430 (75%) were patent, while only 68% of the individual SVGs were patent ($P = 0.03$). The features of the sequential conduits are presented in Table 2.

3.4. Comparison of patency rates for different coronary artery systems

Distal *anastomoses* are classified and the patency is compared *between* the individual and sequential grafting groups, and also in regard to involved coronary systems *inside* each group (Table 3). No significant difference was observed between the two methods in regard to major coronary artery systems.

3.5. Impact of the coronary vessel characteristics on patency

Coronary arteries of poor run-off or small diameter (<1.5 mm) had lower patency rates. Of 135 *anastomoses* on such vessels, 77 (57%) were patent in the sequential SVG group

and only 17 (28%) of 61 were patent in the individual SVG group ($P = 0.001$). The difference in the patency rate was especially pronounced if a grafted coronary artery was of poor quality and/or small (<1.5 mm) diameter (patency was 28% for the individual grafts and 57% for the sequential grafts connected at least one such vessel, $P = 0.001$). Also, when a most distal coronary artery on a sequential graft is an unfavorable one as described, a considerably lower patency rate for the entire conduit must be anticipated (in our study, 42.5%).

3.6. Impact of the localization of poor run-off coronary vessels on a sequential graft

In regard to the location of a poor quality/small diameter coronary artery on a sequential graft, the patency of the entire conduit was inferior when most distally located (42.5%, 21/47), in comparison to the anastomoses in medial (65.3%, 32/49, $P = 0.03$) or proximal (66.6%, 26/39, $P = 0.03$) locations. Coronary vessels with such unfavorable characteristics were present in nine (25%) of 36 totally occluded sequential grafts versus only 12 (9.5%) of 126 patent sequential grafts ($P = 0.04$).

4. Discussion

Sequential grafting was introduced by Flemma et al. [4] and amplified by Bartley et al. [5]. A single vein may revascularize the entire heart as a so-called snake graft; however, more conservative sequential grafts use one segment of vein for each major coronary system and sequential anastomoses for branches. This is our standard approach today, either using SVG or radial artery segments as supplements to IMA to LAD grafting. The major advantages of sequential grafting are decreased total resistance to graft flow, minimizing impedance mismatch, and complete revascularization with shorter vein segments in a presumably shorter operation time. On the other hand, its main drawback is that proximal conduit failure compromises blood flow to a substantially large mass of myocardium. However, if a sequential SVG occludes proximally but its distal part remains open, it may act as a large inter-coronary collateral. In such situations percutaneous trans-luminal coronary angioplasty (PTCA) of a stenosis in one of the
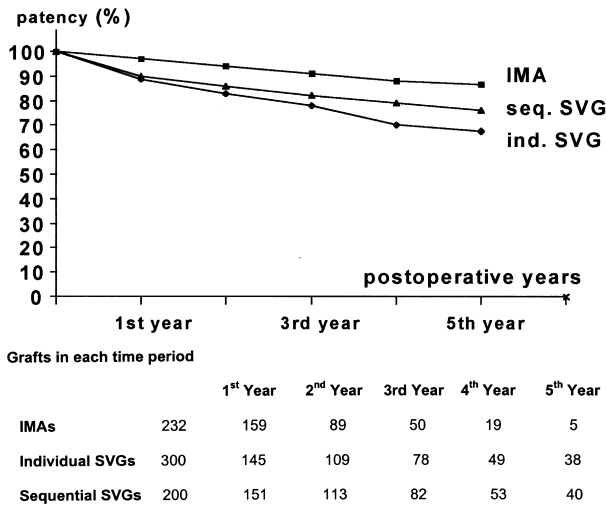

Fig. 1. Patency rates for different types of grafts: IMA, internal mammary artery; SVG, saphenous vein graft; Ind., individual; Seq., sequential.

Grafts in each time period

	1st Year	2nd Year	3rd Year	4th Year	5th Year
IMAs	232	159	89	50	19	5
Individual SVGs	300	145	109	78	49	38
Sequential SVGs	200	151	113	82	53	40

Table 3
Patency of anastomoses

Coronary system[a]	Individual anastomoses			Sequential anastomoses			P value[b]
	Patent	Occluded	Patency rate (%)	Patent	Occluded	Patency rate (%)	
LAD system	73	26	74	146	43	77	0.5
Cx system	50	24	68	217	70	76	0.2
RCA system	81	46	64	67	32	68	0.5
P value[c]	0.2			0.3			

[a] LAD, left anterior descending; Cx, circumflex; RCA, right coronary artery.
[b] Comparison between individual and sequential grafts.
[c] Comparison between coronary artery systems inside each group (individual or sequential).

recipient native vessels may restore the function of the graft [6].

As time passes, another advantage of the sequential grafts arises. The principal determinant of the patency rate in a coronary bypass graft in the late postoperative period is flow rate throughout this graft [7,8]. According to Rittgers et al. [9], there is a reverse relationship between the flow rate and intimal proliferation. Faulkner et al. [8] also reported that an increased flow rate was associated with less intimal proliferation. The variables used in estimating the flow rate are SVG diameter, graft resistance and the resistance posed by the native coronary vessel. Since the diameters of SVG segments are relatively constant for a given patient, and the resistance posed by a SVG segment is negligible when compared to that of its coronary counterpart, the native coronary vessel's resistance remains as the principal determinant of the flow rate. If individual resistances of the grafted coronary arteries are assumed to be equivalent, a double sequential graft possesses only half of the resistance of an individual graft. Thus, the individual SVGs are more resistant than the sequential ones [10,11]. Increased blood flow especially in the proximal segments of a sequential graft is directly related to the reduction in the resistance. According to Grondin and Limet [12] and O'Neill et al. [10], the proximal anastomoses of a sequential graft have better patency than the distal ones or the individual grafts. In our study, we demonstrated that if a poor run-off coronary artery is anastomosed to the proximal part of a sequential graft, patency is better than that of a distally located one. In addition, patency is suboptimal when such a vessel is grafted by an individual graft instead of a sequential graft. One should avoid anastomosing a poor quality artery at the distal end of a sequential graft, because this decreases the blood flow rate throughout the entire conduit and thrombosis may ensue. In contrast, if the most distal anastomosis has a good run-off, total blood flow is increased throughout the graft and this helps decrease the incidence of thrombosis in the whole conduit, as well as in an anastomosis to a poor quality vessel which is proximal or medially located on the sequential graft. One should follow an anastomotic sequence to keep the graft flow at a maximum by placing the best run-off coronary artery at the distal end. This mini-

mizes a drastic complication, proximal graft failure in a sequential graft [7]. It is suggested that the LAD must be grafted individually, because of the greater demand of blood flow in the myocardial mass supplied by this artery [13]. If an IMA graft will not be used for this revascularization, it is better to use an individual graft for LAD for that reason. Kieser et al. [14] reported a long-term follow-up of 212 double sequential grafts studied at 1 and 5 years postoperatively and compared with 424 single grafts anastomosed to the same vessels. The patency rate of side-to-side anastomoses (85%) was better than that of end-to-side anastomoses (66%) for sequential grafts at 5 years ($P < 0.005$). As a group, the 5-year patency of all side-to-side anastomoses was better than that of all the single end-to-side anastomoses (85 vs. 76%, $P < 0.05$). The patency of sequential end-to-side anastomoses, however, was less than that of single end-to-side anastomoses (66 vs. 76%, $P < 0.05$). Side-to side double sequential grafts were reported to have better patency than end-to-side anastomoses. Single grafts have better patency than end-to-side anastomoses of sequential grafts, and therefore, that author recommends single grafts, unless there are other considerations such as limited availability of graft material.

Our study demonstrated that the patency of a sequential vein graft conduit is generally better than that of an individual one, especially for poor run-off coronary vessels, provided that the most distally located anastomosis is done on a good coronary artery in terms of quality and diameter. We analyzed the anastomoses and grafts instead of the patients, since one patient may harbor both sequential and individual types of grafts. Also, the deaths were not included in the study population. The retrospective nature of the presented study may be considered another possible limitation.

In conclusion, sequential grafting typically puts all the eggs in one basket. This approach may be considered risky. However, if one properly and wisely arranges the sequence of the eggs, it is a good alternative with all its advantages described above. Sequential grafting is technically more demanding than individual grafting, and the technical expertise in constructing a sequential anastomosis is perhaps among the major determinants of short- and long-

term patency. The LAD must be grafted individually, preferably with an in situ IMA, and separate sequential grafts should be used for each major coronary system. Also, the sequence of the anastomoses should be arranged in such a way that the anastomosis at the distal end of a sequential graft has good run-off to sufficiently augment blood flow throughout the conduit and thus the long-term expectations in terms of patency.

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