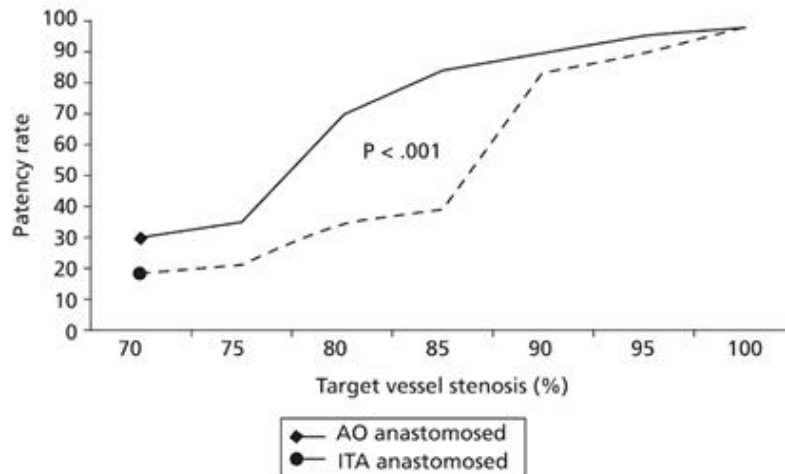


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**Figure 1.2** Mid-term patency rate of radial artery grafts in relation to the site of proximal anastomosis and the severity of target vessel stenosis.

Reprinted from Gaudino *et al.* (2004) Effect of target artery location and severity of stenosis on mid-term patency of aorta-anastomosed vs. internal thoracic artery-anastomosed radial artery grafts. *European Journal of Cardio-Thoracic Surgery* 25(3):424–8 with permission from Oxford University Press on behalf of the European Association for Cardio-Thoracic Surgery

- c) The proximal site of anastomosis influences the patency of the RA graft. The RA can be anastomosed as an aortocoronary graft or as a composite graft from the LITA. Jung and colleagues<sup>92</sup> stated that increased drive pressure from a direct aortic anastomosis would improve flow through the RA when compared with anastomosis to the left internal mammary artery (LIMA). Gaudino and colleagues<sup>93</sup> studied the same phenomenon. They concluded that ITA-anastomosed RA grafts seem to be more vulnerable to the detrimental effect of chronic native competitive flow than aorta-anastomosed conduits; Y-grafts should then probably be reserved to target vessels with subocclusive stenosis (Figure 1.2).
- d) Sequential grafting improves the RA patency,<sup>94–95</sup> especially in coronary targets of less than 1.5 mm diameter and with poor distal runoff.

### Saphenous vein graft (SVG)

Since the late 1960s,<sup>96</sup> CABG using saphenous vein conduits has been championed as the solution to CAD. However, it was soon evident that CABG provides only palliation to an ongoing process that is further complicated by the rapid development of vein graft atherosclerosis.

Early thrombosis and neointimal hyperplasia with subsequent atherosclerosis are thought to be the primary causes of graft failure. The cause of this failure may stem from thrombosis within the vein graft, caused by a combination of structural and physiological alterations in the vessel wall.

Neointimal hyperplasia, defined as the accumulation of smooth muscle cells and extracellular matrix in the intimal compartment of the vein, is the major disease process in

venous grafts within the first year. Nearly all veins implanted into the arterial circulation develop intimal wall thickening within 4–6 weeks, thereby reducing the lumen size. Smooth muscle cells in the media of normal adult arteries proliferate at a very low rate (<0.1%/day) but can switch very rapidly from quiescence to a proliferative state in response to appropriate stimuli.<sup>97</sup>

Injury to the intima results in migration and proliferation of smooth muscle cells from the media to the intima. The resulting luminal narrowing of the vein graft is not usually flow-limiting in itself. However, over time the area of neointimal hyperplasia may become an atherosclerosis-prone region that may lead to subsequent stenosis (Box 1.1).<sup>98</sup>

### Anatomy

The SVG is the large (subcutaneous) superficial vein of the leg and thigh. The SVG originates from the joining of the dorsal vein of the first digit and the dorsal venous arch of the foot. After passing anterior to the medial malleolus (where it often can be visualized and palpated), it runs up the medial side of the leg. At the knee, it runs over the posterior border of the medial epicondyle of the femur bone. The SVG then courses laterally to lie on the anterior surface of the thigh before entering the saphenous opening in the fascia lata. It joins with the femoral vein in the region of the femoral triangle at the saphenofemoral junction.

### Histology

**Intima** This intima consists of the endothelium and a thin subendothelial layer with smooth muscle cells among the connective tissue elements. A thin internal elastic membrane may or may not be present; if present, it is not nearly as prominent as in arteries.

**Media** This media is much thinner relative to that of an artery, and consists mostly of circularly arranged smooth muscle and collagen fibers. The tunica intima and media therefore tend to be less distinct from one another than is the case in arteries.

**Adventitia** The adventitia is usually thicker than the media and is made up mostly of collagen fibers. It may contain longitudinally oriented smooth muscle bundles.

## Box 1.1 Pathogenesis of venous coronary artery bypass graft (CABG)

Phase I: Acute thrombotic phase (<1 month)

Phase II: Intimal hyperplasia (1–12 months)

- ◆ Hyperplasia of smooth muscle cells in the media
- ◆ Smooth muscle cell migration from the media to the intima
- ◆ Smooth muscle cell proliferation and extracellular matrix production

Phase III: Atherosclerosis (>3 years)

**Endothelial function** The superiority of the IMA over the SVG is thought to result from favorable biological properties of the endothelium to protect this vessel against vasospasm, thrombus formation, and atherosclerosis.

Unlike ITA grafts, SVGs constrict in response to ergotamine (ERGO) and do not dilate in response to ISDN.<sup>99</sup> These differences in vasomotor response could reflect heterogeneity in the sensitivity of vascular smooth muscle to these agents or differences in the basal level of vasomotor tone.

**Patency** It is estimated that during the first year after coronary bypass surgery, 10–15% of venous grafts occlude.<sup>100–101</sup> The graft attrition rate has been estimated at 1–2% per year between 1 and 6 years, and at 4% per year between 6 and 10 years after surgery. By 10 years after surgery, approximately 60% of the vein grafts are patent; only 50% of these patent vein grafts remain free of significant stenosis.

The following list describes the relationship of patient variables to graft patency:

1. Younger age and left ventricular ejection fraction <30% significantly reduced graft patency.<sup>102</sup> A possible explanation is that younger patients have a higher prevalence of risk factors (such as smoking and cholesterol) and more severe coronary disease. Reduced ejection fraction may indicate large areas of infarcted myocardium with poor distal runoff.
2. Year of operation significantly affected graft patency. For any given angiogram interval, more recently performed operations were associated with better graft patency. This observation could be due to routine use of aspirin, vigorous treatment with cholesterol-lowering agents, and the improved harvesting, preparation, and storage techniques that have evolved over the last three decades. Aspirin (325 mg/d) is associated with improved SVG patency during the first year after surgery.<sup>103</sup> The Post-coronary Bypass Graft Trial<sup>104</sup> demonstrated that aggressive decreasing of low-density lipoprotein cholesterol to <100 mg/dL decreased obstructive changes in SVGs by 31%. Harvesting, preparation, and storing techniques significantly affect graft patency.<sup>105</sup>
3. The interval from operation to angiogram significantly affected graft patency. Graft patency of angiograms studied at less than 1 year, 1–4 years, 5–9 years, 10–14 years, and >15 years was 78%, 78%, 60%, 50%, and 50%, respectively.

Operative variables were related to graft patency as follows:

1. The target coronary artery grafted significantly affected graft patency. Grafts to the RCA had the worst patency, and those to the LAD had the best patency. The order of increasing patency was RCA > obtuse marginal artery > posterior descending artery > diagonal > LAD.<sup>106</sup>
2. Target coronary artery diameter significantly affected graft patency with endarterectomy presenting the worst patency.<sup>107</sup> The most likely reason is that a large-diameter vessel has a better runoff and, therefore, better graft patency.
3. Conduit diameter significantly affected graft patency.<sup>102</sup> Large-diameter veins were associated with worse graft patency; better graft patency was associated with smaller conduit size.

4. Conduit wall thickness showed a trend toward affecting graft patency.<sup>102</sup> The conduit wall thickness was graded as thick, normal, and thin. A thick wall was defined as >1.5 mm, normal as 1.0–1.5 mm, and thin as <1.0 mm. Thick-walled veins were associated with worst graft patency. Poor results that followed the use of large-diameter and thick-walled saphenous veins may stem from low-velocity flow within the conduit, leading to deposition of oxidized low-density lipoprotein in the graft wall.
5. Target coronary artery stenosis was not significantly associated with graft patency.<sup>108</sup> Venous grafts, as opposed to arterial grafts, are less susceptible to spasm and are less affected by competitive flow and autoregulation.
6. Distal anastomosis type, that is, end to side or side-to-side (sequential), was associated with better graft patency with the latter.<sup>109–110</sup>

## Graft configuration

### Strategies to revascularize the left coronary system

BITAs have clearly demonstrated their superiority over all other types of grafts in terms of patency, freedom from arteriosclerosis, and survival benefit for revascularization of the left coronary system. Several meta-analyses have demonstrated the benefits of BITA vs. single ITA (SITA) grafting. Seven to ten years of follow-up were required before the advantages of BITA grafting were apparent,<sup>111</sup> but from 10 to 20 years, the benefits of BITA are statistically and clinically significant (Figure 1.3). However, even if the ideal graft has clearly been demonstrated, the method of use is still controversial. Therefore, several configurations of BITA have been proposed to achieve complete left-sided myocardial revascularization.

There are two major BITA assembly strategies to revascularize the left coronary system with two ITA: *in situ* and free:

- 1a. *In situ* LITA to the LAD territory and *in situ* RITA to the circumflex territory through the transverse sinus (Figure 1.4a);
- 1b. *In situ* RITA to the LAD and *in situ* LITA to the circumflex territory (Figure 1.4b);
- 2a. *In situ* LITA to the LAD territory and free RITA implanted in a Y or T fashion into the LITA (Figure 1.4c);
- 2b. *In situ* LITA to the LAD territory and free RITA implanted in the aorta (Figure 1.4d).
- 1a. *In situ* LITA to the LAD territory and *in situ* RITA to the circumflex territory through the transverse sinus (TS)

Advantages:

- a) Each ITA is used *in situ* and therefore is able to consistently provide sufficient blood flow to each target vessel;
- b) The RITA does not cross the mid-line of the chest in front of the aorta in case of redo sternotomy or aortic valve surgery.<sup>112–115</sup>