The Radial Artery: Current Concepts on Its Use in Coronary Artery Revascularization

Syed M. Rehman, MRCS, Gijong Yi, MD, and David P. Taggart, FRCS

The radial artery (RA) can be used as part of an arterial revascularization strategy in coronary artery bypass grafting (CABG). It is easy to harvest and several randomized controlled trials and meta-analyses have reported superior long-term patency over saphenous vein grafts. However, the RA is not used as frequently as the saphenous vein and questions remain regarding its optimum use as a conduit. This article comprehensively appraises current evidence surrounding outcomes, patient selection, harvesting technique, intraoperative strategy, and graft spasm prophylaxis to provide a contemporary review of the use of the RA as a conduit in CABG.


Trends in RA Use

The RA was first described as a conduit by Carpentier and colleagues [4] in 1973. However, this group subsequently advised against its use in 1975 because of a higher rate (35%) of occlusion or narrowing attributed to spasm than when the LSV was used [5]. Therefore, the RA was widely abandoned by cardiac surgeons. In 1992, Acar and associates [6] demonstrated that occluded or narrowed RA grafts from the first Carpentier and colleagues’ series were patent at 18 years’ follow-up. They also reported a series of patients receiving RA grafts using a refined harvesting technique and pharmacologic measures to minimize spasm. The early patency of 56 RA grafts was 100%. These developments stimulated a revival of interest in the RA.

The Society for Cardiothoracic Surgery in Great Britain and Ireland 2008 Database Report states that nearly 95% of patients undergoing CABG received at least 1 arterial graft, usually the LIMA, a consistent annual increase since 1998 [7]. The proportion of patients receiving 2 arterial grafts increased from 10% in 1998 to more than 20% in 2002 but has decreased to about 15% since then. Approximately 5% of patients received 3 or more arterial grafts through 1998 to 2008. The Society for Thoracic Surgery database showed that 92.4% and 4% of 541,368 patients from 2002 to 2005 received at least 1 internal mammary artery (IMA) and BIMA respectively, with an increasing trend for both [8]. The Society for Thoracic Surgery also reported that 6% of patients in the United States received an RA graft in 2008 [9]. These figures demonstrate general reluctance to use RA and multiple arterial grafts.

Vascular Biological Features of the RA, LSV, and IMA

The RA has a thin continuous intima of endothelial cells, a single internal elastic lamina, and relatively thick media...
of tightly packed smooth muscle cells (Fig 1), which predisposes to spasm [10]. Furthermore, histopathologic comparison of proximal and distal RA segments suggests significantly reduced luminal diameter and increased intimal hyperplasia distally [11]. Although the incidence of atherosclerosis is greater in the RA than in the IMA (5.3% versus 0.7%), it is still very low and demonstrates overall resistance to atherosclerosis [10].

The IMA has a discontinuous internal elastic lamina and relatively thinner media with multiple elastic laminas (Fig 2) [10]. Its relatively less muscular and more elastic structure may explain its reduced tendency to spasm or develop atherosclerosis when compared with the RA.

The LSV has a thinner more permeable endothelium and thinner less elastic media (Fig 3). It is also more susceptible to thrombosis and atherosclerosis because of inherent differences in arteries in response to endothelial damage and lipid metabolism. After grafting, LSV endothelium is prone to the development of intimal hyperplasia, which is a precursor to atherosclerosis [12].

Results
Comparison of RA and LSV
Several randomized controlled trials (RCTs) compare RA and LSV patency at various intervals (Table 1). The RAPS (Radial Artery Patency Study) trial randomized 440 patients such that the RA and LSV were grafted to the circumflex artery and the right coronary artery (RCA), respectively, or to the RCA and circumflex artery, respectively [13]. Follow-up angiography showed that significantly more LSV grafts (13.6%) than RA grafts (8.2%) were occluded at 1 year. However, diffuse narrowing was more common in the RA (7.0% versus 0.9%) and associated with anastomosis to targets with less than 90% stenosis. Overall, this equated to similar 1-year rates of functional occlusion. Long-term results (mean follow-up of 269 patients at 7.7 ± 1.5 years) revealed significantly lower rates of functional occlusion (12.0% versus 19.7%) and complete occlusion (8.9% versus 18.6%) in RA grafts [14].

Goldman and associates [9] randomized 733 patients to RA (366 patients) or LSV (367 patients) grafts to the next most important vessel after the LAD. Angiography demonstrated no significant difference in 1-year patency (89% for both groups).

The RSVP (Radial Artery Versus Saphenous Vein Patency) trial studied 142 patients randomized to either an RA or LSV graft to the lateral wall of the left ventricle. Angiography in 103 patients showed significantly more...

Fig 1. Photomicrograph of section of radial artery (×100, Elastic-Van Gieson stain).

Fig 2. Photomicrograph of section of left internal mammary artery (×4, hematoxylin and eosin stain).

Abbreviations and Acronyms
BIMA = bilateral internal mammary arteries
CABG = coronary artery bypass grafting
CSA = cross-sectional area
IMA = internal mammary artery
LAD = left anterior descending
LIMA = left internal mammary artery
LSV = long saphenous vein
MI = myocardial infarction
PVD = peripheral vascular disease
RA = radial artery
RAPCO = Radial Artery Patency and Clinical Outcomes
RAPS = Radial Artery Patency Study
RCT = randomized controlled trial
RSVP = Radial Artery Versus Saphenous Vein Patency
VG = verapamil with nitroglycerin
patency RA grafts (98.3%) than LSV grafts (86.4%) at 5-year follow-up[15].

The RAPCO (Radial Artery Patency and Clinical Outcomes) trial compared RA patency to the LSV and right internal mammary artery (RIMA) [16, 17]. Midterm results (mean 6-year follow-up) showed no significant difference between RA patency (90.0%) in 113 patients and LSV patency (87.0%) in 112 patients. Ten-year results are awaited.

In 2010, a meta-analysis of 5 RCTs showed no difference between RA (14.1%) and LSV (16.6%) failure at mean follow-up of 22 months [18]. Hu and colleagues [19] reported a meta-analysis comparing occlusion between RA and LSV grafts to non-LAD artery target vessels at a mean follow-up of 56 (12-74) months. Their analysis showed a significantly reduced risk of occlusion in RA grafts (relative risk [RR], 0.507).

Athanasiou and colleagues [20] compared RA and LSV patency in the short term (less than 1 year), medium term (1 to 5 years) and long term (more than 5 years) [20]. The analysis of 35 studies, comparing 3,678 RA to 7,506 LSV grafts, showed significantly better RA patency in the medium (odds ratio [OR], 2.06) and long (OR, 2.28) term, but not significantly better in the short term (OR, 1.04).

As a supplement to the RAPS 5-year results, Deb and associates [14] updated the meta-analysis by Athanasiou and colleagues [20] to include their results and other new data up to April 2011. They compared 522 RA and 880 LSV grafts to show reduced occlusion in RA grafts beyond 5 years (OR, 0.52).

Cao and colleagues [21] analyzed 5 RCTs to compare 859 RA and 849 LSV grafts at 1 year and beyond 4 years for complete occlusion, string sign, failure, and complete patency. They found no significant difference in 1-year occlusion between RA and LSV grafts (9.1% versus 12.7%; OR, 0.71), although RA occlusion was significantly lower beyond 4 years (2.7% versus 14.7%; OR, 0.17). String sign was present in significantly more RA grafts at 1 year (7.4% versus 1.0%; OR, 7.97), although beyond 4 years the difference was not significant (2.7% versus 0%; OR, 3.55). RA and LSV failure was similar at 1 year (18.4% versus 15.5%; OR, 1.26) but was significantly lower in RA grafts beyond 4 years (6.0% versus 17.5%; OR, 0.31).

Again, no difference in complete patency was demonstrated at 1 year (79.2% versus 82.5%; OR, 0.79), but RA grafts had significantly higher complete patency beyond 4 years (89.9% versus 63.1%; OR, 5.19).

Overall, none of the preceding studies reported inferior outcomes and some, including additional studies, have reported better outcomes with RA grafts. RAPS attributed late outcomes of death from cardiac causes, nonfatal MI, and repeated revascularization more commonly to LSV grafts than to RA grafts in a predominantly male population with mean age of about 60 years [14]. Goldman et al [9] showed no difference in death, MI, stroke, and repeated revascularization between RA and LSV grafts in a male (99%) population of similar mean age but higher prevalence of diabetes (42%). The RSVP trial showed no difference in mortality between the 2 groups at 5 years in an older population (mean age >70 years) with more than 40% of patients having diabetes [15]. A further study compared 478 patients in whom the RA (LIMA, RA, and LSV) was used and in 956 patients in whom the LSV (LIMA and LSV) was used; the RA group had a significantly greater prevalence of diabetes (34% versus 25%), peripheral vascular disease (PVD, 21% versus 13%) and hypertension (53% versus 47%) [22]. Although mortality was identical perioperatively, MI was significantly higher in the LSV group (3% versus 1%), and RA grafting was shown to be protective against early mortality and morbidity (MI, low-output syndrome, intraaortic balloon pump support, and stroke; OR, 0.58) and late mortality and morbidity (MI, revascularization, and readmission for cardiac-related causes; RR, 0.60). Furthermore, the RA group demonstrated greater actuarial survival from death, MI, revascularization, and readmission for cardiac-related causes at 36 months. Zacharias and coworkers [23] compared 925 patients in whom the RA was used and 925 patients in whom the LSV was used in propensity-matched analysis at up to 6-year follow-up. Cumulative survival was 67% higher in the RA group. This survival benefit was also observed before and beyond 3-year follow-up in women with 3-vessel disease, age older than 65 years, and diabetes, and beyond 3-year follow-up in men without 3-vessel disease, older than 65 years, and without diabetes. Tranbaugh and colleagues [24] compared clinical outcomes between 862 (RA used) and 862 (LSV used) propensity-matched patients at up to 14-year follow-up [24]. They demonstrated 52% higher mortality for patients in whom the LSV was used compared with patients in whom the RA was used. They also showed a strong survival benefit in men, in those aged less than 65 years and in both those with and without diabetes. In particular, they found that diabetic...
patients had a 57% greater 10-year mortality with LSV grafting compared with RA grafting. Therefore, the literature appears to strongly support no difference in functional patency between RA and LSV grafts over the first year, presumably because both are susceptible to technical failures. However, there is robust evidence now for superior mid- and long-term RA patency over the LSV graft, presumably reflecting the well-documented continuing long-term attrition of vein grafts. The evidence also supports the use of RA over LSV to improve early and late clinical outcomes including survival. Figure 4 shows an angiogram demonstrating a patent RA graft to the circumflex territory in one of our patients at 15-year follow-up.

Surgical Factors Affecting Patency

Severity and Location of Target Stenosis

The severity of target coronary artery stenosis is recognized as a major predictor of RA patency because of its effect on competitive flow. Several studies have demonstrated significantly reduced RA patency to coronary

<table>
<thead>
<tr>
<th>Study</th>
<th>≤1 Year</th>
<th>≤5 Years</th>
<th>&gt;5 Years</th>
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<tbody>
<tr>
<td>Desai (2004) [13]</td>
<td>Occlusion: RA, 8.2%  LSV, 13.6% (P = 0.009)</td>
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<td></td>
<td>String sign: RA, 7.0%  LSV, 0.9% (P = 0.001)</td>
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<td></td>
<td>Patency: RA, 98.3%  LSV, 86.4% (P = 0.04)</td>
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<tr>
<td>Collins (2008) [15]</td>
<td>Patency: RA, 90.0%  LSV, 87.0% (P = 0.29)</td>
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<td>Hayward (2010) [16]</td>
<td>Patency: RA, 90.0%  LSV, 87.0% (P = 0.29)</td>
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<tr>
<td>Goldman (2011) [9]</td>
<td>Patency: RA, 89.0%  LSV, 89.0% (P = 0.98)</td>
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<tr>
<td>Deb (2012) [14]</td>
<td>Functional occlusion: RA, 12.0%  LSV, 19.7% (P = 0.03) Complete occlusion: RA, 8.9%  LSV, 18.6% (P = 0.002)</td>
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<tr>
<td>Benedetto (2010) [18]</td>
<td>Failure: RA, 14.1%  LSV, 14.6% (P = 0.372)</td>
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<tr>
<td>Hu (2011) [19]</td>
<td>Occlusion: RA versus LSV: pooled OR, 0.507 (95% CI, 0.41–0.63; P &lt; 0.05)</td>
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<td>Athanasiou (2011) [20]</td>
<td>Patency: RA versus LSV: pooled OR, 2.06 (95% CI, 1.29–3.29; P = 0.002)</td>
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<td>Deb (2012) [21]</td>
<td>Patency: RA versus LSV: pooled OR, 2.28 (95% CI, 1.32–3.94; P = 0.003)</td>
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<tr>
<td>Cao (2012) [12]</td>
<td>Complete occlusion: RA, 9.1%  LSV, 12.7% (OR, 0.71; P = 0.15)</td>
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<tr>
<td></td>
<td>String sign: RA, 7.4%  LSV, 1.0% (OR, 7.97; P &lt; 0.00001)</td>
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<td></td>
<td>Failure: RA, 8.4%  LSV, 15.5% (OR, 1.26; P = 0.34)</td>
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<td></td>
<td>Complete patency: RA, 79.2%  LSV, 82.5% (OR, 0.79; P = 0.33)</td>
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CI = confidence interval; LSV = long saphenous vein; OR = odds ratio; RA = radial artery; RAPS = Radial Artery Patency Study; RAPCO = Radial Artery Patency and Clinical Outcomes; RCT = randomized controlled trial; RR = relative risk; RSVP = Radial Artery Versus Saphenous Vein Patency.
arteries with native stenosis less than 80% to 90% in the short term [25–27], less than 75% to 90% in the medium term [25, 28–32], and less than 70% in the long term [33–35] (Table 2).

In addition, anastomosis to the RCA [25, 28, 29, 32], because of its relatively larger luminal diameter, and even to the circumflex coronary artery [25], may predict graft failure. However, this finding is not supported by other studies [26, 27, 34]. Furthermore, RAPCO data demonstrated RA patency of 86.9% at mean follow-up of almost 6 years, when anastomosed to the right coronary artery [36] (Table 2).

It should be noted that visual assessment of the percentage of stenosis at angiography does not reliably predict the physiologic effects of coronary lesions and is subject to intraobserver variability [37]. The following coronary artery characteristics have been demonstrated to accurately predict improved functional arterial graft patency in favor of visual assessment: minimal lumen diameter less than 0.64 to 1.30 mm [38], fractional flow reserve less than 0.75, and target vessel diameter 2.0 mm or greater [39]. Indeed, the cross-sectional area (CSA) of a 5.0-mm RCA with 90% stenosis is 1.96 mm², which compares with a normal 2.0-mm vessel (CSA, 3.1 mm²) and a 1.5-mm vessel (CSA, 1.7 mm²). Thus, even with 90% RCA stenosis, the residual lumen is substantial and may be competitive; this does not consider the geographic vagaries of the atherosclerotic lesion and our presumption in relying on visual assessment. Therefore, it is important to move toward using objective measures to select suitable targets for RA grafting.

Harvesting Technique
The RA can be harvested in an open procedure or endoscopically, pedicled or skeletonized, or obtained with an ultrasonic scalpel or traditional instruments.

Endoscopic harvesting confers patency (72%–5.9%) comparable to the open approach (74%–94%) at mean follow-up of 1 to 3 years [40–42]. In addition, although both have a low complication profile, endoscopic harvesting is reported to reduce postoperative wound infection, hematomas, and neurologic dysfunction [41, 43–48]. It is also associated with less pain [48, 49], improved wound cosmesis, and greater patient satisfaction than is the open approach [49].

Two studies report satisfactory patency with both skeletonized and pedicled RA grafts, although they suggest that skeletonization may improve patency at up to 1-year follow-up (96.5%–100% versus 77.5%–86.7%) [50, 51]. However, this improvement may result from using an ultrasonic scalpel, which has been associated with significantly increased RA blood flow [52, 53], shorter harvesting times, and a reduced requirement for hemostatic clips [52–55].

Aortocoronary or Composite Grafting?
The RA can be anastomosed as an aortocoronary or composite graft, often from the LIMA. Composite grafting allows a no-touch aortic technique when performing off-pump CABG, with the major advantage of almost eliminating neurologic injury from dislodged aortic debris. However, a potential disadvantage is that perfusion to more than 1 distal anastomosis is supplied by a single inflow.

Jung and colleagues [25] argued that increased drive pressure from a direct aortic anastomosis would improve flow through the RA when compared with anastomosis to the LIMA. Their study compared postoperative computed tomographic angiograms in patients undergoing CABG with aortocoronary (531 patients) and composite RA grafts (513 patients). They demonstrated significantly better early (98.3% versus 94.5%), 1-year (93.8% versus 90.5%), 2-year (90.5% versus 85.3%), and 5-year (74.3% versus 65.2%) patency in aortocoronary grafts. However, similar studies have reported no difference in patency in the medium term [29, 56, 57] or long term [34, 58]. Comparison of aortocoronary and composite grafts using transit-time flow monitoring shows no significant difference in graft flow [59].

Sequential Grafting
Several studies describe the safe use of the RA for sequential anastomosis to multiple targets in on-pump and off-pump CABG [60–66]. In fact, Schwann and associates [60] showed a 10-year survival benefit for sequential RA grafting compared with LIMA-LSV grafting. Furthermore, a prospective study of 296 patients demonstrated that sequential grafting provided significantly better patency than did single grafting (89.2% versus 66.7%, respectively) at a mean follow-up of 57.3 months [61]. This trend continued in targets of less than 1.5 mm diameter and poor distal runoff (66.6% versus 49.1%, respectively), although patency rates of more distal anastomoses were lower in such targets. They also showed significantly better patency of sequential RA (94.1%) than of sequential LSV grafts (85.3%).
colleagues [67], however, suggested no difference in 1-year (96.3% versus 92.3%) and 5-year (88.9% versus 88%) patency between 27 sequential and 26 single RA grafts, respectively, to the left coronary artery system [67]. Akinci and associates [62] suggested that sequential RA patency is greater when combined with aortocoronary (96.8%) rather than composite grafting (45.0%). Nakajima and coworkers [63] reported a 95.6% early patency to a mean of 2.8 targets and that the most important predictor of RA patency was severity of stenosis in the most distal of the sequential anastomoses. They also showed no difference in patency between single (96.8%) and sequential RA grafts with 2 to 4 anastomoses (96.3% to 99.4%) at 5-year follow-up [68]. Silva and coworkers [69] reported a nonsignificant difference in patency between single (71%) and sequential (90%) RA grafts in 16 patients.

**Patient Selection**

Preoperative assessment of RA suitability should exclude Dupuytren’s contracture, carpal tunnel syndrome, or a current or future requirement for an arteriovenous fistula for dialysis. In addition, duplex ultrasonography enables assessment of RA diameter and identification of poor-quality conduits to preclude their use [70]. The RA is usually harvested from the nondominant arm after

<table>
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<tr>
<th>Study</th>
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<th>Severity of Target Stenosis</th>
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<td>≥70%–80%</td>
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<td>32</td>
<td>79%</td>
<td>94%</td>
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<td>Gaudino (2004) [34]</td>
<td>228</td>
<td>78</td>
<td>67%</td>
<td>94%</td>
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<td>79%</td>
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<tr>
<td>Ito (2009) [41]</td>
<td>100</td>
<td>12</td>
<td>96%</td>
<td>94%</td>
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<td>36 (endoscopic)</td>
<td>84%</td>
<td>79%</td>
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<td>Miyagi (2006) [50]</td>
<td>131</td>
<td>~ 0.5</td>
<td>98%</td>
<td>87%</td>
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<td></td>
<td></td>
<td>~ 9 (skeletonized)</td>
<td>100%</td>
<td>78%</td>
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<tr>
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<td></td>
<td>~ 12 (pedicled)</td>
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<td>14.9 (composite)</td>
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<td>Iaco (2001) [57]</td>
<td>164</td>
<td>48</td>
<td>100%</td>
<td>93.8–95.6%</td>
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<td>Carneiro (2009) [58]</td>
<td>123</td>
<td>64</td>
<td>84%</td>
<td>81%</td>
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<td>Gaudino (2004) [34]</td>
<td>228</td>
<td>78</td>
<td>90%</td>
<td>84%</td>
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| Anastomosis            |          |                    |                            |                   |
| Aortocoronary          |          |                    |                             |                   |
| Silva (2009) [69]      | 16       | 28                 | 90%                         | 71%               |
| Oz (2006) [61]         | 65       | 49.4               | 89%                         | 67%               |
| Nakajima (2012) [68]   | 601      | 60                 | 96.3%–99.4%                 | 96.8%             |
|                        |          |                    |                             |                   |
| Composite              |          |                    |                             |                   |
| Oz (2006) [61]         | 65       | 49.4               | 67%                         | 49%               |
| Akinci (2005) [62]     | 51       | 13 (aortocoronary) | 97%                         | 45%               |
|                        |          | 9 (composite)      |                             |                   |

Table 2. Analysis of RA Graft Patency (%) According to Surgical Factors
performing the Allen’s test to check collateral ulnar circulation. This depends on correct technique and can therefore be unreliable. A modification of this simple test was reported to have a 0% false-negative rate in more than 600 patients [71]. Our unit has previously described the use of duplex ultrasonography in patients with positive Allen’s test to enable use of 99% of RAs in patients undergoing total arterial CABG [72].

Several studies have identified patient factors associated with RA graft failure. Among the RAPS population, PVD was the strongest predictor of RA graft occlusion at 1 year [26]. Hata and colleagues [30] showed that univariate predictors of late graft failure were female sex, smoking history, PVD, lack of statin therapy, and use of only 1 antiplatelet agent, with PVD the only multivariate predictor (apart from degree of native coronary stenosis). Bartnes and coworkers [73] identified diabetes and female sex as predictors of RA graft failure at 2 to 3 years [73]. They also found angiotensin-inhibiting medication to protect against graft failure. A cautious approach to RA grafting in patients with the preceding risk factors, particularly in women with PVD, may therefore be prudent.

Pharmacologic Management

Pharmacologic prophylaxis includes the use of systemic and topical antispasmodic agents (Table 3).

Systemic vasodilators can cause unwanted systemic effects. For example, diltiazem may cause low cardiac output, bradycardia, or complete heart block. Similarly, nitroglycerin can significantly reduce mean arterial blood pressure.

Common topical agents include papaverine, verapamil with nitroglycerin (VG solution), diltiazem, and phenoxylbenzamine. The duration of action of papaverine to inhibit most or all of the vasoconstrictor effects of agents such as norepinephrine and potassium is 30 minutes to 2 hours [74–76]. In addition, papaverine-treated RA segments in patients undergoing CABG showed poor relaxation in response to acetylcholine [74]. In a retrospective study comparing papaverine to VG solution in 215 patients undergoing CABG, multivariate analysis showed papaverine to be an independent predictor of RA graft occlusion at 1-year follow-up [77]. VG solution has a longer duration of action (5–24 hours) and inhibits a greater variety of vasoconstrictor agents than does papaverine [75, 77, 78]. Comparison of diltiazem to other topical vasodilators, including papaverine and nitroglycerin, showed that diltiazem was the only agent that did not increase RA graft flow rates from before treatment to after treatment in 85 patients [79]. It was also found to be less protective against phenylephrine-induced spasm than nitroglycerin, urapidil, and nicorandil. Our group previously reported that phenoxybenzamine prevents RA spasm for at least 6 hours compared with up to 1 hour for papaverine [74, 75]. Phenoxybenzamine prevents catecholamine-induced spasm by binding irreversibly to α-adrenoceptors before new receptors develop after 48 hours. At least 18 hours’ inhibition to norepinephrine has been demonstrated [76]. We also showed that although papaverine caused endothelial damage in 70% of RA segments, the endothelium of all segments bathed in phenoxybenzamine was preserved. It must be noted that the literature fails to distinguish between papaverine-induced cell injury and that caused by the acidity of inadequately buffered papaverine solutions. For example, in the study by Dipp and colleagues [74] papaverine was in saline solution of pH 5.75, which is consistent with other reports documenting that acidity is injurious to endothelium [80]. The standard practice in our unit is to use a solution of phenoxybenzamine (2 mg/mL) and verapamil (0.1 mg/mL) in heparinized blood, applied intraluminally and topically to the RA.

Calcium channel blockers are often prescribed as a postoperative antispasmodic agent, although the evidence to support this practice is inconclusive.

Comment

Data from large RCTs and meta-analyses suggests that RA patency is comparable to LSV patency in the short term but is superior over the medium term and long term. Evidence also suggests improved early and late

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Table 3. Comparison of Topical Agents for Prevention of Radial Artery Spasm

<table>
<thead>
<tr>
<th>Agent</th>
<th>Vasooconstrictors Inhibited</th>
<th>Duration of Action</th>
<th>Impair Endothelial Function?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Papaverine [74–76]</td>
<td>Epinephrine Phenylephrine Potassium Norepinephrine</td>
<td>30 min–2 h</td>
<td>?*</td>
</tr>
<tr>
<td>Phenoxybenzamine [74–76]</td>
<td>Dopamine Epinephrine Phenylephrine Potassium Norepinephrine</td>
<td>≥18 h</td>
<td>No</td>
</tr>
<tr>
<td>Verapamil with nitroglycerin</td>
<td>Angiotensin II Epinephrine Phenylephrine Potassium Prostaglandin F(2 alpha)</td>
<td>5–24 h</td>
<td>No</td>
</tr>
</tbody>
</table>

* Uncertainty whether or not impaired endothelial function results from papaverine or inadequately buffered acidic solution.
clinical outcomes, including survival with RA grafting. RA grafts should be reserved for coronary arteries with at least 70% to 80% stenosis, preferably 90%, although there should be a move toward the use of objective measures to assess likelihood of competitive flow, such as fractional flow reserve and minimal luminal and vessel diameter. Endoscopic RA harvesting reduces morbidity and improves patient satisfaction while providing comparable patency to open harvesting. Skeletonization may improve short-term patency, although more data are required to establish clear differences at short-term to long-term follow-up. Both aortocoronary and composite RA configurations may be safely used, although sequential anastomoses may improve patency compared with single anastomosis. Preoperatively, duplex ultrasonography and consideration of risk factors for RA occlusion, particularly PVD, should be used in patient selection. Topical vaso-dilators are essential to minimize the occurrence of early graft failure. Phenoxylepamine with verapamil or nitroglycerin, or both, are more effective than papaverine.

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References


