**Arterial Grafts in Coronary Artery Bypass Surgery**

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**Abstract**

Coronary artery bypass grafting (CABG) is the optimal surgical treatment for multi-vessel coronary artery disease. CABG operation has successful short- and intermediate-term results, but the long-term results are variable. The variability of results in long-term particularly depends on the nature of the vascular grafts used. Angiographic studies in long-term have showed that patency rates of arterial grafts were superior to patency rates of vein grafts. Numerous studies documented an incremental survival and events free benefit by utilizing increased number of arterial grafts during CABG. Long survival has improved by total arterial revascularization compared to using left internal thoracic artery (LITA) and saphenous vein grafts (85% to 90% at 10 years versus 75% to 80%, respectively). Total arterial revascularization patients also have lower rate of cardiac-related events including new myocardial infarction, recurrence of angina, severe arrhythmia, congestive heart failure requiring hospitalization and reoperations.

Thus, total arterial revascularization for CABG may be beneficial for long-term outcome. The LITA, the right internal thoracic artery (RITA), the radial artery (RA), the right gastroepiploic artery (RGEA) and the inferior epigastric artery (IEA) can be used as arterial conduits. In this paper we review these arterial conduits and clinical results associated with their use in CABG.

**ABBREVIATIONS**

CABG: Coronary Artery Bypass Grafting; PCI: Percutaneous Coronary Intervention; ITA: Internal Thoracic Artery; LITA: Left Internal Thoracic Artery; RITA: Right Internal Thoracic Artery; LAD: Left Anterior Descending; SVG: Saphenous Vein Graft; MIDCAB: Minimally Invasive Direct Coronary Artery Bypass; RA: Radial Artery; RGEA: Right Gastroepiploic Artery; IEA: Inferior Epigastric Artery; Cx: circumflex coronary artery; RCA: right coronary artery; BITA: Bilateral Internal Thoracic Arteries; BMI: Body Mass Index;

**INTRODUCTION**

Coronary artery bypass grafting (CABG) has been shown to be superior to percutaneous coronary intervention (PCI) and is established as the standard of care for treating patients with multi-vessel coronary artery disease [1,2]. Clinical studies have documented the successful short- and long-term results of CABG. But these studies have also documented that the choice of conduits for surgical revascularization plays a major role in long-term outcomes. These studies showed good long-term patency in arterial conduits and poor long-term patency in venous conduits [2,3]. So, total arterial revascularization for CABG becomes of great interest to many surgeons [2,4].

In this paper we review different arterial conduits and the clinical results associated with their use in CABG.

**Internal Thoracic Artery**

Internal thoracic artery (ITA) was used in humans as early as 1945 by Vineberg, who implanted left internal thoracic artery (LITA) directly in the myocardium of the left ventricle [4]. Demikhov, first described the directly grafting LITA to the left anterior descending (LAD) coronary artery in dogs in 1952. In 1964, Kolesov performed the first CABG operation by anastomosing the LITA to left circumflex artery [4]. Although the LITA had been started to routinely used by surgeons as early as the 1970s, improved clinical outcomes with the use of LITA graft when compared to vein graft was first reported in mid-1980s [2,5]. Since then LITA has been the first graft of choice during CABG with its excellent patency rates.

Numerous structural features provides superiority of ITA over saphenous vein graft (SVG) with increased survival and greater patency rates (>90% at 10 years) [2,6]. Predominantly, ITA demonstrates resistance to the development of atherosclerosis. It is adapted to higher arterial pressures [7]. The endothelium is more resistant against harvest injury and has higher basal production of the vasodilators nitric oxide and prostacyclin [8].
The endothelium relaxes in response to aggregating platelets. The medial layer is thinner, with fewer smooth muscle cells and a lesser proliferative response to mitogens and mechanical stretch [7]. It has a fenestrated internal elastic lamina that inhibits cellular migration and prevents intimal hyperplasia. The flow through it is laminar with a large diastolic component characteristic of native coronary artery flow. The increase in flow velocity in response to exercise is great. It can dilate in response to increased myocardial blood flow demand [7,8].

The ITA can be harvested by conventional technique or minimal invasive techniques. In the majority of CABG operations, ITA is harvested by conventional technique using median sternotomy. Three surgical options are available for harvesting the ITA by minimal invasive techniques. These options can be applied during standard minimally invasive direct coronary artery bypass (MIDCAB), thoracoscopic MIDCAB, and robotically assisted MIDCAB [9]. During thoracoscopic ITA takedown for MIDCAB, one lung ventilation is mandatory and three ports are placed in mid axillary line in the 3rd, 5th, and 7th spaces, respectively. Finally, during robotically assisted MIDCAB, single lung ventilation is essential and the chest cavity is insufflated with carbon dioxide to create additional space.

The ITA can be harvested as with its satellite veins, part of the intercostal muscles and intrathoracic fascia (pedicled graft) or without accompanying tissue (skeletonized graft). Skeletonization makes a longer graft possible, protects the vascularization of the sternum and is so less harmful for the thoracic wall. On the other hand, harvesting the ITA in skeletonized fashion is technically more troublesome with greater possibility of damage. The other disadvantage is that Skeletonization deprives the graft of the venous and lymphatic greater possibility of damage. The other disadvantage is that Skeletonization deprives the graft of the venous and lymphatic drainage [10]. The question whether Skeletonization of the ITA improves in CABG has been investigated by a best-evidence-topic study recently [11]. The study reviewed 17 papers and patency was assessed with the use of angiography, performed on average within four years of CABG surgery. The authors concluded that short- and medium-term patency rates of both skeletonized and pedicled conduits were excellent [11].

The harvested ITA can be used as in situ graft or free graft. The ITA is preferably used as a free graft when there is a stenosis at the origin of the subclavian artery or in case of the length of the ITA graft is insufficient for the target coronary artery. A less frequently usage of free ITA might be consequence of damage on proximal part of graft during harvesting. Furthermore, the ITA can be used for revascularization of a single vessel or several vessels by using it as a sequential graft [10].

He at al proposed a functional classification for arterial grafts to be used clinically [12]. According to this classification, three types of arterial grafts are as follows: type I (somatic arteries), type II (splanchnic arteries) and type III (limb arteries). Somatic arteries are located in and supply blood to the body wall, and the ITA is a typical example of this type of artery. Type I arterial grafts are less reactive than type II or II arterial grafts. Therefore, ITA is less prone to vasospasm compared to radial artery (RA), right gastroepiploic artery (RGEA) or inferior epigastric artery (IEA) grafts.

Left internal thoracic artery is preferably used to revascularize the LAD or its diagonal branches. Only in patients where revascularization of the LAD is unnecessary, the LITA can be used for the second most important coronary artery. The use of LITA to LAD has patency rates of 90-95% ten to twenty years after CABG (while SVG has a patency of 50% five to ten years after CABG) [2,13]. The patency is lower when it is used at other coronary arteries. Tatoulis et al showed the 15-year patency of the LITA grafts. In this study the patency rates were 97% in LITA-LAD grafts. The patency decreased to 91% and 84% in those the LITA used at the circumflex coronary artery (Cx) and right coronary artery (RCA), respectively [14].

The RITA has identical anatomic and histological characteristics with the LITA and this makes it’s an excellent conduit, too. Patency of the RITA to LAD is identical to that of LITA to LAD at 10 years (94-96%). As with LITA, the patency of the RITA is also lower when it is used at the Cx or RCA [15]. These lower patency rates were attributed to smaller runoff of the Cx system and competitive flow effect of large RCA [16]. In the case of LITA-LAD anastomosis, better patency rates could be obtained by directing to RITA to the most important branch of Cx artery through the transverse sinus or over the aorta anteriorly as insitu conduit. If the length is major concern, RITA can be used either as free graft or composite graft along with LITA as T or Y graft to reach the lateral target vessels [16,17].

Following successful long-term results of single ITA grafting to the LAD, many groups suggested that the use of both ITA's (BITA) would further improve the outcomes. The study of the Cleveland group in 1999 confirmed that the use of both ITA's was associated with greater survival and reduced reoperation in compare with the use of a single ITA (80-90% for BITA grafting versus 50-60% for single ITA+ SVG at 10 years) [18]. Since then, numerous other studies have also supported the survival benefits of BITA grafting [19,20]. Despite these results, only 5-10% of patients receive BITA grafts. The major concern with the use of BITA is the increased risk of sternal infection and mediastinitis [20]. Although there are no absolute contra-indications for the use of both ITA's, it should be avoided in morbidly obese (BMI>40), insulin dependent diabetics and those with severe chronic obstructive airways disease [21].

**Radial Artery**

Alain Carpentier first introduced the use of the RA for CABG in 1971 [2,4]. However, four years later, Carpentier reported that one-third of the RA grafts were occluded [4]. Consistent with this finding, at the same year, use of RA as a graft was reported to result in significant intimal hyperplasia and early graft failure [4]. Graft failure was attributed to harvesting technique of radial artery [4]. Eventually, use of RA was almost completely abandoned. The RA remained a ‘forgotten conduit’ until its use was revived by Acar et al in 1992 [4]. The author refined the technique of graft harvesting and used calcium-channel blockers rather than mechanical vasodilatation to overcome RA spasm. Since then, RA is considered as a reasonable alternative to other grafts that complement the LITA.
According to functional classification for arterial grafts, RA is considered as a type III arterial graft and has a higher tendency for spasm compared to somatic arteries [8]. Structurally, the RA has a thin continuous intima of endothelial cells, a single internal elastic lamina and a relatively thick media of tightly-packed smooth muscle cells, which predisposes to spasm, occlusion and thrombosis [8]. Magnitude of vasospasm in arterial grafts also related to their endothelial function. The ITA releases more nitric oxide and has higher endothelium derived hyperpolarizing factor –mediated relaxation than RA, which may prove to have the best endothelial function among arterial grafts [8]. Furthermore, a histopathological and morphometric study showed that distal RA segments have significantly reduced luminal diameter and increased intimal hyperplasia compared to proximal RA segments [22]. Thus, trimming off the small and highly reactive distal end of the graft may be important to help preventing vasospasm.

Before harvesting the RA, it is mandatory to assess the adequacy of forearm collateral circulation to the hand. Methods to detect adequate forearm collateral flow include the clinical modified Allen test, pulse oximetry, digital blood pressure measurement, flow measurement with photoplethysmography, segmental pressure measurements, laser Doppler flowmetry, modified Allen test with Doppler ultrasonography and color Doppler with pulsed wave spectral trace of flow. In clinical practice, modified Allen test is the widely preferred method for preoperative evaluation. The radial artery is not used if the Allen test is positive or the perfusion index is less than 45% [23]. Other contraindications to RA harvesting include damaged RA due to trauma of previous cannulations, renal failure requiring hemodialysis, vasculitis, carpal tunnel syndrome, Raynaud’s disease, Dupuytren contracture, rheumatoid arthritis and subclavian stenosis [23].

The surgical options for RA harvesting are open and endoscopic approach. A meticulous operative technique is of paramount importance influencing the long-term patency of the RA graft. The surgeon harvesting the RA by open approach must be aware of particular anatomic structures which can be summarized by ‘two muscles, two nerves, and two branches’. The two muscles are the brachioradialis muscle and the flexor carpi radialis muscles, together which describe the crevice wherein lies the RA. The two nerves are the lateral antebrachial cutaneous nerve and the superficial radial nerve. Finally, the two branches, the recurrent radial artery and the superficial palmar artery define the proximal and distal limits of the RA harvest respectively. The RA gives off numerous perforating branches that supply the forearm and hand, most of them arising from the dorsal hemi circumference of the RA. These perforating branches should be transected traumatically and safely to mobilize RA during harvesting. For this purpose, options of surgical techniques include; electrocautery alone, sharp dissection with clips, a combination of electrocautery and clips, and ultrasonic dissection. Despite concerns about heat generation from the electrocautery, injury can be minimized by keeping the electrocautery current low [23].

Endoscopic approach for RA harvesting has been gaining popularity in recent years. There are two different systems for endoscopic approach: the open system and the sealed system. Proponents of the endoscopic approach propose that endoscopic radial artery harvesting significantly improves wound healing and pain, reduces neurologic complications and provides outstanding cosmetic results [23]. However, endoscopic harvesting takes longer than the open approach and there is also a learning curve.

In addition to meticulous surgical technique during RA harvesting, various pharmacologic agents are used to avoid or reverse vasospasm. Vasodilator agents include calcium channel blockers, nitroglycerin, phosphodiesterase inhibitors, α-adrenergic antagonists and a mixture of drugs [12]. During operation, once the harvesting of the RA has initiated low dose vasodilator agent is given systematically, and after dissection of RA from the arm completed, it is stored in blood solution with one of the aforementioned vasodilator agent at the room temperature. Oral long-acting nitrates or calcium channel blockers are continued for up to 6 months postoperatively [12, 23].

During CABG operations, depending on the location of proximal anastomosis, RA grafts can be used as a single conduit or as a composite conduit. The most commonly used options for proximal anastomosis are the ascending aorta (aortocoronary conduit) and ITA, in a T or Y fashion (composite conduit) [2,24,25]. Whether a RA proximally anastomosed to the pedicled ITA rather than to the aorta improves graft patency remains debatable. The proponents of composite conduit claim that the shear stress increased when the RA is anastomosed to aorta and advocated performing the proximal anastomosis to a vascular region with a lower dp/dt, such as an ITA graft [26]. Although the use of composite arterial conduits composed of RA anastomosed to ITA has gained acceptance and popularity recently, its superiority over direct RA anastomosis to the aorta has not been proved. Furthermore, Gaudino et al. [27] reported that flow competition occurs more frequently in the composite RA conduits than in the aortocoronary conduit.

A number of angiographic studies showed that RA graft achieved acceptable patency rates in range of 93 to 100% in short-term [25,26], 88 to 99% in mid-term [25,26,28], and 84 to 96% in long-term [25,28], respectively.

At present, the LITA is accepted as the best arterial graft due to its excellent patency rates in range of 90 to 95% ten to fifteen years after CABG [29]. However, the second choice of graft after LITA remains controversial. For this purpose, graft patency comparing the RA and SVG has been investigated by systematic reviews. The Radial Artery Patency Study (RAPS), a multi-center trial, enrolled 561 patients undergoing CABG with 3 vessels and compared RA and SVG occlusion rates in both short and long-term [30]. In this study, target vessels for RA and SVG were the right and circumflex coronary arteries with > 70% proximal stenosis. The primary end point was graft occlusion, determined by angiography in short-term (8 to 12 months) and long-term (7.7±1.5 years) after surgery. Both in short-term and in long-term, the rate of occlusion in RA was lower than in SVG (8.2% vs 13.6%) and (12.0% vs 19.7%), respectively [30]. A recently published meta-analysis including five randomized controlled trials by Cao et al. [31] compared the rates of occlusion of RA (n=859) and SVG (n=849) by angiography at one and four years. Although the rates of occlusion of RA and SVG were not
The RGEA or the IEA is rarely used unless the above-described conduits are unavailable or inadequate. According to functional classification for arterial grafts, RGEA and IEA are considered as type III arterial grafts and they have a thick smooth muscle media that is prone to spasm [12]. Furthermore, harvest of the arteries requires intra-abdominal entry or an extra abdominal incision which increases operative time and may be associated with additional complications [32].

The RGEA has been used clinically in humans since the late 1980s and has been reported to have satisfactory early and midterm results. Harvesting is definitely more time consuming, although some minutes may be saved by simultaneous dissection with the ITA. Indications for its use are total arterial revascularization, paucity of venous conduit, especially with patients undergoing repeat coronary bypass [32]. It has been used in young patients with Kawasaki disease by many investigators. Mills and coworkers found this graft particularly useful in conjunction with right ITA grafting in patients with ascending aortic atherosclerosis, in which a no-touch technique of the aorta is used [32]. Contraindications for RGEA grafting include previous gastric resection. Patients with extreme obesity are poor candidates for its use as are those with abdominal visceral atherosclerosis. A prime consideration for RGEA grafting is the severity of coronary atherosclerosis. RGEA grafts to minimally stenotic coronary arteries are destined to become string signs because of competition of flow with the native circulation. This is more certain with the RGEA graft as opposed to other conduits because of their longer lengths [33]. Many surgeons prefer the posterior descending coronary artery for RGEA anastomosis. On occasion, this conduit is large and very long and the distal 5 to 9 cm may be transected and used as a separate free graft. The RGEA may be used as a sequential graft to two or more coronary branches only if it is 2.25 mm internal diameter (ID) or larger at the site for sequential anastomosis. Because the graft is relatively thin compared with other conduits, sequential anastomoses to smaller diameter sections of conduit tend to fail for technical reasons [32,34].

Although the RGEA graft is primarily harvested by detaching it from the greater curvature of the stomach as a pedicle with surrounding tissues, skeletonized RGEA harvesting was introduced by Gagliardotto et al in 1998. Based on the recent paper, the skeletonized RGEA graft is proposed to obtain longer and larger conduit which facilitates the use of composite and sequential grafts [33].

Glineur et al. compared the outcomes of patients undergoing BITA anastomosis with either a RGEA or SVG. After 16 years follow-up, they found that addition of RGEA to BITA grafting decreased mortality compared to a SVG [34].

The IEA was used in clinical practice by Puig et al in the 1980s. Many reports were published about its use as a conduit in CABG in the early 1990s [35]. The IEA originates from the medial side of the distal part of the iliac artery, approximately behind the inguinal ligament. There are no major differences between the right and left IEAs. Although the IEA follows the superior epigastric artery, one of the branches of the internal thoracic artery, a great difference exists between the two arteries, in terms of elastic internal membrane fenestrations and the muscular component of the media layer. The distal size of IEA is usually small (1 to 1.2 mm). The IEA is a muscular graft like the RGEA and RA. Its flow is easily affected from coronary resistance and competitive flow by native coronary artery [35]. These features are deemed to be responsible from decrease patency rate of IEA graft. Therefore, the use of IEA has significantly declined recently [34].

Multiple Arterial Grafting

Myocardial revascularization with arterial grafts may be considered as a spectrum ranging from adding RA graft to conventional LITA plus SVG operation to total arterial revascularization [2]. Total arterial revascularization can be achieved by various graft configurations. Buxton et al described the options of these configurations well in a recently published paper [36]. According to their descriptions, mainly five methods are available as follow:

Option 1: in situ LITA to Cx or intermediate coronary artery on the left side, RITA to LAD and RA to right coronary system

Option 2: in situ LITA to LAD and Y configuration with an arterial graft to diagonal if needed, RITA to Cx coronary artery via transverse sinus, and RA to right coronary system

Option 3: LITA to LAD, RA to Cx coronary artery and in situ RITA to right coronary system

Option 4: LITA to LAD and bilateral RA grafts to Cx coronary artery and to right coronary system

Option 5: in situ LITA to LAD and joining the free RITA or RA as a Y graft to the LITA for distal sequential anastomoses to the branches of the Cx and right coronary system.

Besides above descriptions, RGEA may be used in patients with poor graft options or as an adjunct to more complete arterial revascularization. The most favorable target for the in situ RGEA conduit is the right coronary artery, preferably the PDA, but the conduit can be used also for the distal part of Cx artery [20,37].

One should be kept in mind, as a second arterial conduit for CABG as an adjunct to LITA-LAD anastomosis, the RA and RITA can be considered for anterolateral wall when coronary stenosis is higher than 70% and the RA and RGEA can be considered to graft to the distal part of right coronary system when stenosis is sub-occlusive or higher than 90% [20, 37].

Although plenty of options for graft configurations are available, and superior patency rates and clinical benefits of arterial grafts are being documented by numerous studies, majority of surgeons are reluctant to use arterial grafts during CABG operations. Currently, over 95% of all CABG operations in the United States and over 90% in the United Kingdom are being
completed by using only one arterial graft [36,37]. Commonly raised concerns regarding BITA grafts use can be summarized as follow: surgeons not trained in RITA harvest, not comfortable with the actual use of the RITA to perform coronary grafting, uncertainty about how best to deploy the RITA (in situ, free or Y?), prolonging the operation, concern regarding sternal infection, necrosis and non-union and lack of randomized trials [38]. However, RITA harvest is the same as LITA harvest and the RITA has usually larger diameter than the LITA in most right handed individuals. Sternal infection, necrosis and non-union can be minimized by skeletonized harvest of RITA, meticulous surgical technique and perioperative glucose management [38]. Glineur et al. demonstrated that a Y-graft configuration with free right ITA anastomosed to an in situ left ITA allows good revascularization of the whole coronary system [34]. They also stated that ITA used in a Y fashion has an increased risk of competitive flow compared with the in situ graft. Commonly raised concerns regarding RA graft use are potential vasospasm, prolonging the operation, calcification in RA and length of RA. Spasm prophylaxis is particularly important for RA graft and available antispasm protocols have been described earlier in the relevant section of the present manuscript. Likewise, inadequacy of forearm collateral circulation, calcification, previous trauma and other contraindications preclude RA harvest in 5% to 11.6% of patients [24]. The RGEA requires the abdominal incision (in addition to sternotomy) and exposure for harvesting which might increase sternal wound healing and affect bowel function [37]. The advantages and disadvantages of each arterial graft are shown in Table 1.

There is growing body of evidence that patency rates of arterial grafts are superior compared to patency rates of vein grafts after CABG. Patency rates of arterial grafts and SVG in short-, mid- and long-term are shown in Table 2. Once better patency rates of arterial grafts had been established, then studies focused on investigating whether this superior patency rates translate into substantial improvements in clinical outcomes. A large-scale study from Mayo Clinic reported that in patients undergoing isolated CABG with LIMA to LAD, arterial grafting of the non-LAD vessels yielded a survival advantage at 15 years compared with SVG [39]. Zacharias et al. also investigated the effect of total arterial grafting on late survival in patients with multi vessel disease undergoing CABG [6]. They found that total arterial revascularization was associated with significantly better 12-year survival compared with the standard single ITA with SV grafting, in particular for triple-vessel disease patients [6].

The severity of stenosis in the target coronary artery determines both early and long term patency of arterial grafts. Since the term ‘competitive flow’ indicates that flow from the native coronary artery reduces the amount of flow through the graft, grafted conduits may perform better in the case of high-grade stenosis or occlusion of target coronary arteries. A large body of literature proves that grafting the arterial grafts to target coronary arteries with moderate stenosis (<70%) results in significantly reduced conduit patency due to negative effects of competitive flow [20,38,40]. The weight of the evidence indicates that the coronary stenosis should be at least 70% for left coronary vessels and 90% for the right coronary, and probably the left main although there are not specific data for the latter [20,38,41] (Table 3).

RCTs are performed with the primary goal of understanding the efficacy of a new therapy in a selected group of patients [42-52]. Beside this, to draw straightforward reliable conclusion, patient characteristics such as the degree of coronary stenosis, comorbidities and other demographic features should be similar in the study related to coronary artery disease and its surgical treatment. Furthermore one should be kept in mind that planned control angiographic strategy would add more valuable contribution than that angiogram which is done when patients have symptoms to reveal best graft selection for coronary bypass surgery.

### Table 1: The advantages and disadvantages of each graft.

<table>
<thead>
<tr>
<th>Graft</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
</table>
| ITA   | Excellent long-term patency | - BITA not suitable for IDDM, obesity and COPD  
- Longer harvesting time  
- More bleeding than RA  
- Not suitable for proximal anastomosis to aorta |
|       | Resistant to atherosclerosis |  |
|       | Resistant to harvest injury |  |
|       | Increased intimal nitric oxide production |  |
|       | Reduced tendency to vasospasm than RA |  |
| RA    | Superior long-term patency | - Prone to vasospasm  
- Not always available (positive Allen test, CRF)  
- Potential numbness and sensory dysfunction  
- Not suitable for less-than-severe lesions |
|       | Enough length to any coronary territory |  |
| RGEA  | Available in redo CABG | - Laparotomy  
- Not better patency than of SV  
- More spasmodic than ITA  
- Not suitable in obese patients |
|       | Substitute for RA composite graft |  |
| SV    | Easy to harvest | - Inferior long-term patency  
- Not available if varicose veins exists  
- Susceptible to intimal hyperplasia and atherosclerosis  
- Postoperative leg edema  
- Potential problems with wound healing |
|       | Enough length to any coronary territory |  |

**Abbreviations:** BITA: Bilateral Internal Thoracic Artery; CABG: Coronary Artery Bypass Grafting; COPD: Chronic Obstructive Pulmonary Disease; CRF: Chronic Renal Failure; IDDM: Insulin Dependent Diabetes Mellitus; ITA: Internal Thoracic Artery; LITA: Left Internal Thoracic Artery; RA: Radial Artery; RGEA: Right Gastroepiploic Artery; SV: Saphenous Vein
### Table 2: Patency rates of arterial grafts and SV graft in short-, mid- and long-term.

<table>
<thead>
<tr>
<th>Reference</th>
<th>No of patients</th>
<th>Year</th>
<th>Type of trial</th>
<th>Time to reangiography</th>
<th>LITA</th>
<th>RA</th>
<th>SV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possati et al[43]</td>
<td>68</td>
<td>1998</td>
<td>Prospective</td>
<td>4.9±0.5 years</td>
<td>98.2%</td>
<td>88.6%</td>
<td>74%</td>
</tr>
<tr>
<td>Bhan et al[44]</td>
<td>62</td>
<td>1999</td>
<td>Prospective</td>
<td>16.2±5.1 months</td>
<td>98.2%</td>
<td>96.8%</td>
<td>-</td>
</tr>
<tr>
<td>Amano et al[45]</td>
<td>475</td>
<td>2001</td>
<td>Prospective</td>
<td>&lt;3 months</td>
<td>99%</td>
<td>98.6%</td>
<td>89.5%</td>
</tr>
<tr>
<td>Zacharias et al[46]</td>
<td>1850</td>
<td>2004</td>
<td>Retrospective</td>
<td>1.8±1.4 years</td>
<td>93.9%</td>
<td>68.2%</td>
<td>63.3%</td>
</tr>
<tr>
<td>Schwan et al[47]</td>
<td>532</td>
<td>2009</td>
<td>Retrospective</td>
<td>2.65±2.49 years</td>
<td>94.2%</td>
<td>70.6%</td>
<td>59.4%</td>
</tr>
<tr>
<td>Hayward et al[48]</td>
<td>334</td>
<td>2007</td>
<td>Prospective</td>
<td>3.9 years</td>
<td>95.5%</td>
<td>83%</td>
<td>-</td>
</tr>
<tr>
<td>Tranbaugh et al[49]</td>
<td>1851</td>
<td>2012</td>
<td>Prospective</td>
<td>5.0±3.8 months</td>
<td>85%</td>
<td>82%</td>
<td>47%</td>
</tr>
<tr>
<td>Tautoulis et al[14]</td>
<td>2127</td>
<td>2004</td>
<td>Retrospective</td>
<td>76.2±47 months</td>
<td>97.1%</td>
<td>87.1%</td>
<td>60.2%</td>
</tr>
<tr>
<td>Possati et al[28]</td>
<td>90</td>
<td>2003</td>
<td>Prospective</td>
<td>8.8±0.8 years</td>
<td>96.3%</td>
<td>90.5%</td>
<td>67.1%</td>
</tr>
</tbody>
</table>

**Abbreviations:** LITA: Left Internal Thoracic Artery; RA: Radial Artery; SV: Saphenous Vein

### Table 3: Differences in survival obtained by arterial grafts versus SV graft.

<table>
<thead>
<tr>
<th>Reference (No of Patients)</th>
<th>Type of trial</th>
<th>Graft/Interval/Survival</th>
<th>Graft/Interval/Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lin et al[50] (520)</td>
<td>Retrospective</td>
<td>LITA-RA/1 year/95%</td>
<td>LITA-SV/1 year/94%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LITA-RA/5 years/82%</td>
<td>LITA-SV/5 years/78%</td>
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<td></td>
<td></td>
<td>LITA-RA/12 years/52%</td>
<td>LITA-SV/12 years/43%</td>
</tr>
<tr>
<td>locker et al[39] (8622)</td>
<td>Retrospective</td>
<td>MultArt/10 years/83%</td>
<td>LITA-SV/10 years/80%</td>
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<tr>
<td></td>
<td></td>
<td>MultArt/15 years/70%</td>
<td>LITA-SV/15 years/60%</td>
</tr>
<tr>
<td>Puskas et al[38] (3527)</td>
<td>Retrospective</td>
<td>BITA/1 year/98%</td>
<td>LITA/1 year/94%</td>
</tr>
<tr>
<td>Grau et al[51] (6313)</td>
<td>Prospective</td>
<td>BITA/5 years/91%</td>
<td>LITA/5 years/81%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BITA/8 years/89%</td>
<td>LITA/8 years/68%</td>
</tr>
<tr>
<td>Cameron et al[52] (8271)</td>
<td>Prospective</td>
<td>LITA/15 years/71%</td>
<td>SV/15 years/61%</td>
</tr>
</tbody>
</table>

**Abbreviations:** BITA: Bilateral Internal Thoracic Artery; MultArt: Multiple Arterial Grafting; LITA: Left Internal Thoracic Artery; RA: Radial Artery; SV: Saphenous Vein

**CONCLUSION**

Ample evidence suggests that arterial grafts have superior patency rates compared to SVG after CABG operations. Since graft patency predominantly determines prognosis in CABG operations, even adding an arterial graft to conventional LITA/SVG policy by using RITA or RA grafts improves survival. In addition, revascularization of all areas of myocardium with arterial grafts can be achieved by various operative strategies including composite arterial grafts, Y or T graft configurations and sequential grafting. Therefore, total arterial revascularization may yield the greatest possible long-term benefit of CABG with the same low mortality and morbidity risks of conventional CABG.

**REFERENCES**

9. Itagaki S, Reddy RC. Options for left internal mammary harvest in...


