

Radial and gastroepiploic arteries. Harvesting and utility

Bruno B. Camacho-Álvarez

Department of Cardiothoracic Surgery, Centro Médico Nacional de Occidente., Instituto Mexicano del Seguro Social. Guadalajara, Jalisco, MÉXICO.

The radial artery graft in myocardial revascularization outperforms in survival, freedom from cardiovascular events/death and patency to venous grafts. The myocardial revascularization guidelines consider it as the second arterial graft if the double breast is not possible. It requires clinical and sonographic evaluation; the exclusion criteria are clear. The technique for harvesting is very similar to that of the saphenous vein, preserving the brachioradialis nerve, recurrent radial nerve, and arterial interosseous branches. Pharmacological schemes for graft preservation depend on their availability. There are no studies that compare the proximal anastomosis site, which can be the ascending aorta or mammary arteries. The distal anastomoses can be single or sequential. The gastroepiploic artery graft is a little used graft whose reported effectiveness is similar to the rest of the arterial grafts in experienced centers, with no greater morbidity if harvested. It resembles the internal mammary artery, but with less long-term patency being up to 70%. It is an alternative for multiple arterial revascularization with target vessels located in an accessible location to this graft and given the limited availability in number and quality of other grafts. The myocardial revascularization guidelines do not refer specifically to this graft. Criteria for its selection are clear. Harvesting requires extending the sternotomy to the abdomen and traversing the diaphragm with the graft. Anastomosis variants depend on the target vessel. Postoperative care is similar to that for other arterial grafts. Complications are related to distortion of the vessel.

Key words: Arterial grafts; Gastroepiploic artery; Internal mammary artery; Myocardial revascularization; Radial artery; Saphenous vein.

El injerto de arteria radial en revascularización miocárdica supera en sobrevida, libertad de eventos cardiovasculares/muerte y permeabilidad a los injertos venosos. Las guías de revascularización lo consideran como el segundo injerto arterial si la doble mamaria no es posible. Requiere evaluación clínica y sonográfica, los criterios de exclusión son claros. La técnica para la cosecha es muy similar a la vena safena preservando el nervio braquioradial, radial recurrente y ramas interóseas arteriales. Los esquemas farmacológicos de preservación del injerto dependen de su disponibilidad. No hay estudios que comparen el sitio de anastomosis proximal, puede ser aorta ascendente o arterias mamarias, las anastomosis distales pueden ser únicas o secuenciales. El injerto de arteria gastroepiploica es un injerto poco utilizado cuya efectividad reportada es similar al resto de los injertos arteriales en centros de experiencia, no se reporta mayor morbilidad si se cosecha, asemeja a la arteria mamaria con menor permeabilidad a largo plazo siendo de hasta 70%. Es una alternativa para revascularización arterial múltiple con vasos diana de localización accesible a este injerto y ante poca disponibilidad en número y calidad de otros injertos. Las guías de revascularización no hacen alusión específica a este injerto, los criterios para su elección son claros. Su cosecha requiere extender la esternotomía al abdomen y atravesar el diafragma con el injerto. Las variantes de anastomosis dependen del vaso diana. El cuidado postoperatorio es similar al de otros injertos arteriales. Las complicaciones se relacionan con distorsión del vaso.

Palabras clave: Injertos arteriales; Arteria gastroepiplóica; Arteria mamaria interna; Revascularización miocárdica; Arteria radial; Vena safena.

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RADIAL ARTERY

General overview

Since the 1990's, comparative anatomical studies of the

grafts used for myocardial revascularization have been published, demonstrating the usefulness and advantages of arterial grafts over the venous ones in terms of durability and flow quality [1]. The initial reports using the radial artery as a graft for myocardial revascularization are described by Carpentier in 1973, concluding that long-term follow-up was required to assess its durability [2]. The advantages described in his publication of the radial artery

Corresponding author: Dr. Bruno B. Camacho Alvarez
email: brunocamacho@hotmail.com

graft over venous grafts included a 2.25 mm lumen, superficiality that facilitates dissection, a resistant wall, an average length of 22 mm, its dissection does not cause hand ischemia, and a rare tendency to form atherosclerosis. It was not until 1989 when Carpentier himself corroborated angiographic patency in some cases for up to 18 years that it was decided to review the dissection technique and modify the technique as "en bloc" harvesting (along with satellite veins) as well as administering intraluminal diltiazem and in impregnated gauze for preservation. Currently, there are some groups with up to 49 years of experience that emphasize when it should be used given its proven advantages over vein grafts. Current publications include multicenter studies with a follow-up of more than 20 years, with evidence of average patency of 80%, freedom from cardiovascular events closely to 90%, being much lower than in the venous graft groups, and freedom from reoperation greater than 90%. Survival of the left mammary and radial graft group was comparable to the total arterial revascularization group and superior to the venous graft groups by more than 10% at 20 years [3,4,5]. The 2018 myocardial revascularization guidelines describe the alternative of the radial artery with insignificant morbidity. The endoscopic harvest has not yet fully demonstrated its safety and efficacy. Recent angiography approach trends through this access rules out its use. The suggested extraction method is as pediculate with injection of vasodilators and considers it as the second option when double mammary graft is not possible in stenosis >70% and ideally >90% with clear evidence of providing greater survival. Primary results in randomized studies when compared with saphenous vein report lower rates of death, infarction and revascularization at 50 months, which suggests its use with a level of evidence IB regarding the choice of graft, as well as IA with respect to aspects of the procedure. [6].

Preoperative evaluation for the use of the radial artery graft

The use of the radial graft requires evaluation by means of the Allen test with its oximetric variant and arterial Doppler ultrasound. Sensitivity rates of 54.5%, specificity of 91.7% and diagnostic accuracy of 78.5% have been reported in general with respect to the viability of its use, with variability at 5 seconds of 75.8%, 81.7% and 79.6% respectively, as well as at 3 seconds of 100%, 27% and 52%. Meharwal et al. report a safe dissection in their series of 3,977 patients using the Allen test in addition to pulse oximetry [7]. Abu-Omar et al. published a series with 287 cases using the Allen test combined with evaluation by arterial Doppler ultrasound in cases where there was doubt or the test was abnormal, with evidence of being a safe evaluation for its viability, highlighting that the Allen test alone was an evaluation performed by a senior surgeon in 88% of cases [8].

Exclusion criteria for the radial artery as a graft

In addition to the Allen test, the specific characteristics of the vessel rather than the variability of vascular distribu-

tion in the arm are important, being the anatomical ones: a size <1.5 mm (0.5% especially in women), calcification (greater than in the mammary up to 6% vs 2%), occlusion in the arm in diabetic patients (medial calcinosis), phosphate/calcium disorders, kidney failure, post-traumatic injury, vasculitis, Raynaud's disease, among others.

Surgical technique for harvesting the radial artery graft

It is fundamentally important to know the topography of the radial and ulnar artery up to its proximal limits with the brachial artery and distal in its division in the palmar arch, the non-dominant extremity being the choice. The brachioradialis and recurrent radial nerves must be gently handled, as well as the interosseous arteries being respected as much as possible. The technique does not differ so much from that used for saphenous vein graft harvesting. It is suggested to start an exploration 3 cm proximal to the wrist to assess the characteristics of the vessel that may exclude this alternative as a graft. For the anatomical delimitation of the graft, it is important not to extend dissection above the elbow when it presents a high birth. It has been documented that the radial artery emerges proximally in the middle part of the arm in up to 4% or in the axillary region and extends superficially in the forearm anterior to the brachioradialis muscle. At the opposite end, when it presents a high termination, it can be used with its branches as a Y graft. In fact, a termination of the radial artery in the middle third of the forearm has been reported in up to 1% of cases [7]. The use of a harmonic scalpel or surgical ligation to separate the graft from collateral branches does not jeopardize its viability as long as stumps are left with a length of at least 2 mm. An alternative technique is the hydrodissection with crystalloid solution and ligation of the collateral branches with hemostatic clips. It is suggested to ligate the distal and proximal stumps with silk or 4-0 polypropylene to avoid discomfort caused by the artifact when a hemostatic clip is used at that level.

Radial artery graft preservation

There are multiple drugs available for graft preservation. Papaverine usually reaches action in minutes and a maximum of 1 hour, with a duration of 8 hours. It has the disadvantage of its acidity (pH 4.4 to 4.8) that is usually buffered with Ringer's solution 30 mg in 30 mL of heparinized blood at 37°C. Nitroglycerin has rapid action and short life; when used with topical verapamil, it can prolong its duration up to 8 hours. Topical nitroprusside is less popular due to profound systemic effects and its lack of familiarity. Among the calcium channel blockers, diltiazem has a weak effect, nifedipine is 15 times more powerful, although it has little availability in infusion. Verapamil combined with nitroglycerin is usually the most accessible. Milrinone has a duration of 2 hours reporting up to 15 years of experience in its use in some centers mixing up 5 mg in 50 mL heparinized blood. Phenoxybenzamine may probably be better than papaverine as it is less acidic with a duration of up to 18 hours, since it blocks norepinephrine unlike vasopressin having no effect on angiotensin or thrombohexane. It

is often used in conjunction with verapamil; however, is poorly available.

Myocardial revascularization technique with radial graft

Regarding the site of the proximal anastomosis for the use of the radial artery graft in coronary revascularization, there are currently no prospective randomized studies that analyze the clinical and angiographic results. Onoratti et al. in a series of 114 patients demonstrated similar hemodynamic results as well as flow reserve when the proximal anastomosis is to the ascending aorta compared to when it is connected to the left mammary artery [8]. Berreklouw et al. in a retrospective review compared the two variants and found that mammary artery anastomosis is a risk factor for postoperative ischemic events; however, the analysis was of a single variable [9]. Lemma reports in a cohort of 512 patients no difference in terms of hospital stay or late results with respect to the two variants [10]. The reported alternatives with mammary artery anastomosis are as an extension of the right mammary artery graft, as a T or Y graft to the left mammary artery, distal anastomoses are usually single or sequential depending on the number of target vessels to be revascularized [7].

Postoperative management in myocardial revascularization with radial artery

Patients who receive a radial coronary graft require the use of nitroglycerin in the first 24 postoperative hours at a dose of 10-100 mg/min, while allowing perfusing mean arterial pressures. Topical nitroglycerin or oral nitrates are useful during the first 72 hours, or you can opt for the use of milrinone or diltiazem infusion for 24-48 hours. The use of these drugs requires optimizing the patient's hemodynamic status, maintaining cardiac indices greater than 2.5 L/min/m², adequate urinary output, and venous oxygen saturations in blood gases above 55%. The use of norepinephrine should be reserved only for those cases of hypotensive emergency or with data of systemic inflammatory response with compromised vascular resistance. The goals in this area are less than 1500 dynes-sec/cm²/m² with a cardiac index greater than 3 L/min/m². Once out of critical care, the patient benefits from the use of calcium channel blockers. Since in several meta-analyses its use was related to fewer adverse cardiac events and better clinical results, a 6-month schedule using amlodipine 2.5 to 5 mg daily is suggested.

Complications of the use of the radial artery graft

The most feared complication is motor dysfunction, being extremely rare. Common sensory disorders are greater with the open technique and are usually transient due to traction of the superficial radial nerve and edema, which manifest as discomfort in the thenar eminence, thumb and adjacent fingers. Reported incidence is around 30%, and is self-limited to the first 12 postoperative months. Infection rates are inferior to 1%. Other complications such as hematomas and seromas have an incidence of less than 1%.

Patients who present with decreased strength and dexterity at onset often do not notice any limitations at 1-year follow-up [11].

GASTROEPIPLOIC ARTERY

General overview

The right gastroepiploic artery used as a graft in coronary artery bypass grafting was initially described in 1960 by Bailey as an indirect revascularization method for the inferior or posterior aspect of the heart. In the Vineberg procedure, patency was demonstrated at 9 years by Hirose et al. Currently, centers with experience in its use report mortality rates of 1.26% with a 15-year survival rate of 71.3%. Freedom from cardiac death rates at 15 years are close to 90%. The evidence of patency in these centers at 10 years is 70%, considering it a safe graft with adaptable physiology similar to that of the mammary artery [12]. The gastroepiploic artery is the largest terminal branch of the gastroduodenal artery that emerges from the common hepatic artery in 75% of cases, or in the minority from the right, left hepatic, left accessory, or celiac trunk. When there is absence of the gastroduodenal artery, the emergence is from the superior mesenteric artery. It usually runs along the posterior surface of the proximal duodenum and the anterior surface of the head of the pancreas at the inferior margin of the pylorus and through the greater curvature of the stomach along the gastroepiploic vein to the left between the two leaves of the gastrocolic omentum. The diameter of the right gastroepiploic artery is 3 mm or greater at its origin and 1.5 to 2 mm at the midpoint of the greater curvature of the stomach. The form of termination is variable; it forms a continuous arcade with the left gastroepiploic artery in 35%, plexiform anastomoses in 15%, has no communication in 45%, and forms indirect anastomoses to the epiploic artery in 5% of cases. Histologically, it has abundant smooth muscle proliferation in the tunica media wall, making it more susceptible to spasm and less susceptible to atherosclerosis. It has physiological reactions to chemotactic agents in a very similar way to the internal mammary artery, being more sensitive to potassium chloride, serotonin and norepinephrine. Histamine, unlike the internal mammary artery, causes dilation in the gastroepiploic artery.

Gastroepiploic artery graft selection criteria

The use of a right gastroepiploic artery graft is justified in cases in which the objective is to revascularize with arterial grafts and it is impossible to reach the coronary arteries on the posterior-inferior surface of the heart by using in situ or free internal mammary artery grafts, when the need is a third graft despite a sequential mammary graft is an alternative to consider, and when it is anatomically feasible to revascularize initially or in reoperation but there is a deficiency in quantity or quality of conventional grafts such as the mammary, radial or internal mammary arteries, and vein grafts. Likewise, extensive disease of the ascending aorta that requires a no-touching technique. Among the widespread indications are young patients with aggressive atherosclerosis that predicts poor results with vein grafting,

coronary anatomy more favorable for total arterial revascularization using the gastroepiploic artery in the posterior descending right coronary artery, distal anterior descending artery or extremely posterior obtuse marginal arteries. Severe proximal lesions or coronary occlusions within reach and that are compatible in size with the gastroepiploic artery. Relative contraindications for its use are previous or future gastric surgery, morbid obesity, advanced age (unless no other graft is available), asymptomatic patients with a low risk of myocardial infarction or death, increased frailty, chronic obstructive pulmonary disease and a life expectancy of less than 6 months. Multiple arterial grafting is not suggested in patients with unstable angina who failed to respond to medical treatment prior to surgery [13,14]. In the 2018 guidelines for myocardial revascularization, there is no specific reference to the gastroepiploic artery. However, at least one additional arterial graft is suggested when possible as the treatment of choice [6].

Surgical technique: harvesting and revascularization

For gastroepiploic artery harvesting, the sternomy extends inferiorly as far as the umbilical scar; afterwards, the stomach is exposed and a tactile-visual examination of the vessel is performed while assessing thickness, length, pulsatility and sensitivity to spasm. A pedunculated dissection of the greater curvature is performed, sectioning the branches of the omentum with electrocautery; the gastric branches must be ligated with silk sutures or hemostatic clips. Mobilization begins at the lower margin of the pylorus, taking care to respect the posterior aspect of the duodenum, extending up to half or even two thirds of the greater curvature, trying to keep the pedicle as large as possible. Prior to its distal section, total heparinization was performed after hemostasis was verified at the dissection site. The preservation solution of choice is papaverine at a rate of 40 mg dissolved in 10 ml of 0.9% saline solution, with intraluminal injection, taking care not to place clamps in the proximal portion. Distal clamping favors pulsatile and pharmacological dilation. After assessing the length of the graft, the distal 2 or 3 cm are skeletonized by ligating the adjacent gastroepiploic vein. For a skeletonized dissection, the use of a harmonic scalpel or its equivalent is preferred. The anterior layer of the greater omentum is divided and the gastroepiploic artery is exposed in its full extent. The epiploic and short gastric branches are divided. Extension and preservation are similar to the

pedunculated technique by wrapping the graft in papaverine-impregnated gauze. The approach to the pericardium is made through a window in the diaphragm (one or two finger spans) in proximity to the atrioventricular junction made with electrocautery. Any twisting of its pedicle is avoided, and finally the graft follows a path anterior to the stomach and liver. The technique of the distal anastomosis in the gastroepiploic artery graft depends on the topography to be revascularized. The antegrade modality (heel proximal to the direction of the coronary artery) is preferred for the distal right coronary artery or posterior descending artery; the retrograde modality (heel distal to the direction of the coronary artery) is the choice for the anterior descending artery or, rarely, for the proximal right coronary artery. In the case of the circumflex artery, the antegrade alternative is preferred. It is important to verify that there is no kinking and that the pedicle is not excessively pulled out of the abdomen. It is suggested to fix the distal portion of the pedicle to the epicardium to avoid twisting. Abdominal drains are not usually needed. In cases where it is used as a free graft, the proximal anastomosis can be to the ascending aorta, the saphenous vein graft or the internal mammary artery graft [12].

Postoperative care and complications of gastroepiploic artery revascularization

To prevent spasm, diltiazem infusion 1.5 to 2.5 mg/kg/min is suggested, followed by oral diltiazem 30 mg 3 times a day, although the importance of calcium antagonists in the postoperative period is uncertain.

Complications related to the gastroepiploic artery graft are usually hemorrhage or hematoma at the level of the omentum or stomach, kinking or torsion of the pedicle in its course through the diaphragm or at the site of anastomosis [14,15].

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REFERENCES

- van Son JA, Smedts F, Vincent JG, van Lier HJ, Kubat K. Comparative anatomic studies of various arterial conduits for myocardial revascularization. *J Thorac Cardiovasc Surg.* 1990;99(4):703-7.
- Carpentier A, Guernonprez JL, Deloche A, Frechette C, DuBost C. The aorta-to-coronary radial artery bypass graft. A technique avoiding pathological changes in grafts. *Ann Thorac Surg.* 1973 Aug;16(2):111-21. doi: 10.1016/s0003-4975(10)65825-0.
- Achouh P, Isselmou KO, Boutekadjirt R, et al. Reappraisal of a 20-year experience with the radial artery as a conduit for coronary bypass grafting. *Eur J Cardiothorac Surg.* 2012;41(1):87-92. doi: 10.1016/j.ejcts.2011.05.027.
- Royse AG, Brennan AP, Ou-Young J, Pawanis Z, Cauty DJ, Royse CF. 21-Year Survival of Left Internal Mammary Artery-Radial Artery-Y Graft. *J Am Coll Cardiol.* 2018;72(12):1332-1340. doi: 10.1016/j.jacc.2018.06.064.
- Gaudino M, Benedetto U, Fremes S, et al; RADIAL Investigators. Radial-Artery or Saphenous-Vein Grafts in Coronary-Artery Bypass Surgery. *N Engl J Med.* 2018;378(22):2069-2077. doi: 10.1056/NEJMoa1716026.
- Neumann FJ, Sousa-Uva M, Ahlsson A, et al; ESC Scientific Document Group. 2018 ESC/EACTS Guidelines on myocardial revascularization. *Eur Heart J.* 2019;40(2):87-165. doi: 10.1093/eurheartj/ehy394.
- Gaudino M, Crea F, Cammertoni F, Mazza A, Toesca A, Massetti M. Technical issues in the use of the radial artery as a coronary artery bypass conduit. *Ann Thorac Surg.* 2014;98(6):2247-54. doi: 10.1016/j.athoracsur.2014.07.039.
- Onorati F, Rubino AS, Cristodoro L, et al. In vivo functional flowmetric behavior of the radial artery graft: is the composite Y-graft configuration advantageous over

- conventional aorta-coronary bypass? *J Thorac Cardiovasc Surg.* 2010;140(2):292-297.e2. doi: 10.1016/j.jtcvs.2009.10.028.
9. Berreklouw E, Rademakers PP, Koster JM, van Leur L, van der Wielen BJ, Westers P. Better ischemic event-free survival after two internal thoracic artery grafts: 13 years of follow-up. *Ann Thorac Surg.* 2001;72(5):1535-41. doi: 10.1016/s0003-4975(01)03040-5.
 10. Lemma M, Mangini A, Gelpi G, Innorta A, Spina A, Antona C. Is it better to use the radial artery as a composite graft? Clinical and angiographic results of aorto-coronary versus Y-graft. *Eur J Cardiothorac Surg.* 2004;26(1):110-7. doi: 10.1016/j.ejcts.2004.03.020.
 11. Tatoulis J. The radial artery: An important component of multiarterial coronary surgery and considerations for its optimal harvest. *JTCVS Tech.* 2020 Nov 11;5:46-55. doi: 10.1016/j.xjtc.2020.10.042.
 12. Suma H. Gastroepiploic artery graft in coronary artery bypass grafting. *Ann Cardiothorac Surg.* 2013;2(4):493-8. doi: 10.3978/j.issn.2225-319X.2013.06.04.
 13. Pym J, Brown P, Pearson M, Parker J. Right gastroepiploic-to-coronary artery bypass. The first decade of use. *Circulation.* 1995;92(9 Suppl):II45-9. doi: 10.1161/01.cir.92.9.45.
 14. Vaidya Y, Bishop MA, Ludhwani D. Coronary Artery Bypass Graft of the Gastroepiploic Artery. (2022). In: *StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan.*
 15. Suma H. Gastroepiploic artery graft: coronary artery bypass graft in patients with diseased ascending aorta-using an aortic no-touch technique. *Oper Tech Thorac Cardiovasc Surg* 1996; 1(2): 185-195. doi: 10.1016/S1085-5637(07)70056-6.