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REVIEW ARTICLE

Total arterial revascularization: A superior method of cardiac revascularization

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Abstract For over 40 years, the left internal thoracic artery has been used as the gold standard for myocardial revascularization and anastomosis over the left anterior descending artery due to its excellent patency rates. However, the right internal thoracic artery behaves in the same manner as the left, also having excellent long-term patency. Hence, no patient should be deprived of the benefits of total arterial revascularization allowed by the bilateral use of both internal thoracic arteries.

1. Introduction

Half a million patients per year worldwide are estimated to undergo coronary artery bypass grafting (CABG)[1] CABG remains a superior option for revascularization compared to percutaneous coronary intervention (PCI) in cases of severe coronary artery disease (CAD)[2,3] owing to its major advantage of no need for repeat intervention.[3] Accordingly, an appropriate graft selection is a sine qua non to minimize mortality and reintervention. Currently, the left internal thoracic artery to the left anterior descending coronary artery (LITA or LIMA-LAD) graft is unanimously considered the gold standard of conduits.[4] Conduit selection for the grafting of the other coronary arteries varies. Provided that half of the saphenous vein (SV) grafts are patent without significant stenoses at 10 years,[5] some surgeons have fueled an interest in total arterial revascularization using one or both internal thoracic arteries (BITA or BIMA) and other arterial conduits such as the radial artery (RA) or the right gastroepiploic artery (GEA). Given the numerous advantages of BITA grafting and arterial conduits in terms of survival and extended patency rates, patients referred for surgery should not be denied the benefits of total arterial revascularization.[6]

2. Indications-contraindications

Every eligible patient should receive total arterial revascularization, the cornerstone of which is BITA grafting. Patients with a body mass index (BMI) of over 35, diabetes

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or severe airway disease or who are undergoing radiotherapy or immunosuppression are only relatively contraindicated for BITA use.[7] If more conduits are required, the RA can be prepared at the same time as the LITA, and its harvesting is associated with favorable early outcomes.[4] Prior to harvesting, a modified Allen test is performed. If a hyperemic response to the previous ischemic hand is noticed within 5 s, the collateral ulnar circulation is adequate. Restoration of the blood circulation to the ischemic hand later than 10 s after the ulnar release excludes the RA from being used.[8] Duplex examination and pulse oximetry can also be used to preoperatively evaluate the RA and ulnar artery. Moreover, the RA should be avoided when cardiac catheterization has been recently preceded by injuring the vessel and when the RA might be used for future fistulae in patients who are receiving or who are likely to receive dialysis.[7] RAs less than 2 mm in diameter are also avoided due to the possibility of vasospasm.[9] Finally, the extent of stenosis of the target coronary vessel may also constitute a contraindication for arterial conduit use due to competitive flow. Hence, stenoses of less than 70% in the left coronary bed and less than 90% in a dominant right coronary artery should prevent the use of an arterial graft.[7]

3. Graft patencies

High occlusion rates of vein grafts due to atherosclerosis of 12%, 25% and 50% within 1 year, 5 years and 12 years after CABG, respectively,[10,11] result in an increased need for repeat revascularization. Therefore, three percent of patients who have received vein grafts undergo a repeat revascularization procedure within 5 years, 10% within 10 years and 25% within 20 years.[12] Veins appear to be 2.6 times more prone to dysfunction than arteries.[13] Consequently, grafts with superior patency rates are sought either to prolong intervals to repeat revascularization or to prevent the need for repeat operations.[1]

As many as 80% of ITA conduits have been shown to be free from failure in the third decade after CABG.[7] RITA patency is 96% at 5 years and 81% after 10 years, levels that are comparable to LITA patency of 98% and 95%, respectively.[14] Tatoulis et al. reported similar patency between RITAs and LITAs when grafted to the same target vessel of 96.5% vs. 94.5%, respectively, when grafted to the LAD and 90.5% vs. 88.5%, respectively, when grafted to the circumflex artery.[15] Several angiographic studies from 6.7 to 12 years following surgery have reported that RITA graft patency ranges from 86% to 97% at levels similar to LITA patency rates.[16–19]

Conversely, the patency rates of the RA range from 83% to 93% at one to seven years postoperatively,[20] thus demonstrating a superior patency of the RA compared to the SV.[21,22] A meta-analysis has compared 419 RA to 412 SV grafts at follow-up times beyond three years. The complete occlusion rate of the RA was 6.7% vs. 17.2% for the SV grafts. RA graft failure was also significantly lower compared to SV grafts (9.6% vs. 18.8%). The graft patency of RAs of 88.6% was superior to that of the SVs of 75.8%. Similar findings have been reported by a recent single-institution study involving 1,851 patients showing a superiority of the RA compared to the SV in terms of graft patency and graft failure,[23] as well as a meta-analysis by Athanasiou and colleagues that observed better mid-term patency (1–5 years) for RA grafts.[24]

For gastroepiploic artery grafts, the 5-year patency rates are similar to those of the SV grafts of 62% and 86% in two large studies.[25,26] However, skeletonized gastroepiploic arteries appear to have superior outcomes when compared to SV grafts.[27]

4. Morbidity-mortality

Total arterial revascularization using BITA is also advantageous in terms of long-term survival, as well as reoperation and the need for angioplasty.[28–34] A clear benefit is seen in the first postoperative decade in cases using BIMA, and its advantage becomes even more apparent during the second postoperative decade.[35,36] A retrospective study by Lytle[29] has demonstrated a survival advantage associated with the use of BITA. Survival in the BITA group was 94%, 84% and 67% vs. 92%, 79% and 64% in the LITA group at 5, 10, and 15 years postoperatively, respectively ($p<0.001$). Another study by the same authors[28] showed a survival benefit of greater than 10% for BITA grafting at 20 postoperative years, except for in patients with a small body surface area and for those of advanced age, in whom BITA was inferior to LITA in terms of survival. Survival in the BITA group was 89%, 81%, 67% and 50% vs. 87%, 78%, 58% and 37% in the LITA group at 7, 10, 15 and 20 years, respectively ($p<0.0001$). Similar results were observed by Stevens and colleagues,[30] who reported survival benefit for BIMA on the order of 5% at 10 years (88% for the single-graft group versus 93% for the BIMA group; $p<0.001$). Grau et al.[37] compared 1459 BIMA and 4854 LIMA patients. Although the in-hospital and 30-day mortality rates were not significantly different between the two groups (0.8 vs. 1.1%, respectively; $P = 0.47$), BIMA grafting was superior to LIMA with regards to long-term survival. This survival benefit was once again demonstrated to be more in favor of the BIMA group throughout the 17-year follow-up period (96 versus 91% at 5 years, 89 versus 79% at 10 years and 79% versus 61% at 15 years). Interestingly, the late mortality risk was almost twice as high in patients undergoing on-pump LIMA grafting compared to those with off-pump BIMA grafting.[37] Taggart et al.[34] performed a meta-analysis of seven observational studies comparing 11,269 LIMA patients to 4,693 BIMA patients in 2001. A significant average survival benefit of 8 years was observed throughout the follow-up for the BIMA group. Similar results showing a statistically significant survival advantage with BIMA throughout a 7.6-year follow-up period even in diabetic patients was reported by another larger meta-analysis including 27 studies that compared 19,277 BIMA to 59,786 LIMA patients. Long-term mortality was also significantly reduced among patients receiving BIMA grafting.[38] Moreover, statistically significantly lower mortality and the need for percutaneous coronary intervention and decreased myocardial infarctions after BITA use at 20 postoperative years were reported by Rankin et al.[39] More postoperative deaths were also reported for the LITA group according to a retrospective study by Konstanty-Kalandyk[40] including 147 patients with coronary artery disease and diabetes (3.67 for

the LITA vs. 2.63% for the BITA). Diabetic patients who underwent BITA harvesting had an increased 10-year survival rate[41] and a lower perioperative mortality rate compared to the LITA group.[42] Stevens et al.[43] reported lower mortality and total hospital mortality rates (0 vs. 0.5%, 0.9 vs 2.6%) when comparing BITA to LITA in diabetic patients. Thirty-day mortality was also lower in the BITA than in the LITA group for diabetic patients (3.1 vs. 4.7%), according to Gansera et al.[44]

As far as morbidity is concerned, the BITA procedures also appear to be superior to the LITA ones. Although no benefit is observed during the first 4 years after the operation, a clear benefit is gained from the use of BITA after 15 years, as a 9% decrease is reported for angina recurrence.[45] BITA is also associated with an additional 7 years of freedom from reoperation as a result of better graft patency rates, as reported by Endo and colleagues.[32] The same authors also observed an advantage of BITA use in terms of 10-year freedom from adverse events only when the ejection fraction was >40%.[41] According to Berreklouw and colleagues,[33] 49.4% of LIMA patients either died or experienced angina recurrence, new myocardial infarction and underwent CABG again at 13 years compared to 33.3% of the BIMA patients ($p=0.0004$). Similarly, BIMA use was also an independent predictor of greater freedom from recurrent angina, late myocardial infarction and adverse cardiac events in a study by Pick and colleagues.[46] Grau et al. reported no significant differences with regard to perioperative complications and postoperative length of stay between BITA and LITA use, although more BIMA patients required blood transfusions.[37] Momin et al.[47] further reported that sternal wound infection risk was not increased when BITA was used in insulin-dependent diabetic patients, similar to the results of Svensson et al.,[48] who concluded that the use of the right internal thoracic artery is not related to a higher incidence of deep sternal wound infection in diabetic or non-diabetic patients. However, reoperation for bleeding is significantly more likely to occur in BIMA than in LIMA patients (2.9% vs. 0.6%), and sternal revision is also significantly more likely for BIMA patients (1.4% vs. 0.6%), according to Gansera et al.[44]

5. Objections to the use of BITA. Does skeletonization solve the problem?

Most patients with three-vessel CAD can receive total arterial revascularization.[49] However, its use is not widespread. The most cited disadvantages in the use of BITA are deep sternal wound infection (DSWI) and a higher risk of death. DSWI is perceived to be the result of sternal hypoperfusion due to the bilateral use of IMA.[37] Diabetes has been recognized as an additional independent risk factor for sternal wound infection.[50] Resternotomy for bleeding is another strong risk factor for DSWI, as is peripheral arteriopathy.[6] Savage et al.[42] observed that diabetic patients are more prone to DSWI when BITA is used and when they are insulin dependent and obese (BMI >35) and have peripheral arteriopathy. Similarly, Konstanty-Kalandyk et al.[40] reported that older and more obese diabetic patients were at increased risk of DSWI. According to Zhang et al.,[51] diabetic patients were 3.47 times more prone to DSWI for every 10 years of age and 6.80 times more prone to DSWI with BMIs of greater than 30. However, the bilateral use of IMAs in diabetic patients did not increase the risk of DSWI compared to unilateral use. According to De Paulis et al.,[6] 28% of the diabetic patients with chronic obstructive pulmonary disease, peripheral arteriopathy and a BMI>30 experienced DSWI, whereas only 2.3% of those without the aforementioned risk factors had DSWI. De Paulis et al.[6] reported that sternal infection was clearly more common in BIMA patients than in LIMA patients (1.1% vs. 4.2%; $P = 0.004$). However, when skeletonized ITA grafts were used, BITA use was no longer an independent predictor of DSWI.[6]

Skeletonization of the ITA, which was first used by Keeley in 1987,[52] refers the untouched mobilization of the artery and its accompanying veins and surrounding tissues.[53] In this way, the artery branches are ligated close to the artery so that collateral circulation to the sternum is maintained.[54] Thus, bilateral skeletonized IMAs minimize sternal infection risk at levels comparable to those for LIMA patients, particularly in diabetic patients.[55,56] Although some cardiac surgeons suspect that skeletonization damages the endothelium, a review of the literature by Athanasiou et al.[57] revealed neither damage of the ITA nor a worsening of its patency when skeletonized ITAs were compared to pedicled ITAs. Ali et al., upon examining 17 papers, reported excellent patency rates for both pedicled and skeletonized arteries that exceeded 95% at three postoperative years.[58] Therefore, we can conclude that patients can gain the full benefits from BITA grafting and maintain sternal, collateral circulation if skeletonized pedicles are used.[6]

6. Conclusions

Most patients with multivessel CAD can successfully receive total arterial revascularization. Total arterial revascularization is associated with higher graft patency rates, excellent long-term survival rates, fewer harvest site complications, lower CAD progression and reduced adverse cardiac events resulting in reoperation.[1,7,53] Patients referred to surgery should in no way be denied the advantages of total arterial revascularization. BIMA grafting can be safely performed,[1] and skeletonization of both ITAs minimizes sternal infection complications, thus increasing the number of candidates for BITA grafting by including many diabetic patients.[6] However, patients with many risk factors for wound complications should not receive BITA grafting. Furthermore, postoperative bleeding requiring resternotomy in BITA patients should also be avoided, as reexploration is a potent risk factor for sternal infection.[6] Consequently, total arterial revascularization with the use of bilateral ITAs should be the method of choice for revascularization procedures, as it has numerous benefits that cannot be ignored.[4,6,38]

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References

1. Parissis H, Soo AW, Al-Alao B. Is there any further advantage of using more than one internal mammary artery? Literature review and analysis. *Asian CardiovascThorac Ann*. 2013;21:101—113.
2. Mohr FW, Morice MC, Kappetein AP, et al. Coronary artery bypass graft surgery versus percutaneous coronary intervention in patients with three-vessel disease and left main coronary disease: 5-year follow-up of the randomised, clinical SYNTAX trial. *Lancet*. 2013;381:629—638.
3. Cao C, Manganas C, Bannon P, Vallely M, Yan TD. Drug-eluting stents versus coronary artery bypass graft surgery in left main coronary artery disease: a meta-analysis of early outcomes from randomized and nonrandomized studies. *J ThoracCardiovascSurg*. 2013;145:738—747.
4. Lytle BW. Bilateral internal thoracic artery grafting. *Ann CardiothoracSurg*. 2013;2:485—492.
5. Motwani JG, Topol EJ. Aortocoronary saphenous vein graft disease: pathogenesis, predisposition, and prevention. *Circulation*. 1998;97:916—931.
6. De Paulis R, de Notaris S, Scaffa R, et al. The effect of bilateral internal thoracic artery harvesting on superficial and deep sternal infection: the role of skeletonization. *J ThoracCardiovascSurg*. 2005;129:536—543.
7. Buxton BF, Hayward PA. The art of arterial revascularization—total arterial revascularization in patients with triple vessel coronary artery disease. *Ann CardiothoracSurg*. 2013;2:543—551.
8. Conklin LD, Ferguson ER, Reardon MJ. The technical aspects of radial artery harvesting. *Tex Heart Inst J*. 2001;28:129—131.
9. Blitz A, Osterday RM, Brodman RF. Harvesting the radial artery. *Ann CardiothoracSurg*. 2013;2:533—542.
10. FitzGibbon GM, Kafka HP, Leach AJ, Burton JR. Interventions for coronary stenosis—a Canadian experience of 30 revolutionary years. *Can J Cardiol*. 1996;12:893—900.
11. Bourassa MG. Long-term vein graft patency. *CurrOpinCardiol*. 1994;9:685—691.
12. Cohn LH. *Cardiac surgery in the adult*. New York; London: McGraw-Hill Medical; 2008.
13. Magee MJ, Alexander JH, Hafley G, Ferguson Jr TB, Gibson CM, Harrington RA. Coronary artery bypass graft failure after on-pump and off-pump coronary artery bypass: findings from PREVENT IV. *Ann ThoracSurg*. 2008;85:494—499.
14. Tatoulis J, Buxton BF, Fuller JA. Patencies of 2127 arterial to coronary conduits over 15 years. *Ann ThoracSurg*. 2004;77:93—101.
15. Tatoulis J, Buxton BF, Fuller JA. The right internal thoracic artery: the forgotten conduit—5,766 patients and 991 angiograms. *Ann ThoracSurg*. 2011;92, 9-15; discussion 15—17.
16. Chow MS, Sim E, Orszulak TA, Schaff HV. Patency of internal thoracic artery grafts: comparison of right versus left and importance of vessel grafted. *Circulation*. 1994;90(suppl II):129—132.
17. Dion R, Glineur D, Derouck D, et al. Long-term clinical and angiographic follow-up of sequential internal thoracic artery grafting. *Eur J CardiothoracSurg*. 2000;17:407—414.
18. Gansera B, Schmidtler F, Angelis I, Kiask T, Kemkes BM, Botzenhardt F. Patency of internal thoracic artery compared to vein grafts—postoperative angiographic findings in 1189 symptomatic patients in 12 years. *ThoracCardiovascSurg*. 2007;55:412—417.
19. Shah PJ, Durairaj M, Gordon I, et al. Factors affecting patency of internal thoracic artery graft: clinical and angiographic study in 1434 symptomatic patients operated between 1982 and 2002. *Eur J CardiothoracSurg*. 2004;26:118—124.
20. Ngaage DL, Cowen ME, Griffin S, Guvendik L, Cale AR. The impact of symptom severity on cardiac reoperative risk: early referral and reoperation is warranted. *Eur J CardiothoracSurg*. 2007;32:623—628.
21. Cao C, Manganas C, Horton M, et al. Angiographic outcomes of radial artery versus saphenous vein in coronary artery bypass graft surgery: a meta-analysis of randomized controlled trials. *J ThoracCardiovascSurg*. 2013;146:255—261.
22. Schwann TA, Engoren M, Bonnell M, Clancy C, Habib RH. Comparison of late coronary artery bypass graft survival effects of radial artery versus saphenous vein grafting in male and female patients. *Ann ThoracSurg*. 2012;94:1485—1491.
23. Tranbaugh RF, Dimitrova KR, Friedmann P, et al. Coronary artery bypass grafting using the radial artery: clinical outcomes, patency, and need for reintervention. *Circulation*. 2012;126:S170—S175.
24. Athanasiou T, Saso S, Rao C, et al. Radial artery versus saphenous vein conduits for coronary artery bypass surgery: forty years of competition—which conduit offers better patency? A systematic review and meta-analysis. *Eur J CardiothoracSurg*. 2011;40:208—220.
25. Suma H, Tanabe H, Takahashi A, et al. Twenty years experience with the gastroepiploic artery graft for CABG. *Circulation*. 2007;116:I188—I191.
26. Takahashi K, Daitoku K, Nakata S, Oikawa S, Minakawa M, Kondo N. Early and mid-term outcome of anastomosis of gastroepiploic artery to left coronary artery. *Ann ThoracSurg*. 2004;78:2033—2036. discussion 2036.
27. Suzuki T, Asai T, Matsubayashi K, et al. In off-pump surgery, skeletonized gastroepiploic artery is superior to saphenous vein in patients with bilateral internal thoracic arterial grafts. *Ann ThoracSurg*. 2011;91:1159—1164.
28. Lytle BW, Blackstone EH, Sabik JF, Houghtaling P, Loop FD, Cosgrove DM. The effect of bilateral internal thoracic artery grafting on survival during 20 postoperative years. *Ann ThoracSurg*. 2004;78:2005—2014.
29. Lytle BW, Blackstone EH, Loop FD, et al. Two internal thoracic arteries are better than one. *J ThoracCardiovascSurg*. 1999;117:855—872.
30. Stevens LM, Carrier M, Perrault LP, et al. Single versus bilateral internal thoracic artery grafts with concomitant saphenous vein grafts for multivessel coronary artery bypass grafting: effects on mortality and event-free survival. *J ThoracCardiovascSurg*. 2004;127:1408—1415.
31. Kurlansky PA, Traad EA, Dorman MJ, Galbut DL, Zucker M, Ebra G. Thirty-year follow-up defines survival benefit for second internal mammary artery in propensity-matched groups. *Ann ThoracSurg*. 2010;90:101—108.
32. Endo M, Nishida H, Tomizawa Y, Kasanuki H. Benefit of bilateral IMA grafts over single IMA graft for multiple coronary artery bypass grafting. *Circulation*. 2001;104:2164—2170.
33. Berreklouw E, Rademakers PPC, Koster JM, van Leur L, van der Wielen BJW, Westers P. Better ischemic event-free survival after two internal thoracic artery grafts: 13 years of follow-up. *Ann Thorac Surg*. 2001;72:1535—1541.
34. Taggart DP, D'Amico R, Altman DG. Effect of arterial revascularization on survival: a systematic review of studies comparing bilateral and single internal mammary arteries. *Lancet*. 2001;358:870—875.
35. Avgerinos DV, Charitakis K. Hybrid coronary revascularization: present and future. *HJC*. 2015;56:193—196.
36. Doumas A, Christoforidis T, Iakovou I, Mosialos L, Bobotis G, Karatzas N. Incidence of reversible defect seen on myocardial perfusion scintigraphy using dipyridamole pharmacologic test early after primary percutaneous coronary intervention: how

safe is it to perform this protocol? *Hellenic J Cardiol*. 2014;55:492—498.
37. Grau JB, Ferrari G, Mak AW, et al. Propensity matched analysis of bilateral internal mammary artery versus single left internal mammary artery grafting at 17-year follow-up: validation of a contemporary surgical experience. *Eur J Cardiothorac Surg*. 2012;41:770—776.
38. Weiss AJ, Zhao S, Tian DH, Taggart DP, Yan TD. A meta-analysis comparing bilateral internal mammary artery with left internal mammary artery for coronary artery bypass grafting. *Ann Cardiothorac Surg*. 2013;2:390—400.
39. Rankin JS, Tuttle RH, Wechsler AS, Teichmann TL, Glower DD, Califf RM. Techniques and benefits of multiple internal thoracic artery bypass at 20 years of follow-up. *Ann ThoracSurg*. 2007;83:1008—1014.
40. Konstanty-Kalandyk J, Piatek J, Rudzinski P, Wrobel K, Bartus K, Sadowski J. Clinical outcome of arterial myocardial revascularization using bilateral internal thoracic arteries in diabetic patients: a single centre experience. *Interact CardiovascThorac Surg*. 2012;15:979—983.
41. Endo M, Tomizawa Y, Nishida H. Bilateral versus unilateral internal thoracic revascularization in patients with diabetes. *Circulation*. 2003;108:1343—1349.
42. Savage EB, Grab JD, O'Brien SM, et al. Use of bilateral internal thoracic arteries in diabetic patients increases deep sternal wound infection. *Ann ThoracSurg*. 2007;83:1002—1006.
43. Stevens LM, Carrier M, Perrault LP, et al. Influence of diabetes and bilateral internal thoracic artery grafts on long-term outcome for multivessel coronary artery bypass grafting. *Eur J CardiothoracSurg*. 2005;27:281—288.
44. Gansera B, Schmidtler F, Gillrath G, et al. Does bilateral ITA grafting increase perioperative complications? Outcome of 4462 patients with bilateral versus 4204 patients with single ITA bypass. *Eur J CardiothoracSurg*. 2006;30:318—323.
45. Naunheim KS, Barner HB, Fiore AC. 1990: results of internal thoracic artery grafting over 15 years: single versus double grafts. 1992 update. *Ann ThoracSurg*. 1992;53:716—718.
46. Pick AW, Orszulak TA, Anderson BJ, Schaff HV. Single versus bilateral internal mammary artery grafts: 10-year outcome analysis. *Ann ThoracSurg*. 1997;64:599—605.
47. Momin AU, Deshpande R, Potts J, et al. Incidence of sternal infection in diabetic patients undergoing bilateral internal thoracic artery grafting. *Ann ThoracSurg*. 2005;80:1765—1772.
48. Svensson LG, Mumtaz MA, Blackstone EH, et al. Does use of a right internal thoracic artery increase deep wound infection and risk after previous use of a left internal thoracic artery? *J ThoracCardiovascSurg*. 2006;131:609—613.
49. Itagaki S, Cavallaro P, Adams DH, Chikwe J. Bilateral internal mammary artery grafts, mortality and morbidity: an analysis of 1 526 360 coronary bypass operations. *Heart*. 2013;99:849—853.
50. Filsoufi F, Rahmanian PB, Castillo JG, Mechanick JI, Sharma SK, Adams DH. Diabetes is not a risk factor for hospital mortality following contemporary coronary artery bypass grafting. *Interact CardioVascThoracSurg*. 2007;6:753—758.
51. Zhang X, Wu Z, Peng X, et al. Prognosis of diabetic patients undergoing coronary artery bypass surgery compared with nondiabetics: a systematic review and meta-analysis. *J CardiothoracVascAnesth*. 2011;25:288—298.
52. Keeley SB. The skeletonized internal mammary artery. *Ann ThoracSurg*. 1987;44:324—325.
53. Hu X, Zhao Q. Skeletonized internal thoracic artery harvest improves prognosis in high-risk population after coronary artery bypass surgery for good quality grafts. *Ann Thorac Surg*. 2011 Jul;92:48—58.
54. Berdajs D, Zünd G, Turina MI, Genoni M. Blood supply of the sternum and its importance in internal thoracic artery harvesting. *Ann ThoracSurg*. 2006;81:2155—2159.
55. Kamiya H, Akhyari P, Martens A, Karck M, Haverich A, Lichtenberg A. Sternal microcirculation after skeletonized versus pedicled harvesting of the internal thoracic artery: a randomized study. *J ThoracCardiovascSurg*. 2008;135:32—37.
56. Deo SV, Shah IK, Dunlay SM, et al. Bilateral internal thoracic artery harvest and deep sternal wound infection in diabetic patients. *Ann ThoracSurg*. 2013;95:862—869.
57. Athanasiou T, Crossman MC, Asimakopoulos G, et al. Should the internal thoracic artery be skeletonized? *Ann Thorac Surg*. 2004;77:2238—2246.
58. Ali E, Saso S, Ashrafian H, Athanasiou T. Does a skeletonized or pedicled left internal thoracic artery give the best graft patency? *Interact CardiovascThoracSurg*. 2010;10:97—104.