Original Research Paper

Volume - 12 | Issue - 12 | December - 2022 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Radio-Diagnosis

CABG GRAFT EVALUATION USING MDCT

Dr. Sandeep Mahajan

Dr. Narendra Tembhekar

Dr. Ankita Jadhao

ABSTRACT Coronary artery bypass graft (CABG) surgery is considered as standard treatment for advanced coronary artery disease, typically triple vessel artery disease. Conventionally, invasive coronary angiography has been used to assess graft status and evaluate for graft occlusion. Nowadays multidetector computed tomography (MDCT) is commonly used in the assessment of bypass grafts due to new advancements in CT technology. The after-effects of myocardial revascularization depend on the patency of the bypass grafts. Multidetector CT scanners combine high spatial resolution with its the ability to demonstrate anatomy through volume-rendered images is nowadays considered as an important diagnostic tool for evaluation of bypass grafts in post CABG patients to demonstrate graft patency. Postoperative CABG patients who are symptomatic remain ideal candidate to undergo MDCT to detect early as well as late postoperative complications. Furthermore, the volume-rendered multidetector CT images are also helpful in preoperative planning for repeat CABG surgery. In our study we discuss the use of MDCT for evaluation of bypass grafts in post-CABG patients and review commonly used vascular bypass conduits, their typical CT appearances, and complications that may be evident at imaging after surgery.

KEYWORDS : CT Angiography; Post CABG; Graft evaluation.

INTRODUCTION

Coronary artery bypass graft (CABG) surgery remains the standard of care in the treatment of advanced, most commonly triple vessel coronary artery disease. Conventionally, invasive coronary angiography has been used to assess graft status and evaluate for graft occlusion. Nowadays use of multidetector computed tomography (MDCT) in the assessment of bypass grafts continues to grow with advances in CT technology. Multidetector CT scanners combine high spatial resolution with the ability to demonstrate anatomy through volume-rendered images, thus producing a more sensitive evaluation over conventional or spiral CT. The addition of electrocardiographic gating minimizes cardiac and coronary graft motion, further improving the sensitivity and specificity of multidetector CT evaluation for graft patency. These advances have also increased the ability to estimate the extent of intraluminal graft occlusion with noninvasive imaging techniques.

With increased success in imaging grafts for patency, multidetector CT is being used more widely in the postoperative chest pain evaluation after CABG surgery. Variety of etiologies, including recurrent angina secondary to graft occlusion, sternal infection, pleural or pericardial effusion, and less common but potentially lethal complications such as pulmonary embolism or pseudoaneurysm formation can be detected by the MDCT which offer a rapid, convenient, and noninvasive means of discerning the correct underlying diagnosis. In addition, the volume-rendered multidetector CT images are useful in preoperative planning for repeat CABG surgery.

In our article we discuss the current multidetector CT protocol for post CABG graft evaluation and review commonly used vascular bypass conduits, their typical CT appearances, and complications that may be evident at imaging after surgery.

Material & Methods :

Aims & objective:

1. To evaluate the patency of coronary artery bypass graft on MDCT angiography.
2. To evaluate the native artery.
3. To look for any complications involving the post operative grafts.

This was a retrospective study conducted during Feb-2021 to April-2022 at our institute. Total 92 post-CABG patients of all ages and both sex, referred from Cardiovascular & Thoracic Surgery (CVTS) department were undergone CT angiography study using standard CTA-CABG protocol on 128 slice Toshiba CT scanner. Post processing was done and images were analyzed for presence and patency of graft, native artery status and any associated complications. The referred patients whose CT angiography could not be performed due to history of allergy to contrast reagent or deranged renal function (KFT) of subjects were excluded.

Multidetector CT Protocol

Patients were scanned by using a 128-slice multidetector CT scanner (Toshiba Acquillion, Japan). Patients were positioned in the gantry supine and feet first with electrocardiographic leads placed on the anterior thorax to enable a retrospectively gated scan. Scan parameters were 120 kV, 0.4-second rotation speed, 85mAs, and 128 × 0.5 detectors. Pitch, which was dependent on the heart rate, averaged 0.3. The CT system automatically recommended a pitch value to optimize the temporal resolution by the number of sectors reconstructed from each scan. The scanner used a “beat-2-beat” algorithm as part of the retrospectively gated reconstruction, which encompassed variations in heart rate throughout the scan. Scans were performed in the caudal to cephalic direction, with a scan range from the thoracic inlet through the lung bases. The proximal subclavian arteries were also included.

We haven't used the beta-adrenergic blocking agents in any of the subjects of our study. Iohexol (Omnipaque 350 mg/ml, GE healthcare), a nonionic, iodinated, low-osmolar contrast medium, was injected intravenously in doses ranging from 80 to 120 ml, without direct variation with respect to patient weight, and saline flush of 30 ml was used. The rate of bolus contrast material administration was 5.5 ml/sec. A duel-head injector (IMAXEON, Byer) was used. An automatic bolus tracking method was used to optimize graft visualization. A region of interest was placed in the ascending aorta by using a preset threshold of 140 HU; a 10-second delay followed before scanning was begun to ensure filling of the distal vessels with contrast material.

All scans were reconstructed by using retrospective gating (75% of the R-R interval), with 1-mm-thick images reconstructed every 0.4 mm. A multisector approach was used, which was automatically determined by the scanner software and chiefly determined by the patient's heart rate using multi segment reconstruction. Axial images were automatically transferred to a freestanding workstation (Vitrea Extend; Toshiba Medical Systems). In conjunction with axial source images, three-dimensional volume-rendered images, multiplanar reformation images, and less frequently maximum intensity projection images were generated. Volume rendering parameters were selected from preset protocols; within each protocol, there were specific Hounsfield unit ranges depicted by set colors. Although axial images remain an important part of the baseline evaluation, we found that multiplanar reformation and three-dimensional volumetric images often optimally demonstrated the relationships between graft anastomoses and individual grafts.(Fig.1 a and 1 b)

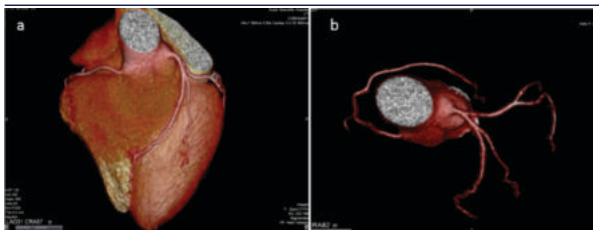


Fig.1a and 1 b. 3D volume rendered images of CT angiography of coronary arteries depicting normal anatomy.

DISCUSSION :

Types of Grafts and Their Normal Radiologic Appearances

The various conduits used for CABG surgery may be divided into arterial and venous grafts. Venous grafts have demonstrated a tendency to develop partial or complete occlusions with time, whereas arterial grafts have shown relative resistance to plaque formation and obstruction. However, arterial conduits are more limited in their availability and ease of procurement compared with venous grafts, specifically the saphenous vein. Therefore, saphenous vein grafts (SVGs) remain the most commonly used conduits.

A) Saphenous Vein Graft

A segment of the saphenous vein was used to perform the first CABG operation in 1962. Since then, the susceptibility of SVGs to occlusive failure in both early and late postoperative settings has been well documented and extensively investigated. Early graft occlusion is primarily due to vascular damage that can occur at surgery, whereas vessel wall changes resulting from exposure to systemic blood pressure may predispose to occlusion in later stages. Nevertheless, continued improvements in surgical techniques, combined with use of antiplatelet or anticoagulant agents and lipid-lowering drug therapy, have allowed SVGs to remain an important, convenient, and readily available choice for bypass grafting (22).

Saphenous vein conduits are harvested from the legs and grafted from the ascending aorta to the distal coronary artery beyond the obstructive coronary lesion. The vein is usually attached to the anterior aspect of the aorta. Left-sided grafts are typically anastomosed distally to the LAD artery, diagonal artery, circumflex artery, or the obtuse marginal branches of the circumflex artery. Right-sided grafts are usually connected to the distal right coronary artery or posterior descending artery (Fig.2). At postoperative multidetector CT, the proximal anastomosis of a graft is typically better visualized than its distal counterpart. Even if the distal anastomosis is not well visualized, if contrast material is demonstrated within the graft column at multidetector CT, it suggests graft patency.

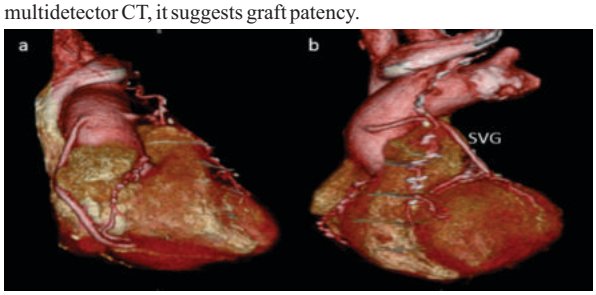


Fig.2 3D volume rendered images of saphenous vein grafts. a) depicting saphenous venous graft from ascending aorta to posterior descending artery, and b) saphenous venous graft from ascending aorta to obtuse marginal artery.

B) Internal Mammary Artery (IMA) Graft

Although the IMA was also used for bypass grafting in the early years of CABG surgery, its resistance to thrombosis became recognized only decades later. The advantages of IMA conduits over SVGs are now well documented and include decreased postoperative mortality, improved cardiac event–free survival rates, and long-term patency rates well above 90% at 10 years (22,16). Thus, the IMA has become the preferred bypass graft.

Because of its location near the LAD artery, the left IMA is most often used to revascularize the LAD artery in order to supply the greatest territory of the heart (Fig. 3). The left IMA is typically separated from the chest wall. Its origin at the subclavian artery remains intact and the distal end is connected to the target vessel, distal to the site of occlusion.

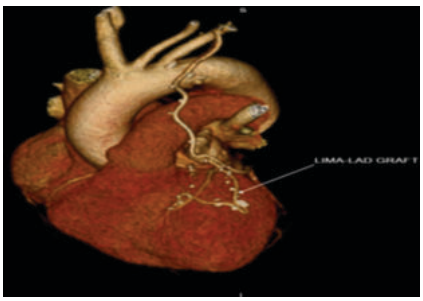


Fig.3 3D volume rendered images showing IMA graft single vessel graft - left internal mammary artery connected to left anterior descending artery

The right IMA may also be used in a variety of ways. As an in situ graft, the right IMA remains attached to the right subclavian artery proximally and anastomoses with the target coronary artery distally. When grafted to the left-sided coronary system, the right IMA will often pass through the transverse sinus, since this has been shown to result in higher patency rates (36). Alternatively, the right IMA may be removed from the subclavian artery and used as a free or composite graft. When used as a composite arterial graft, the right IMA is attached proximally to a left IMA graft so that the left IMA inflow supplies both grafted vessels (Fig. 4 a & 4b)

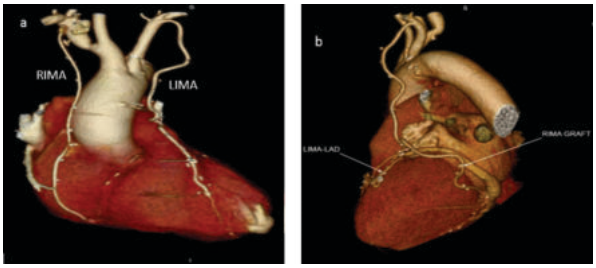


Fig. 4 3D volume rendered images showing IMA grafts a) double vessel graft - left internal mammary artery connected to left anterior descending artery and right internal mammary artery connected to posterior descending artery, b) LIMA-RIMA Y-Graft left internal mammary artery to LAD and composite RIMA graft from LIMA to posterior descending branch.

C) Other Arterial Grafts

Owing to the success of IMA grafts, there has been an initiative to develop other arterial bypass grafts. The radial artery was selected because of its ease of procurement from the forearm. Initial attempts at using radial artery grafts were complicated by frequent graft closure. However, with recent improvements in harvesting, surgical techniques that avoid endothelial disruption, and use of calcium channel blockers postoperatively to overcome graft spasm, the radial artery is currently regarded as a valid arterial graft option. Patency rates are now similar to those seen with IMA grafts, ranging from 95.7% at 12 weeks to 91.6% at 10 years (22,27). As with a right IMA graft, the radial artery may be used as a free or composite graft, with the goal of providing greater arterial revascularization.

The gastroepiploic artery has also been used as a bypass graft. After the median sternotomy is extended toward the umbilicus, the gastroepiploic artery is dissected from the greater curvature of the stomach. It can be grafted to the right or circumflex coronary artery by directing it in a retrograde fashion, or grafted to the LAD artery in an antegrade fashion. This is a technically difficult operation to perform, and the gastroepiploic artery has not become a popular bypass graft

Early Complications

Thrombosis

Within the first postoperative month, the primary mechanism for graft failure is thrombosis resulting from a combination of endothelial and medial damage during surgical retrieval and attachment. Graft closure from thrombosis at 1 month is a recognized complication in 10%–15% of cases (3). Perioperative venous graft failure after off-pump CABG procedures is chiefly determined by the two factors of graft endothelial damage and patient hypercoagulability (including resistance to

antiplatelet therapies) (28). High-pressure distention of venous grafts and their inherently weaker antithrombotic properties contribute to increased rates of early venous graft attrition. Specifically, too short of a graft may result in stretching of the vessel and damage to the endothelium, thereby initiating the cascade of thrombus formation.

Graft Malposition or Kinking

Malposition or kinking of the graft can also result in early graft occlusion (29) particularly in longer grafts. Technical factors associated with use of an aortic connector may predispose venous grafts to kinking (35). The angle of the attachment is critical; if the aortic connector is malpositioned without adequate support for the graft, the vessel may kink as it emerges from the proximal anastomosis. In addition, unlike conventional techniques, use of the connector requires that the proximal anastomosis be created first. This may make selecting the proper length of the vein more challenging, potentially resulting in either a stretched short segment of vein or kinking of an overly long segment of the graft.

Graft Spasm

Radial artery grafts are notably prone to postoperative vasospasm, a complication that may mimic fixed graft stenosis. Cardiothoracic surgeons employ various techniques to minimize this tendency, including intraoperative pretreatment of the graft with topical α-adrenergic antagonist solutions (such as phenoxybenzamine) or pharmacologic prophylaxis with calcium channel blockers (15, 1, 23). The latest generation of multidetector CT scanners shows promise in the demonstration of luminal narrowing in radial artery spasm (7).

Iatrogenic Complications

Iatrogenic causes may directly or indirectly lead to graft occlusion. Damage to the vascular endothelium from any source can result in clot formation. There are reports in the literature of iatrogenic vessel dissection leading to early acute occlusion (31).

Pericardial Effusion

Pericardial effusions are common after coronary artery bypass, occurring with a reported prevalence of 22%–85% (20,26). Important risk factors include postoperative anticoagulant therapy or coagulation abnormalities that are often related to the use of cardiopulmonary bypass. Despite their frequency, postoperative pericardial effusions rarely progress to become hemodynamically significant. Resultant cardiac tamponade has been reported in 0.8%–6% of patients (10). If this develops within the first 24 hours, it is termed early cardiac tamponade and is treated surgically to identify the source of bleeding. Late cardiac tamponade occurs at least 5–7 days postoperatively and may be related to excessive mediastinal drainage (11).

Pleural Effusion

Most patients who undergo coronary artery bypass grafting develop pleural effusions; the prevalence is approximately 90% within the first week after surgery (37,8). These tend to be small, unilateral, and left sided with no relationship to an enlarged cardiac silhouette, atelectasis, or placement of a chest tube (25). Patients are generally asymptomatic, and the effusion usually resolves spontaneously over several weeks (25). Only 1%–4% of CABG surgery patients proceed to develop clinically significant effusions that manifest with chest pain and dyspnea and require thoracocentesis. The pathophysiology of pleural effusion after CABG is unknown, but several etiologies have been postulated such as pericardial inflammation or intraoperative pleural injury, which may lead to lymphatic drainage or increased fluid production (37,25,14,11,9,38,12).

Sternal Infection

Approximately 2%–20% of CABGs are complicated by a surgical site infection (30). Infections can be categorized as involving the presternal, sternal, or retrosternal compartments (13). Much of the literature on surgical site infections after cardiothoracic surgical procedures has focused on retrosternal, deep chest infections, particularly mediastinitis. Although deep sternal infection occurs infrequently after CABG surgery (reported in 1%–4% of patients), it carries a significant mortality rate of nearly 25% (17,32). Risk factors that have been specifically linked to the development of sternal wound infections include obesity, diabetes mellitus, current cigarette smoking, and steroid therapy. Surgical risk factors linked to sternal site infections are numerous and include the following: previous sternotomy, complexity of the surgery, type of bone saw used, type of sternal closure, blood transfusions, and early re-exploration to control hemorrhage. The potential for increased infection risk after bilateral IMA grafting remains controversial.

Pulmonary Embolism

Clinical diagnosis of deep vein thrombosis and pulmonary embolism may be especially challenging after CABG surgery. Complaints of chest pain and dyspnea are common after cardiac bypass. Postoperative atelectasis, pleural effusion, or fluid overload may all contribute to the development of hypoxemia. Similarly, lower extremity edema with pain and swelling at the site of the saphenous vein harvesting are typical findings early after CABG surgery. For all these reasons, it is not uncommon for deep vein thrombosis and pulmonary embolism to remain unrecognized in the early postoperative setting (34).

A recent review of the literature regarding pulmonary embolism in the post–CABG surgery population showed an overall prevalence of 23% for deep vein thrombosis by 1 week after surgery, with less than 2% of these cases identified clinically (34). Although it is uncommon for pulmonary embolism to occur in this population (reported in 0.4%–9.5% of cases), because it is unsuspected, it may manifest as an unexpected and devastating clinical event (34). This diagnostic dilemma underscores the value of multidetector CT in this setting.

Late Stenosis and Occlusion

Occlusion after the first month following CABG surgery is primarily due to thrombosis resulting from progressive pathologic changes related to exposure of the SVG to systemic blood pressure. After surgery, the vein graft undergoes a process of arterialization. This results from progressive thickening of the media and neointimal formation, which begins within days of implantation and continues over months to years. These changes form a foundation for eventual atherosclerotic narrowing, which may ultimately lead to late graft occlusion.

In contradiction, IMA grafts are strikingly resistant to atheroma formation, resulting in higher long-term patency rates than for SVGs. Late IMA graft failure more commonly occurs from progressive atherosclerotic disease of the grafted native vessel distal to the anastomosis. Infrequently, stenosis can occur in the IMA graft from intimal hyperplasia, technical errors at the anastomotic site, or rarely atheroma formation (22) (Fig.5).

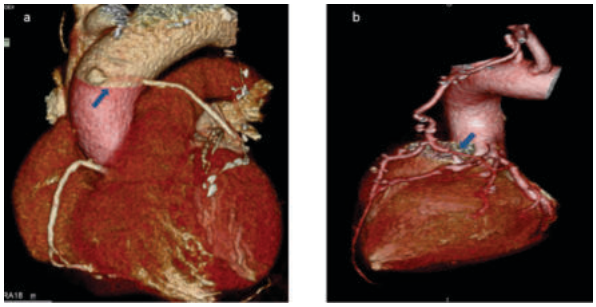


Fig.5 3D volume rendered images of venous and arterial bypass grafts a) depicting venous graft stenosis and b) arterial graft stenosis.

Graft Aneurysms

Aneurysmal dilatation of a bypass graft requiring surgical correction is generally regarded as exceeding 2 cm (19). True aneurysms typically arise more than 5 years after bypass and occur in the body of the graft. The dominant mechanism is related to accelerated atherosclerosis (21,2). Pseudoaneurysms more commonly occur within 6 months after surgery, although they may also arise several years later. Pseudoaneurysms arise at either proximal or distal anastomotic sites. Earlier-onset cases may be related to wound infection or to tension at the anastomosis that leads to suture rupture; the pathogenesis of later pseudoaneurysms most likely involves progressive atherosclerosis (19,21,18). Less common graft body pseudoaneurysms have been reported secondary to host vessel degeneration and technical factors involved in harvesting the SVG (21).

Planning Repeat CABG Surgery

As medical and surgical treatments for coronary artery disease have improved, patients are living longer. Consequently, second CABG operations have become more common. Injury to a preexisting left

IMA graft at sternal reentry is a well-recognized risk in this setting, and there has been extensive investigation into ways to prevent this potentially devastating complication (6,4).Multidetector CT is emerging as a useful means of mapping the course of a left IMA graft before repeat surgery (5,24,33). Three-dimensional volume-rendered images are the result of actively rotating anatomic structures with computer software in order to better delineate relationships between the sternum, ribs, and bypass grafts, thereby minimizing the risk of injury to the graft vessel during surgical reentry.

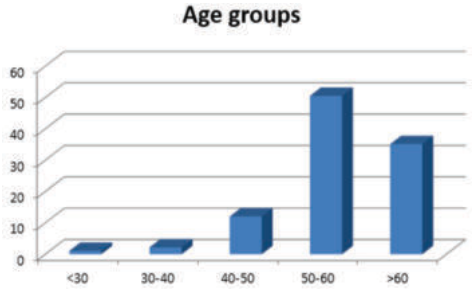
Observations and Results

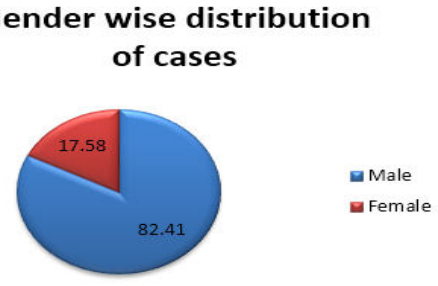
Total 92 cases were studied and the results have been summarized below –

Table 1 Showing agewise distribution of patients

Age group	Frequency	Percentage
<30	1	1.09
30-40	2	2.19
40-50	11	12.08
50-60	46	50.54
>60	32	35.16

Most common age group of the cases was between 50-60 years, followed by more than 60 years.

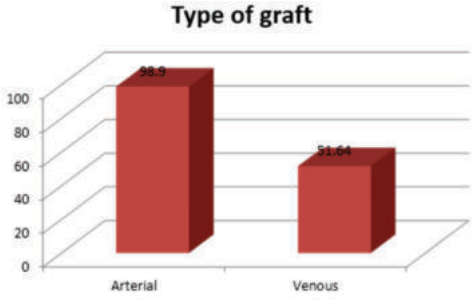




Pie Diagram - showing Sex distribution of cases. Majority of the cases were males.

Table 2 Showing Distribution of Arterial and Venous Grafts

Type of graft	Frequency	Percentage
Arterial	90	98.9
Venous	47	51.64



About 98.9% of the grafts were arterial grafts and 31.64% were venous grafts

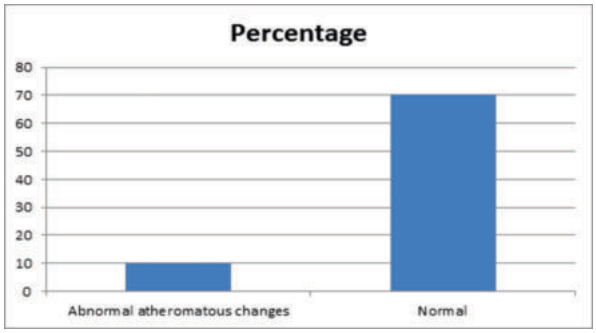
Table 3 Showing Stenosis rates of Arterial & Venous Grafts

	Arterial	Venous
Stenosed/occluded graft	25 (27.78)	12 (25.53)
Normal	65 (72.22)	35 (74.46)

Among the arterial grafts, 72.22% were normal and 27.78% were stenosed or occluded grafts. Among the venous grafts, 74.46% were normal and 25.53 % were stenosed or occluded grafts.

Table 4 Showing Atheromatous changes rates in various Grafts

	Frequency	Percentage
Abnormal atheromatous changes	9	9.89
Normal	64	70.32



About 9 (9.89%) grafts showed abnormal atheromatous changes and 64(70.32%) were normal.

Table 5 Showing Numberwise Frequency of various Grafts

Number of grafts	Frequency	Percentage
1 graft	55	60.43
2 grafts	19	20.87
3 grafts	4	4.39
4 grafts	8	8.79

60.43% had single graft, 20.87% had double grafts , 4.39% had 3 grafts and 8.79% had four grafts.

CONCLUSIONS :

- The advanced technology of electrocardiographically gated multidetector CT now allows the radiologist to access patency of post CABG grafts in a rapid, convenient, and noninvasive manner.
- MDCT is good in evaluating the native artery status.
- The multidetector CT has the added advantage over traditional angiographic evaluation of simultaneously allowing evaluation for alternate postoperative complications that may also manifest with chest pain and dyspnea, thereby mimicking recurrent angina.
- Improvements in spatial resolution and the ability to generate three-dimensional and multiplanar images also permit greater application of multidetector CT in preoperative planning before repeat CABG surgery in order to minimize the risk of injury to a graft vessel during re-entry.

REFERENCES:

1. ConantAR, Shackcloth MJ, Oo AY, Chester MR, Simpson AW, Dihmis WC. (2003). Phenoxybenzamine treatment is insufficient to prevent spasm in the radial artery: the effect of other vasodilators. *J Thorac Cardiovasc Surg*; 126:448–454.
2. DuboisCL, Vandervoort PM.(2004). Aneurysms and pseudoaneurysms of coronary arteries and saphenous vein coronary artery grafts: a case report and literature review. *Acta Cardiol*; 56:263–276.
3. FitzgibbonGM, Kafka HP, Leach AJ, Keon WJ, Hooper GD, Burton JR. (1996). Coronary bypass graft fate and patient outcome: angiographic follow-up of 5,065 grafts related to survival and reoperation in 1,388 patients during 25 years. *J Am Coll Cardiol*; 28:616–626.
4. FullertonDA, St Cyr JA, Fall SM, Whitman GJ. (1994). Protection of the patent internal mammary artery bypass graft from subsequent sternotomy. *J CardiovascSurg (Torino)*; 35:499–501.
5. GilkesonRC, Markowitz AH, Ciancibello L. (2003) . Multi-section CT evaluation of the reoperative cardiac surgery patient. *RadioGraphics*; 23(spec no):S3–S17.
6. GillinovAM, Casselman FP, Lytle BW, et al. (1999). Injury to a patent left internal thoracic artery at coronary reoperation. *Ann Thorac Surg*; 67:382–386.
7. GurevitchJ, Gaspar T, Orlov B, et al. (2003) Noninvasive evaluation of arterial grafts with newly released multidetector computed tomography. *Ann Thorac Surg*; 76:1523–1527.
8. HurlbutD, Myers ML, Lefcoe M, et al .(1990). Pleuropulmonary morbidity: internal thoracic artery versus saphenous vein graft. *Ann Thorac Surg*; 50:959–964.
9. IkaheimoMJ, Huikuri HV, Airaksinen KE, et al. (1988) Pericardial effusion after cardiac surgery: incidence, relation to the type of surgery, antithrombotic therapy, and early coronary bypass graft patency. *Am Heart J*; 116:97–102.
10. KataraAN, Samra SS, Bhandarkar DS. (2003). Thoracoscopic window for a post-coronary artery bypass grafting pericardial effusion. *Indian Heart J*; 55:180–181.
11. KuvinJT, Harati NA, Pandian NG, et al. (2002). Postoperative cardiac tamponade in the modern surgical era. *Ann Thorac Surg*; 74:1148–1153.
12. LeeYC, Vaz M, Ely KA, et al. (2001). Symptomatic persistent post-CABG pleural effusions requiring operative treatment. *Chest*; 119:795–800.
13. LiAE, Fishman EK. (2003) . Evaluation of complications after sternotomy using single- and multidetector CT with three-dimensional volume rendering. *AJR Am J Roentgenol*; 181:1065–1070.
14. LightRW, Rogers JT, Cheng D, Rodriguez M. (1999).Large pleural effusions after

coronary artery bypass grafting. *Ann Intern Med*; 130:891–896.
15. LockerC, Mohr R, Paz Y, et al. (2002). Pretreatment with alpha-adrenergic blockers for prevention of radial artery spasm. *Ann Thorac Surg*; 74:S1368–S1370.
16. LoopF, Lytle B, Cosgrove D, et al.(1986). Influence of the internal mammary artery graft on 10-year survival and other cardiac events. *N Engl J Med*; 314:1–6.
17. LoopFD, Lytle BW, Cosgrove DM, et al. (1990) J. Maxwell Chamberlain memorial paper: sternal wound complications after isolated coronary artery bypass grafting—early and late mortality, morbidity, and cost of care. *Ann Thorac Surg*; 49:179–186.
18. MayglothlingJ, Thomas MP, Nyzio JB, Strong MD, Samuels LE.(2004). Aneurysm of aortocoronary saphenous vein graft: case report and literature review. *Heart Surg Forum*; 7:E317–E320.
19. MemonAQ, Huang RI, Marcus F, Xavier L, Alpert J. (2003) .Saphenous vein graft aneurysm: case report and review. *Cardiol Rev*; 11:26–34.
20. MeurinP, Weber H, Renaud N, et al. (2004).Evolution of the postoperative pericardial effusion after day 15: the problem of the late tamponade. *Chest*; 125:2182–2187.
21. MoharaJ, Konishi H, Kato M, et al. (1998). Saphenous vein graft pseudoaneurysm rupture after coronary artery bypass grafting. *Ann Thorac Surg*; 65:831–832.
22. MotwaniJG, Topol EJ. (1998) . Aortocoronary saphenous vein graft disease: pathogenesis, predisposition, and prevention. *Circulation*; 97:916–931.
23. MyersMG, Fremes SE. (2003). Prevention of radial artery graft spasm: a survey of Canadian surgical centres. *Can J Cardiol*; 19:677–681.
24. OhtsukaT, Akahane M, Ohtomo K, Kotsuka Y, Takamoto S.(2000). Three-dimensional computed tomography for reoperative minimally invasive coronary artery bypass. *Ann Thorac Surg*; 70:1734–1735.
25. PengMJ, Vargas FS, Culier A, et al. (1992) . Postoperative pleural changes after coronary revascularization. *Chest*; 101:327–330.
26. PepiM, Muratori M, Barbier P, et al. (1994). Pericardial effusion after cardiac surgery: incidence, site, size, and haemodynamic consequences. *Br Heart J*; 72:327–331.
27. PossatiG, Gaudino M, Prati F, et al.(2003) Long-term results of the radial artery used for myocardial revascularization. *Circulation*; 108:1350–1354.
28. PostonRS, Prastein D, Gu J, Lee A, Pierson R, Griffith B. (2004) .Virchow's triad, but not use of an aortic connector device, predicts vein graft thrombosis after off-pump bypass. *Heart Surg Forum*; 7:123–128.
29. RicciM, Karamanoukian L, D'Ancona G, et al. (2000) .Reoperative "off-pump" circumflex revascularization via left thoracotomy: how to prevent graft kinking. *Ann Thorac Surg*; 70:309–310.
30. RoyMC. (1998). Surgical-site infections after coronary artery bypass graft surgery: discriminating site-specific risk factors to improve prevention efforts. *Infect Control Hosp Epidemiol*; 19:229–233.
31. RoyP, Finci L, Bopp P, Meier B. (1989). Emergency balloon angioplasty and digital subtraction angiography in the management of an acute iatrogenic occlusive dissection of a saphenous vein graft. *CathetCardiovasc Diagn*; 16:176–179.
32. SarrMG, Gott VL, Townsend TR. (1984). Mediastinal infection following sternotomy. *Ann Thorac Surg*; 38:415–423.
33. SawamuraY, Takase K, Saito H, Kikuchi S, Ito T. (2002). Three-dimensional imaging of coronary artery bypass grafts. *Ann Thorac Surg*; 73:1655.
34. ShammasNW. (2000). Pulmonary embolus after coronary artery bypass surgery: a review of the literature. *Clin Cardiol*; 23:637–644.
35. TraverseJH, Mooney MR, Pedersen WR, et al. (2003). Clinical, angiographic, and interventional follow-up of patients with aortic-saphenous vein graft connectors. *Circulation*; 108:452–456.
36. UraM, Sakata R, Nakayama Y, et al.(1998). Long-term patency rate of right internal thoracic artery bypass via the transverse sinus. *Circulation*; 98:2043–2048.
37. VargasF, Cukier A, Hueb W, et al. (1994).Relationship between pleural effusion and pericardial involvement after myocardial revascularization. *Chest*; 105:1748–1752.
38. WeissJM, Spodick DH. (1984). Laterality of pleural effusions in chronic congestive heart failure. *Am J Cardiol*; 53:951.