Review Article

Coronary Artery Bypass Graft Surgery (CABG)

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Abstract

Coronary artery bypass grafting (CABG) is one of the procedure done worldwide with acceptable results and has the highest impact in the history of medicine. Atherosclerotic Plaque formation in the sub-intimal layer is the main pathophysiology which causes ischemia in cardiac muscle & gives symptoms of coronary artery disease (CAD). There are many ways for revascularization but CABG is the mostly performed procedure & still gold standard. Results of percutaneous coronary interventions (PCI) & other novel approach to coronary revascularization is still compared with conventional CABG. Left internal mammary artery is the most durable conduits & should be used for every patients unless contraindicated. In young non-diabetic patient as much possible arterial conduits should be used. In planned operations results are excellent with inhospital mortality <1% with few morbidities like sternal wound infection <3%, renal and neurological complications <7% & <3%.

Key wards: *CABG= coronary artery bypass graft surgery, LIMA= left internal mammary artery, RIMA= right internal mammary artery. LAD= left anterior descending artery, LCA= left coronary artery, RCA= right coronary artery, LCX= left circumflex coronary artery, OPCAB= of pump coronary artery bypass, CPB= cardio pulmonary bypass, RSVG= reverse saphenous venous graft, PCI= percutaneous coronary intervention.*

Introduction

Coronary artery bypass grafting is one of the procedure with the highest impact in the history of Medicine. No other operation has led to more lives prolonged. CABG is the golden standard and still most widely used modality of treatment for coronary artery revascularization (STS database). Objective of CABG is to Complete revascularization by bypassing all severe stenosis in all affected coronary branches with ≥1-1.5 mm diameter.

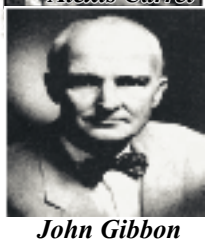
Brief History

Efforts to treat angina by surgical means began more then a century ago.

Alexis Carrel anastomosed a carotid artery segment between the descending aorta and the left coronary artery in a dog & for which he was awarded the Nobel prize in 1910[1].

1953: invention of Cardiopulmonary bypass machine by John Gibbon brought revolution in Cardiac Surgery.

Alexis Carrel



John Gibbon

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1964: First CABG done by Vassilli Kolesov in Leningrad, Russia & it was the frist planned successful CABG[2].

Vassilli Kolesov

1967 DeBakey, Sabiston and Favaloro are each credited with performing CABG using Saphenous vein.

1968 George Green promotes routine use of LIMA.

1995 and onwards due to modern operative monitoring, anesthesia technique and ICU care total arterial grafting and Off-pump CABG became widely used[11].

In Bangladesh Cardiac Surgery started in 1981. Conventional CABG started around 1990 and beating Heart CABG after 2000.

Stenotic Coronary Artery Disease

Definition: Narrowing of the coronary arteries. Caused by thickening and loss of elasticity of the arterial walls. Limiting blood flow to the myocardium.

Major Risk Factors

Hypertension
Diabetes Mellitus
Smoking
Dyslipidaemia
Familial predisposition

Minor Risk Factors

Physical inactivity
Obesity
Stressful life style
Abuse of Alcohol
Homocysteinaemia

Patho-Physiology of Coronary Artery Disease

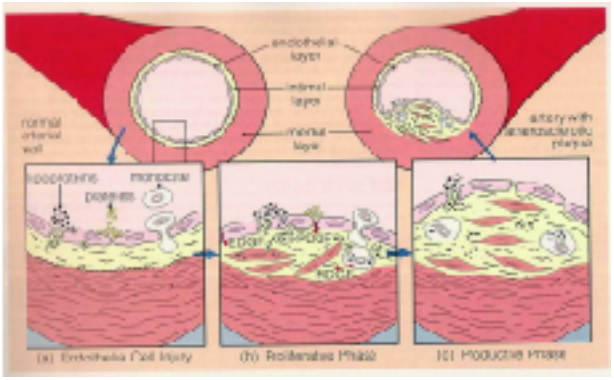


Figure-I: Patho-Physiology of Coronary Artery Disease Inflammation in the atherosclerotic process

Lipoproteins transport cholesterol to vessel walls, where the innermost endothelium (intima) undergoes molecular changes that cause monocytes, T cells, and monocyte-derived macrophages to aggregate and permeate the endothelial layer. As macrophages consume the cholesterol, they become enlarged foam cells, which are prone to rupture. These foam cells, along with the monocytes and T lymphocytes form fatty streaks between the intima and elastica interna.

Platelets aggregate and adhere to the endothellum, while the lesion grows to include smooth muscle cells and debris. The lesion may become necrotic, and a fibrous cap often forms.

As macrophages continue to aggregate and become active, the fibrous cap thins and plaque may rupture, leading to thrombosis.

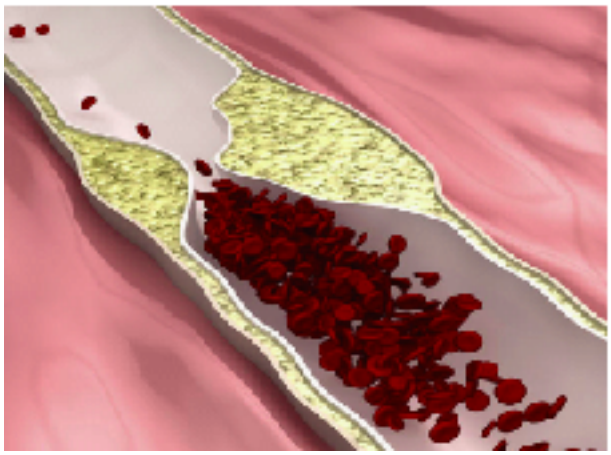


Figure-II: Critical Lesion Causing Flow Limitation

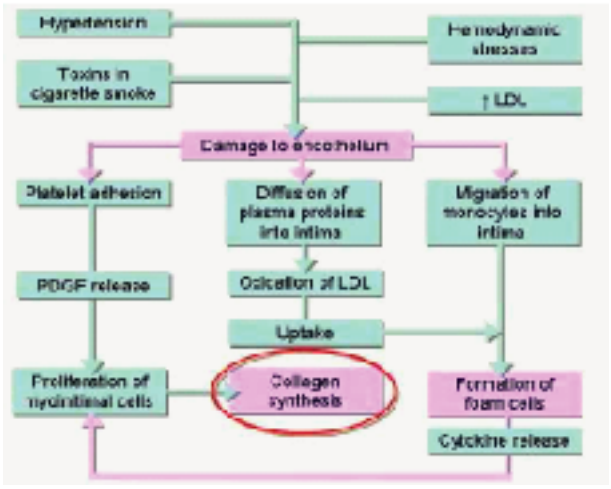
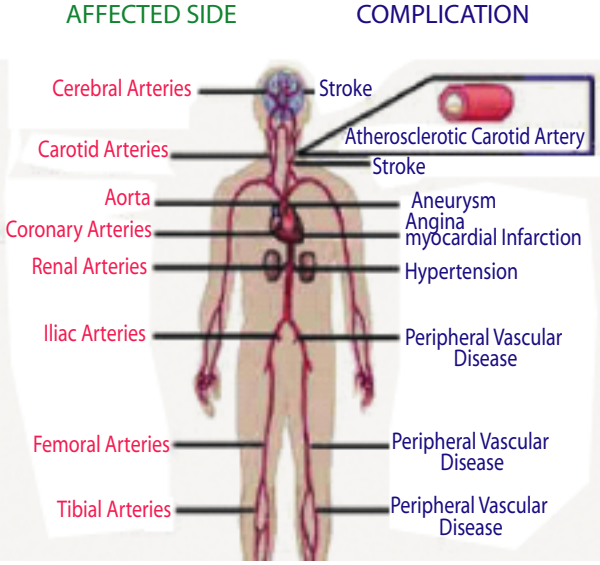


Figure-III: Diagrammatic Presentation of Atherosclerotic process

Complications of Atherosclerosis



Coronary anatomy

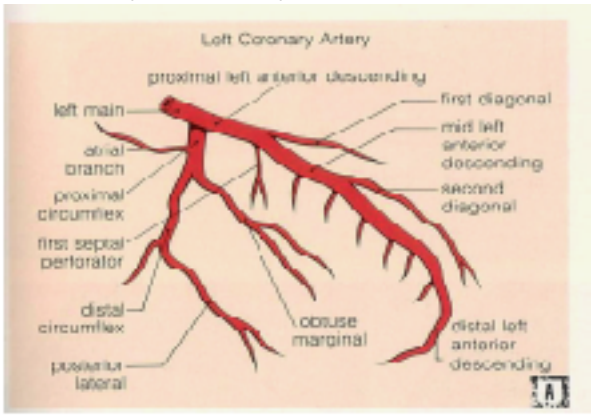


Figure: Left Coronary Artery (LCA) And it's Branches

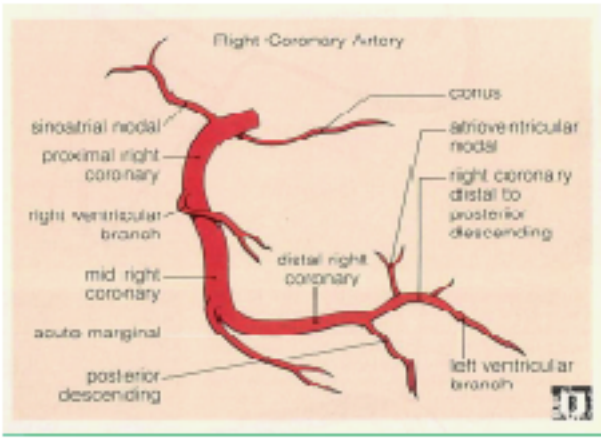


Figure: Right Coronary Artery (RCA) And it's Branches

Pre-Operative Workup for CABG

Virtually all CABG patients are previously diagnosed as Myocardial Ischaemia established by noninvasive testing & undergone a Coronary Angiogram by the Cardiologist prior to surgical referral.

History & Physical Examination: To exclude other co-morbidities if there is any concommittent valvular heart disease, cardiomyopathy, pulmonary HTN, COPD, H/O stroke, TIA, any carotid lesion.
Symptoms of claudication pain, Leriche syndrome, decreased peripheral pulses. Varicose veins, Previous saphanous vein harvesting or sclerotherapy.
If Raynaud's Syndrome, absent ulnar pulse, Allen's Test should be performed.

Laboratory tests: CBC, Serum Chemistry, LFT, Coagulogram, ECG, CXR, Urinalysis, TSH are routinely performed. In suspected cases; USG of W/A. Patient with poor LV function; Thalium scan should be done to asses the myocardial viability.

Coronary angiography (CAG)

CAG has been the road map to assess the severity of CAD and myocardial revascularization. It is usualy done by femoral artery route but can be done by using radial artery route.

Grading of stenoses:
Moderate: 50% diameter = 75% cross-sectional area loss
Severe: ≥ 67% diameter = 90% cross-sectional area loss
Distribution: For description target area is devided into three system 1. LAD & its branches 2. LCX & its branches 3. RCA & its branches. Left main (LM disease) is another entity. If involvement is in single system (SVD), two system (DVD), three system (TVD), Left main (LM disease).

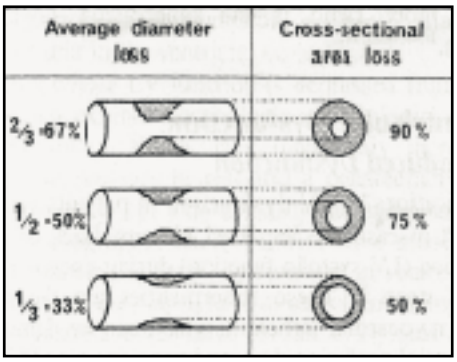


Figure: Diameter loss vs Cross Sectional Area Loss

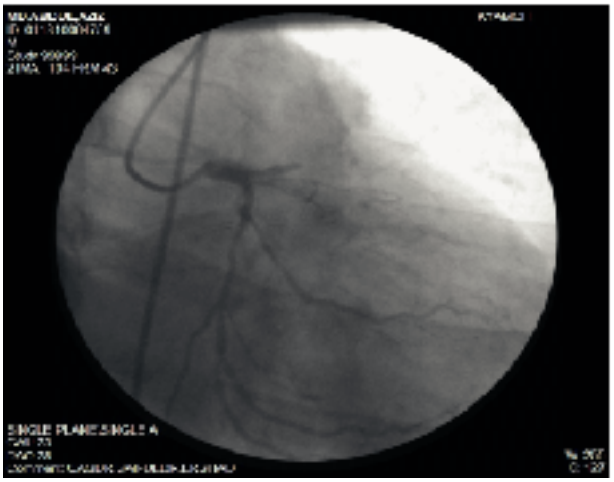


Figure: CAG showing: LAD =100% & LCX= 50% stenosis

Indications of CABG

Definitive Indication In Chronic Stable Angina

1. Left Main Stenosis ≥ 50%
2. Left Main equivalent (atleast 70% stenosis in proximal LAD & Circumflex)
3. Tripple vessel disease (LVEF < 50%)
4. Single or Double Vessel disease when large area of myocardium is at risk.
5. Disabling angina or unacceptable life style despite optimum medical therapy[3,11].

Definitive indication in acute coronary syndrome

1. Unstable Angina/ Non Q wave MI & STEMI in subacute period (> 12 hrs) when there is onging ischaemia and cardiogenic shock despite maximum non surgical therapy like intravenous thrombolytic therapy & primary percutaneous intervention (PCI).

Definitive Indication In Complication of PCI

1. Ongoing ischaemia or threatened occlusion with significant myocardium at risk after failed PCI.
2. Hemodynamic compromise after failed PCI.
3. Coronary artery rupture with impending pericardial temponade[3,11].

Indications in asymptomatic CAD

1. Left main stenosis.
2. Left main equivalent disease.
3. TVD with LVEF < 50%.
4. DVD with proximal LAD lesion & LVEF < 50%.
5. DVD with objective evidence of Ischaemia on non invasive testing[3,11].

Probable & possible indications of CABG

Proximal LAD lesion without a large territory at risk. Foreign body in crucial anatomical position. Objective evidence of myocardial ischaemia in kawasaki disease. Proximal Cronary injury in trauma patient with Objective evidence of ischaemia on ECG or wall motion abnormality in Echo.

Types of CABG

- **Conventional CABG:** done in Arrested Heart under Cardio-pulmonary bypass (CPB).
- **Beating Heart CABG:** Two types (1) Off-Pump Beating (OPCAB)- without help of CPB (2) On-Pump Beating- With the help of CPB (All are done with full sternotmy incision)
- **Minimal invasive CABG:** 1. MIDCAB done by small left antero-lateral thoracotomy. 2. Port Access CABG. 3. Robotic CABG.
- **Hybrid technique**- PCI+ CABG in hybrid OT.

What is conduits ?

Conduit is the tubular graft material by which CABG is performed. A key element for definitive surgical procedure is the selection of the most durable bypass conduits. While the biologic properties of CABG are of utmost importance, the anatomic & pathologic state of the native artery, comorbidites and clinical presentation often dictate the choice.

Types of Conduits

Venous Conduits Include:

Autologous :

Greater SapenousVein (GSV)
Lesser(short) Saphenous Vein
Uper Extremity Vein (cephalic or basillic)

Non-Autologous:

Greater Sapenous Vein (cadaveric, homografts)
Umbilical Vein

Arterial conduits Include:

Autologous (commonlyused):
Internal Thoracic (Mammary) Artery (IMA)
Radial Artery
Right Gastroepiploic Artery
Ulnar Artery
Inferior Epigastric Artery

Non-Autologous:

Bovine Internal Thoracic (Mammary) Artery

Synthetic: PTFE Graft, Dacron graft.

Autologous (not commonly used):
Splenic artery
Inferior mesenteric artery
Left gastric artery
Sub scapular artery
Thoraco dorsal artery

Choice of Conduits

Conduits Factors:

Regarding patency-IMA is the choice
For easy harvest and handling-GSV is the choice of Conduit.
For emergency CABG- vein is the choice of Conduit
Patient Factors: Vein is the conduit of choice for patient with reduced life expectancy. For example: Extreme age, Poor ventricular function, Cancer, Renal Dialysis, Pulmonary Disease, Vein should be preserved for peripheral vascular patients for vascular reconstruction[4,11].

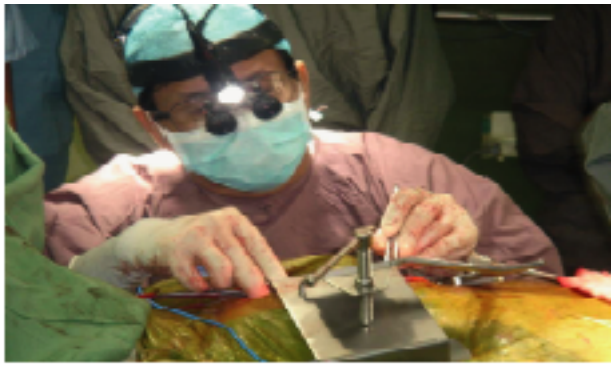
Harvetion of Conduits LIMA/RIMA

Two types of LIMA & RIMA harvesting technique.

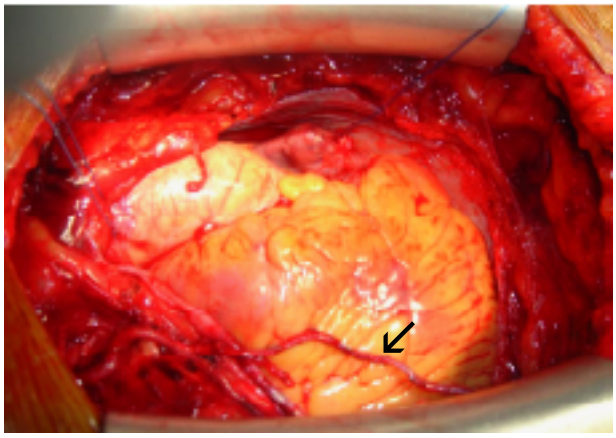
- Pedicle LIMA/RIMA
- Skelitonized LIMA/RIMA

Advantage of Skelitonized LIMA:

- More in length & diameter
- Less chance of spasm
- More flow
- Preserve sternal vascularity but Technically demanding



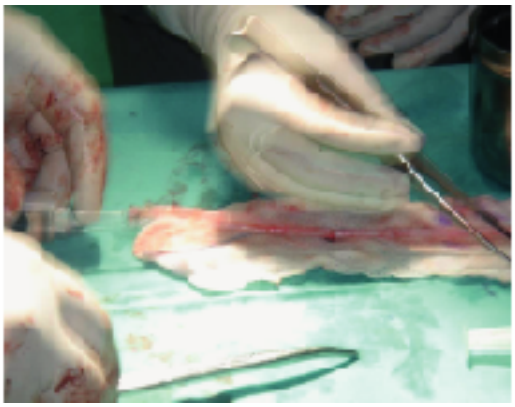
Harvesting LIMA



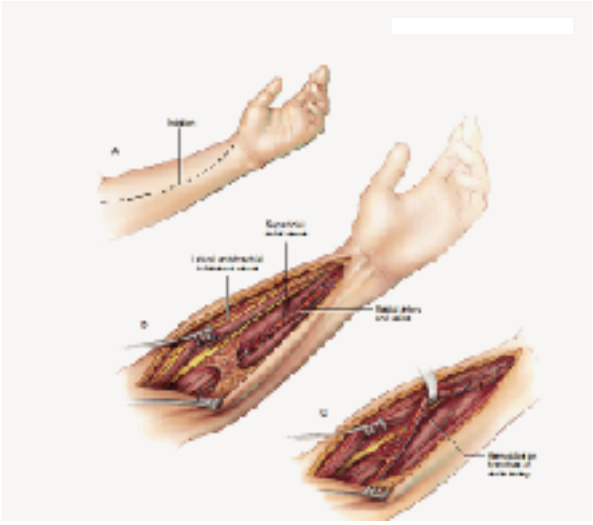
Harvested Skeletonized LIMA in dextrocardia

Vein Harvesting Technique

1. Open Method
   a. Skip incision
   b. Open incision
2. Endoscopic Method



Harvested GSV



Radial Artery Harvesting

Steps of Conventional/Arrest Heart CABG

- Firstly median sternotomy is done.
- Conduit harvesting.
- Heparinzation, cannulation and CPB with mild to moderate hypothermia.
- Cross-clamping of the aorta and cardioplegia.
- Distal anastomoses, rewarming started, cross-clamp removed
- Proximal anastomosis done using a partially occluding clamp, clamp removed, de-airing & CPB discontinued,
- Cannulae removed, nutralization of heparin by protamine.
- Placing of pacing wires, drainage tubes, hemostasis and closure.

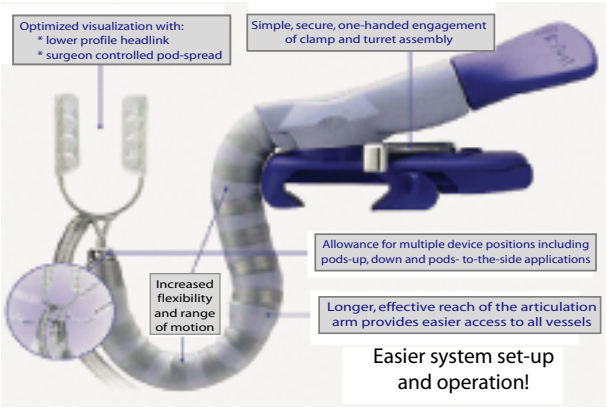
Steps of Off-Pump Beating CABG/ OPCAB

- Attempt to maintain normothermia
- Median sternotomy
- Conduit harvesting
- Heparinization
- Application of suction devices (Octopus, Star fish, Apical suction Cup) for stabilization and positioning of the operative area.
- Maneuvers to maintain hemodynamic stability
- Distal anastomoses using intracoronary shunt.
- Proximal anastomoses using side biting clamp.
- Neutralization of Heparin with Protamine Sulphate.
- Chest drains, haemostasis, closure.
- In OPCAB Cardiac Anaesthetics play tremendous role by positioning the table, maintaining haemodynamics, electrolyte balance and acid-base balance.

Heart Stabilizers for OPCAB

Several suction devices are used for stablizing the operative area and positioning the heart to reach the target vessels. Such as: 1. Octopus 2. Starfish 3. Apical suction cup.

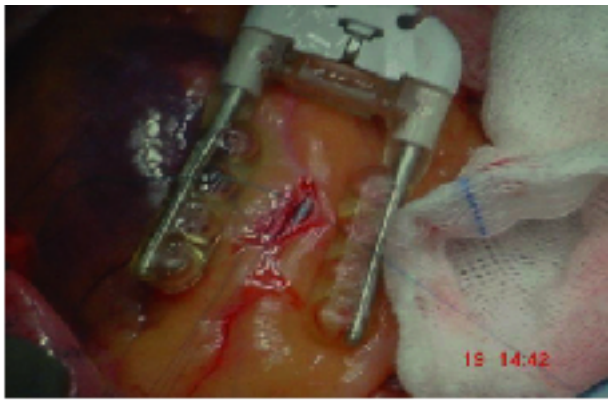
Suction divice: Octopus, Starfish & Apical suction cup



Octopus

Intra coronary Shunt:

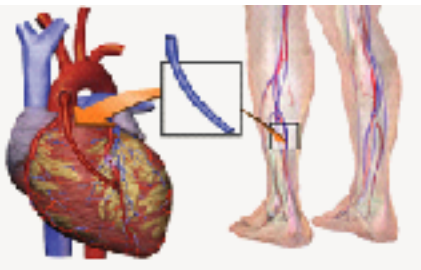
- Maintains coronary flow during OPCAB
- Keeps surgical field clean
- Helps in taking intimal bites



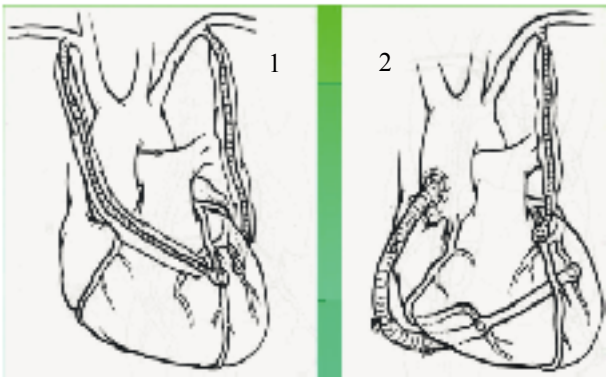
Octopus & Intra coronary Shunt in position

Graft Strategy

Unless contraindicated LIMA to LAD graft is used by all Surgeons. Rest of the Graft are done by using RSVG either singly or in sequential form according surgeons expertise and preference. In young non Diabetic patients maximal arterial Graft is done by using RIMA, Radial and Gasro-epiploic artery. Occassionaly Arterial sequential by LIMA and RIMA- Y pattern done by few surgeons, most surgeons do not like this pattern due to occasional hypoperfusion syndrome[11,12].



Venous Graft from leg to Heart



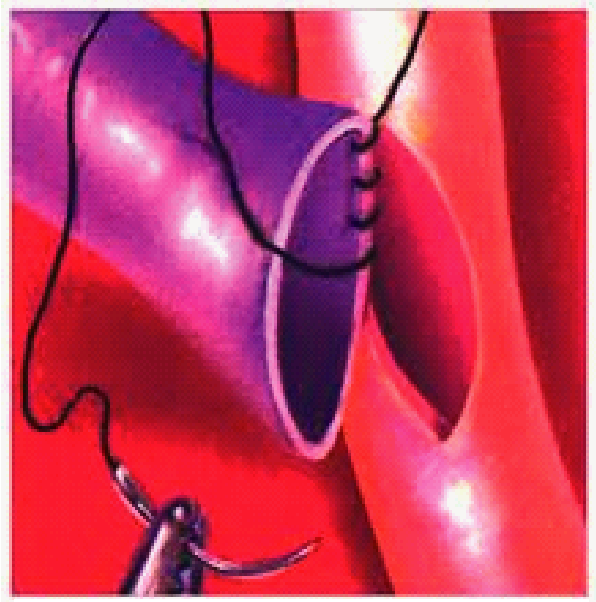
1. RIMA to LAD & LIMA to OM (Total Arterial)

2. RSVG to PDA and OM sequential & LIMA to LAD□(Sequential grafting)□

CABG/Aorto coronary bypass

Distal anastomosis

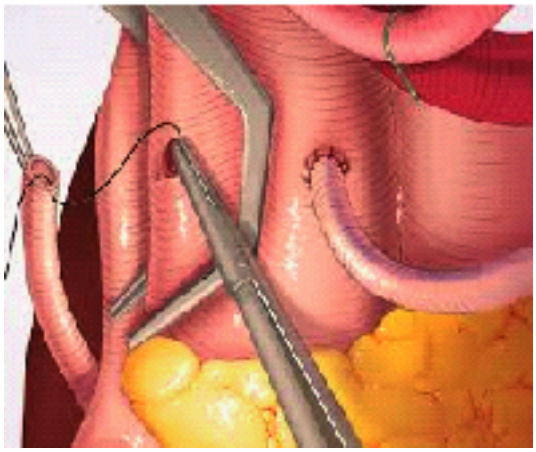
Anastomosis of conduit to native coronary artery.
8/0 or 7/0 prolene is used
12-14 stitches each 2 mm apart[12].



The graft is sewn on the coronary artery to create the bypass

Proximal anastomosis

Proximal anastomosis is done in ascending Aorta. Aorta is partially occluded by using a side biting clamp. Small aortotomy which is shaped by using aortic punch. Anastomosis is done by 6/0 or 7/0 prolene[12]. Clamp is released after proper de-airing.



Morbidity & mortality

Post-Operative bleeding requires Re-exploration in 2% cases.
Post-Operative Renal Dysfunction 7.7% and 1.4% requires dialysis[5].
Neurological Complications up to 3.1%.
Atrial arrhythmia 20-40%.
Peri-Operative MI (PMI) <2%.
Deep Sternal Wound Infection 0.7-2.4%.
Over all mortality 2.4-3% (STS database).
Elective cases in younger patient with good LV function mortality <1%[6,7].

Risk factors for death

Diminished LV function. EF< 30%
Unstable angina.
Acute hemodynamic instability after MI.
Operation within 1 week of acute MI.
Cardiogenic shock at the time of operation.
Older age[7].

Graft patency & outcome of CABG

Graft patency: Venous graft occludes 2.1% per year Venous graft Patency is 88% early Post-Operatively, 81% at 1 year 75% at 5 years and 50% at 15 years. Early patency of IMA to LAD is >98.7 %, 94% at 7 years and 88% at 11 years. Radial artery patency 96% at 4 years.

Freedom from AMI: 86% at 10 years. Freedom from sudden death: 97% at 10 years. 80% of patients can continue their previous Job. Freedom from angina: 63% at 10 years. (All venous graft).

Freedom from angina: 85.7% at 7 years (total arterial graft)[4,8,9,11]. These datas are from pre-aspirin and pre-statin eras. Now a days with structured secondary prevention program, with use of antiplatelet and lipid lowering agent outcome and graft patency is far better[10].

CABG versus PCI

A detailed comparative analysis of the result of CABG versus those of percutaneous catheter interventions is beyond the scope of this chapter. However, a number of general observations can be made after appraisal of the literature available. Approximately seventeen randomized clinical trials have compared CABG with PCI. Taken together, their results nevertheless suggest the following:

1. PCI is associated with a shorter hospital stay and less morbidity than CABG.
2. In patients with diabetes & there-vessel disease, CABG is superior to PCI.
3. Symptomatic improvement & freedom from repeat revascularization are better with CABG then PCI.
4. CABG provides more complete revascularization than PCI which correlates with a greater improvement in angina class.
5. PCI may be safer and better than CABG in high-risk, acutely unstable patient, regardless of diabetes status.
6. Three-four and five year risk adjusted survival of the CABG may be superior to PCI for most patients with three-vessel disease, regardless of diabetic status or left ventricular function[13-15].

Conclusion

Coronary artery bypass grafting remains the most durable method of coronary revascularization available today. Its future will be influenced by the result of future research on the role of complete arterial revascularization, minimally invasive techniques in conjunction with PCI. With advances in surgical techniques and secondary prevention one ambition but achievable goal for all cardiac surgeons should consist of making CABG a routinely infallible, permanent method of coronary revascularization associate with near zero risk for all patients.

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