CABG

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MONUMENT
HEALTH

DISCLOSURES

- NONE

OBJECTIVES

- HISTORY
- PATHOPHYSIOLOGY OF CAD
- INDICATIONS FOR CABG
- CURRENT TECHNIQUE
- EVOLVING TECHNIQUES
- CONDUIT SELECTION

Coronary artery disease

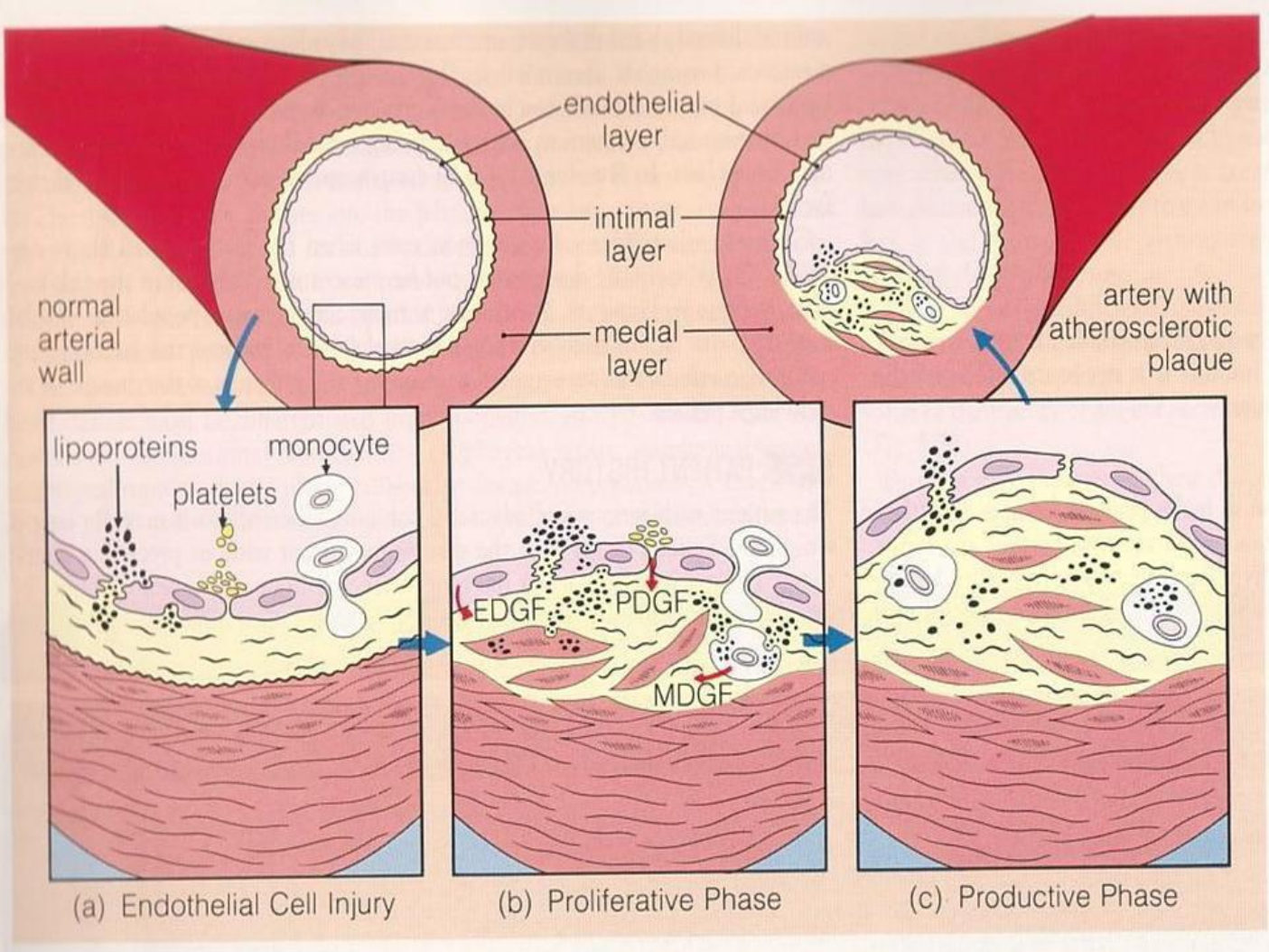
- Definition:
  - Narrowing of the coronary arteries
  - Caused by thickening and loss of elasticity of the arterial walls
  - Limiting blood flow to the myocardium

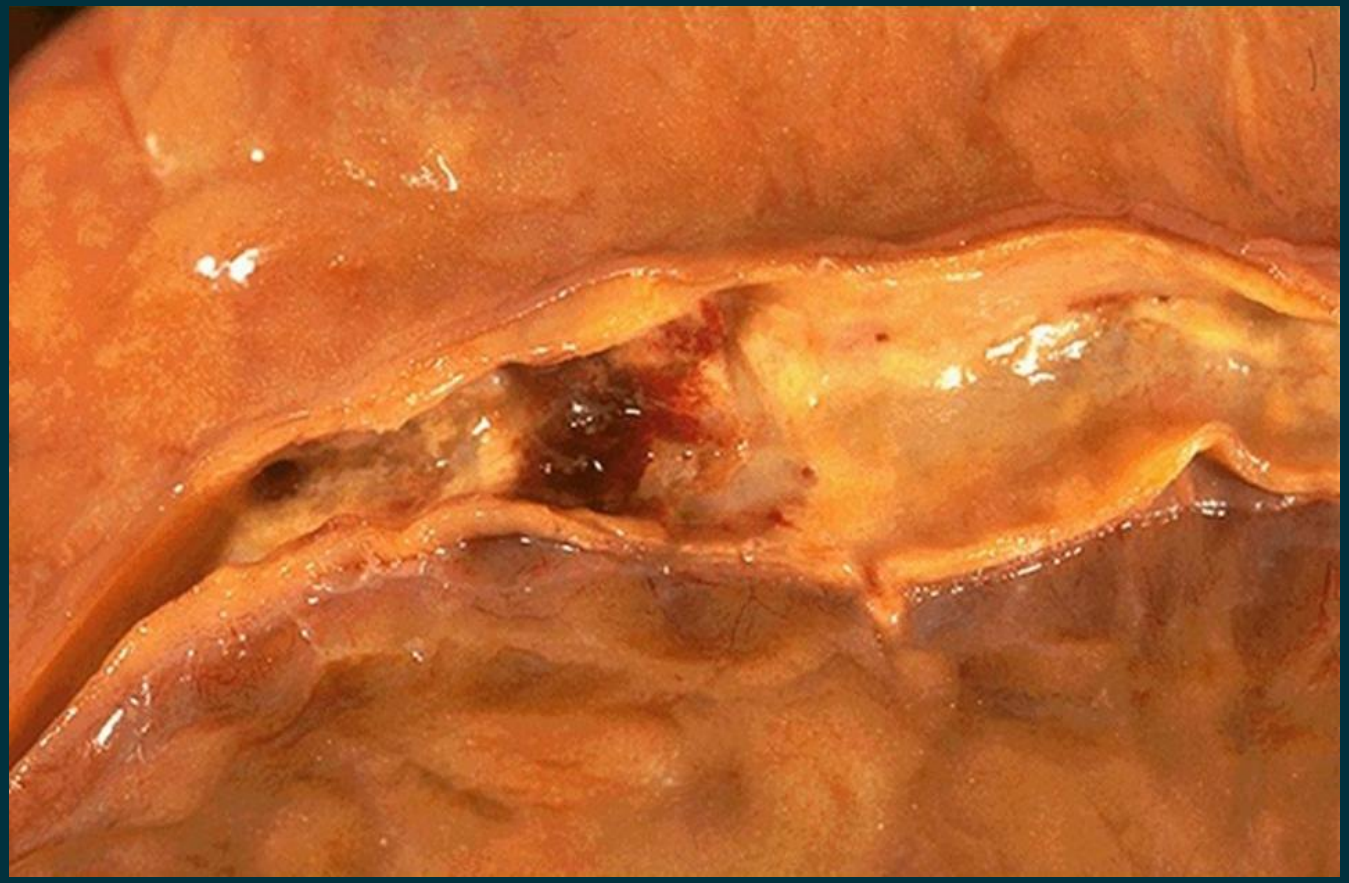
Coronary artery disease

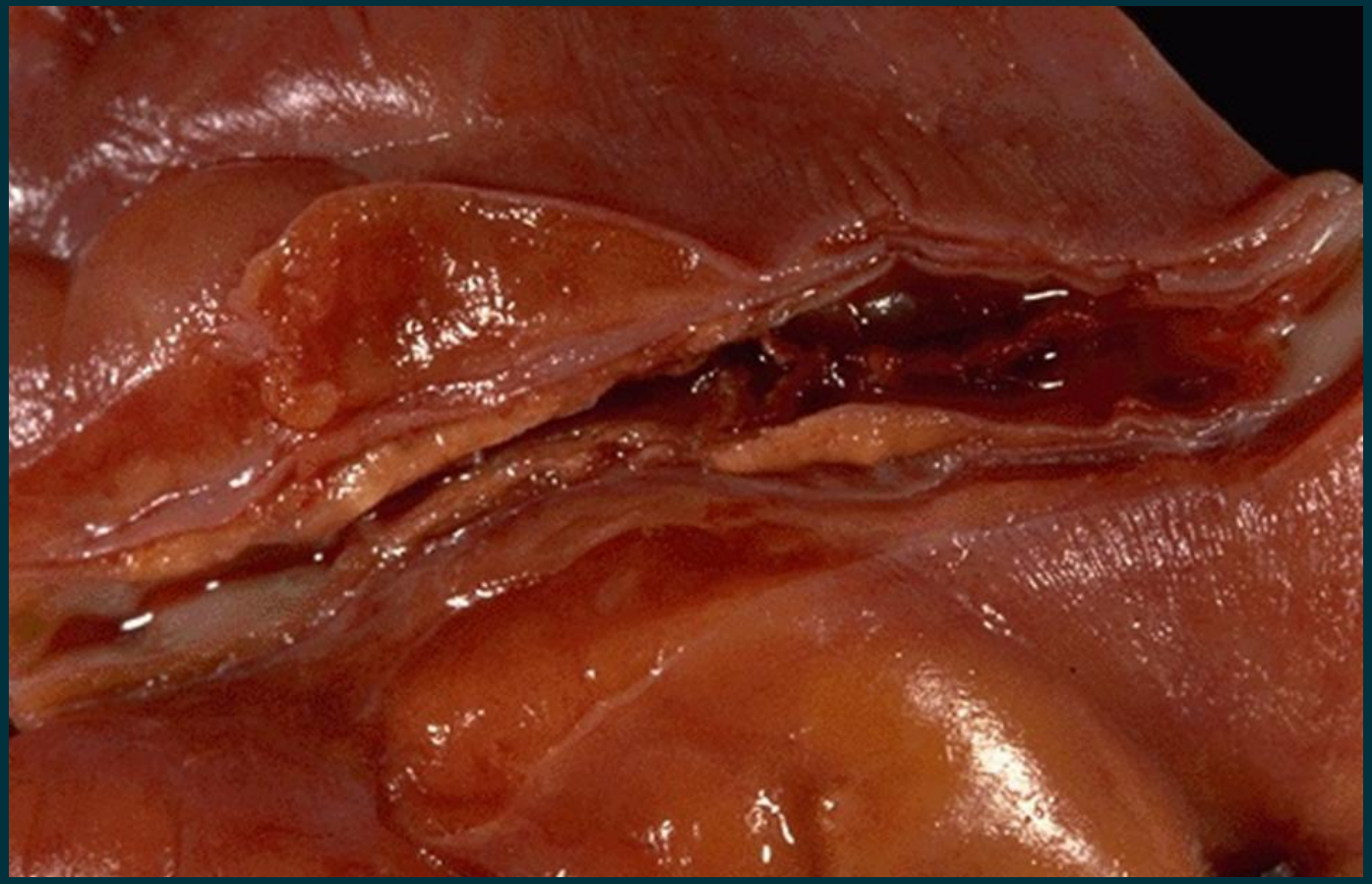
- Morphology and processes:
  - Focal intimal accumulation of lipids, blood elements, fibrous tissue, calcium etc. with associated changes in the media

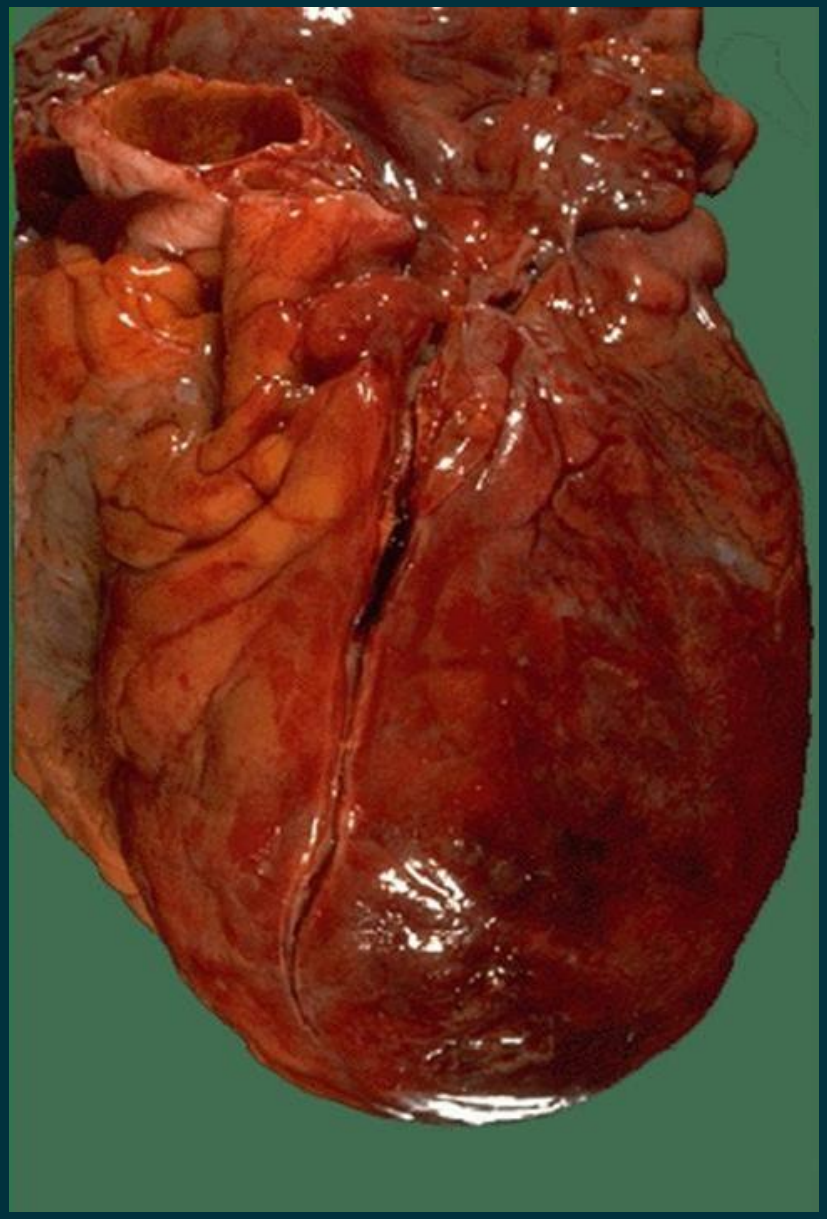
  → Plaque

  → Stenosis
  - Plaque rupture and thrombosis
  - Usually affects multiple coronaries simultaneously, proximally, and at bifurcations


endothelial layer
intimal layer
medial layer
normal arterial wall
artery with atherosclerotic plaque
lipoproteins
monocyte
platelets
EDGF
PDGF
MDGF
(a) Endothelial Cell Injury
(b) Proliferative Phase
(c) Productive Phase

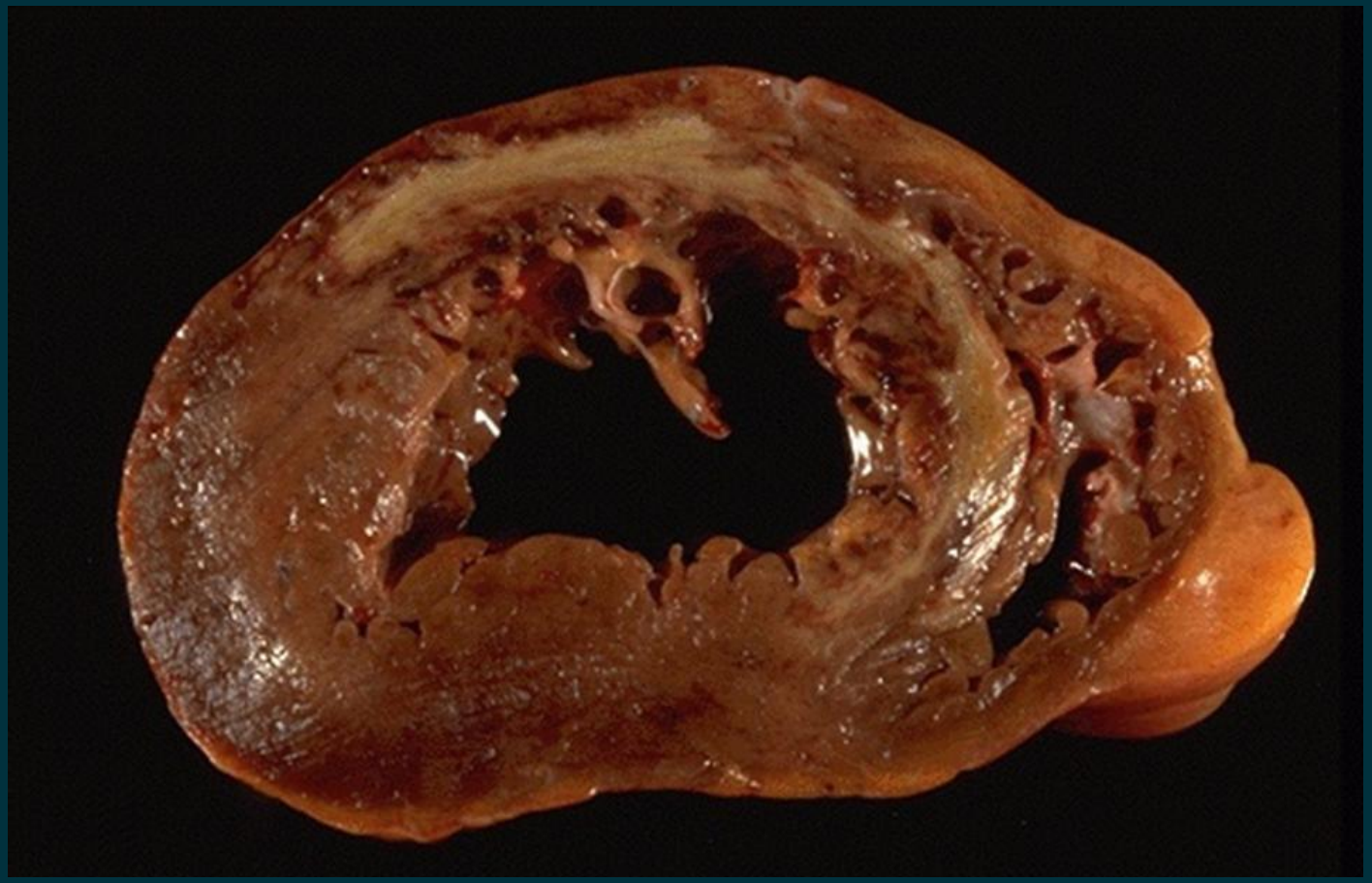


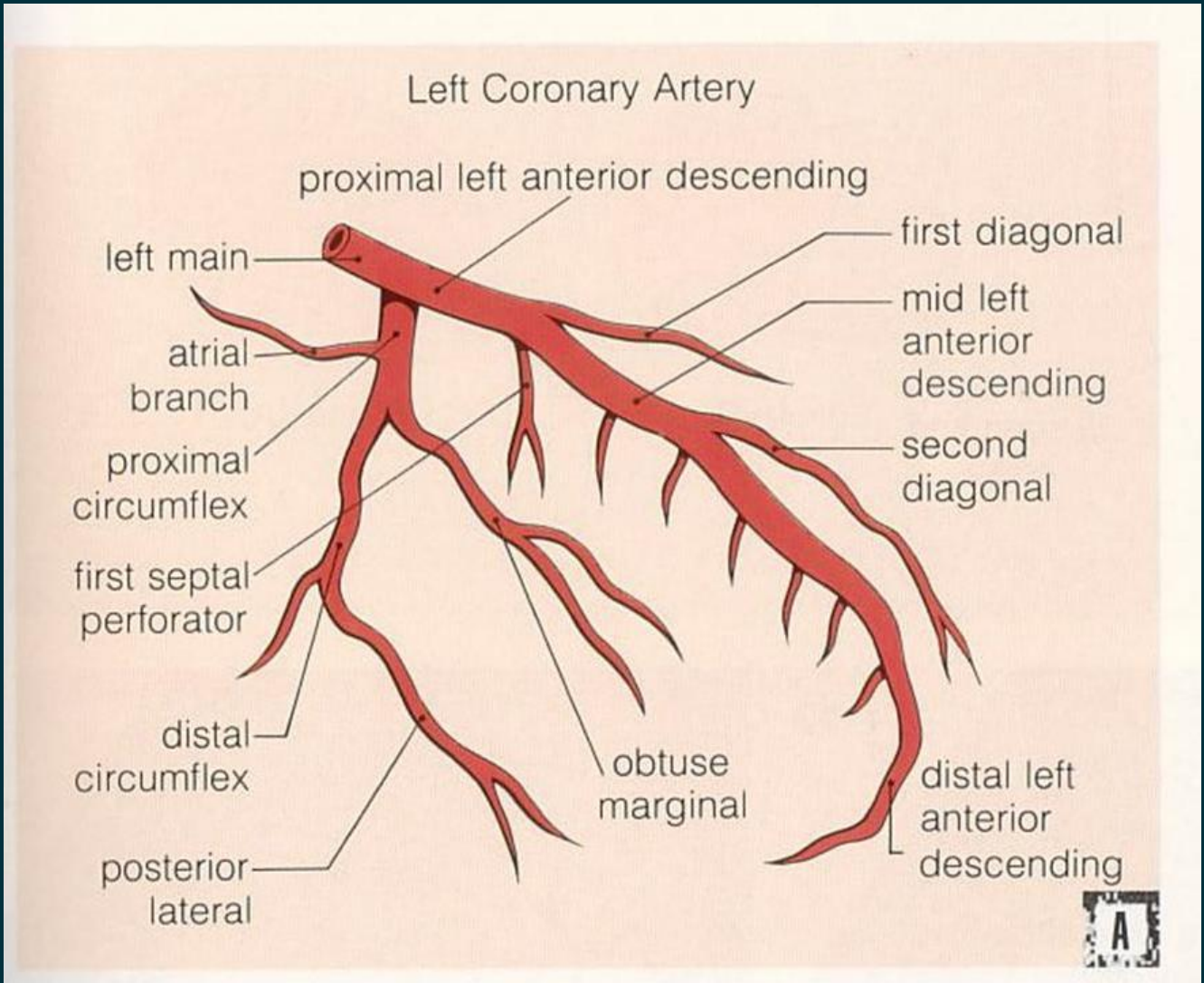


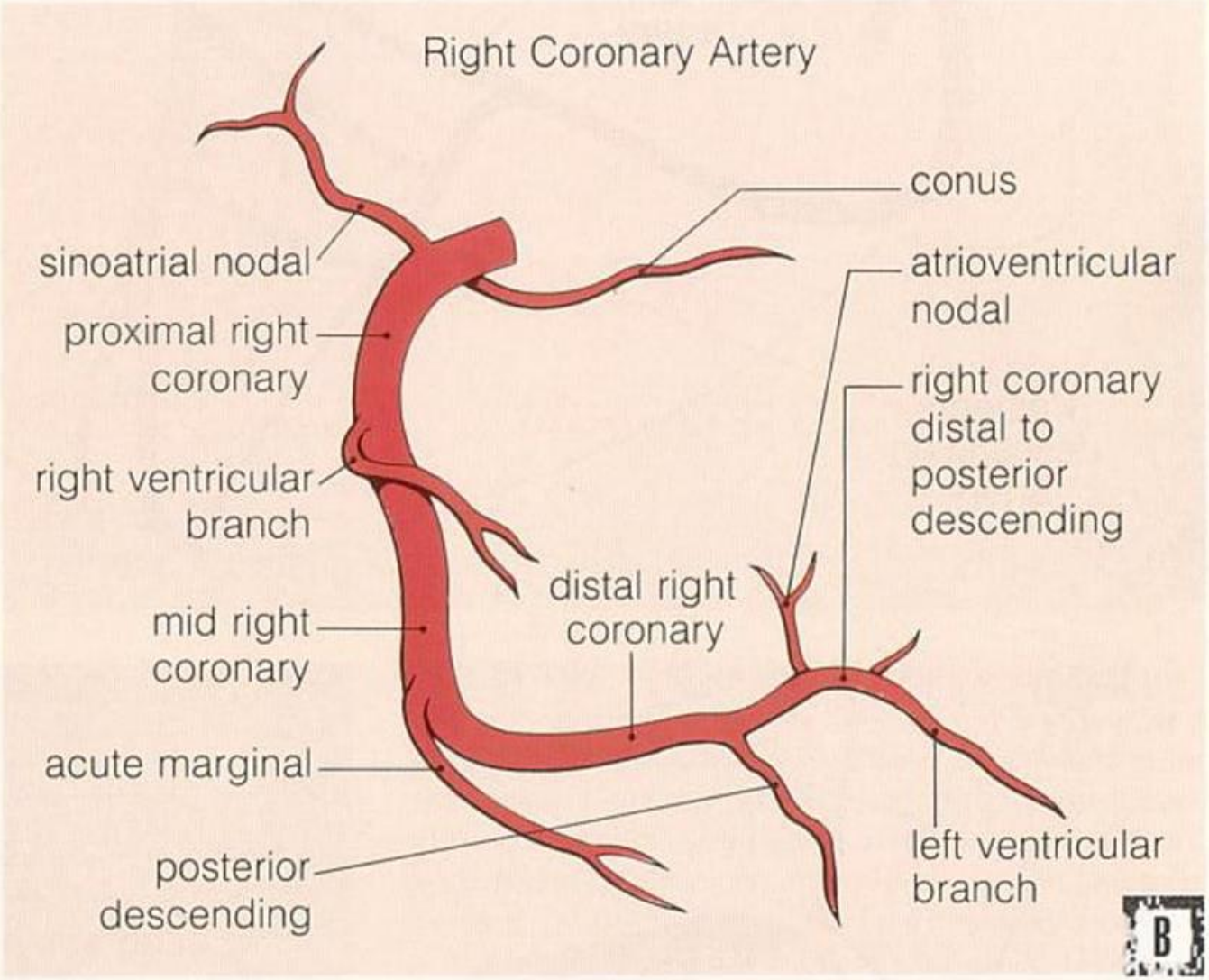


Myocardial infarction

- Imbalance between oxygen supply and demand
- Myocardial necrosis starts after 20 minutes
- Reperfusion within 3-4 hours can limit the extent of myocardial necrosis
- Scarring. LV systolic and diastolic dysfunction. Chronic heart failure.




Left Coronary Artery
proximal left anterior descending
left main
first diagonal
mid left anterior descending
atrial branch
proximal circumflex
second diagonal
first septal perforator
distal circumflex
obtuse marginal
distal left anterior descending
posterior lateral
A


Right Coronary Artery
conus
sinoatrial nodal
atrioventricular nodal
proximal right coronary
right coronary distal to posterior descending
right ventricular branch
distal right coronary
mid right coronary
acute marginal
left ventricular branch
posterior descending
B

CABG History

- 1910 Alexis Carrel. First descending aorta to LAD graft using donor carotid artery.
- 1964 Garret/Howell/Debakey (Houston, TX) . Bypass with saphenous vein.
- 1964 Kolesov (USSR). LIMA to LAD.
- 1968 Green. LIMA to LAD on CPB support.

EVOLUTION

- CPB – 1950/s Gibbon
- Angiography – Sones 1962
- Cardioplegia – made it possible for slow cardiac surgeons to exist (early 1970's; VFIB arrest/ hypothermia)
- OPCAB – 1990's
- MIDCAB/Robotic CABG – 2000's

Early evidence for CABG

- Based on 3 large trials from the 1970s and 80s
- These trials looked at CABG in comparison to **medical therapy**
- <10% of the patients received LIMA graft
- One must realize medical therapy in the 70s and 80s is not what it is today

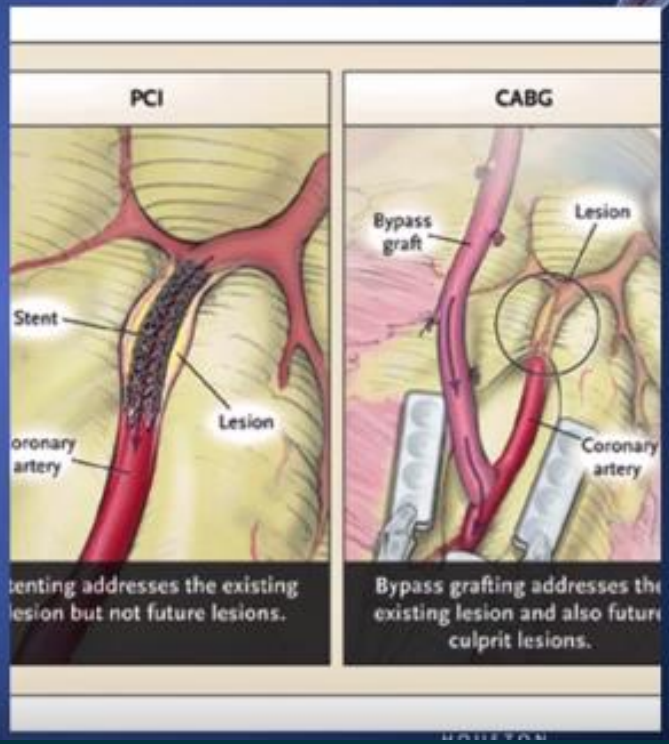
CABG superior in certain subgroups

- CASS – 3V + LVEF 35-50%
  - Circulation 1983; 68:939
- ECSS – L Main, 3V, 2V w/prox LAD
  - Lancet 1980; 2:491
  - NEJM 1988 (update); 319:332
- VA STUDY – 3V + Poor LVEF
  - NEJM 1984; 311:1333

SURGEON'S PERSPECTIVE

Why is CABG better than PCI?

- PCI treats an isolated lesion in the proximal vessel.
- Complexity of lesion affects outcome
- CABG bypasses the proximal 2/3 of the vessel, where the current lesion *and future threatening lesions* occur.
- *Complexity of lesion is irrelevant!*
- *This advantage of CABG will persist, even if Stent restenosis is ZERO.*

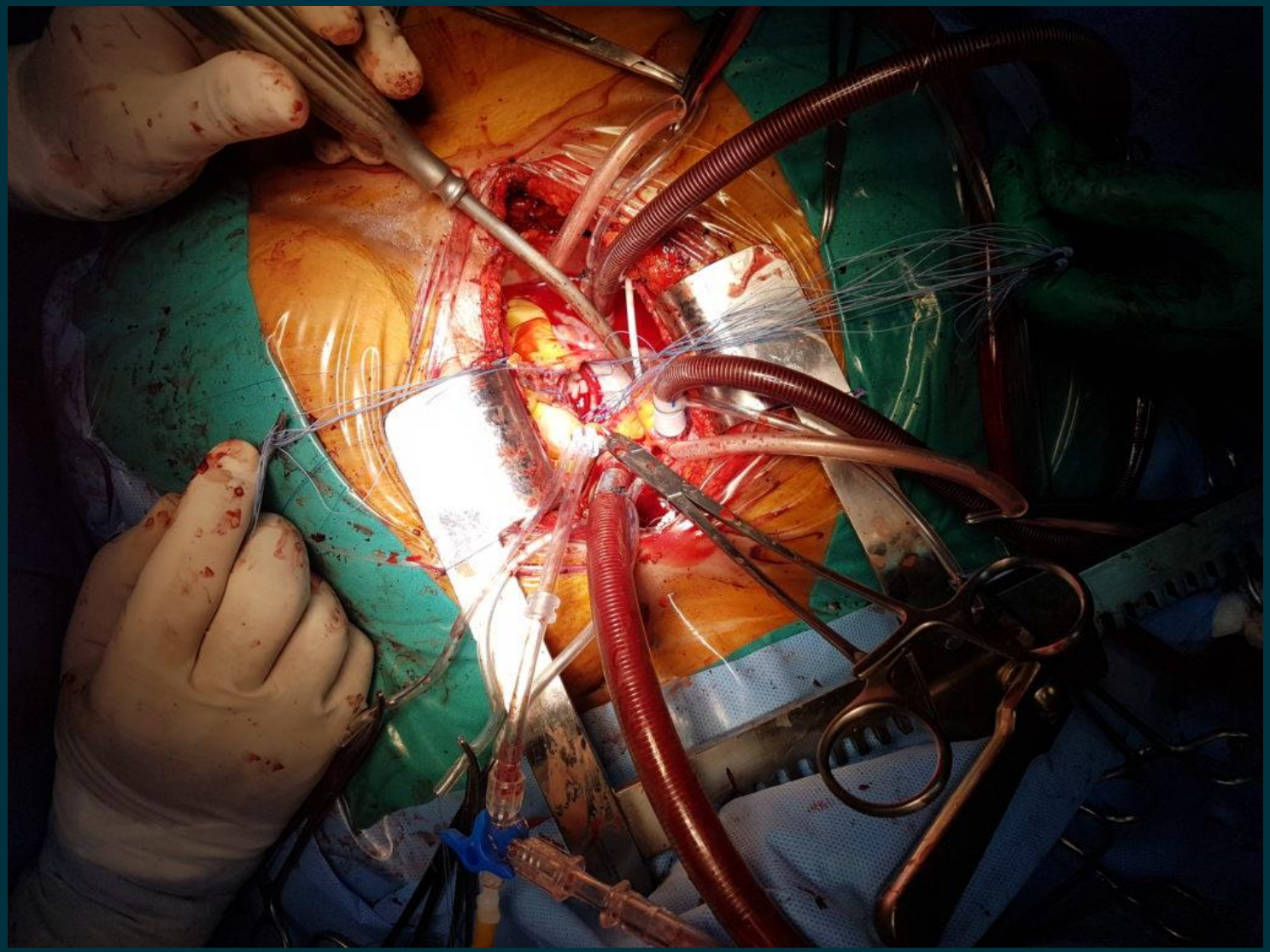


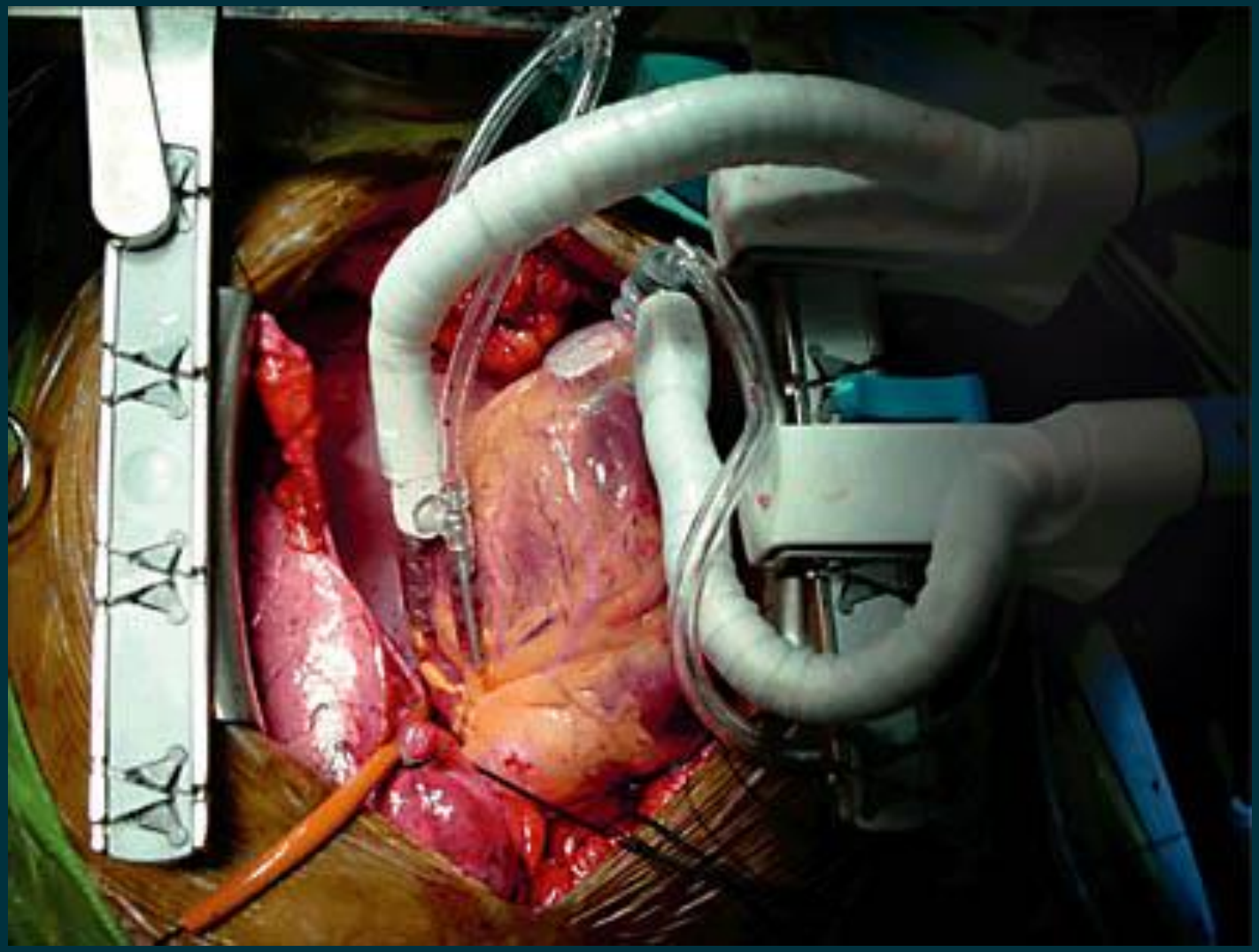
INDICATIONS

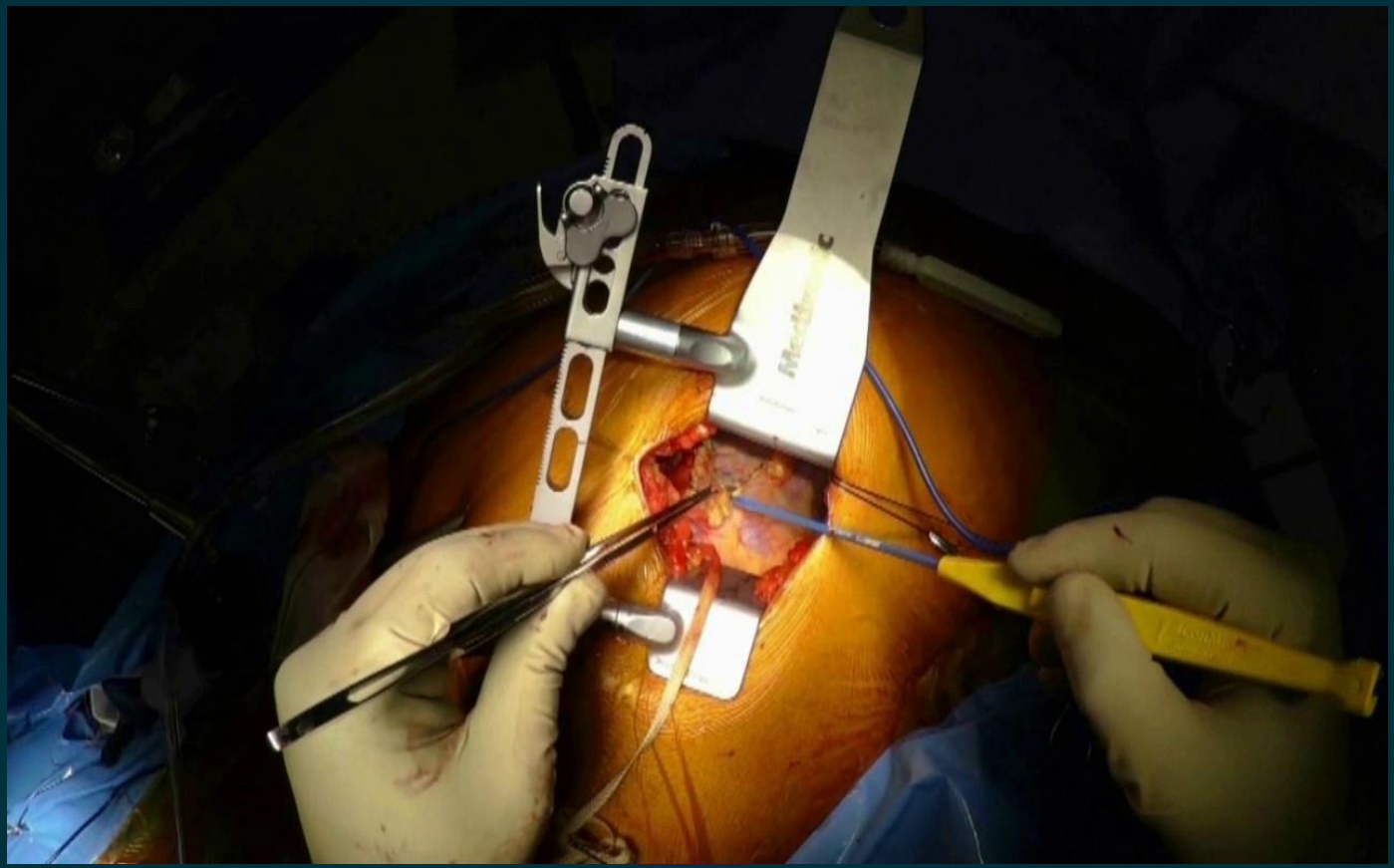
- Left main disease (>50% stenosis)
- Left main equivalent (>70% stenosis of proximal LAD and proximal circumflex)
- Three-vessel disease, especially if EF < 50%
- Two-vessel disease with proximal LAD stenosis and EF < 50%
- Proximal LAD and one- or two-vessel disease (Poor LVEF)
- Disabling angina refractory to medical management
- Failed PCI

Bypass grafting

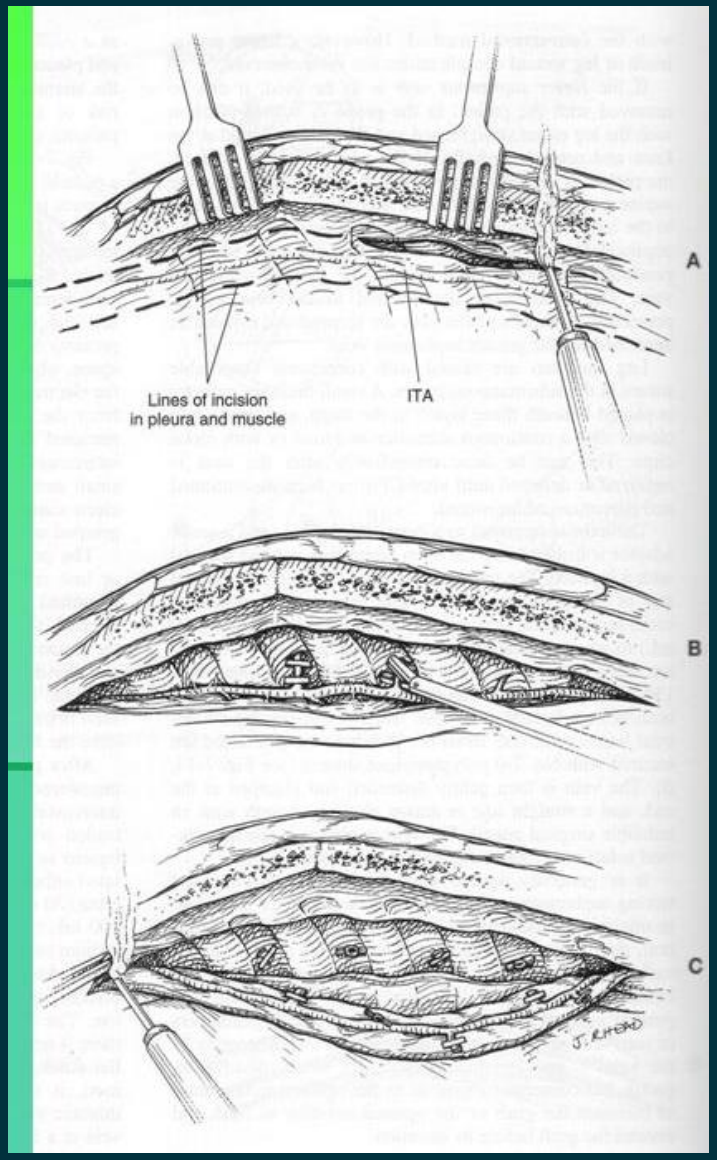
- Full sternotomy and CPB:
  CABG
- Full sternotomy, no CPB:
  OPCAB
- Small sternotomy, parasternal access, thoracotomy, with or without CPB:
  e.g. MIDCAB







Conduits
LIMA / RIMA



Conduits
SVG

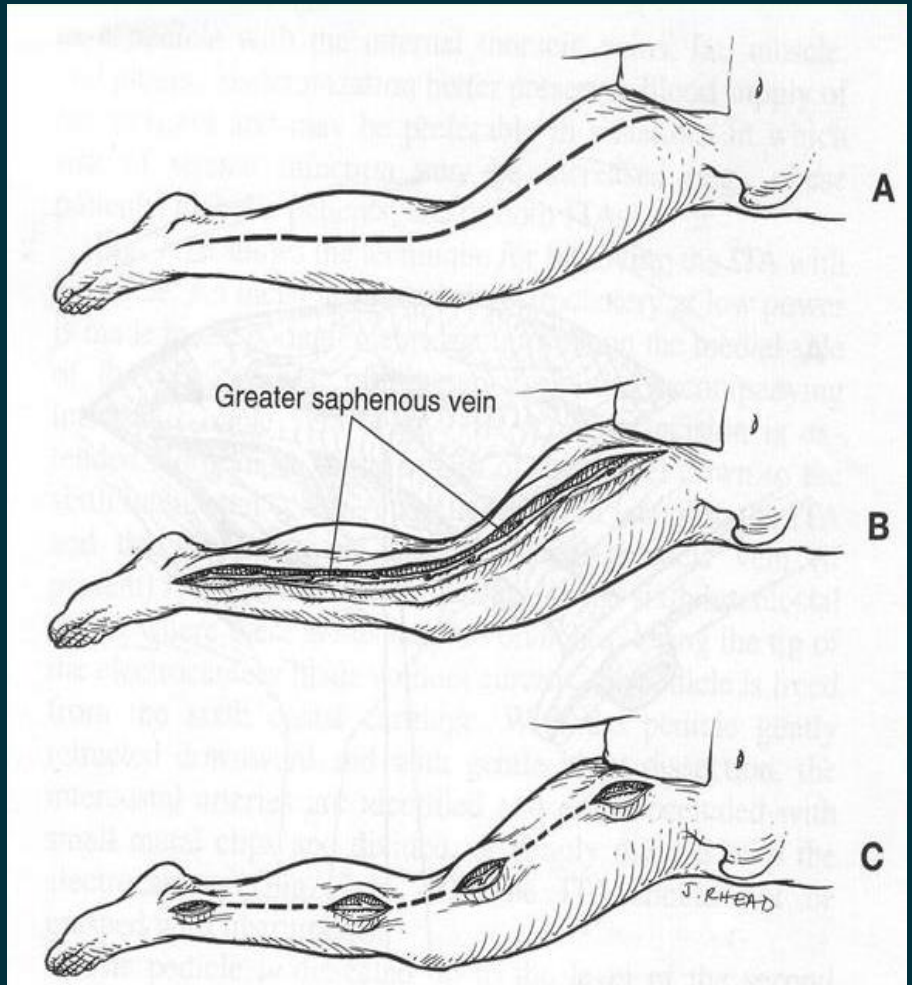
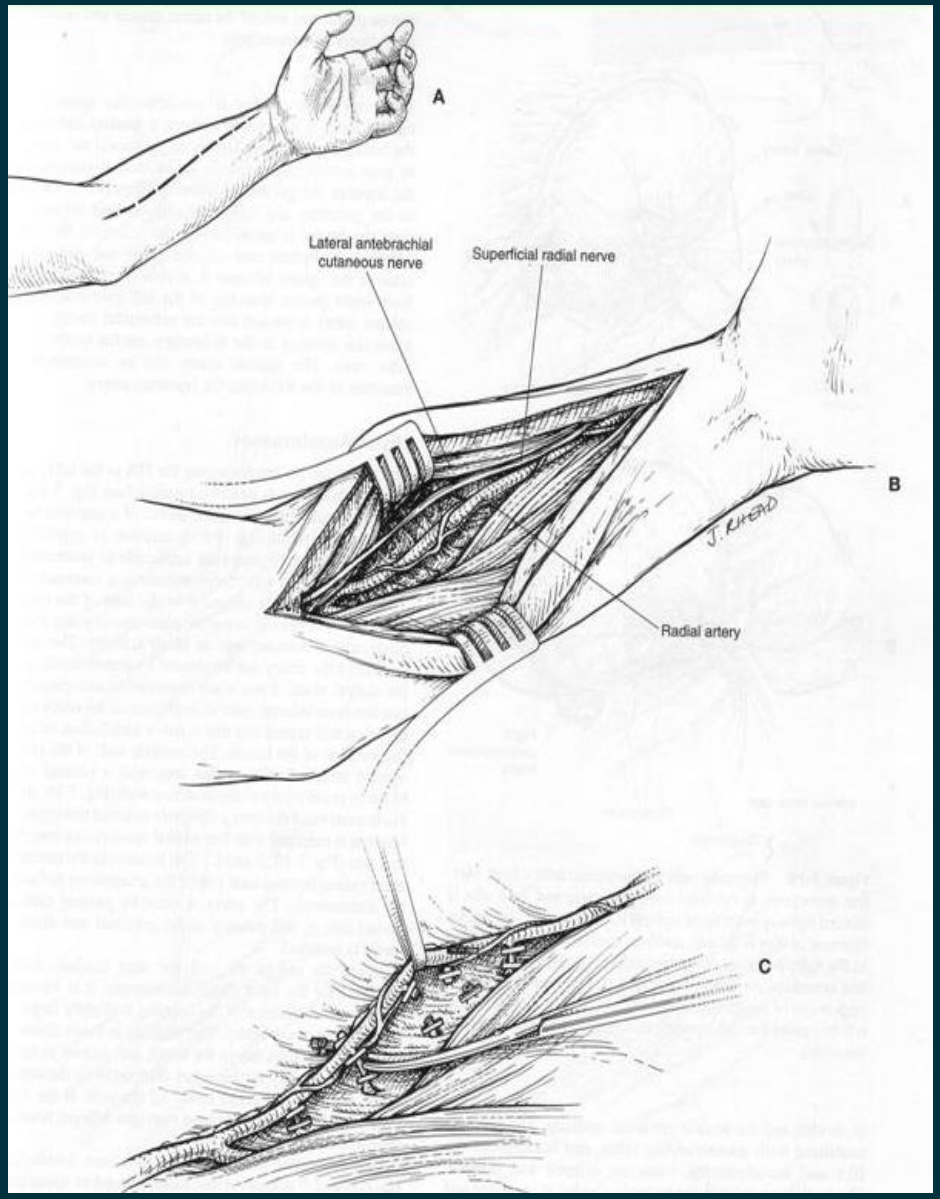
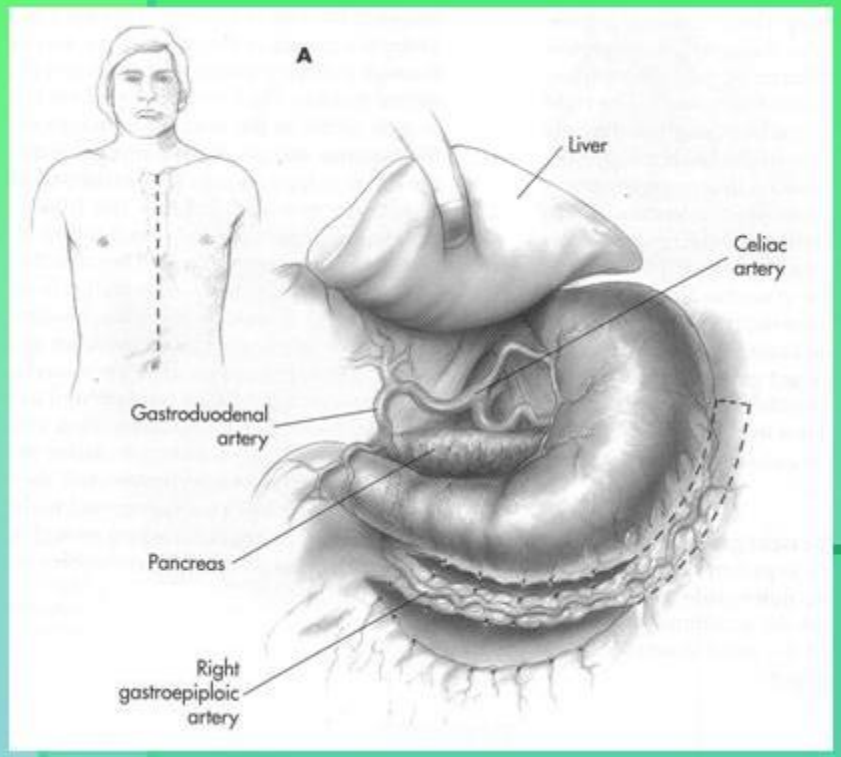


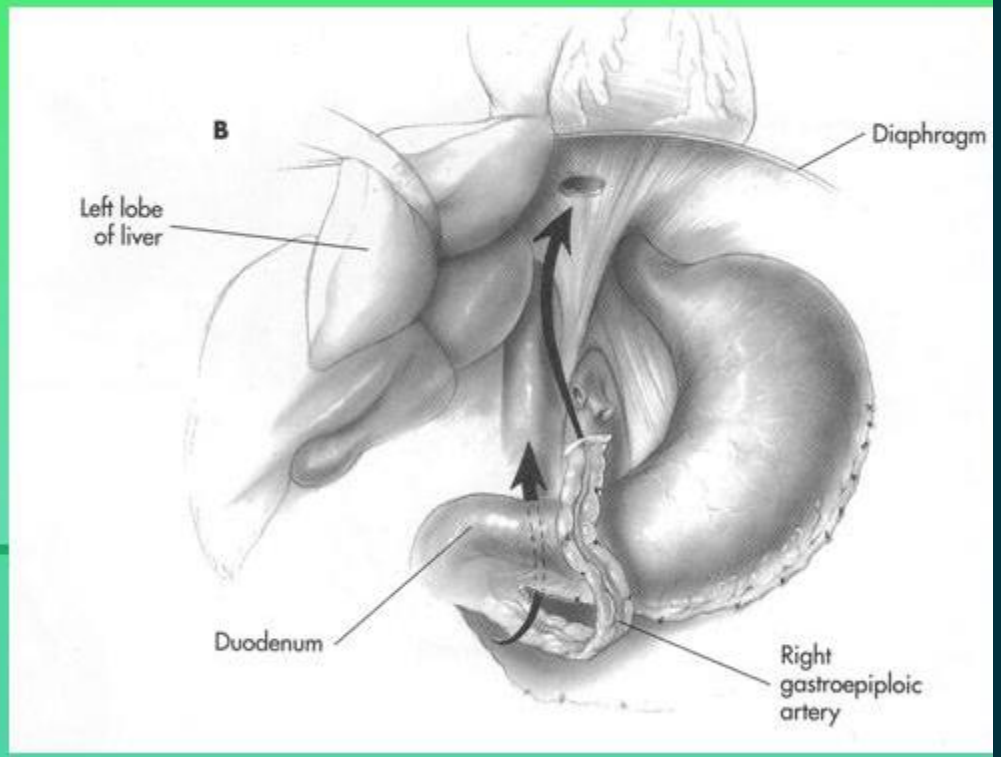
Figure 7-13 Removing greater saphenous vein. **A**, Location of greater saphenous vein and line of incision. **B**, Continuous incision over entire length of saphenous vein. **C**, Multiple small incisions over saphenous vein.

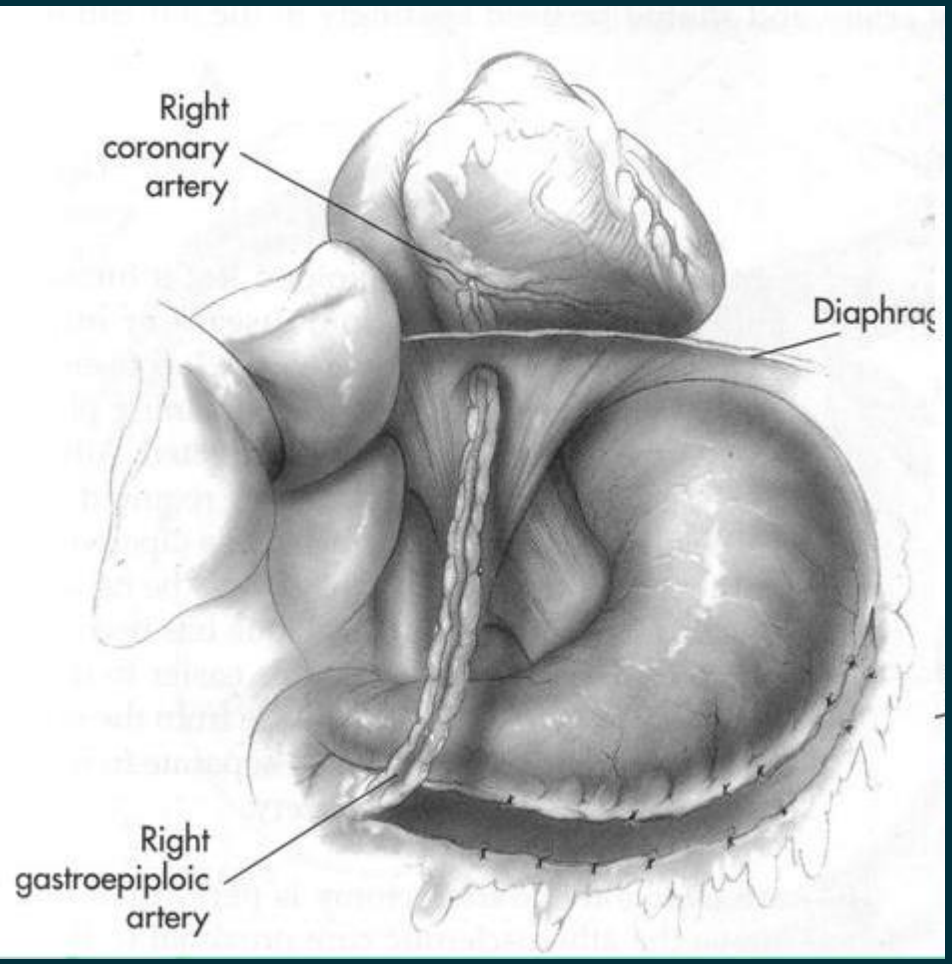
Conduits
Radial

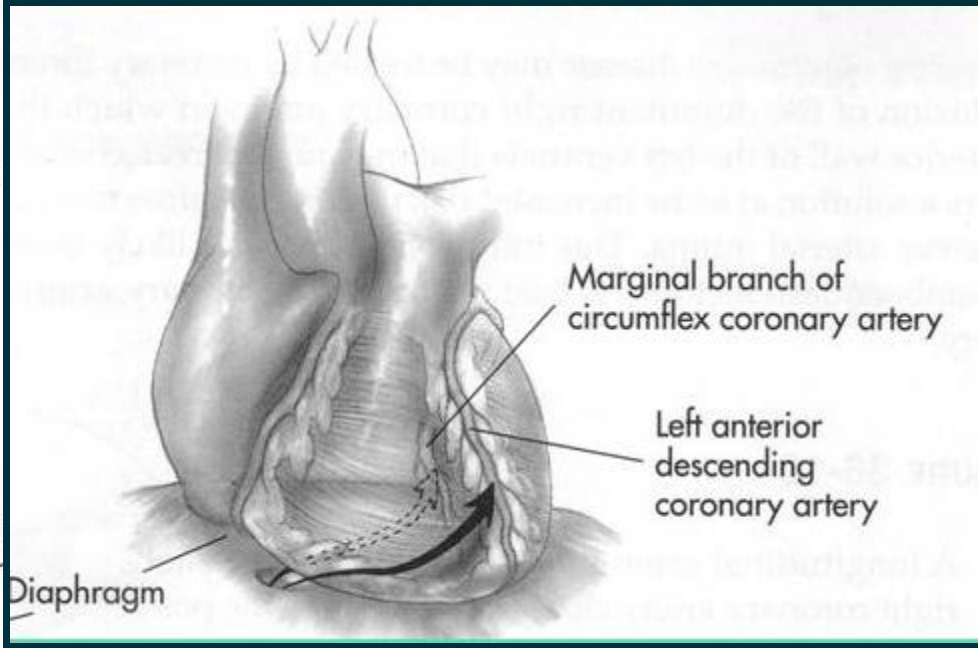


Conduits
Gastro-epiploic

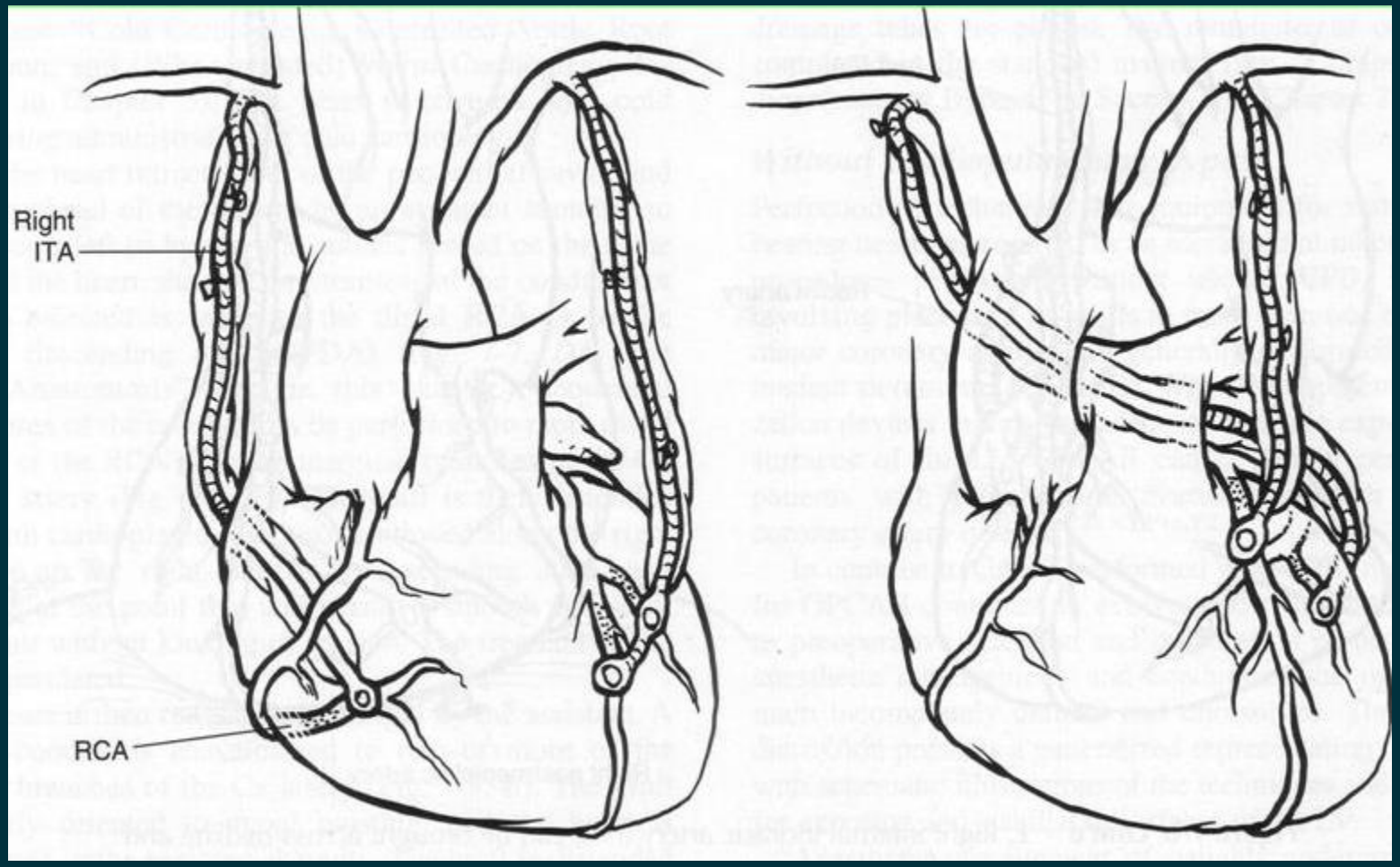


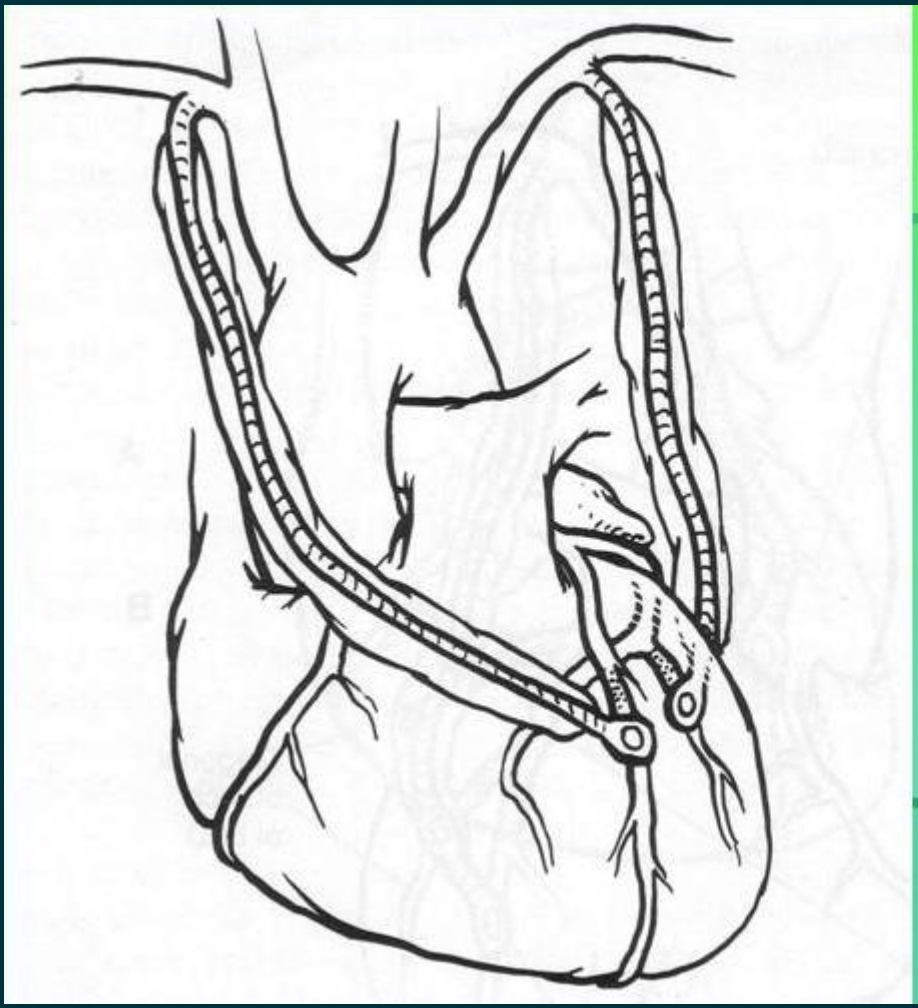


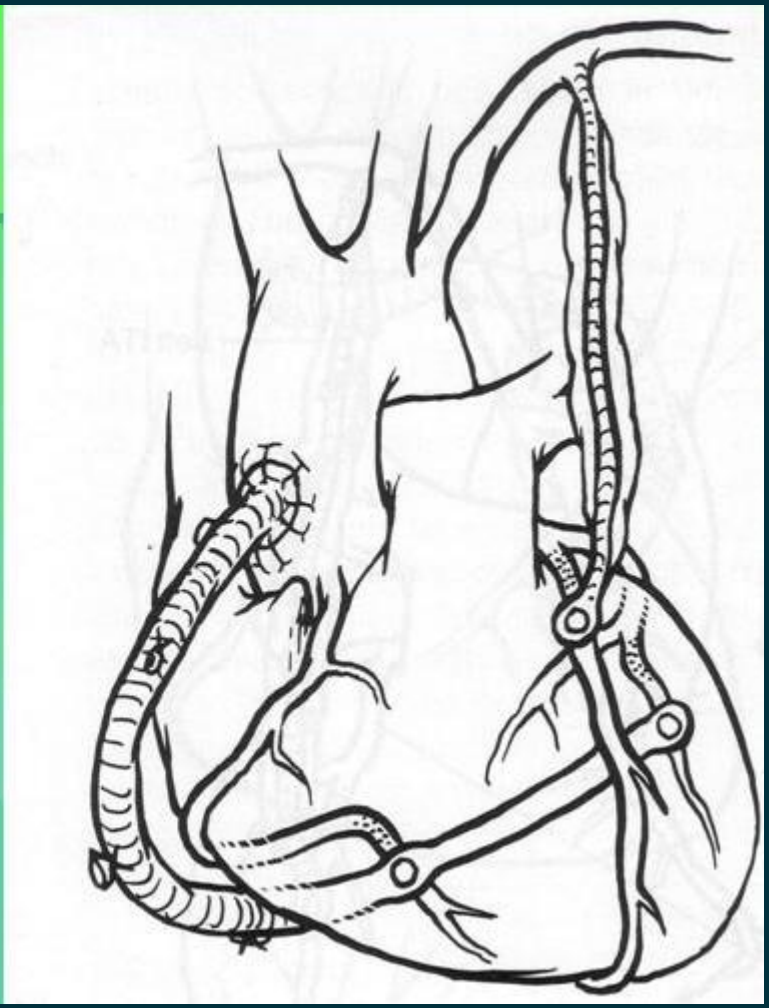

Right
coronary
artery
Diaphrag
Right
gastroepiploic
artery

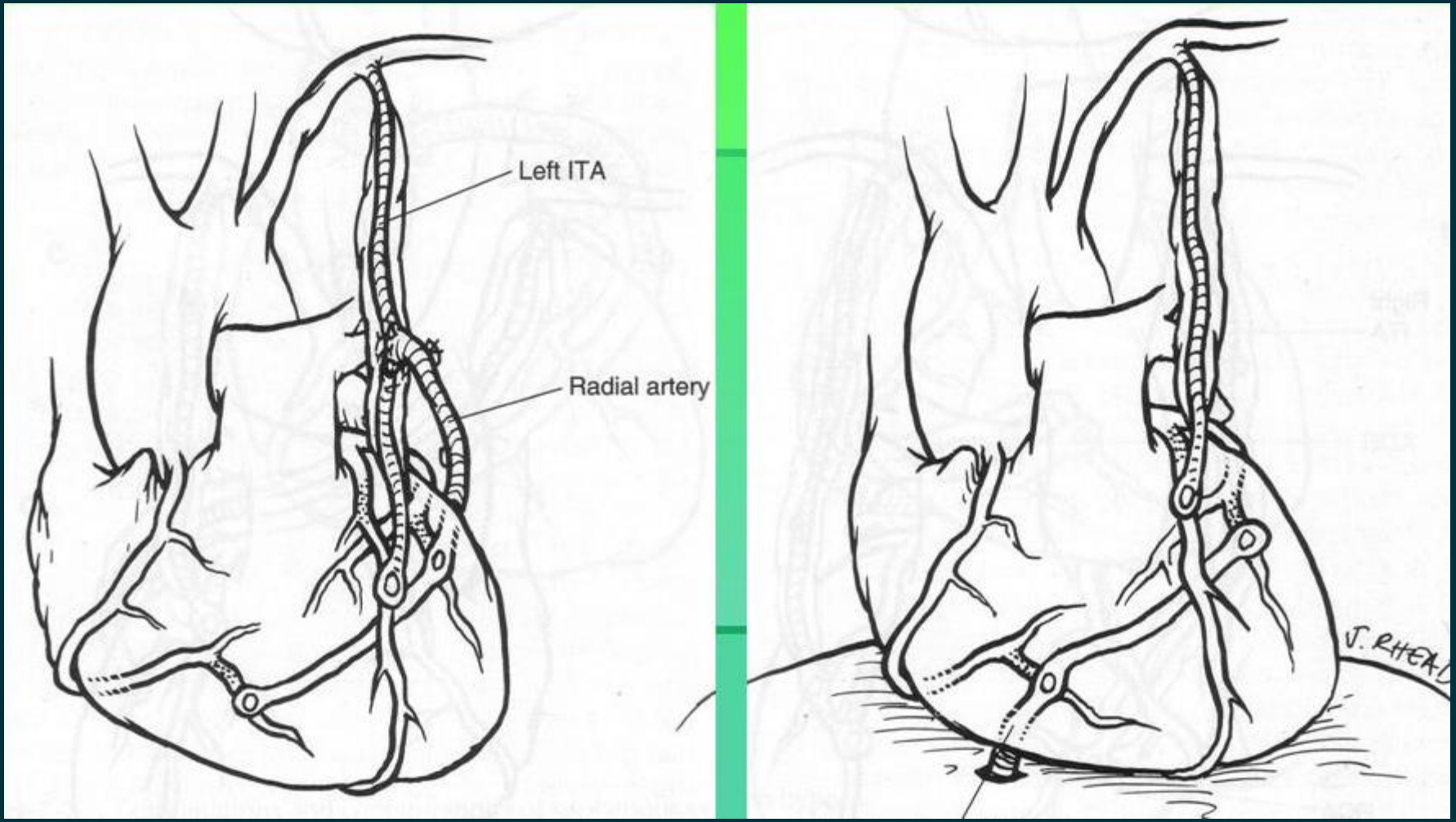

Marginal branch of
circumflex coronary artery
Left anterior
descending
coronary artery
Diaphragm

Conduit configurations (LIMA/RIMA)








Left ITA
Radial artery

CONDUIT CHOICES

- Internal thoracic artery
  - Left
  - Right
- Radial artery
- Greater saphenous vein
- Others
  - Gastroepiploic artery
  - Inferior epigastric artery

Conduit selection

- Patency rates
- Coronary anatomy
  - Degree of coronary stenoses
  - Coronary vessel location
  - Size of coronary vessels, conduit/artery mismatch
  - Patient co-morbidities
- Availability
  - Varicose veins
  - Atheromatous/calcific RA, positive Allen's test

Factors affecting patency

- Conduit
- Patency rates affected by degree of native vessel stenoses
  - Arterial grafts more affected than venous grafts
- FFR measurements
  - Patency rates significantly lower in functionally nonsignificant stenoses (Bothman ATS 2007)
- Post-op risk management, antiplatelet therapy

LIMA

- Has the best long term patency rates
- Improved survival compared with SVG only grafting
- Patency maintained over long term
- ~90% at 10 years for LAD system
- But less so for moderate stenoses (competitive flow) and on RCA territory

RIMA

- Can graft RCA or LCx territories depending on the length available
- Often needs to be used as a free/composite graft
- Patency not as good as LIMA – may be due to non-LAD territory, use as a free graft

Radial artery

- Poor patency rate due to vasospasm when first introduced
- But now increasingly utilised as part of complete arterial revascularisation strategy
- Affected by calcification and intimal hyperplasia (>75%)
- Patency especially poor in moderate stenosis or small target vessels or in patients with DM (Desai et al. Circulation 2007)

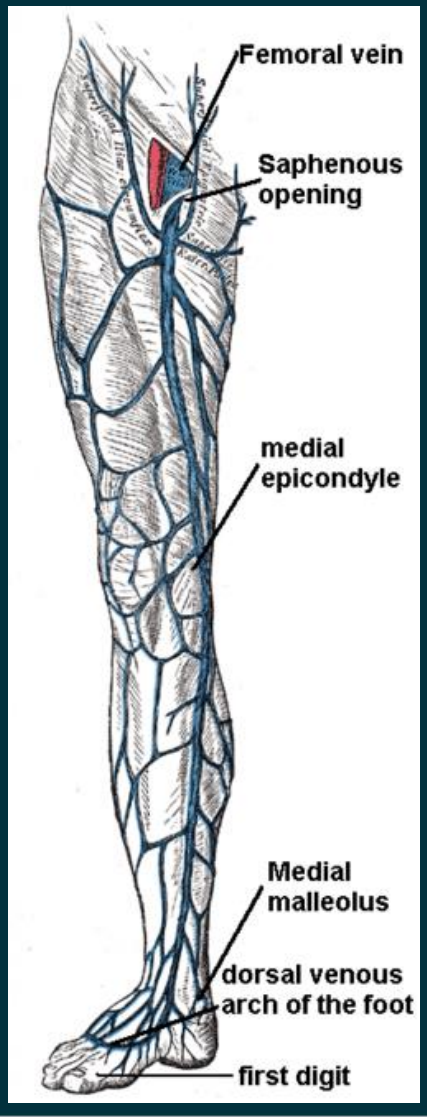
Greater Saphenous Vein

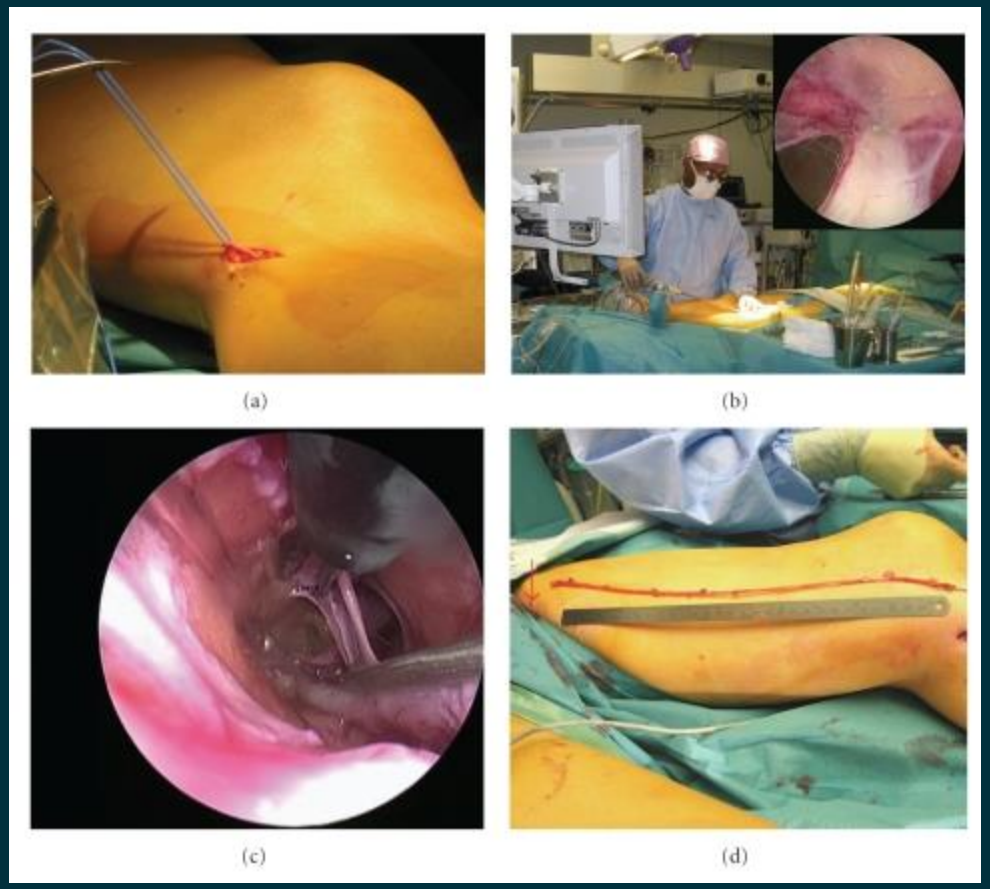
- Historically the most widely used conduit (12.5% failure at 1 week; 50-60% patency at 10 years)
- Convincing evidence that it is inferior to LIMA in all coronary territories except maybe <70% stenosis in RCA (Sabik et al. ATS 2005)

CONDUIT OPTIONS

- In depth look at various conduits

GREATER SAPHENOUS VEIN





Saphenous Vein Graft failure

- Vein graft failure (VGF), defined as complete graft occlusion, greater than 70% stenosis, or extensive conduit narrowing on angiography.
- 10% to 15% of saphenous vein grafts (SVGs) occlude within 1 year of operation, and almost one-half of the conduits fail at 10 years
- Increases the patients' risk of major adverse cardiac-related events.
- Often necessitating repeat revascularization.

- VGF is largely attributable to three temporally distinct processes.
- Acute thrombosis, subacute intimal hyperplasia, and long-term atherosclerosis.
- Intraoperative measures are crucial in avoiding graft failure.
- A no-touch technique, minimizing graft trauma, avoidance of distension, use of expandable external vein graft supports.

ENDOTHELIUM

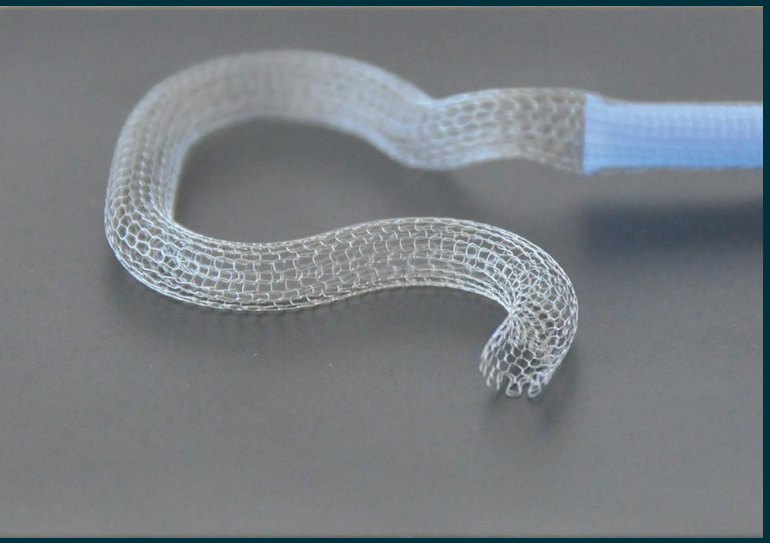
- Maintenance of a structurally intact endothelial barrier at the luminal surface of SVGs is imperative to graft patency, particularly through avoidance of acute thrombosis

GSV PRESERVATION SOLUTION

- Controversy remains as to the ideal preservation solution for short-term intraoperative storage of the SVG after harvesting.
- Studies have failed to consistently substantiate the superiority of storage with autologous blood over crystalloids.
- University of Wisconsin solution (UWS), a preservation medium used widely in organ transplantation – in theory maintains endothelium integrity (never proven in human studies).

VEST – external stent for saphenous vein graft

- Externally stenting saphenous vein grafts reduces intimal hyperplasia, improves lumen uniformity and reduces oscillatory shear stress 1 year following surgery.
- 2015 – cobalt chrome external stent.
- Clinical reports suggest a protective biomechanical effect of a braided cobalt chrome external stent on vein graft remodeling.



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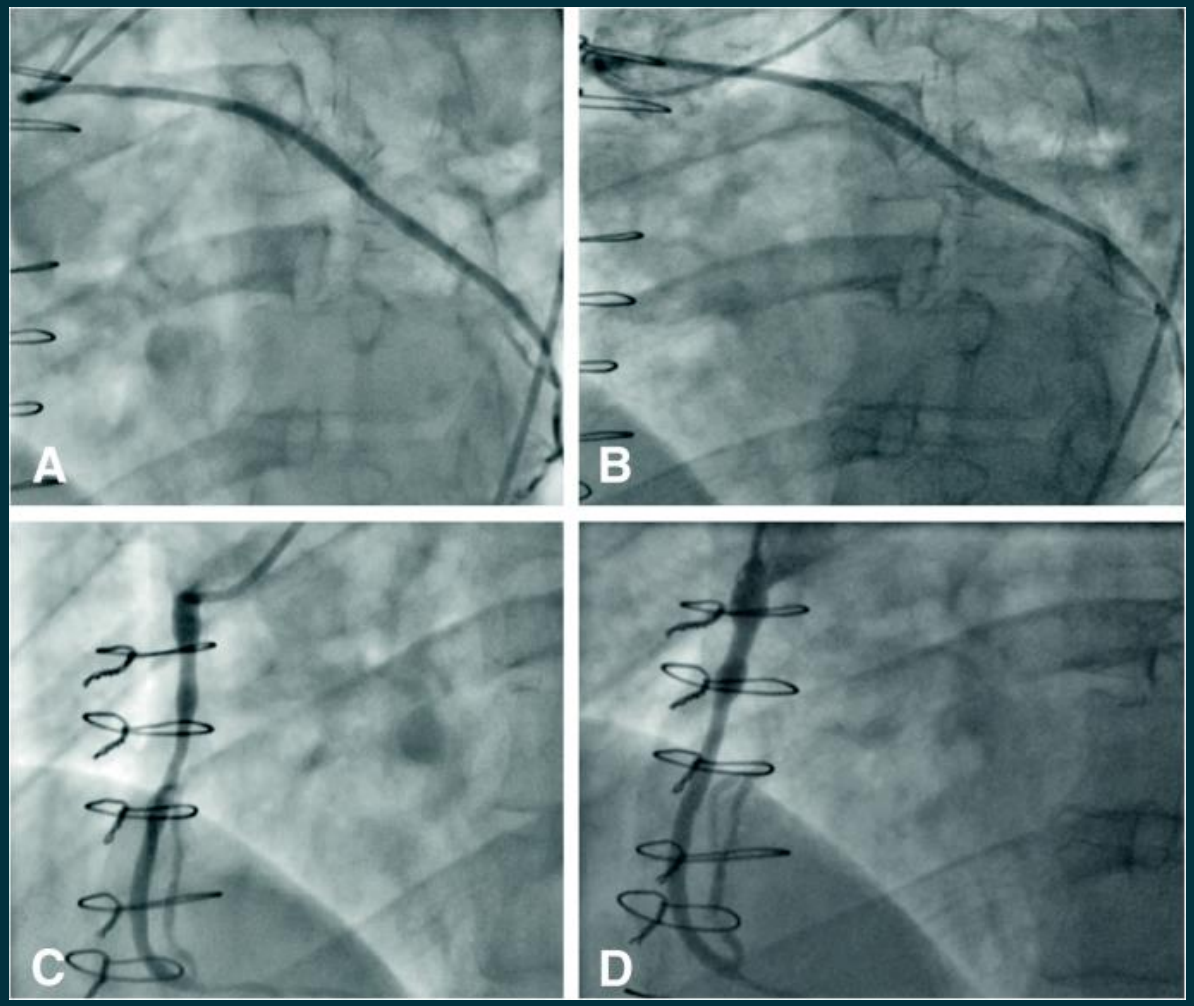
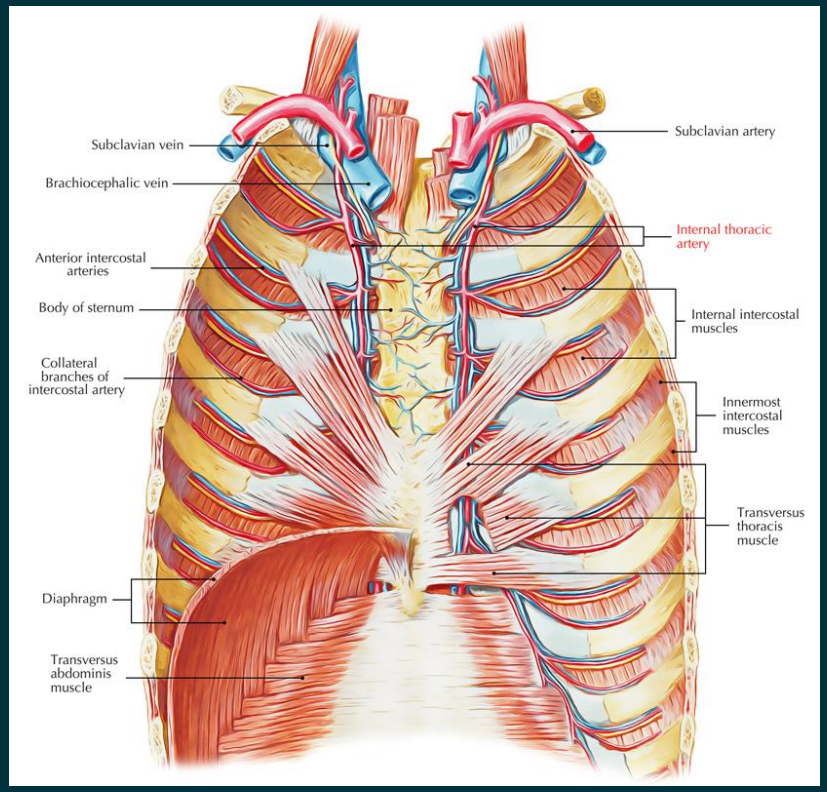
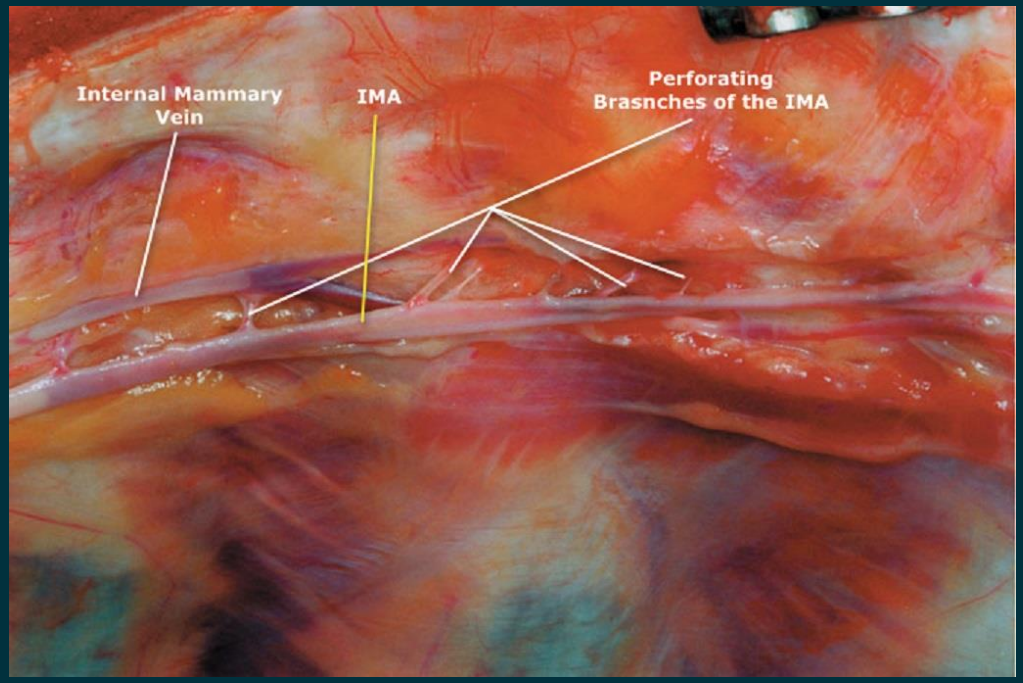
- The early phase of vein graft remodeling is dominated by luminal enlargement followed by a later phase of vein graft thickening and Intimal Hyperplasia.
- Luminal enlargement is generated mainly by the exposure to the high shear stress of the arterial circulation.
- The mitigation of IH and lumen deformation achieved by external stenting was most pronounced in the first year after implantation.

- Angiographic images showing a within-patient comparison of stented and nonstented SVGs at 1 and 4.5 year follow-up. Stented SVG to obtuse marginal artery at 1 year (**a**) and after 4.5 years (**b**). Nonstented SVG to right coronary artery at 1 year (**c**) and 4.5 years (**d**)



Internal Thoracic Artery





Internal Thoracic Artery Superiority

- Greatest long term patency.
- Best conduit for survival.
- Proven benefit irrespective of age, gender, LV function.
- Survival benefit for patient improves with time.

Internal Thoracic Artery Superiority

- Tight endothelium.
- Produces its own nitric oxide and antithrombotic factors.
- Highly resistant to developing atherosclerosis.

Internal Thoracic Artery

- 1.9 to 2.6mm (good size match with coronary anatomy).
- SVG 3.1 to 8.5mm.
- Intima has endothelium (SVG has absence of endothelium).
- Media consists of collagen and smooth muscle cells.

SVG with neo-intimal growth

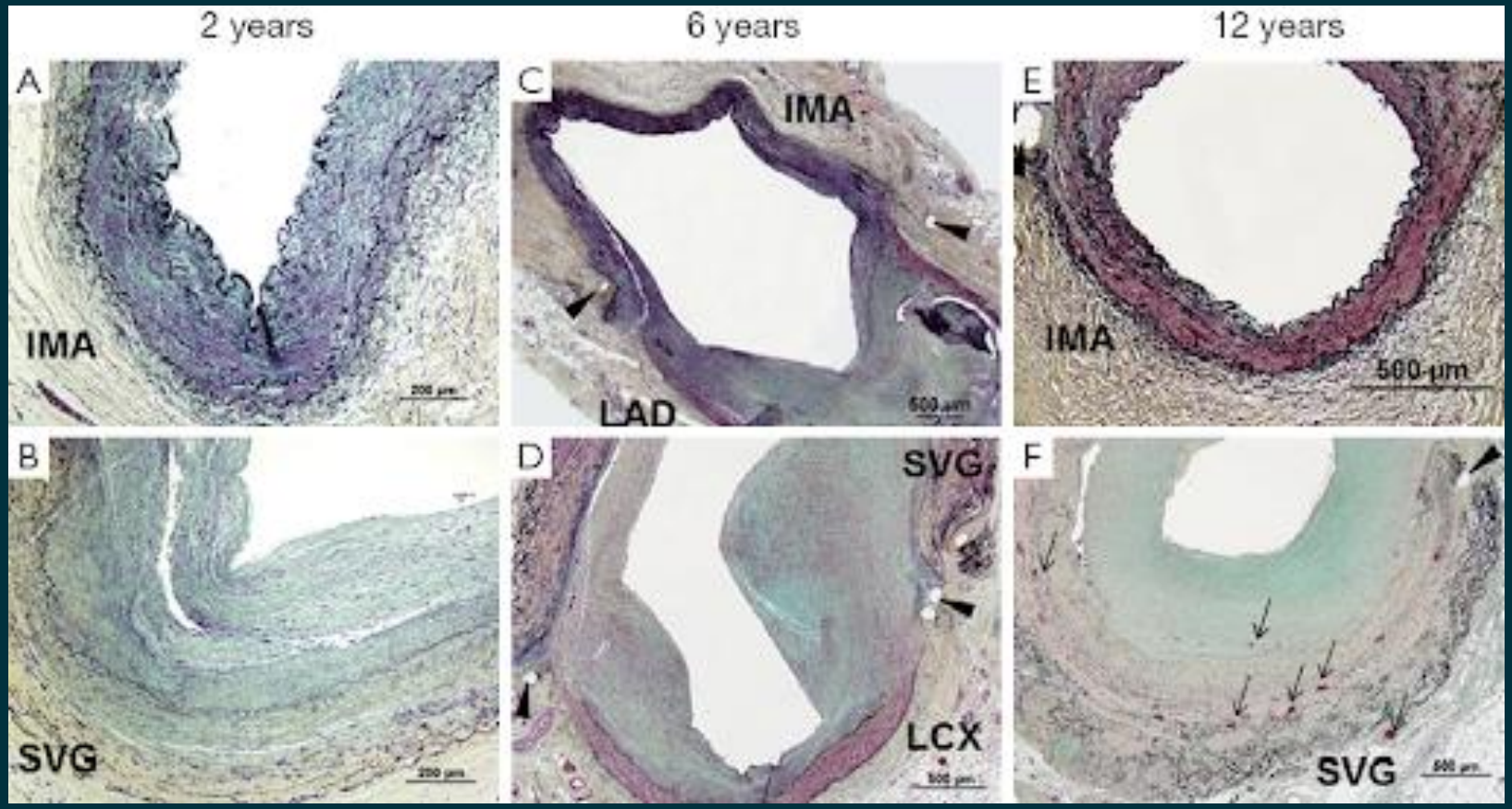
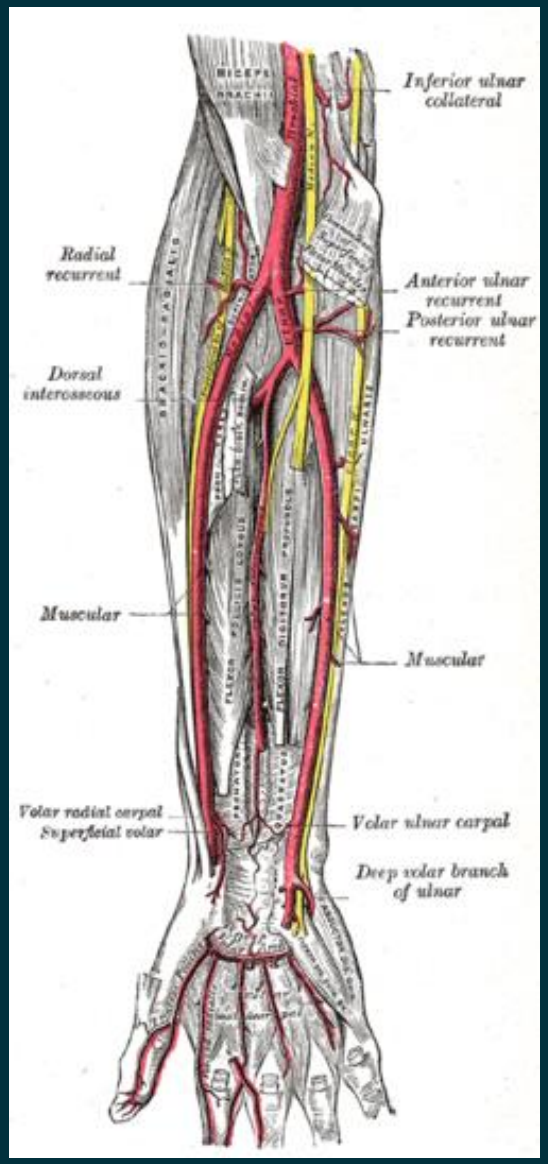
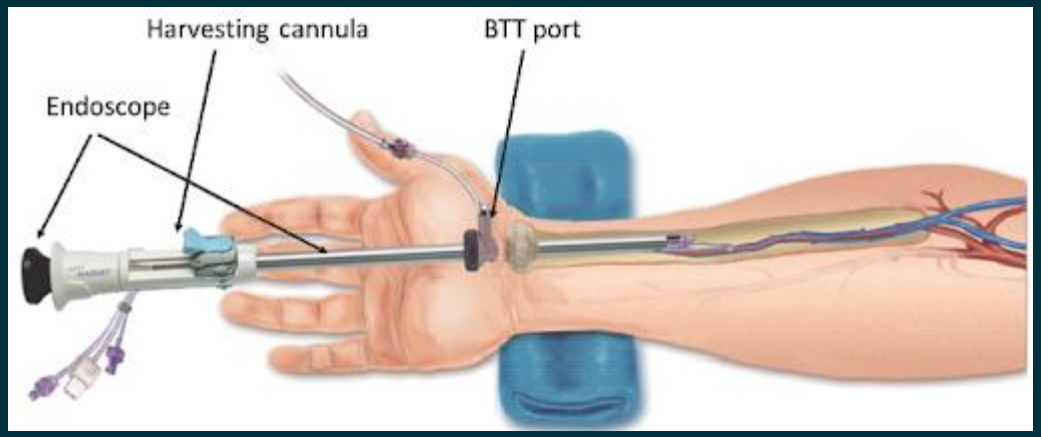


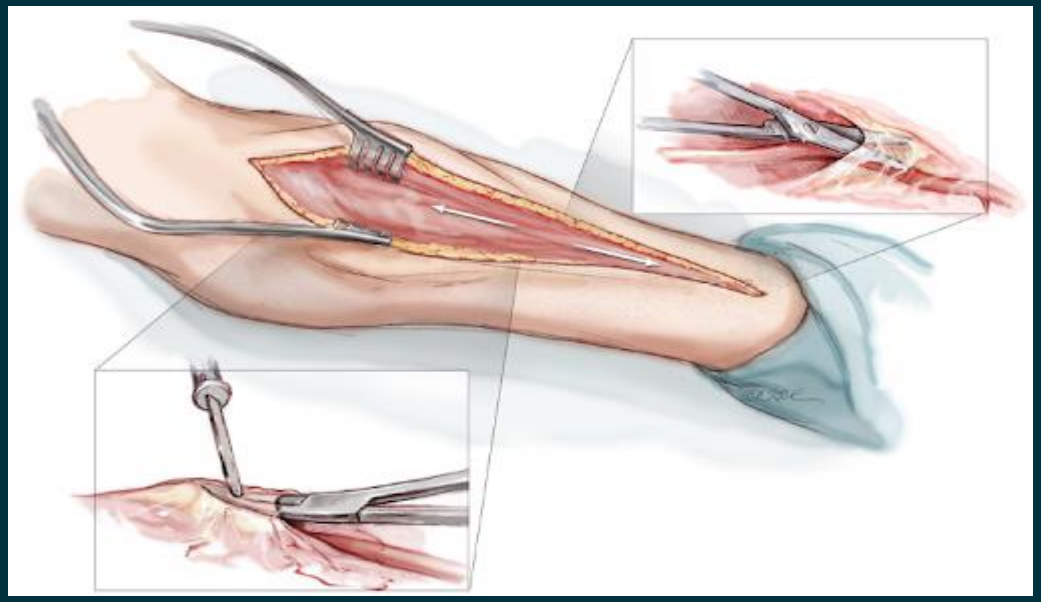
Table 1 Comparative anatomic and physiological properties of internal mammary artery (IMA) and saphenous vein (reproduced with permission from Motwani JG and Topol EJ. Circulation 1998;97:916-31.)

	IMA	Saphenous vein
Anatomic properties		
Endothelial fenestrations	Few	Many
Intercellular (IC) processes	Many	Few
IC junction permeability	Low	High
Internal elastic lamina (IEL)	Well defined	Poorly defined
Heparan sulfate in IEL/media	High	Low
Dependence on vasa vasorum	Minimal	High
Valves	Absent	Present
Size match with grafted native vessel	Good	Poor
Resistance to trauma of harvesting	High	Low
Physiological properties		
Flow reserve	High	Low
Shear stress	High	Low
Nitric oxide/prostacyclin production	High	Low
Vasomotor response to thrombin	Relaxation	Constriction
Vasoconstrictor sensitivity	Low	High
Vasodilator sensitivity	High	Low
Basic fibroblast growth factor receptors	Few	Many (8× IMA)
Lipolysis	Rapid	Slow
Lipid synthesis	Less active	More active
Lipid uptake	Slow	Rapid

RADIAL ARTERY







Radial Artery

- Carpentier 1971.
- Abandoned by that group due to poor patency.
- 1990's the radial came back into favor.
- Ease of handling.
- Ease of harvest (open/endoscopic) – no sternal ischemia issues to deal with.
- Able to reach all targets (15cm-22cm length).
- 2-3mm in diameter.

Radial artery

- Produces Nitric oxide.
- Enhanced resistance to atherosclerosis.
- Minimal size mismatch with coronary anatomy.
- Decrease in media smooth muscle components following implantation to coronary artery.
- Concerns of vasospasm (CCB can mitigate this) and competitive flow issues (best grafted to region with >80% stenosis).

Radial artery Patency (RCT)

- Randomized Control Trials of RA patency.
- 1) RSVP study – Radial artery versus saphenous vein patency - RA 92%@5years; SVG 78%@5years.
- 2) RAPS – Canadian Radial Artery Patency Study – RA 91.1%@ 7 years; SVG 81.4% @ 7 years.
- 3) RAPCO – Australian Radial artery Patency and Clinical Outcomes – RA 92%@ 7 years; SVG 84% @ 7years. RITA shown 90% @ 8 years. High SVG patency in this study!

RA versus SVG

- Early survival and patency rates are similar.
- Survival curves diverge after 7th post operative year.
- RA-MABG associated with fewer major adverse cardiac events; fewer MI; fewer re-operations; less need for repeat revascularization.

RITA/Gastroepiploic artery

- RITA harvesting technically more challenging.
- Risk of DSWI increased.
- Can’t reach all territories.
- GEA – increased use in Asian population.
- Patency in North American trials not as good as seen in Asian population

MABG

- Performed in fewer than 10% of patients.
- Radial graft used less than 7% of patients.
- Why?
- The studies showing superior outcomes have not been replicated in RCT.
- The patency improvement have not always led to improved survival.
- Failure of graft to LAD shows adverse survival; not the case of graft failure to other territories.

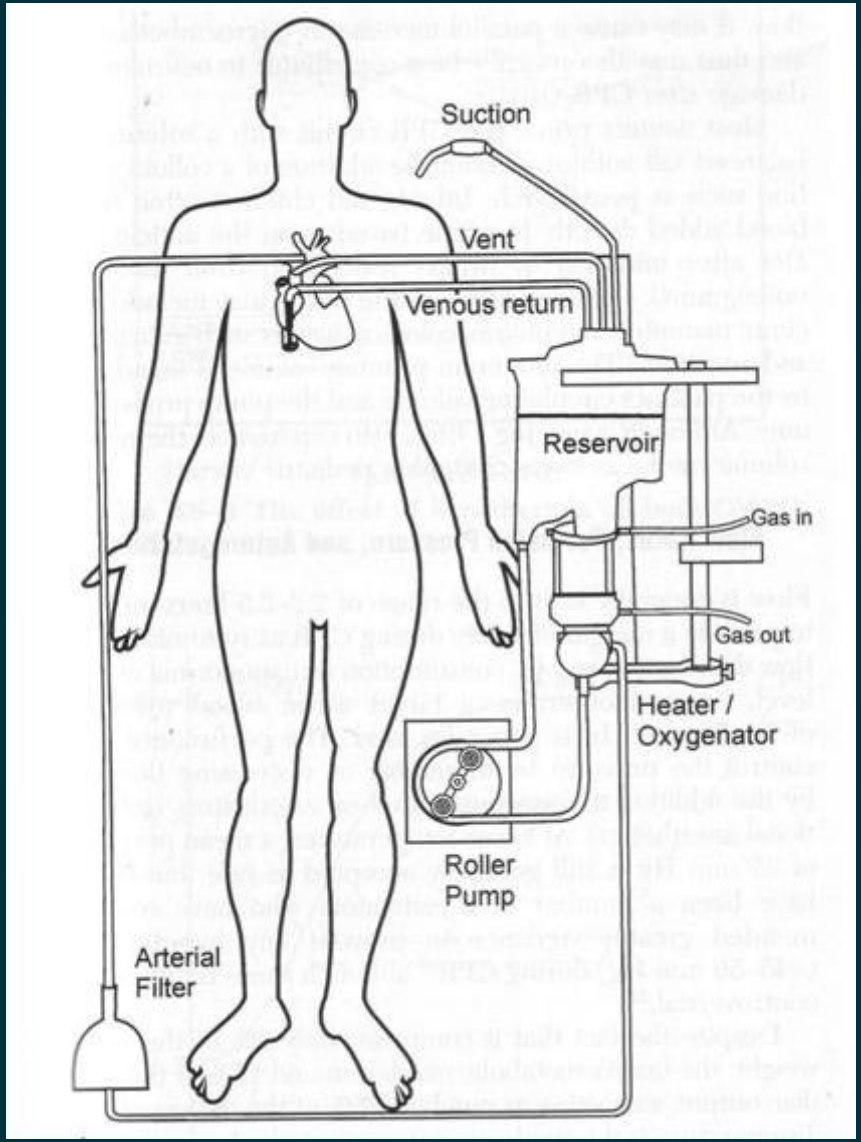
PROCEDURAL STEPS OF CABG

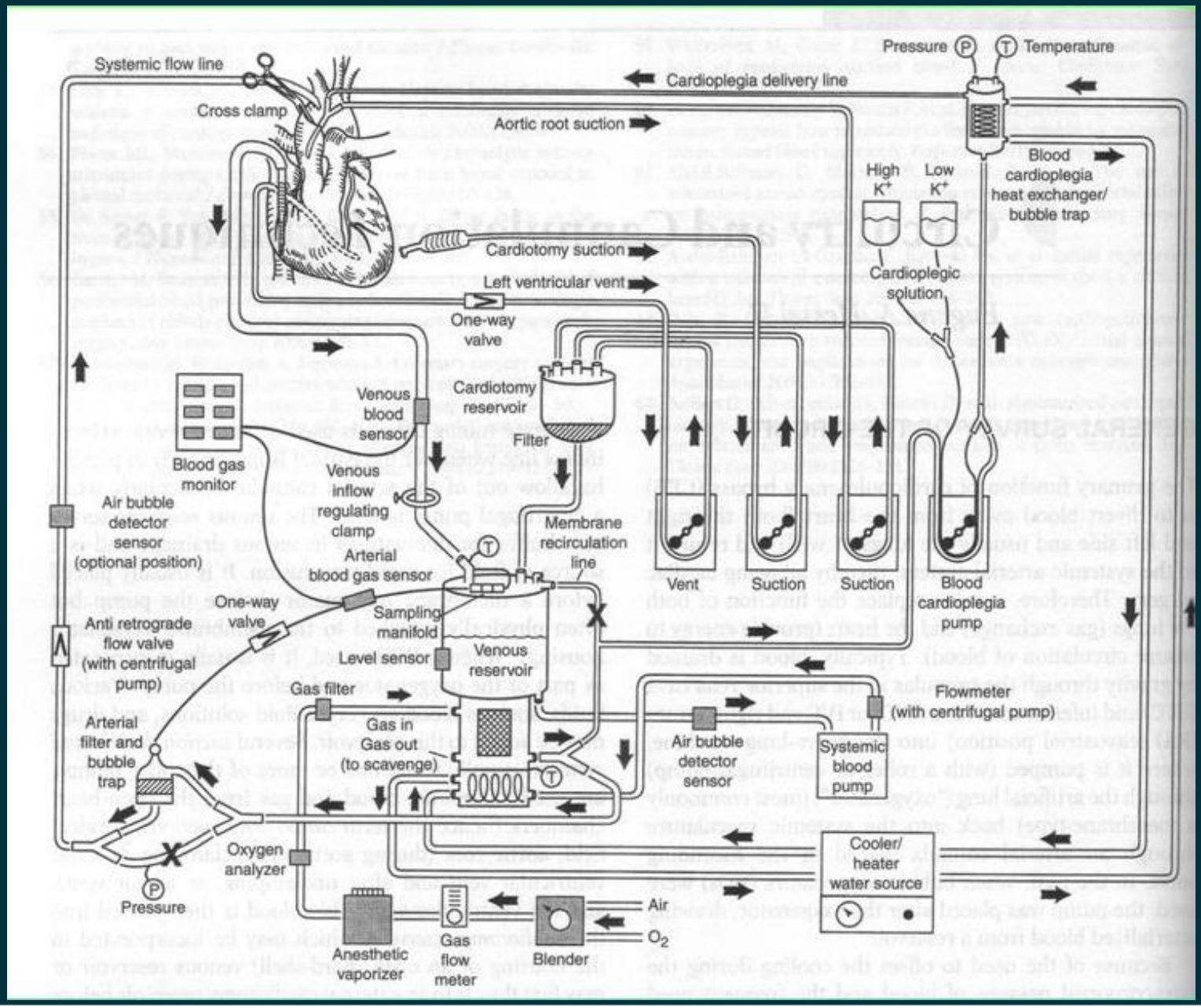
- If time permits…

CABG

- Median sternotomy
- Conduit harvesting
- Heparin, cannulation and CPB with mild to moderate hypothermia
- Cross-clamping of the aorta and cardioplegia
- Distal anastomoses. Rewarming started.
- Cross-clamp removed. Proximal anast. using a partially occluding clamp. Clamp removed. De-airing.
- CPB discontinued, cannulae removed, protamine.
- Pacing wires, drainage tubes, hemostasis and closure.

CABG


Suction
Vent
Venous return
Reservoir
Gas in
Gas out
Heater /
Oxygenator
Roller
Pump
Arterial
Filter



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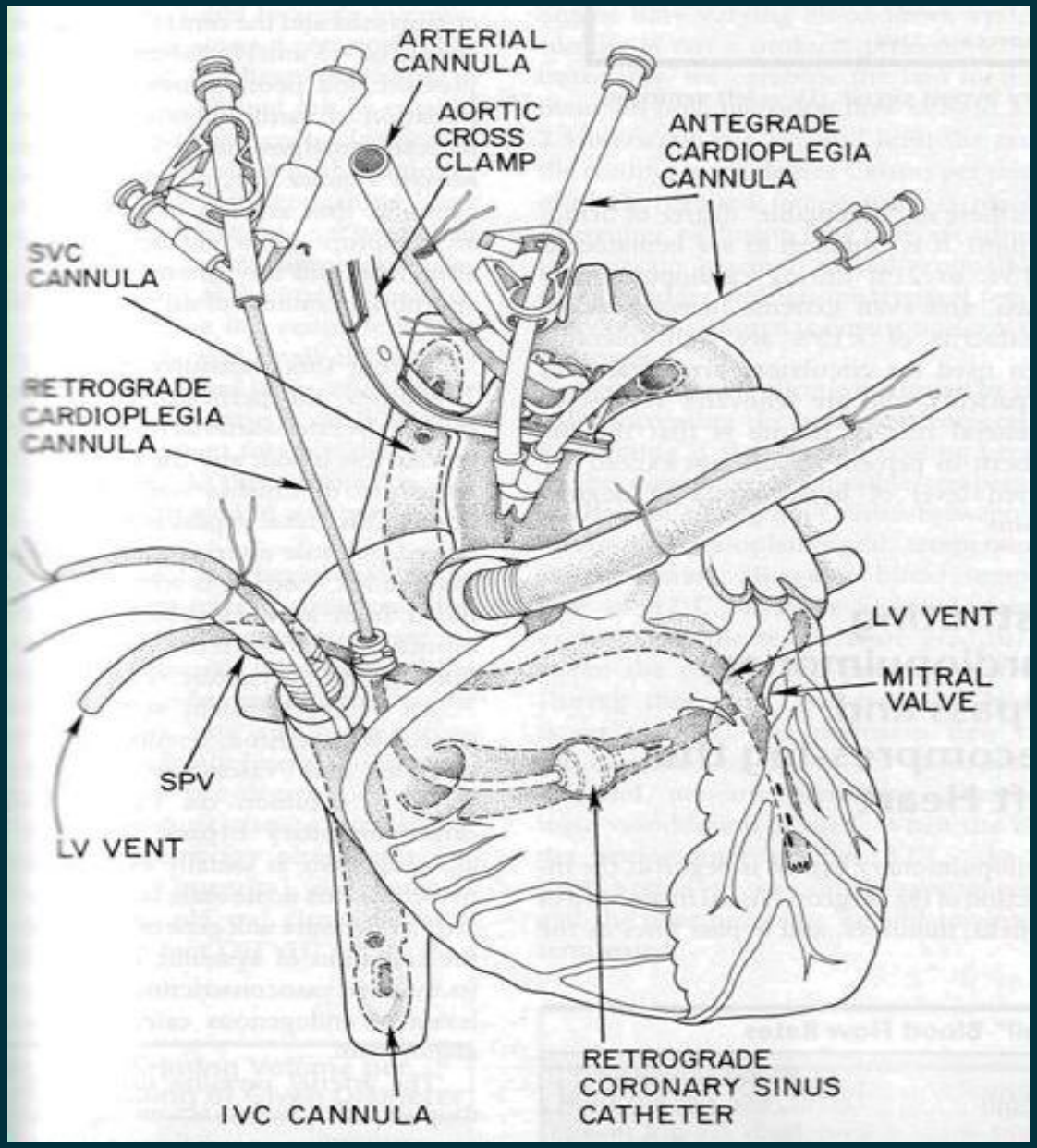

ARTERIAL CANNULA
AORTIC CROSS CLAMP
ANTEGRADE CARDIOPLEGIA CANNULA
SVC CANNULA
RETROGRADE CARDIOPLEGIA CANNULA
LV VENT
MITRAL VALVE
SPV
LV VENT
IVC CANNULA
RETROGRADE CORONARY SINUS CATHETER

OPCAB

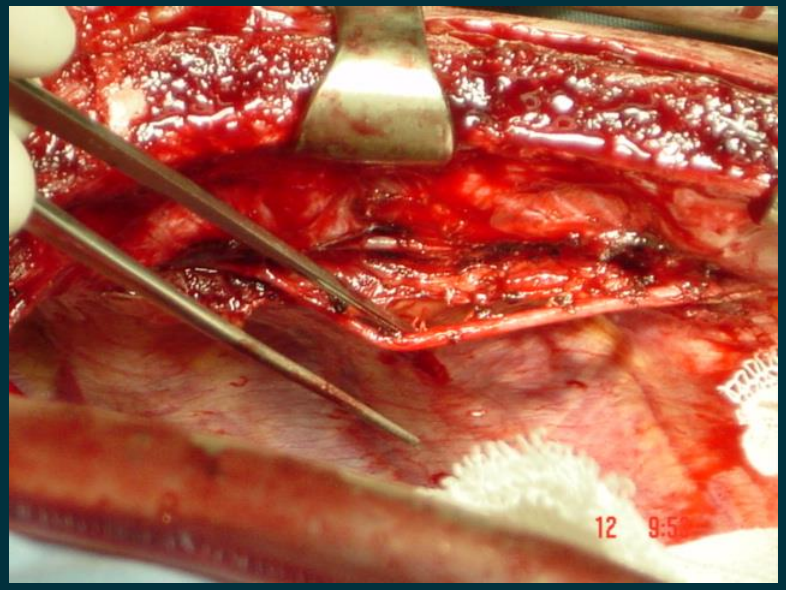
- Attempt to maintain normothermia
- Median sternotomy
- Conduit harvesting
- Heparin.
- Maneuvers to maintain hemodynamic stability (Trendelenburg, table, R pleura,.)
- Pericardial sling
- Stabilization. Distal anastomoses with or without shunting.
- Proximal anastomoses. Protamine.
- Chest drains. Hemostasis. Closure.

Surgery

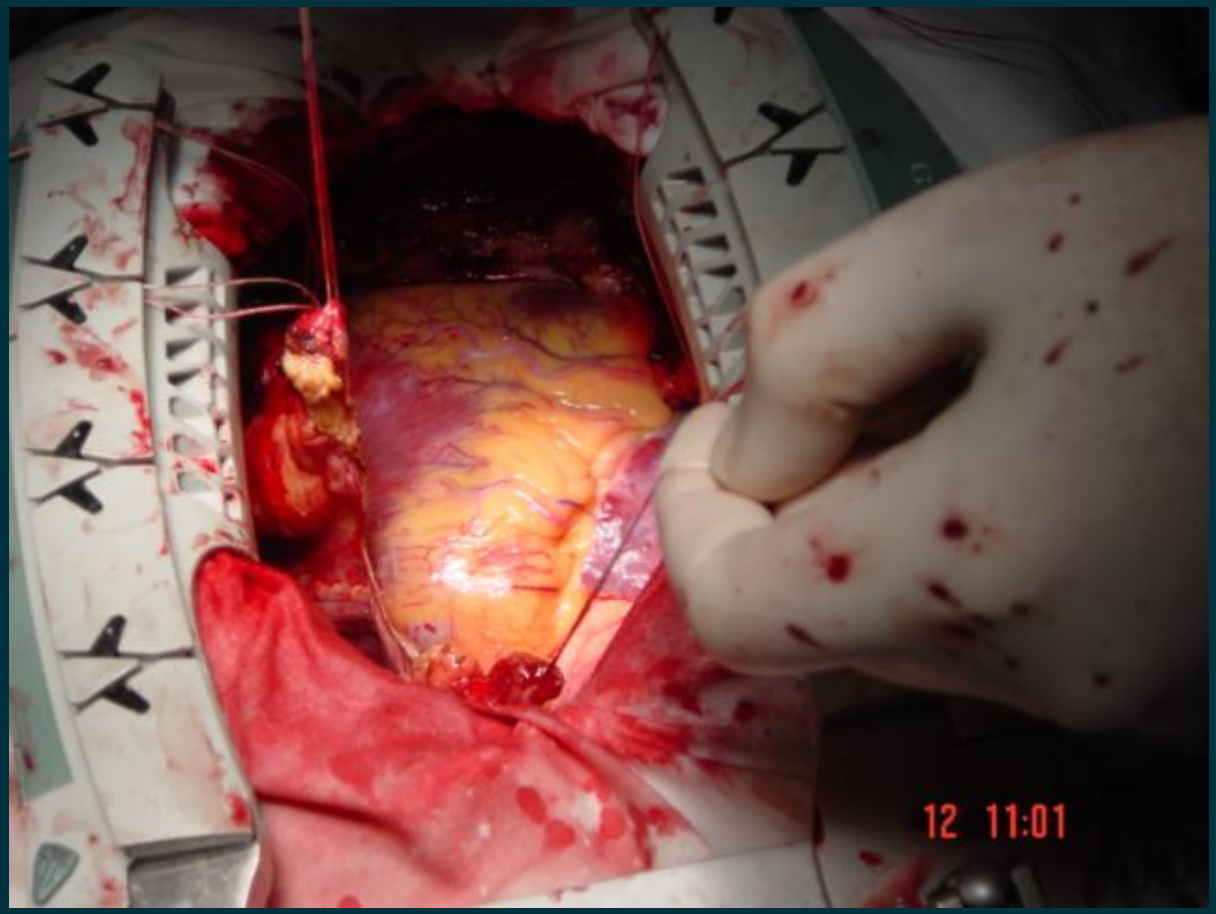
- Surgery
  - On cardiopulmonary bypass.
  - Off cardiopulmonary bypass.
- Grafts
  - ITA.
  - Saphenous vein.
  - Radial artery.

Steps

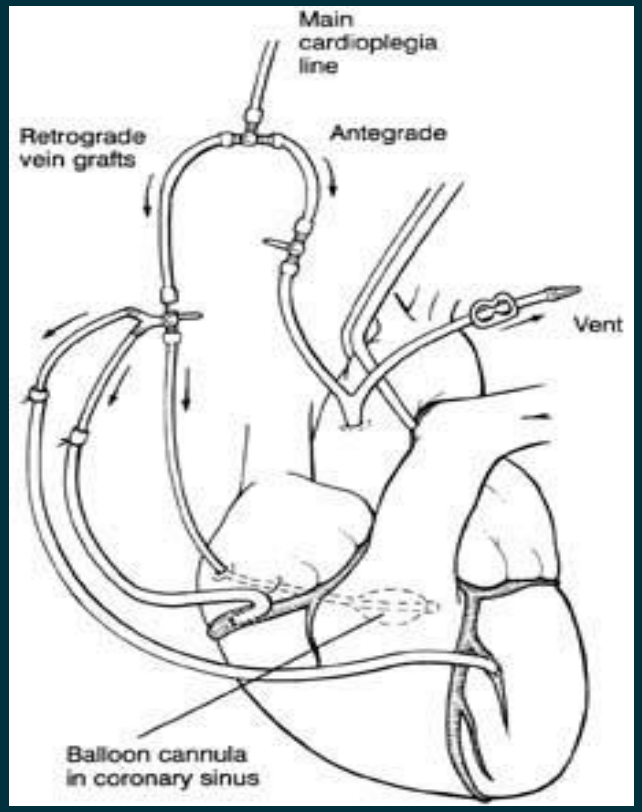
- Median sternotomy.
- Graft harvest.
  - Left internal mammary artery.
  - Saphenous vein graft.

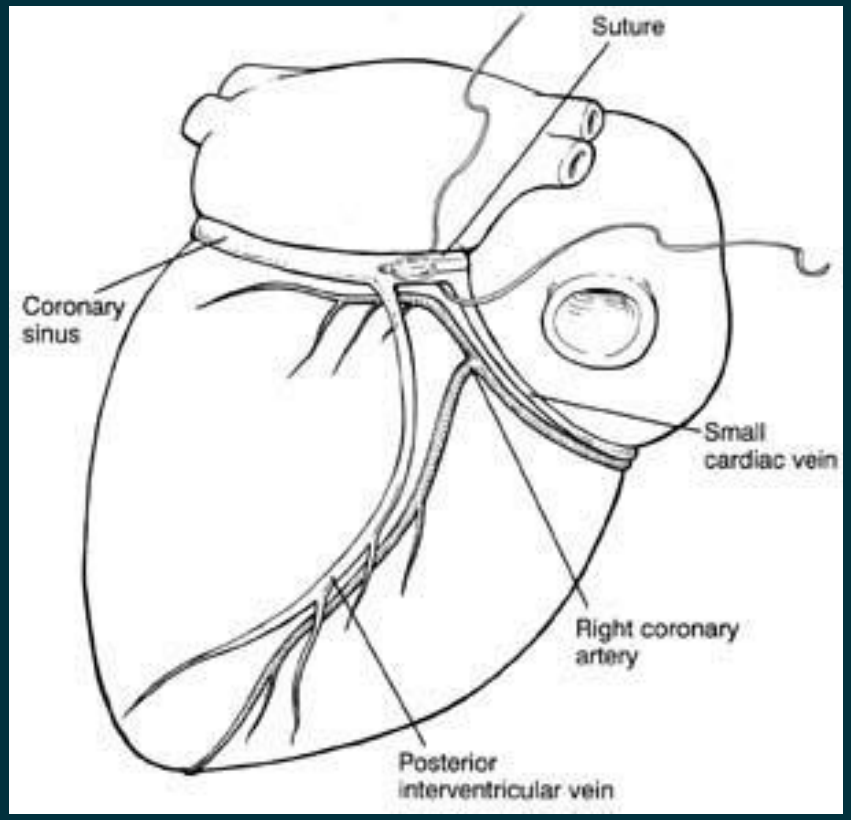


- Pericardial exposure.
- Target vessel inspection.

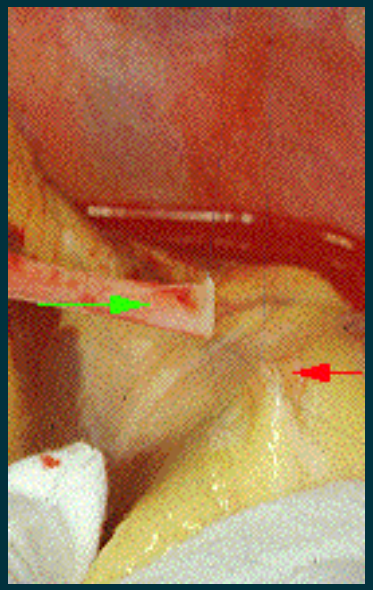
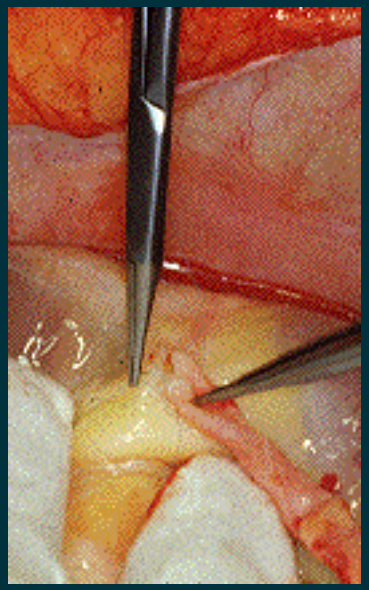
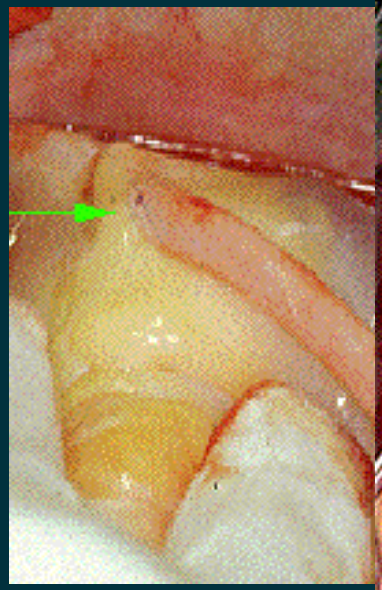
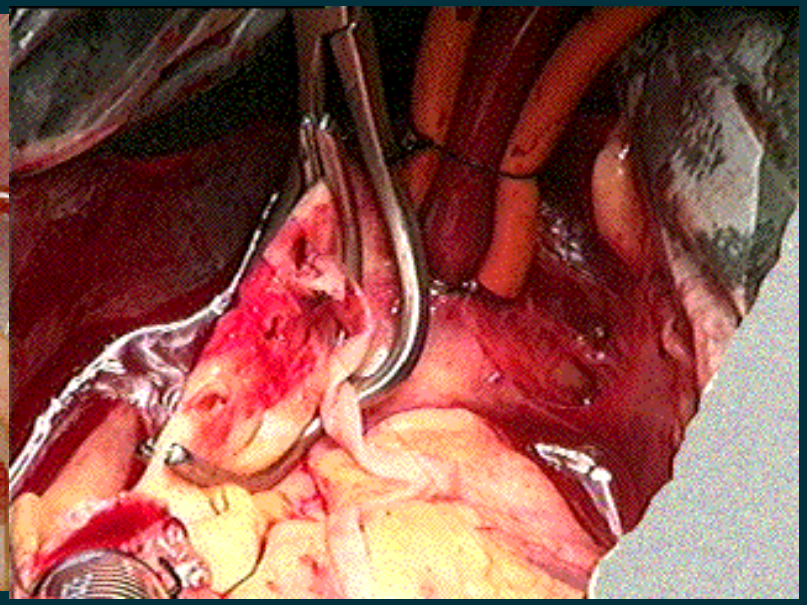


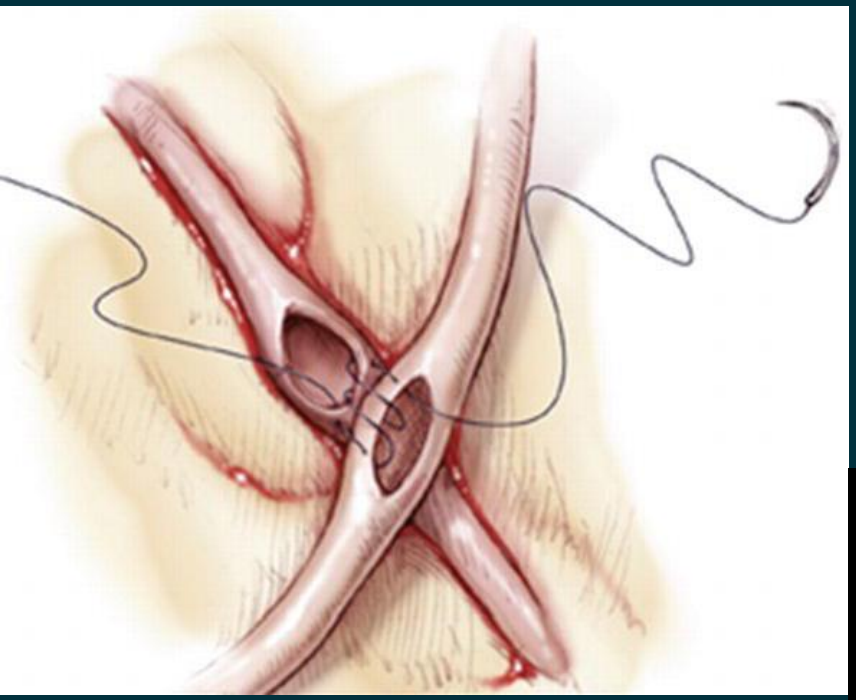
- Insertion of CPB cannulas (arterial and venous).
- Cardioplegia cannula
  - Antegrade.
  - Retrograde.

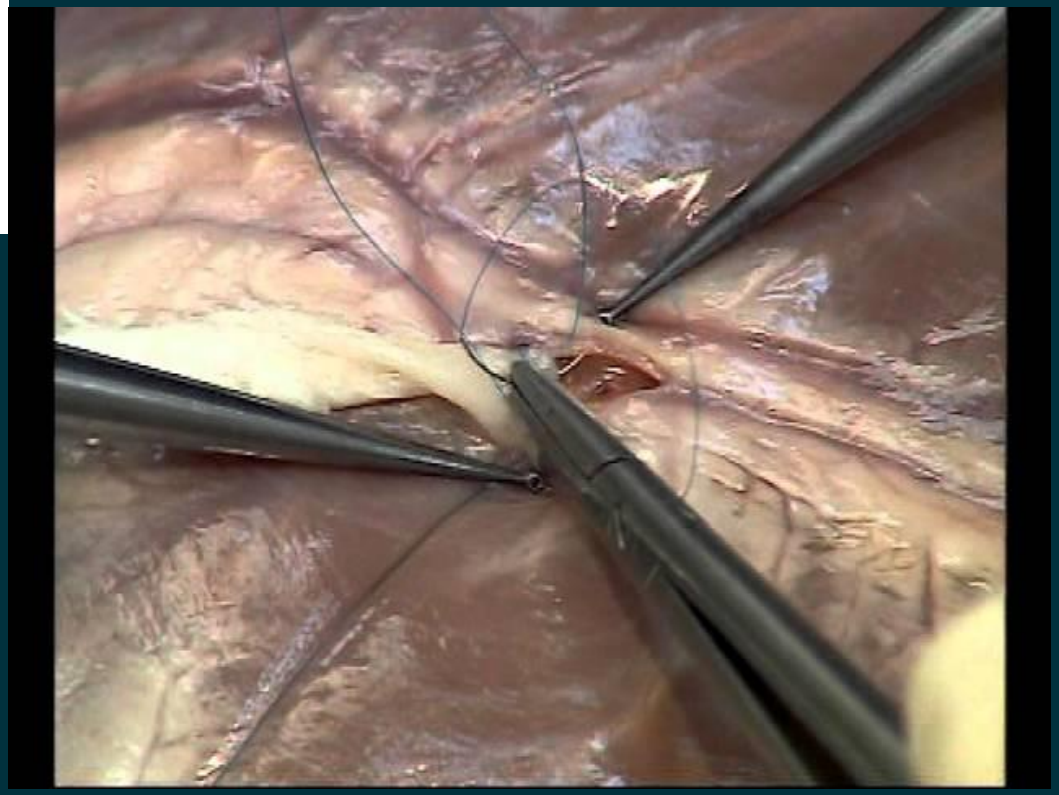


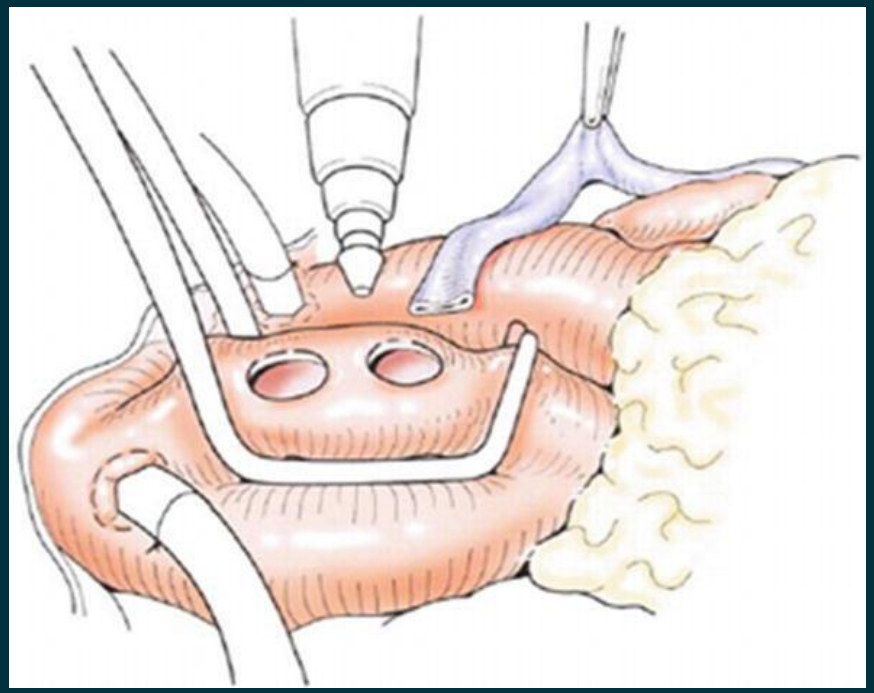


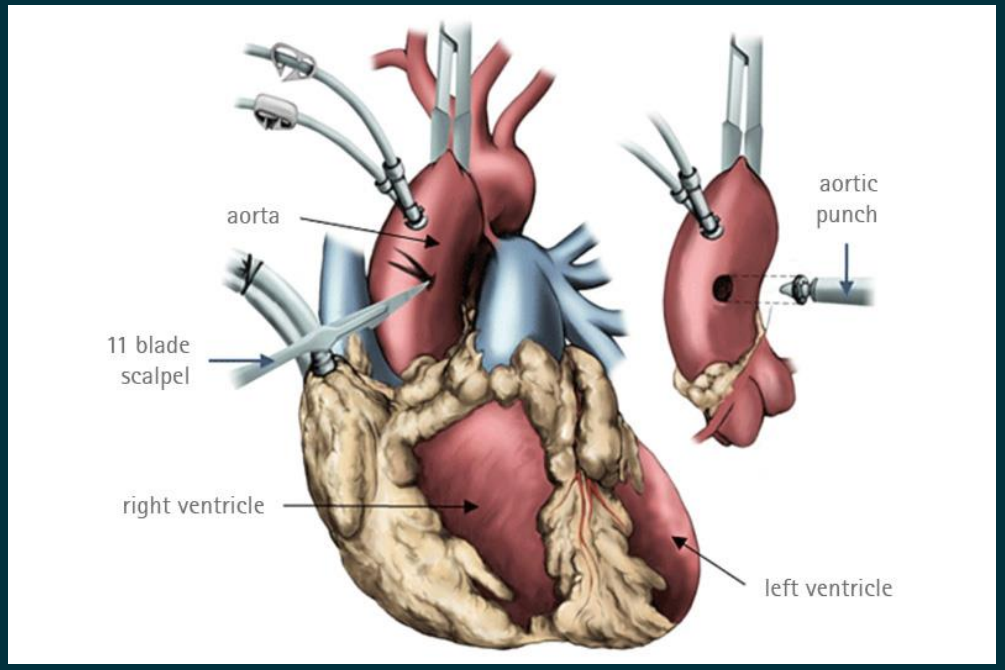
- Aortic clamp.
- Cardioplegia administration
- Distal anastomosis.
  - End-to-side.
  - Sequential (side-to-side).
- Proximal anastomosis.

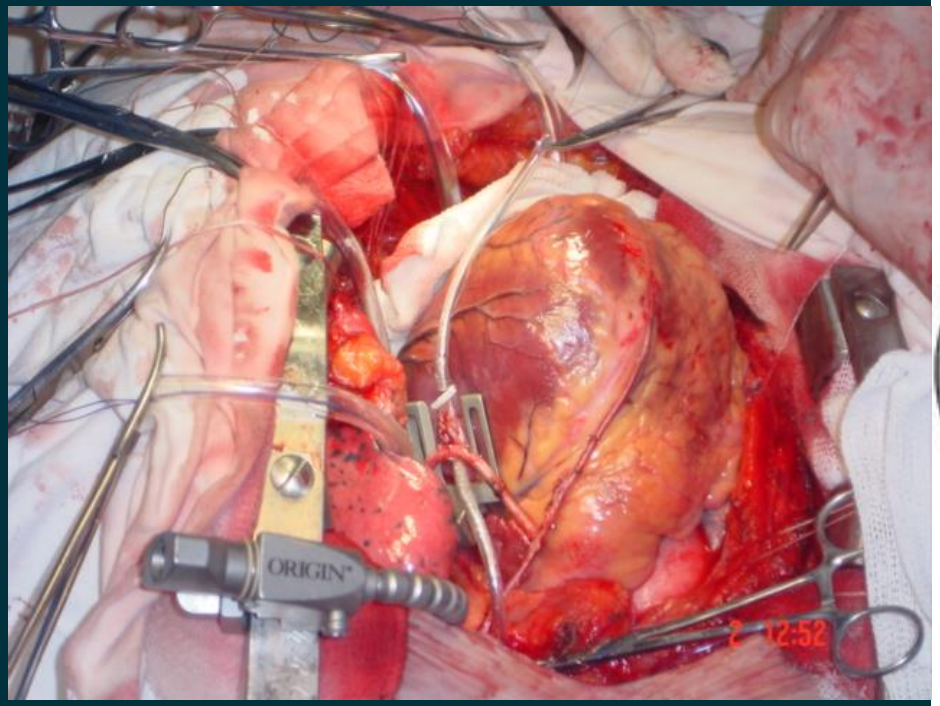


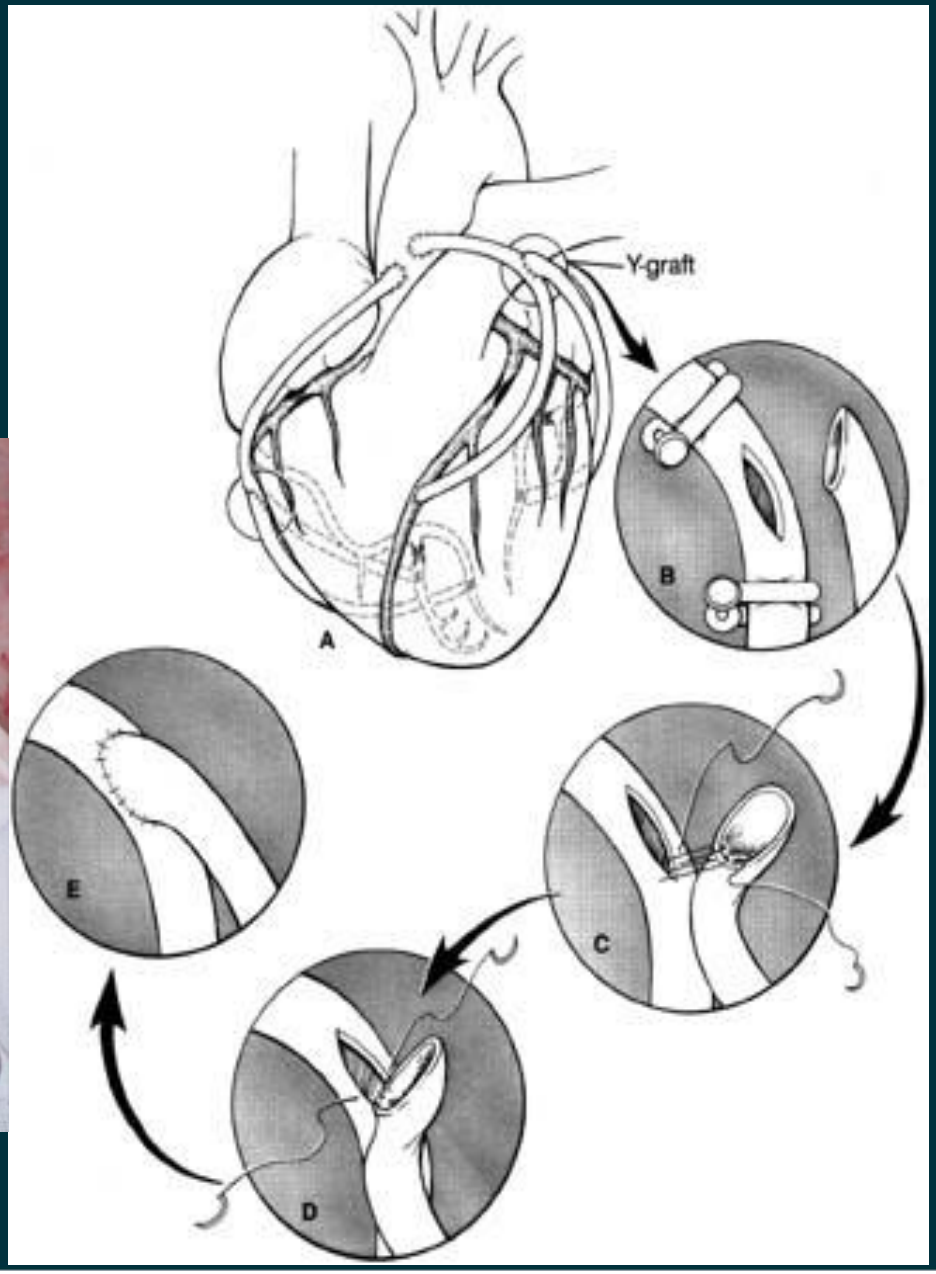





aorta
aortic punch
11 blade scalpel
right ventricle
left ventricle

- “Y” graft.
  - LIMA + RIMA
  - LIMA + radial artery.
  - LIMA + vein graft.





COMPLICATIONS

- *Postoperative bleeding.* Approximately 20% of patients receive transfusions and 2% of patients undergo re-explorations for bleeding. Re-exploration is indicated for bleeding > 400 cc/hr for 1 hour, > 300 cc/hr for 2 hours, > 200 cc/hr for 4 hours, or if tamponade is suspected.[5] Preoperative use of anticoagulant and antiplatelet medications increases the risk of postoperative bleeding. Medications such as aspirin are usually continued up to the day of surgery. Warfarin is discontinued 1 week before surgery and if needed, short-term anticoagulation with low-molecular weight heparin can be started at that time. Ideally, clopidogrel should be stopped 5 to 7 days before surgery, although it may be continued up to the time of surgery in some high-risk patients.

- *Perioperative MI/low cardiac output syndrome.* Perioperative MI occurs in approximately 2% of cases. The prevalence of low cardiac output syndrome, defined as need for inotropic or mechanical support for > 30 minutes after surgery, is approximately 5% to 10%. It is associated with a mortality risk of 17%.

- *Renal failure.* Incidence of postoperative renal failure is approximately 8%, with 1% to 2% of patients requiring dialysis. Risk factors include age > 70 years, DM, CHF, preoperative renal dysfunction, prior CABG, and long pump run.

COMPLICATIONS

- *Neurological complications.* Type 1 deficits (major focal neurological deficits) occur in 1% to 3% of patients, while type 2 deficits (global deterioration of memory or function) occur in approximately 3%. Risk of stroke is higher in older patients (> 70 years of age), with prior strokes, hypertension, renal failure, DM, smoking, and a carotid bruit.

- *Arrythmias.* Atrial fibrillation presents in 20% to 40% of patients after CABG. Risk factors include advanced age, prolonged cross-clamp time, COPD, and beta-blocker withdrawal. Prophylactic regimens with beta-blockers, amiodarone, or biatrial pacing may reduce the risk of atrial arrhythmias.

- *Sternal wound infection.* Mediastinitis and deep sternal wound infection occur in 1% to 3% of cases and carry a mortality of 15%. Risk factors include use of bilateral pedicled IMAs in diabetic patients, obesity, DM, advanced age, male gender, and perioperative hyperglycemia.

Overall mortality after CABG is 1% to 3% and it may be lower on low-risk patients. Risk factors include urgent status, advanced age, female sex, DM, poor EF, CHF, preoperative renal dysfunction, PVD, pulmonary disease, and left main disease.

Results

- Freedom from AMI: 86% at 10 years
- Freedom from sudden death: 97% at 10 years
- 80% of patients are working 1 year postop.
- Graft patency:
  - LIMA (to LAD) ± 90% at 10 and 20 years.
  - Radial artery ± 80% at 7 years
  - Gastro-epiploic artery ± 60% at 10 years
  - SVG ± 50-60% at 10 years, 80% to LAD