Surgery of the coronary arteries and valve surgery

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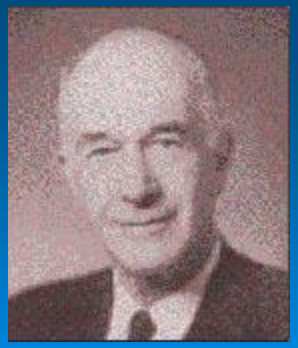
Coronary artery bypass surgery (CABG)

Treatment strategies for coronary artery disease

- Medical
  - Nitrate, anti-TCT, lysis, beta-blocker, …
- Interventional
  - PCI, stent implantation, ballon dilatation, rotablator
- Surgical
  - Coronary artery bypass, endarterectomy, patch, aneurism resection, plication

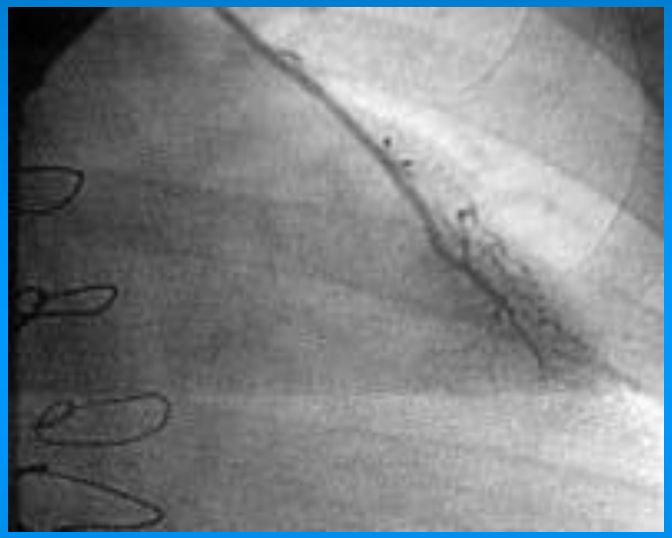
A brief history of coronary surgery

- **1876**: Adam ***Hammer*** establishes that ***angina pain could be attributed to*** interruption of ***coronary blood supply*** and that heart attacks occurred when at least one coronary artery is blocked.
- **1896**: ***Rehn***: First documented heart operation –heart wound suture
- **1910:** Alexis ***Carrell*** presents paper to American Surgical Association ***describing coronary artery bypass.***
- **1928: *Forssmann:*** first cardiac catheterization via cephalic vein on himself
- **1940's: *Vineberg***: direct implantation of LIMA into the myocardium
- **1953:** Dr. John ***Gibbon*** performed first successful open heart operation using cardiopulmonary bypass machine



The Vineberg operation was introduced by Dr Arthur Vineberg in the early 1940s ***for revascularization of ischemic cardiac tissue with direct implantation*** of the left internal mammary artery into the anterior ventricular myocardium.

Angiography of a LIMA implanted in the muscle of the left ventricle. ***Collateral circulation*** between the LIMA, the ***anterior interventricular and septal arteries***.

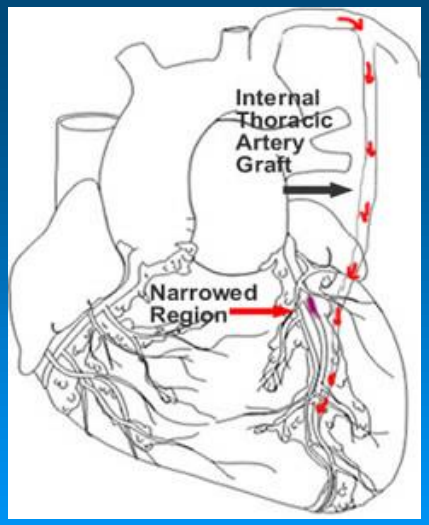


Angiography of a LIMA implanted in the muscle of the left ventricle. ***Collateral circulation with the myocardial sinusoids.***

- For many years, ***Vineberg*** procedure was the most successful surgical therapy of angina.
- In 1956, Charles ***Bailey*** successfully performed the first human ***coronary endarterectomy*** in seven patients. By 1958, William Longmire reported successful coronary endarterectomy without cardiopulmonary bypass in 5 patients.
- Yet, ***without coronary angiography*** all these early attempts for surgical treatment of angina pectoris could not be well planned, and the results could not be objectively verified.

- The idea of direct operative approach to patch, or to bypass diseased coronary arteries was entertained by many cardiologists and cardiac surgeons.
- In 1910, Alexis ***Carrel***, the famous pioneer of vascular anastomosis ***performed aorto-coronary bypass grafting in dogs***, and predicted that such an approach may have a role in the treatment of coronary artery disease in the future.
- ***Coronary bypass operations had to wait until coronary angiography was developed in 1958 by Frank Mason Sones, Jr..***

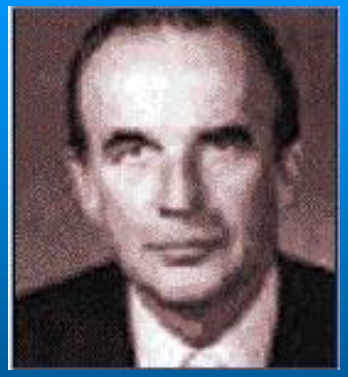
Kolesov in the Sovietunion made the first LIMA to LAD anastomosis in 1964



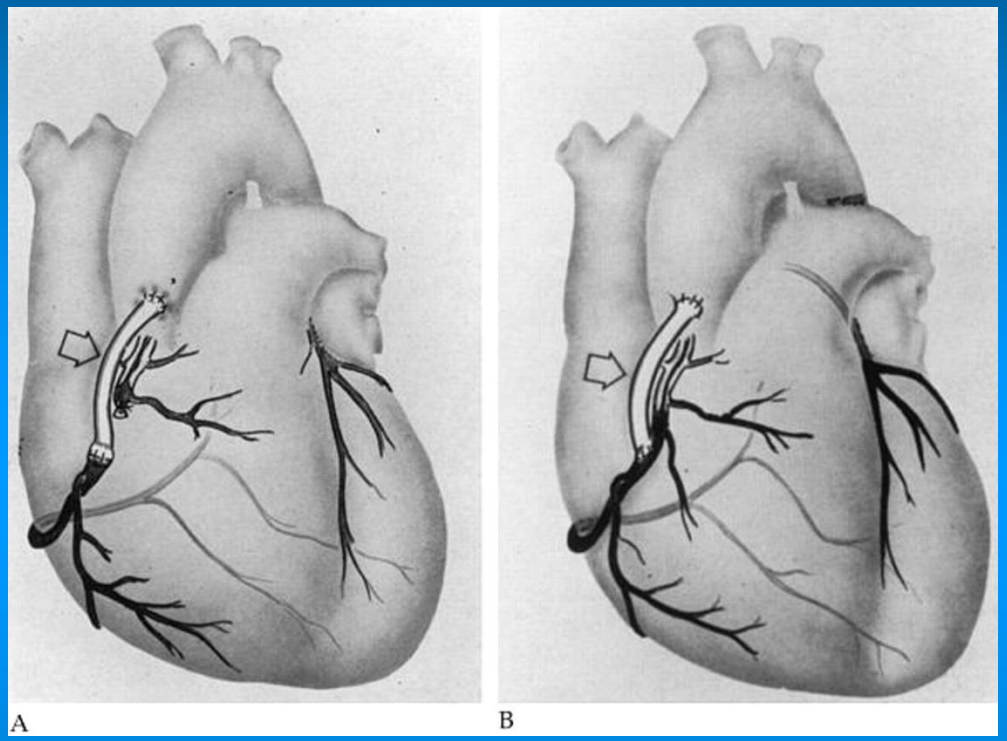
Angiogramm of Favaloro first aorto-coronary bypass graft (CABG) operation performed in 1967 with SVG.

Milestones of coronary surgery

René Gerónimo Favaloro (1923-2000)



Donald Effler (1915-2004)



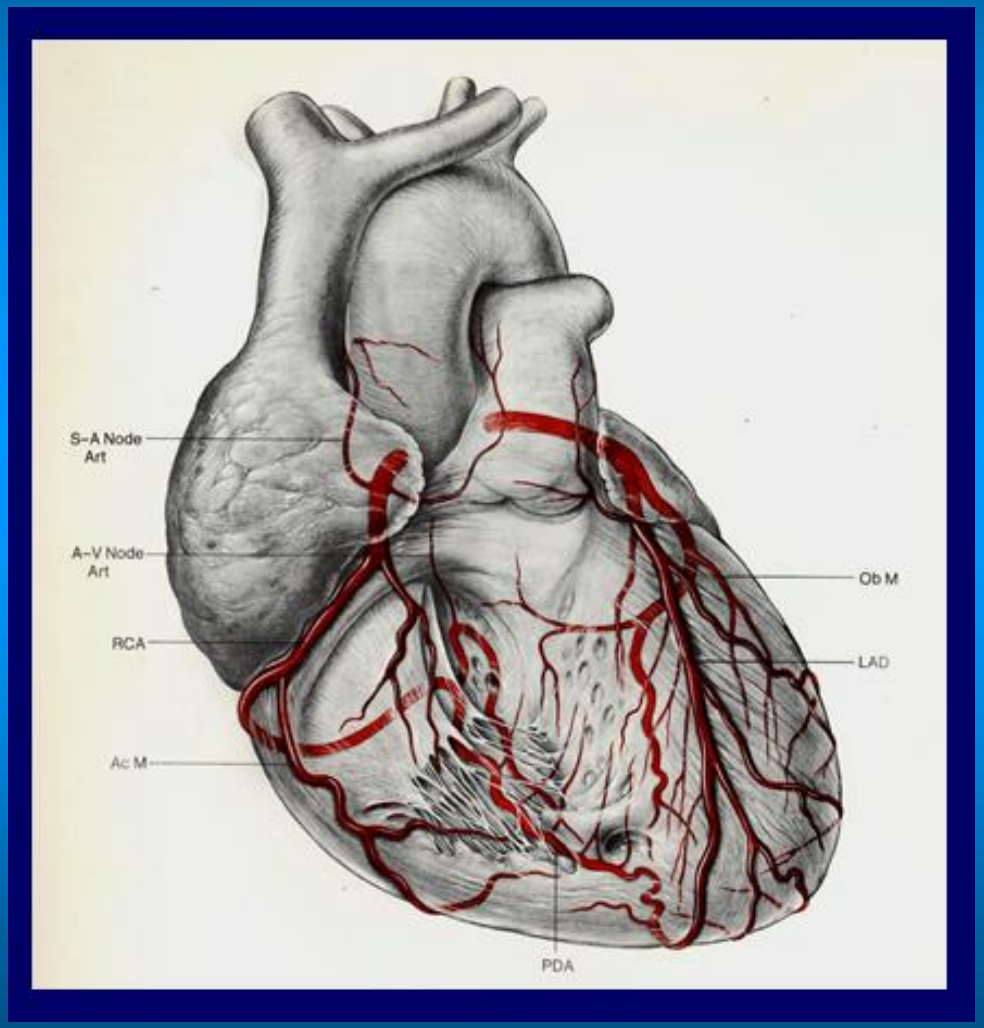
*The saphenous vein bypass graft operations performed on the right coronary artery by Rene Favaloro and Donald Effler, beginning in May **1967**. (A) Aortocoronary bypass graft, end-to-end distal anastomosis. (B) Aortocoronary bypass graft, end-to-side distal anastomosis.*

- 1970s: Worldwide spread of CABG on CPB,
- 1990s: Modern off pump operations (OPCAB, beating heart), minimally invasive direct CAB (MIDCAB)
- 1998: totally endoscopic robot-assisted CAB (TECAB)
- **2000:** The American Heart Association reports that 350,000 U.S. patients undergo CABG each year.

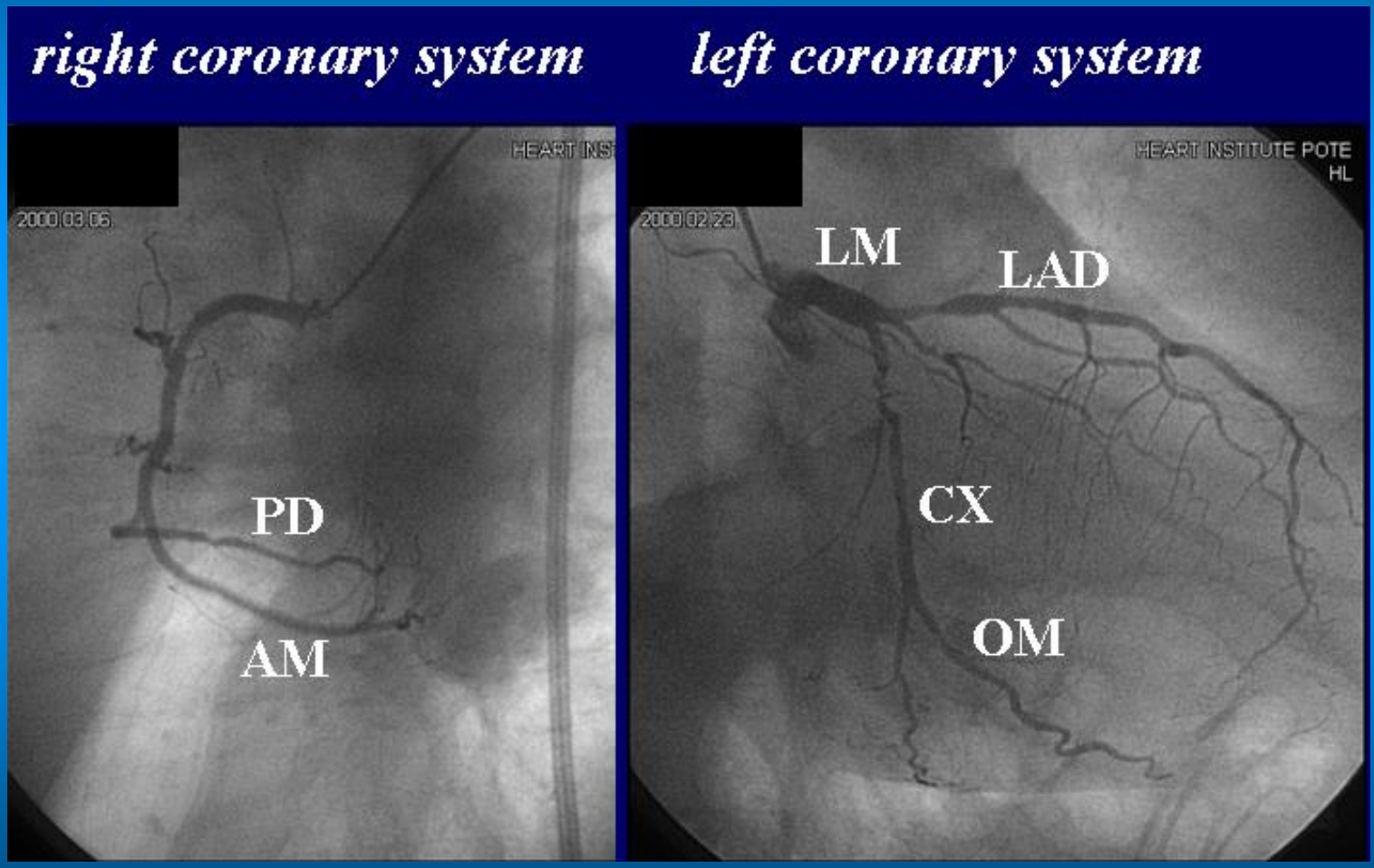
Diagnostic procedures for CABG

- Anamnesis, physical exam, laboratory findings
- ECG, ergometry
- Echocardiography
- Isotope scan
- ***Coronary angiography, heart catheterization***
- Cardiac CT
- Cardiac MRI
- PET

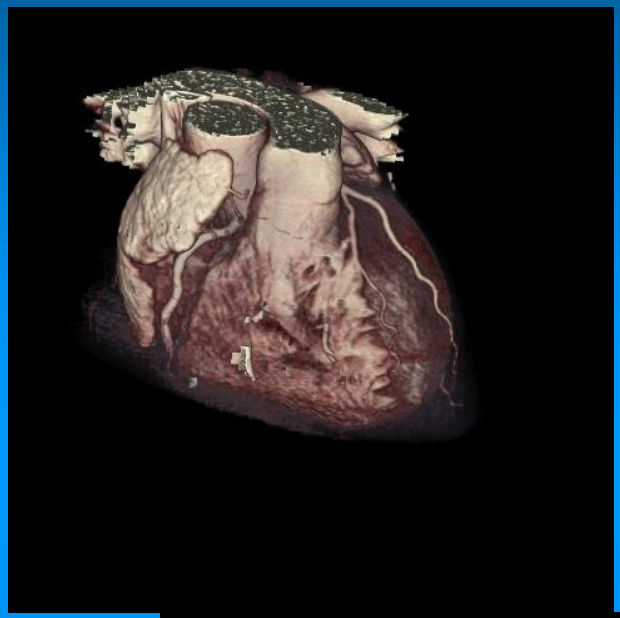
Coronary anatomy

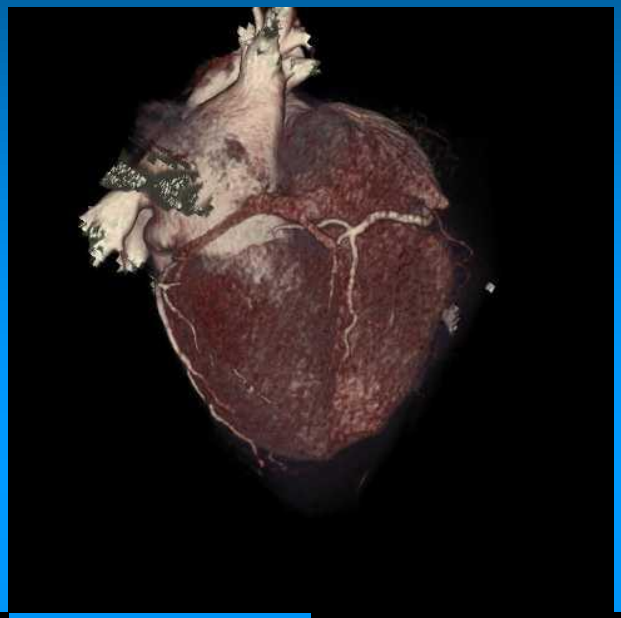


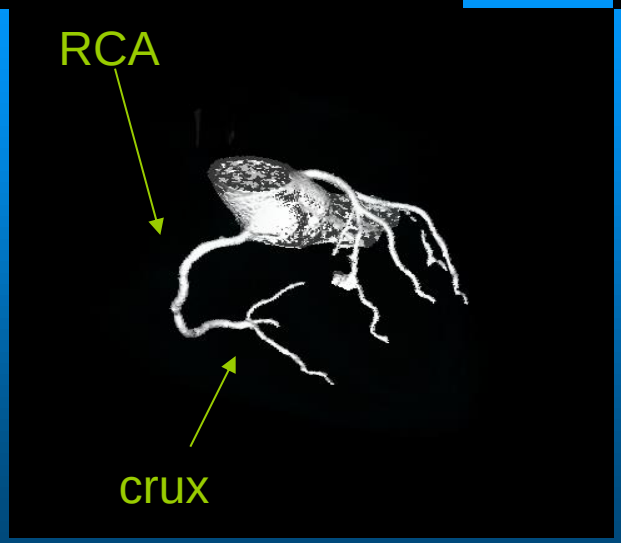
Coronary angiogramm

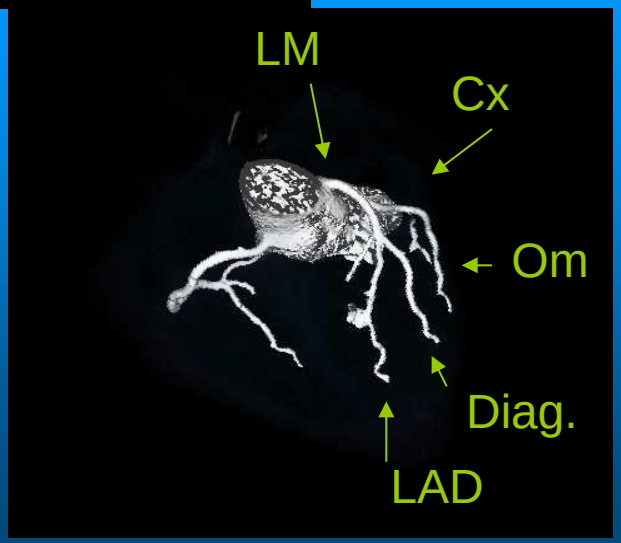


Normal anatomy

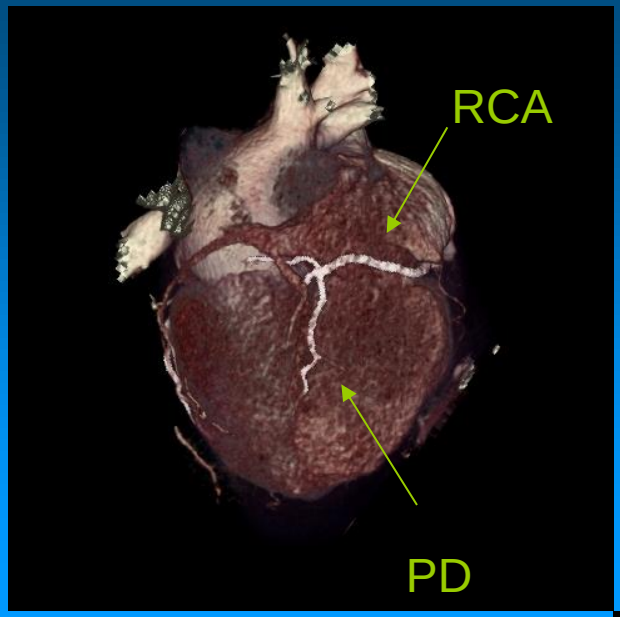




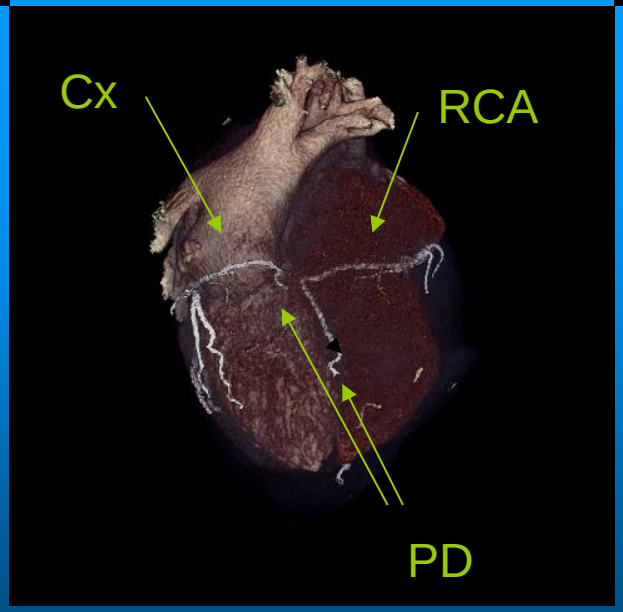




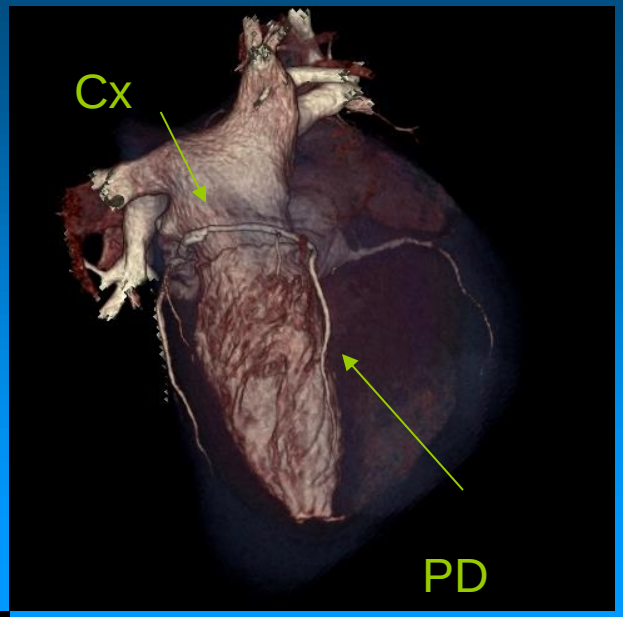
Dominancy of coronary circulation



Right 80 - 90%



Codominant



Left

Indications for CABG

- Significant organic coronary stenosis supplying considerable myocardium
- Viable myocardium

Indication

- Left main stenosis
- Three vessel disease
- Two vessel disease with proximal LAD stenosis
- In-stent restenosis after PCI
- **Significant stenosis: >75%, LM and prox. LAD>50%**

Table 1. ACC/AHA Indications for Coronary Artery Bypass Grafting

Indication	Asymptomatic or Mild Angina	Stable Angina	Unstable Angina/ NSTEMI	Poor Left Ventricular Function
Left main stenosis >50%	Class I	Class I	Class I	Class I
Stenosis of proximal LAD and proximal circumflex >70%	Class I	Class I	Class I	Class I
3-vessel disease	Class I	Class I		Class I, with proximal LAD stenosis
2-vessel disease		Class I if there is large area of viable myocardium in high-risk area Class IIa if there is moderate viable area and ischemia	Class IIb	
With >70% proximal LAD stenosis	Class IIa	Class I with either ejection fraction < 50% or demonstrable ischemia on noninvasive testing	Class IIa	Class I
Involving proximal LAD	Class IIb			
1-vessel disease		Class I if there is large area of viable myocardium in high-risk area Class IIa, if there is viable moderate area and ischemia	Class IIb	
With >70% proximal LAD stenosis	Class IIa	Class IIa	Class IIa	
Involving proximal LAD	Class IIb			

ACC = American College of Cardiology; AHA = American Heart Association; LAD = left anterior descending (artery); NSTEMI = non–ST-segment elevation myocardial infarction.

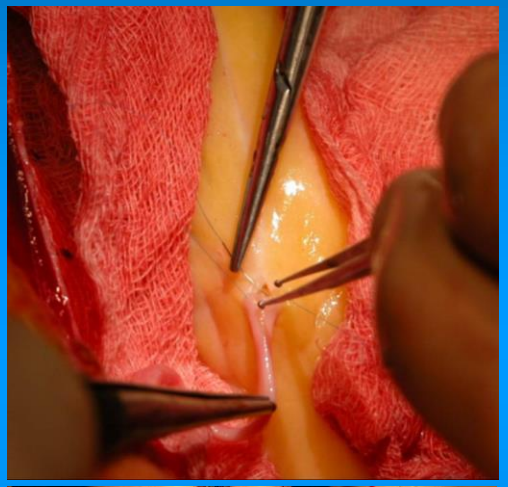
Operative technic for CAD: ***bypass***

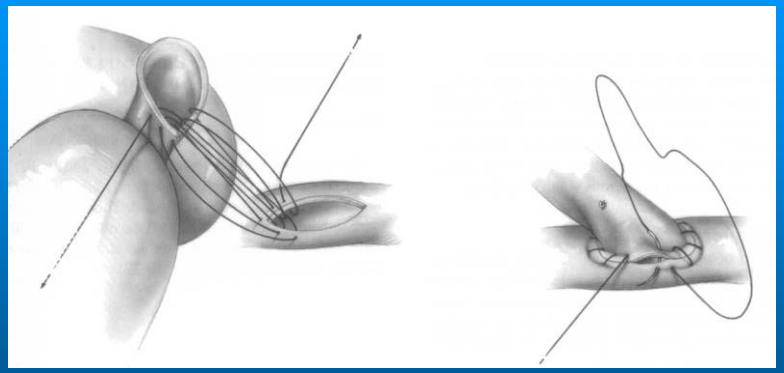
- Coronary artery bypass grafting (CABG)
  - Aorto-coronary bypass (SVG)
  - LIMA, RIMA, radial artery

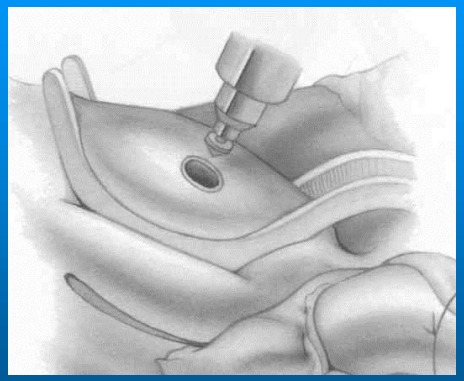
    Continous stitches with

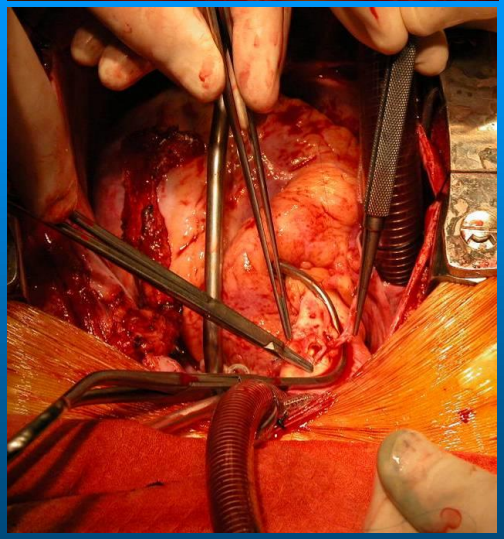
    7-0, or 8-0 non-adsorbable suture

    (Prolene)









Acute coronary operation

High mortality (5-15%)

-no time for correct preparation (foci, carotid Doppler),

-bleeding (ASA, clopidogrel, etc.),

-AMI is going on

Primarily PCI recommended – opening the culprit lesion

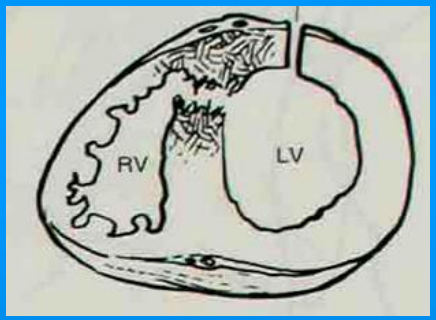
Mechanical complication → urgent operation

Not suitable for PCI → acute CABG

If possible, delayed acute operation after discontinuing anti-TCT drugs (3-7 days), until then observation, LMWH, nitrate

Treatment of acute mechanical complications of AMI

- **Free wall rupture** (tamponade, cardiogenic shock)
- **Ventricular septal rupture** (pulmonary edema, cardiogenic shock)
- **Papillary muscle rupture, chorda rupture** (acute MR, pulmonary edema, cardiogenic shock)

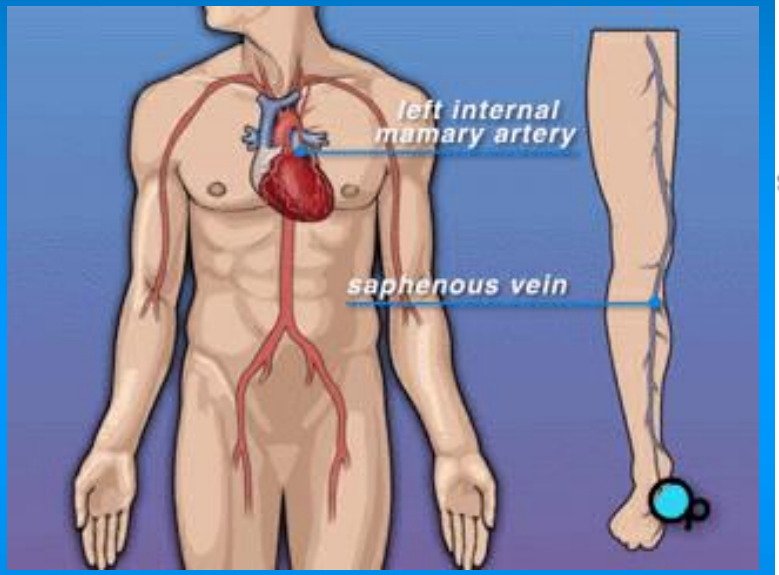


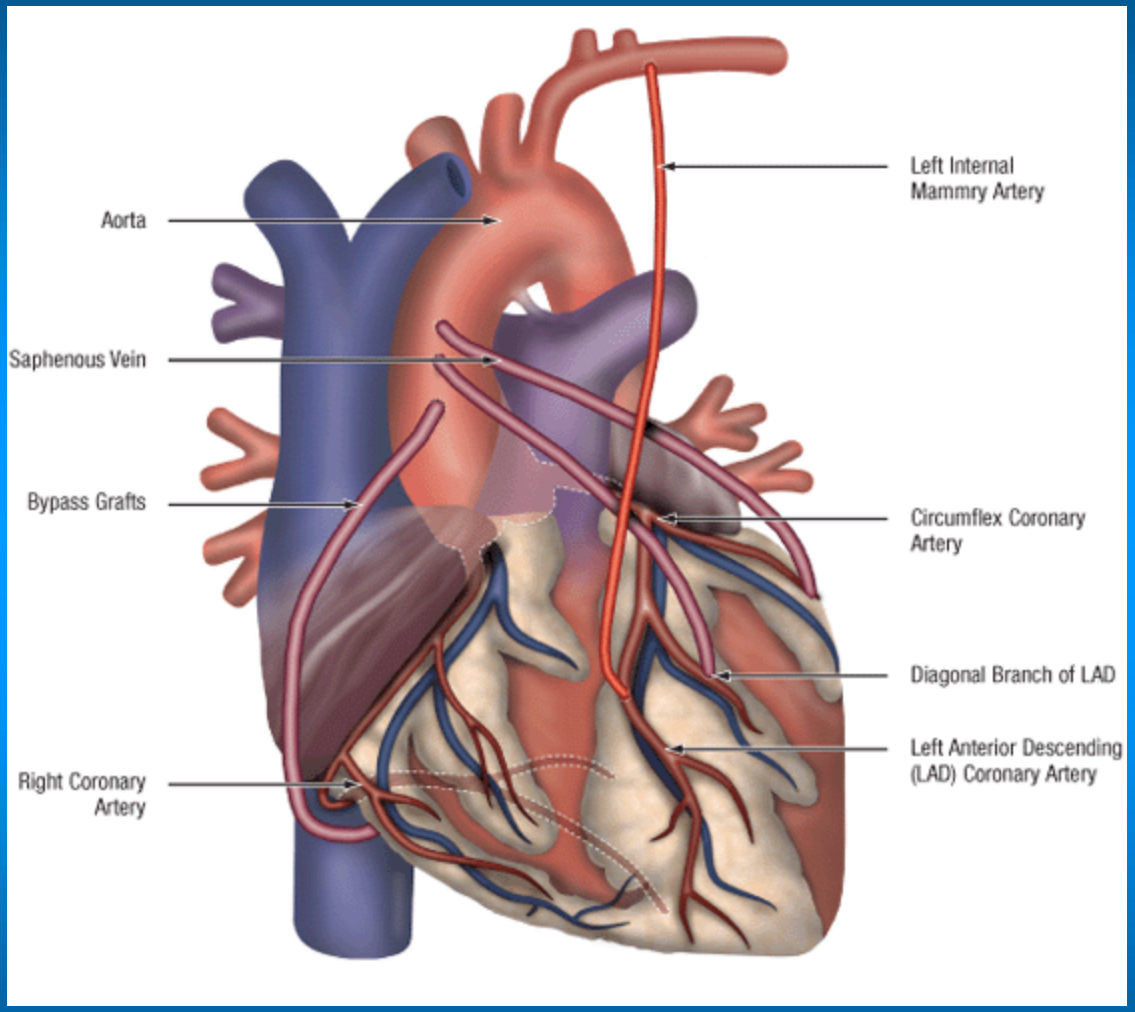
Life-threatening conditions
(~100% mortality), urgent operation is life saving !
Circulatory support (inotropes, IABP in acute MR)

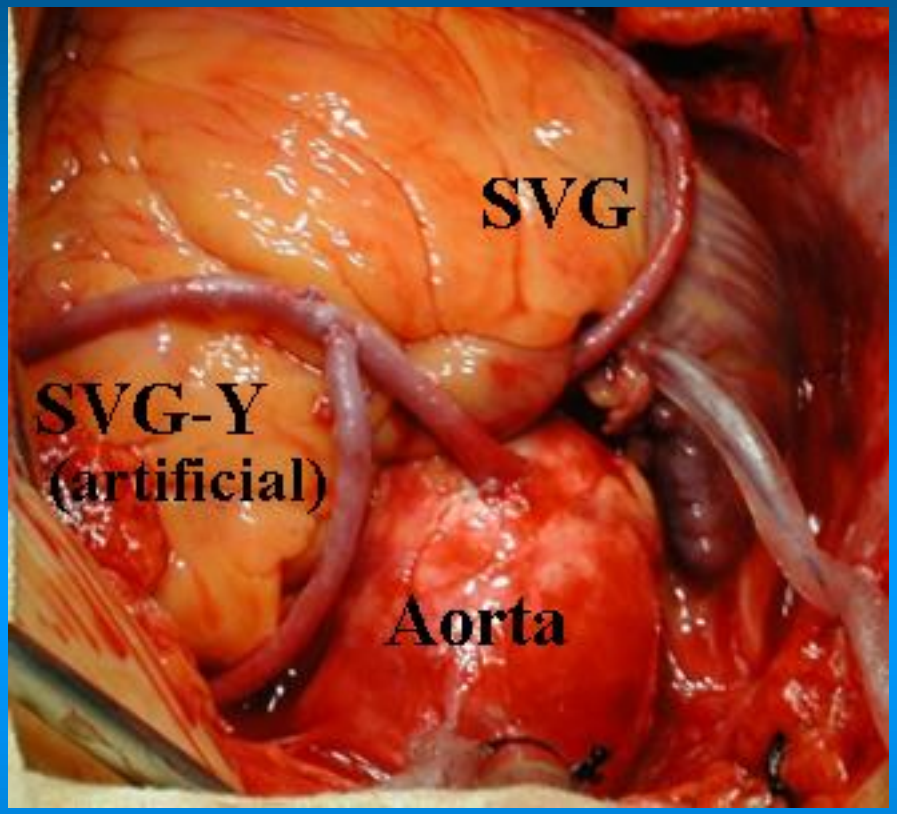
<u>Operation:</u> correcting the mechanical complication + CABG

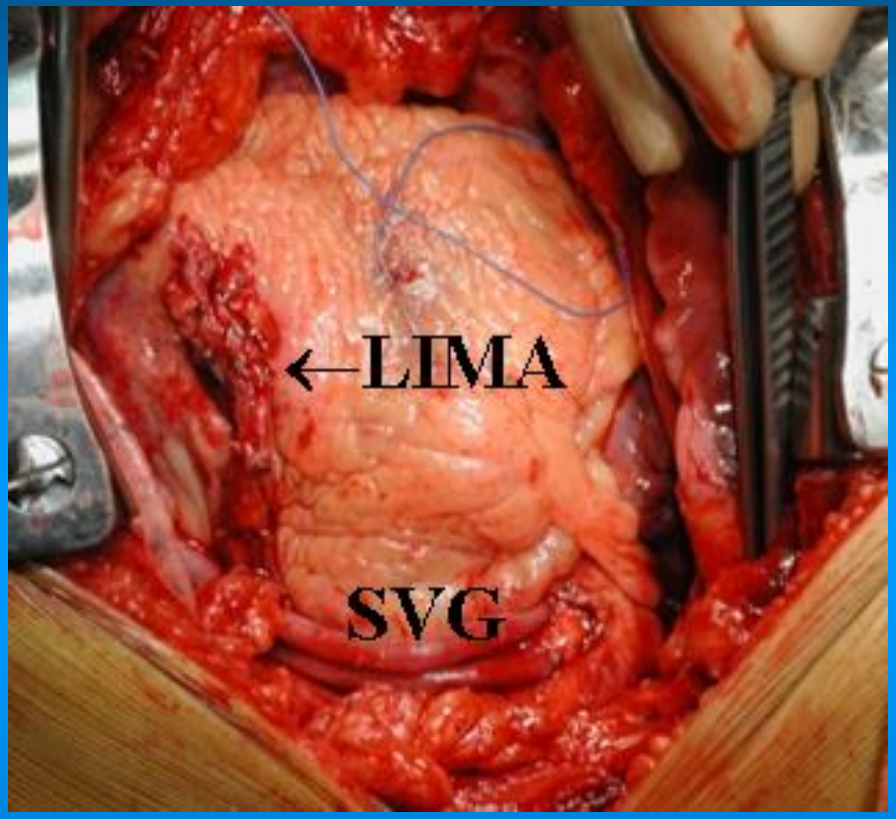
Possible Grafts for CABG

- Great saphenous vein (SVG)
- Internal thoracic artery pedicle (LIMA, RIMA)
- Radial artery free graft (RA)
- Gastroepiploic artery
- Teflon conduit (bad results)


left internal
mamary artery
saphenous vein


Aorta
Saphenous Vein
Bypass Grafts
Right Coronary
Artery
Left Internal
Mammry Artery
Circumflex Coronary
Artery
Diagonal Branch of LAD
Left Anterior Descending
(LAD) Coronary Artery


SVG
SVG-Y
(artificial)
Aorta


←LIMA
SVG


SVG-Y
(natural)

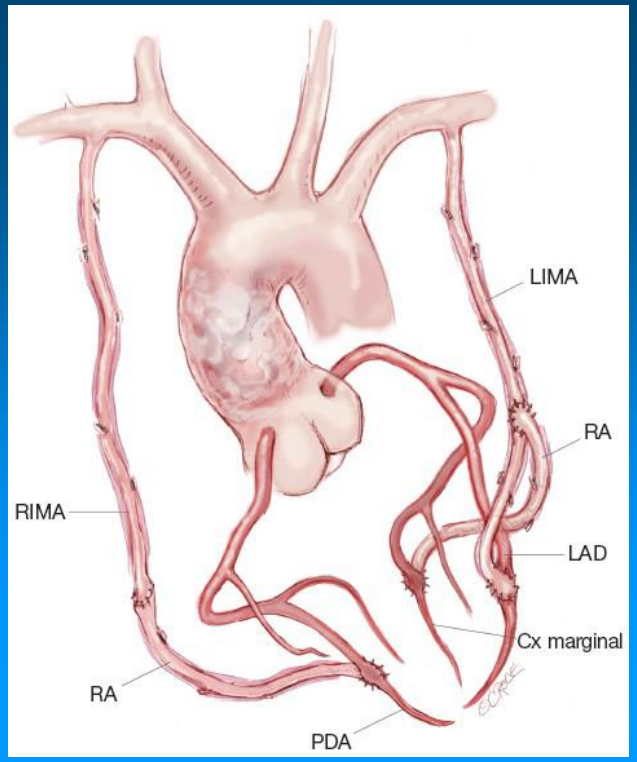

aneurism-plication

Results of CABG

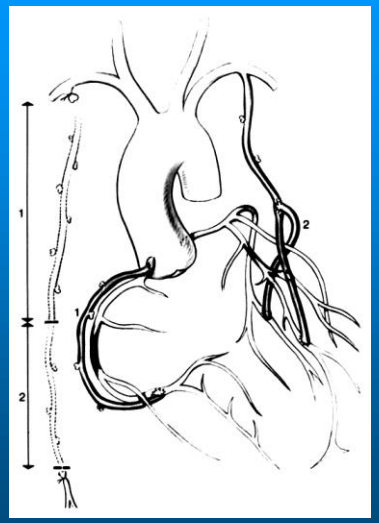
- Operative mortality below 5 %
- Significant improvement of surviving and qualtity of life
- 90% patency rate at 10 years for arterial grafts
- 80% patency rate at 1 year and 60-70% at 5 years for venous conduits

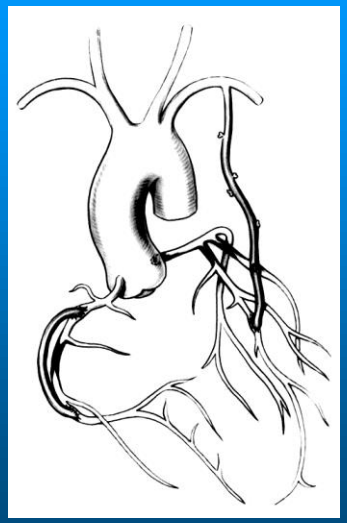
Table 11. Technical Recommendations for Coronary Artery Bypass Grafting

	Recommendation	Level of Evidence
Procedures should be performed in hospital structure and by team specialized in cardiac surgery, using written protocols	Class I	B
Arterial grafting to LAD system is indicated	Class I	A
Complete revascularization with arterial grafting to non-LAD coronary system is indicated in patients with reasonable life expectancy	Class I	A
Minimization of aortic manipulation is recommended	Class I	C
Graft evaluation is recommended before departure from operating theater	Class I	C
LAD = left anterior descending (artery).		



The gold standard for CABG is the left internal mammary artery (LIMA) to the left anterior descending artery (LAD), as this conduit selection provides increased survival and freedom from myocardial infarction, symptoms, and reinterventions compared to a saphenous vein graft (SVG) to the same artery. The proposed mechanism for this increased patency and subsequent improved clinical outcome is due to the inherent characteristics of the internal mammary artery endothelium and improved run-off of the LAD territory

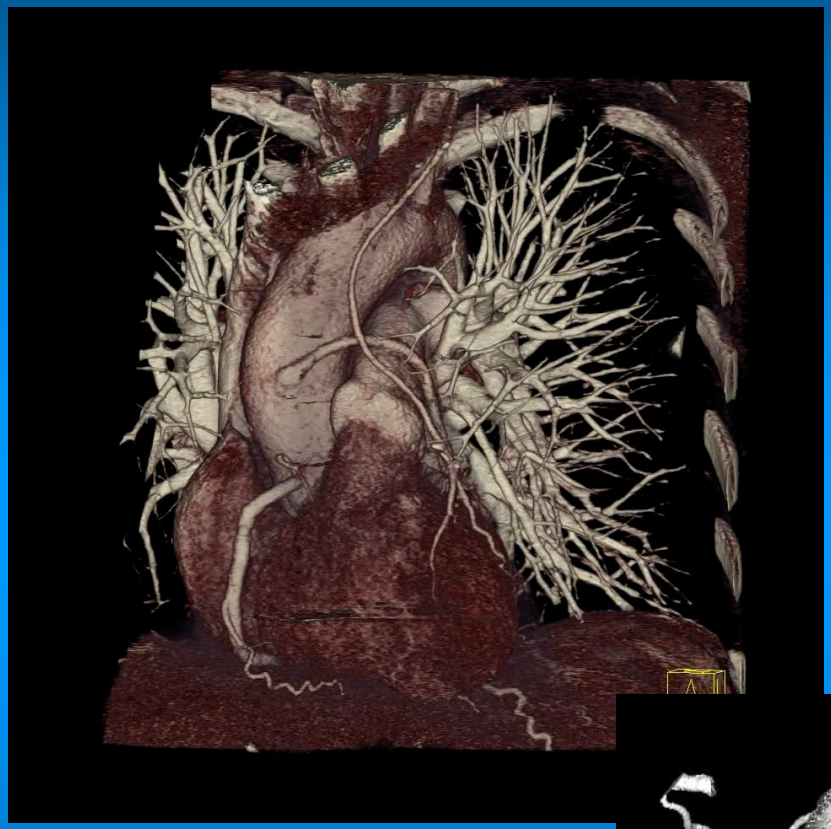


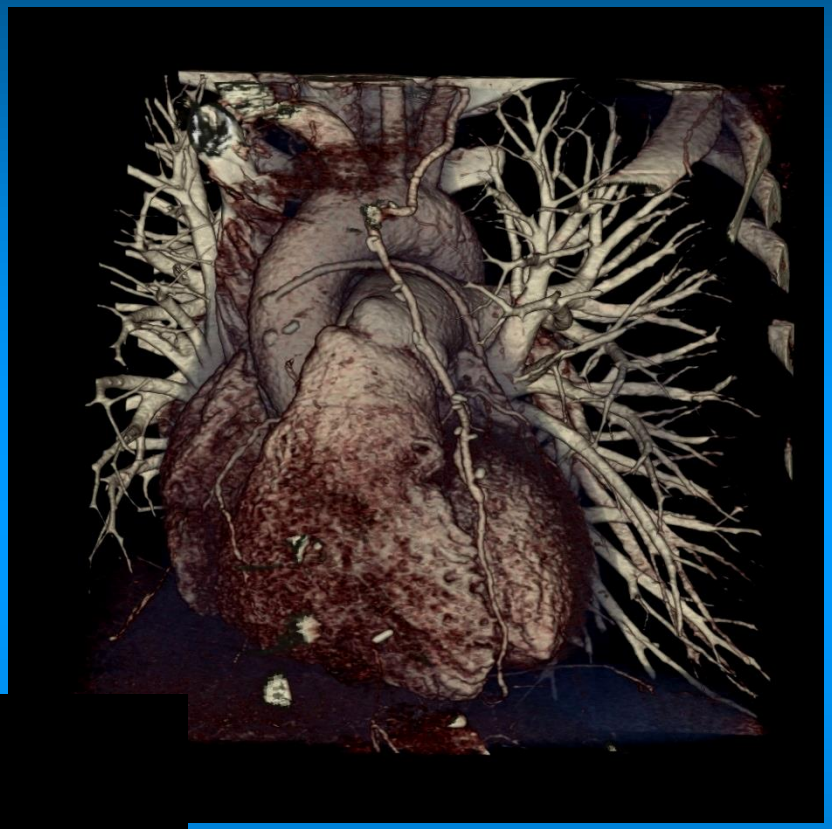


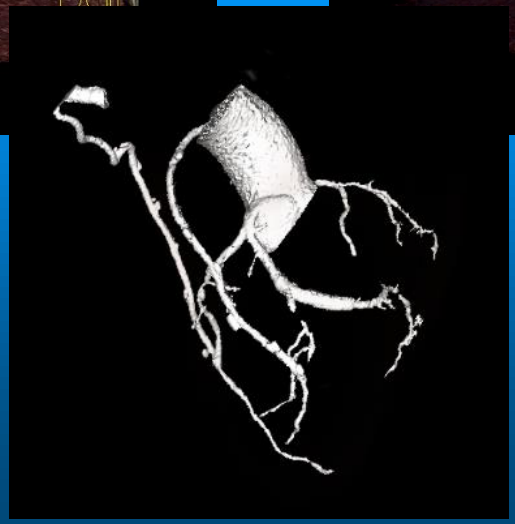
The concept of Total arterial revascularization: CABG with LIMA, radial artery, or both LIMA and RIMA

- No any aortic manipulation (side-clamping of aorta for central anastomosis), No SVG

Cardiac CT images after CABG







Complications after CABG

- Perioperative infarction (unsatisfactory protection of the heart, injury of coronary arteries, competition of flow)
- Bleeding (heparinisation)
- Postoperative atrial fibrillation
- Pericardial, pleural fluid accumulation (tamponade)
- Hypoperfusion of the brain, kidney, ect.
- Occlusion or stenosis of grafts
- Mediastinitis
- Death

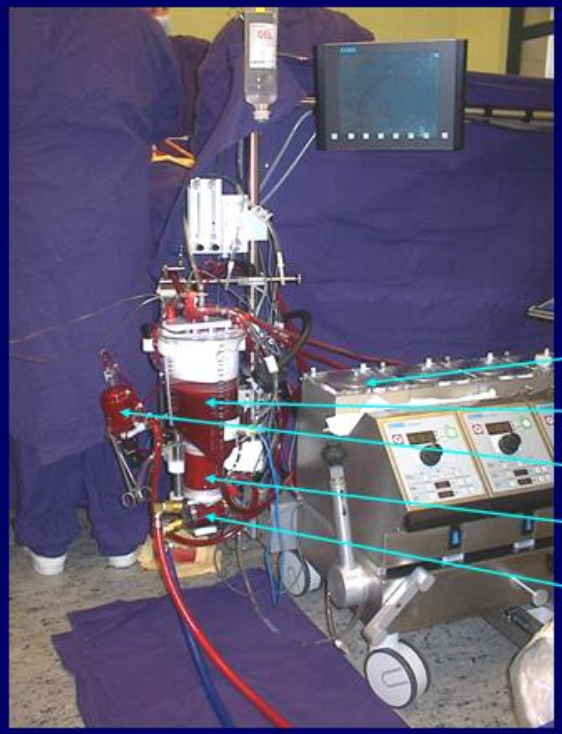
Types of CABG operations

1. Coronary bypass surgery on cardiopulmonary bypass (CPB) - extracorporeal circulation (ECC), heart-lung machine, On-Pump operation

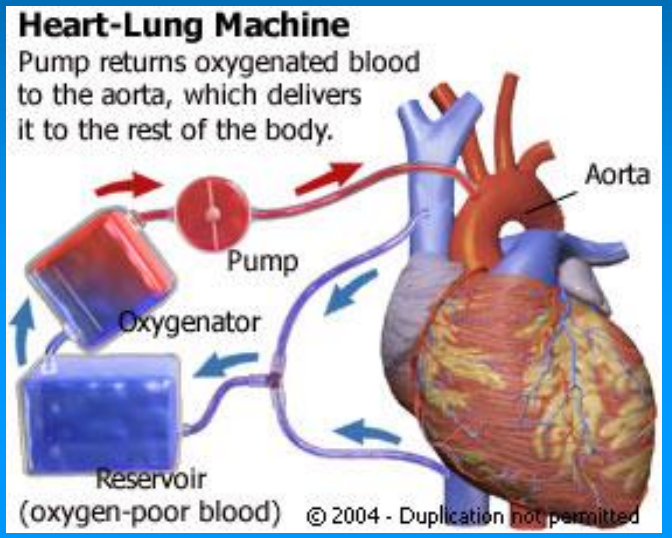
2. **Minimally invasive coronary artery bypass surgery**
   - minimally invasive direct coronary artery bypass (**MIDCAB**),
   - off-pump coronary artery bypass (**OPCAB**),
   - totally endoscopic, robot-assisted coronary artery bypass grafting (**TECAB**)

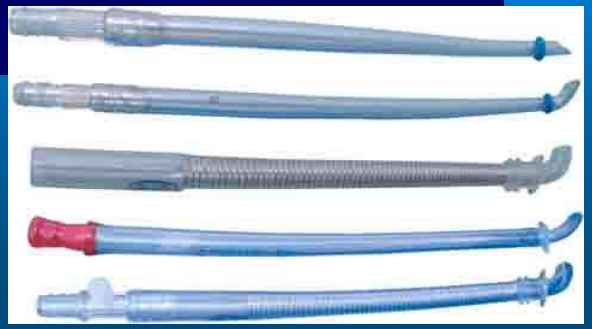
OnPump operations (ECC, CPB)

The heart-lung machine (ECC, CPB)



roller pump (2)
rezervoir (1)
bubble trap (5)
oxygenator (3)
heat exchanger (4)





OnPump operation (CPB)

- Bloodless area with excluding the heart and lungs
- Stable (motionless) operative area
- Stroke volume is independent of manipulations
- Possibility of opening the heart chambers
- Easy access for any coronary artery (bloodless, empty heart)

- Several possible complications of ECC (arteficial surface of the tube system and oxygenator) and cross-clamping of the aorta:
  - Haemolysis, anaemia
  - Systemic inflammatory response
  - Transient immunodeficiency
  - Haemostasis disturbances, DIC
  - Embolization (air, plaque, plastics)
  - Locoregional hypoperfusion (kidney, brain)

Off-pump operations (OPCAB)

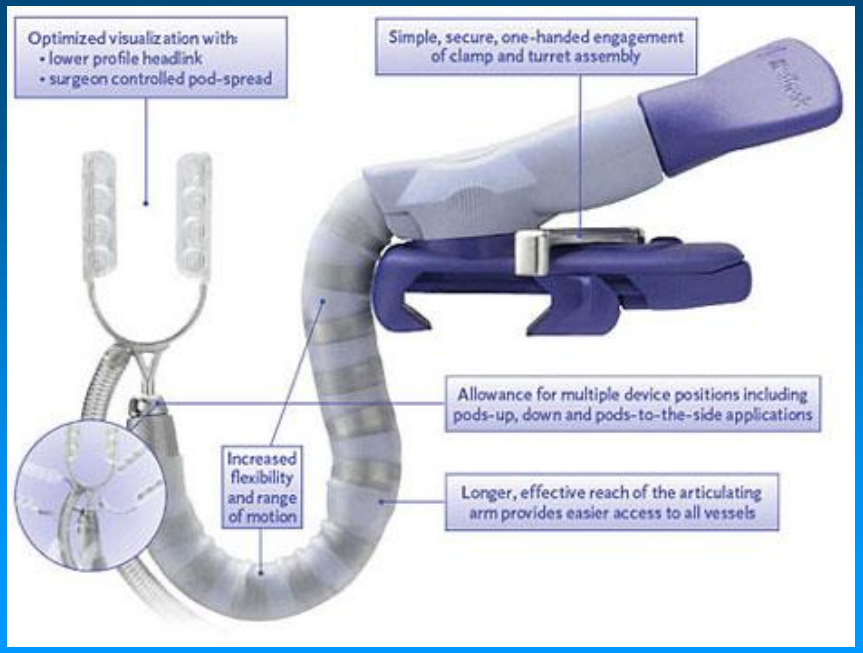
- Avoiding of complications of ECC
- Less operative stress for the patients
- Less manipulations on the aorta

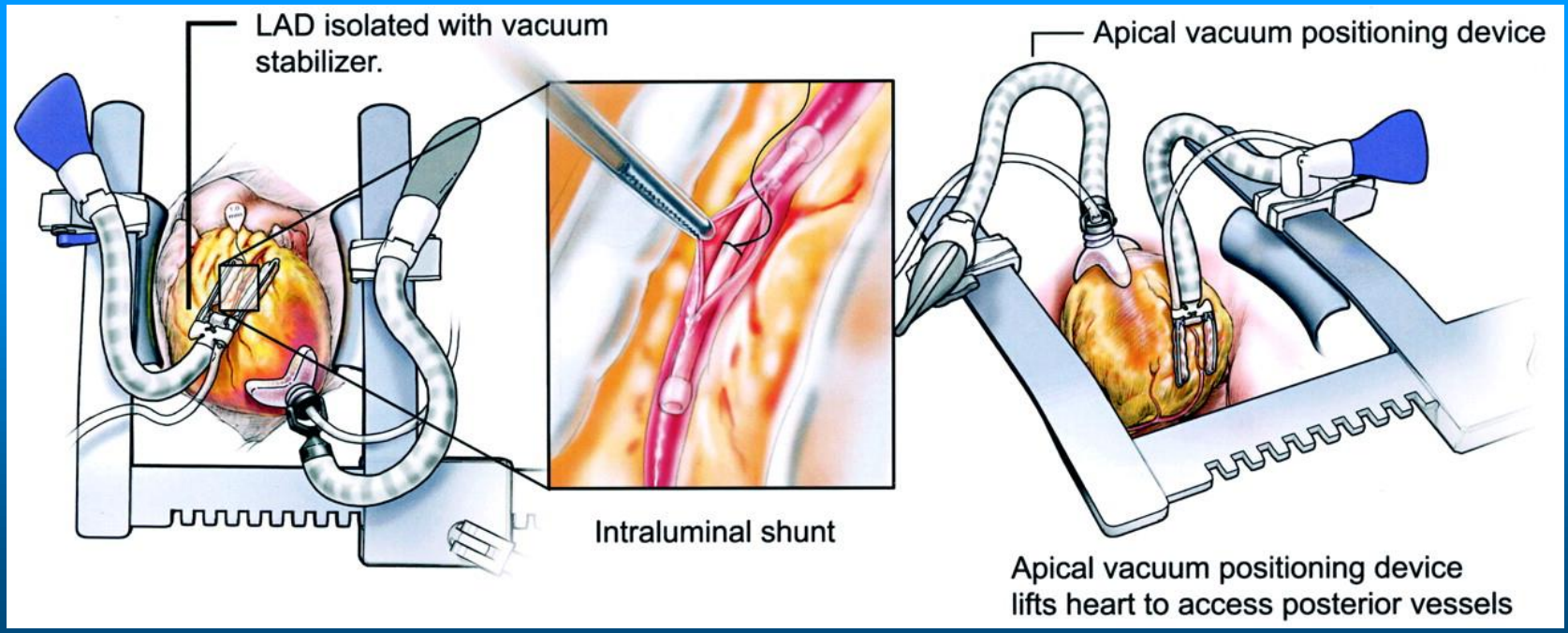
- Need for special stabilizer
- Occluder or shunt occluder
- Difficult access for posterior arteries
- Can not be opened a heart chamber
- Operative manipulation influences the stroke volume

- There are no significant differences between OPCAB and OnCAB operations’s early and late results

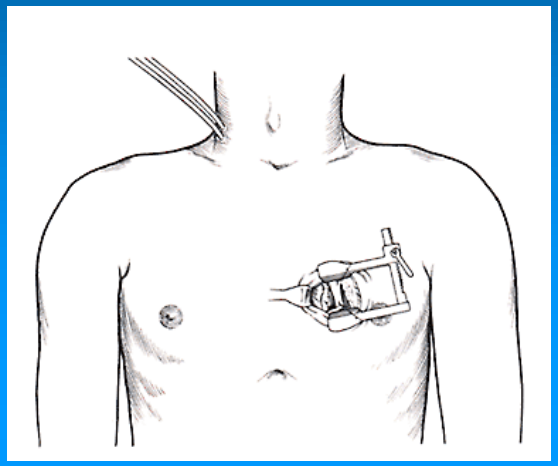
Off-pump technic

- Half dose of Heparine
- Deep stitch into the pericardium (positioning)
- Stabilizer (Octopus – vacuum)
- Stitches under the coronary arteries (bleeding)
- Intra-coronary or aorto-coronary shunt (ischemia)
- First anastomosis: LIMA-LAD, or occluded coronary artery


Optimized visualization with:
• lower profile headlink
• surgeon controlled pod-spread
Simple, secure, one-handed engagement of clamp and turret assembly
Allowance for multiple device positions including pods-up, down and pods-to-the-side applications
Increased flexibility and range of motion
Longer, effective reach of the articulating arm provides easier access to all vessels

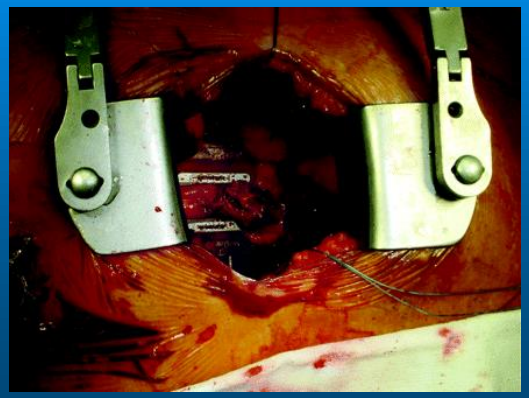

LAD isolated with vacuum stabilizer.
Intraluminal shunt
Apical vacuum positioning device
Apical vacuum positioning device lifts heart to access posterior vessels

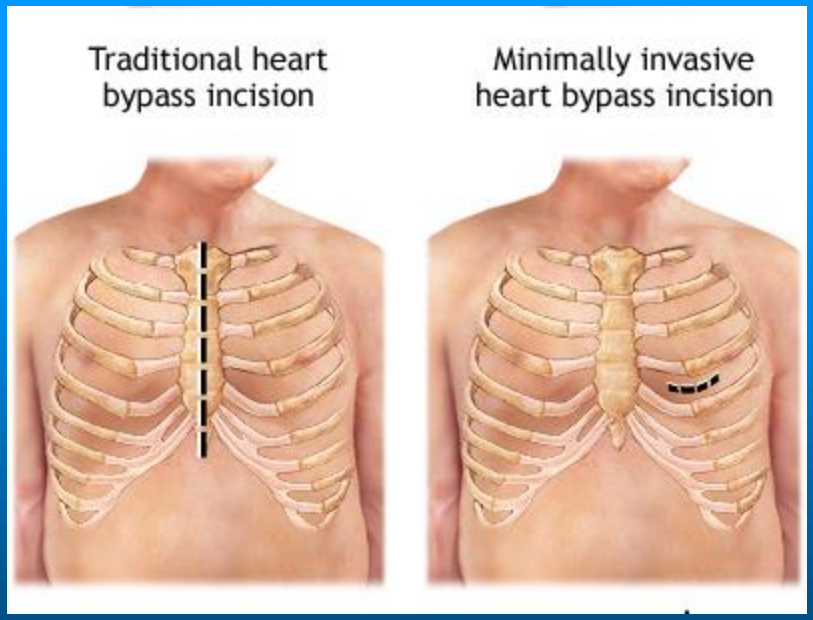
MIDCAB (minimally invasive direct coronary artery bypass)



- Usually: thoracoscopically harvested LIMA to LAD anastomosis

Direct coronary anastomosis performed through a 6-cm anterior minithoracotomy





Robotic totally endoscopic coronary artery bypass (TECAB)

- TECAB is a minimally invasive endoscopic surgical approach using the ***daVinci robotic telemanipulation system*** to perform CABG on the arrested or beating heart.

- The complete surgical procedure is performed through port incisions (3-4, 1cm long) using robotic telemanipulation. Robotic CABG is technically demanding and requires completion of a learning curve.

- The main advantages of robotic TECAB are a significant ***reduction of surgical trauma and preservation of thoracic integrity*** and earlier return to normal activities.

- 1998: Loulmet et al. in Paris performed the first-in-man robotic TECAB in 2 men using the first-generation da Vinci robotic system on arrested heart (LIMA-LAD anastomosis)

- **Hybrid Revascularization**

  For patients with complex lesion another newly emerging ***alternative*** is hybrid revascularization.

Under this paradigm, ***both percutaneous coronary intervention and minimally invasive CABG surgery are performed during the same procedure***. Typically, the LIMA is anastomosed to the LAD, whereas the right and circumflex systems are stented.

(MIDCAB / TECAB LIMA-LAD + CxOM and RCA stent implantation)

Follow-up for CABG

Before discharge screening for ASA efficiency by thrombocyte aggregometry (TAG), adding clopidogrel if necessary, LMWH

Cardiac surgery control at 6-8 weeks: complaints, wound heeling, sternum stability, ECG, Echocardiography

Cardiology control every 6 months or annually (ECG, stress test, Echocardiography), on demand interventional or cardiac surgical control, see family physician

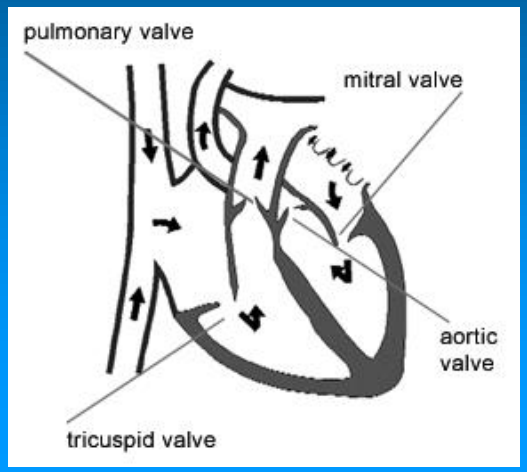
Anti-platelet drugs life-long, if should be stopped before any intervention → administer LMWH

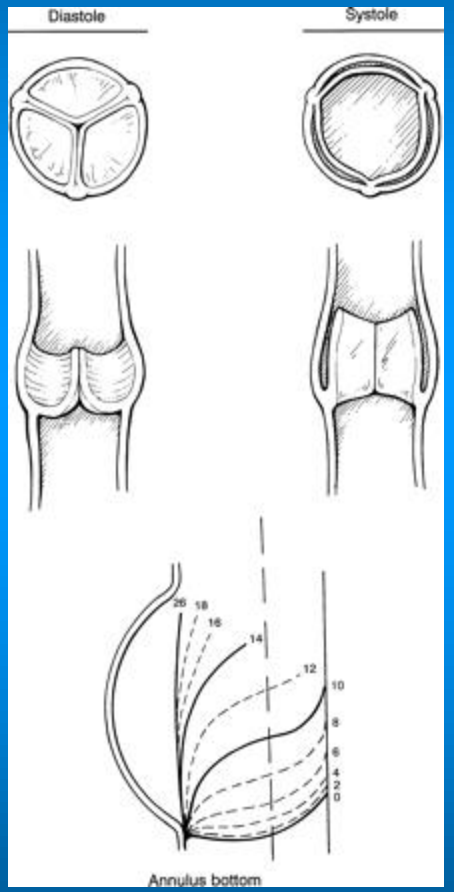
Secondary prevention: lifestyle, diet, drugs (statin, anti-TCT, β-blocker, etc.)

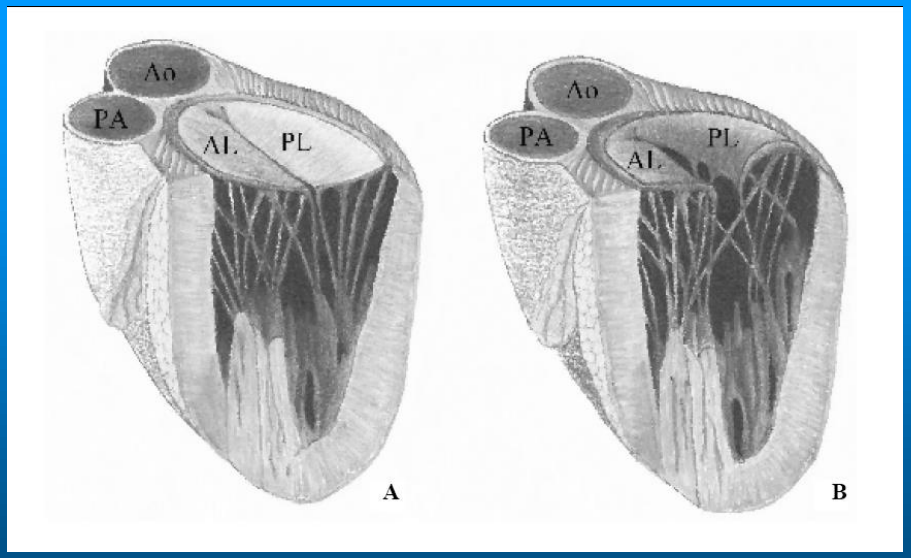
What is the future?

- Stent implantation?
- CABG, MIDCAB,
- TECAB
- Hybrid operation
- Drugs? Prevention
- Gene therapy, stem cell therapy
- Arteficial grafts? Tissue engineering?

Valve surgery







Brief history of valve surgery

- 1923: Cutler: cut the stenotic MV through the apex with a special curved knife
- 1925: Souttar: **Closed mitral commissurotomy**. Digitally opened the MV through the appendage of the LA
- Tubb's dilator
- 1955: open technics on CPB
- **Repair** of the MV (Carpentier, Reed)
- 1961: **mechanical prosthesis** (Starr and Edwards)
- **Bioprosthesis**
- Repair (preserve the native valve)
- Transcatheter aortic valve impl. TAVI, Mitra-Clip

Valvular heart diseases

- Stenotic valve disease
- Regurgitation (insufficiency)
- Combined valve diseases
- Multiple valvular disease
- Acute / chronic

Acute valve disease

- Chordal tearing (mitral)
- Perforation (endocarditis)
- Rupture of aortic valve cusp (acute aortic dissection)
- Acute thrombosis of an arteficial valve
- Papillary muscle rupture (complication of AMI)

Diagnosis is based on Echocardiography

- Diameter and volume of the chambers
- Wall thickness and wall motion, ejection fraction
- Valves: calcification, adhesion, constriction, scarring, thinning or thickening, disruption of chordae, abnormal motion of the leaflets (prolapse), area (cm^2)
- Doppler: direction and speed of flow, abnormal flow

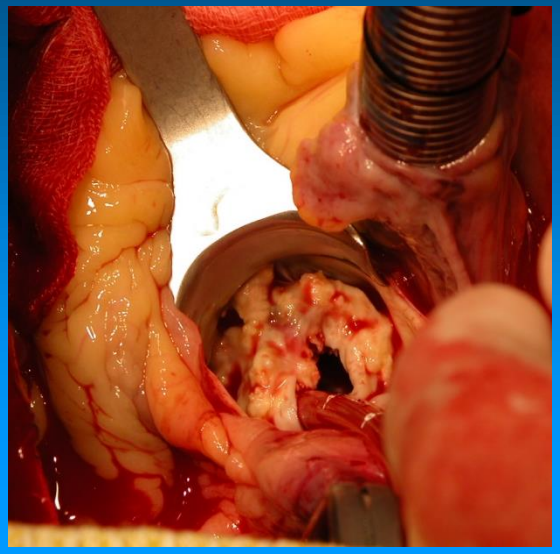
Arteficial valves

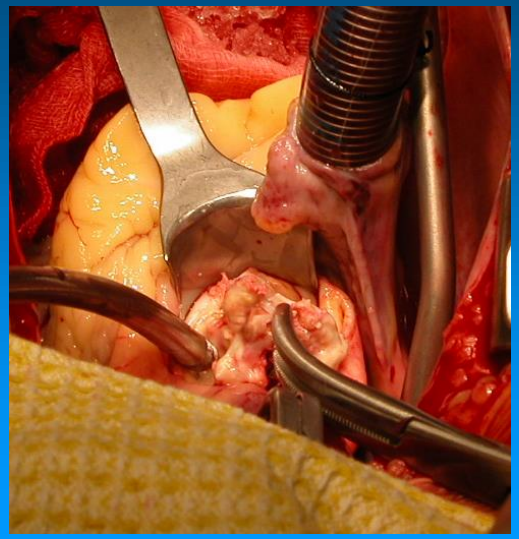
biograft

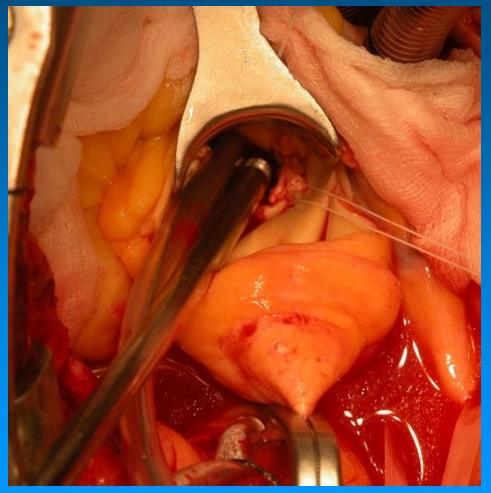
bi-leaflet

mono-leaflet

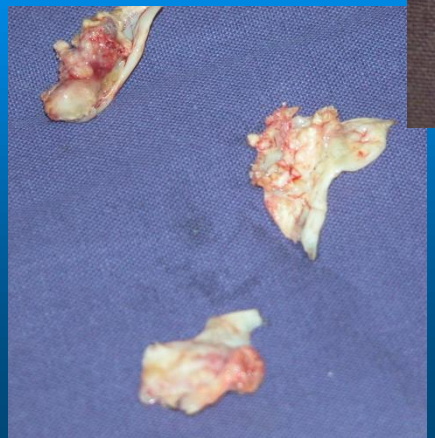
Calcified, stenotic aortic valves in situ

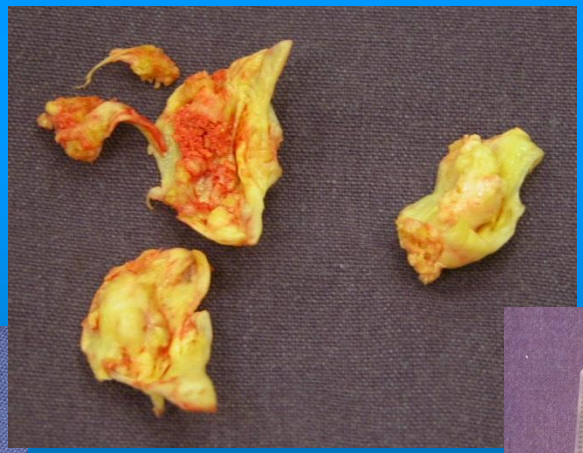




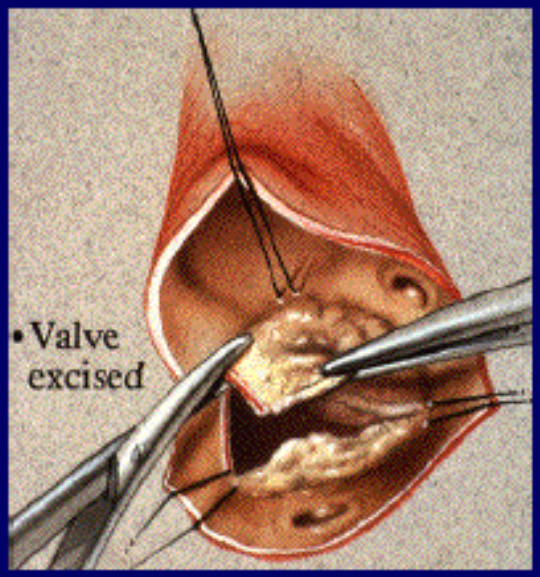


Excised degenerated cusps

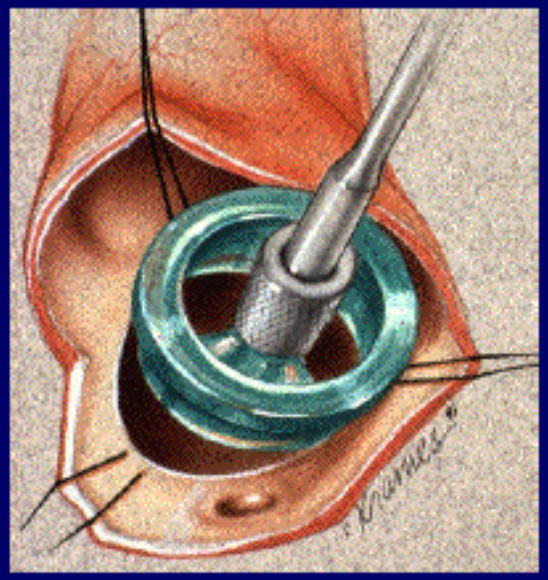




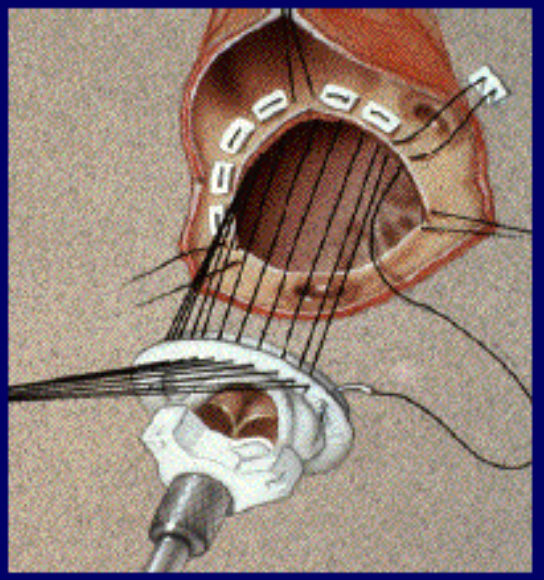
Technic of valve replacement



Excision of the diseased valve

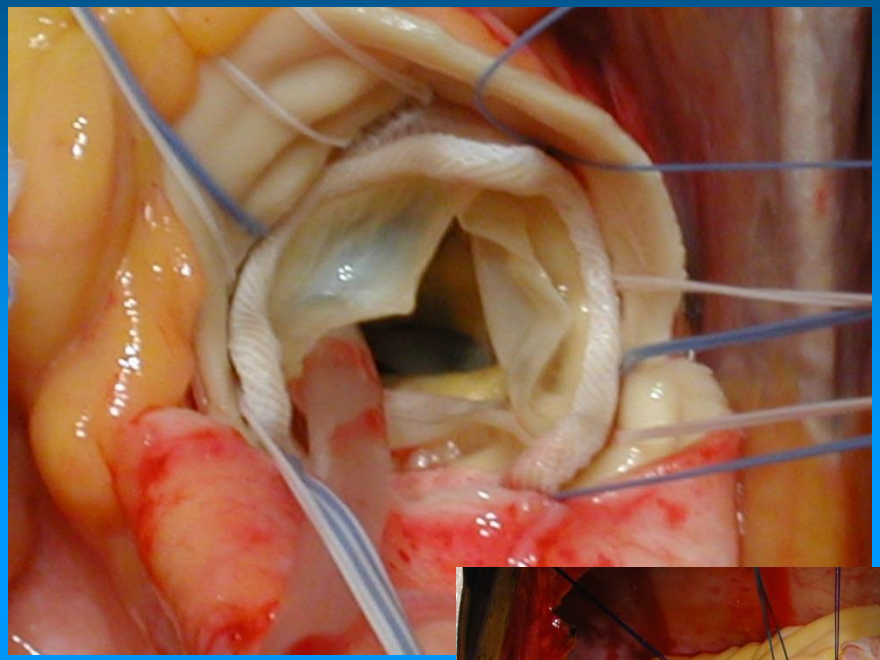


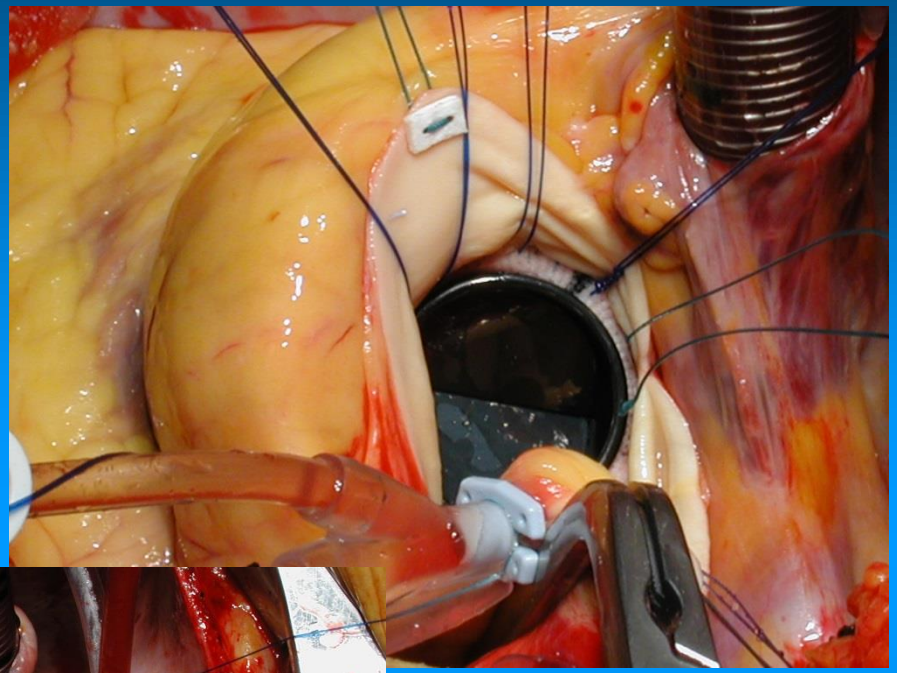
Measuring the annulus

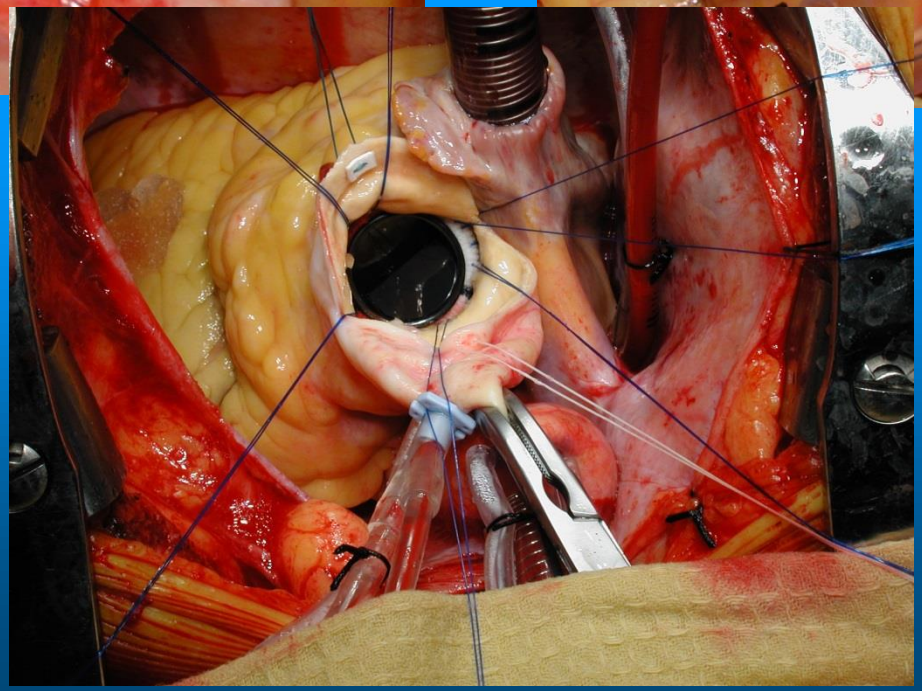


Suturing the valve with teflon-pledgeted stitches

Aortic valve replacement







Diseases of the aortic valve

Stenosis:

Grade	Orifice area
Normal	3.0-4.0 cm^2
Mild	1.5 – 3.0 cm^2
Medium	1.0 – 1.5 cm^2
Serious	<1.0 cm^2

Average transvalvular pressure gradient >50Hgmm

Regurgitation:

Grade I-IV (size of jet)

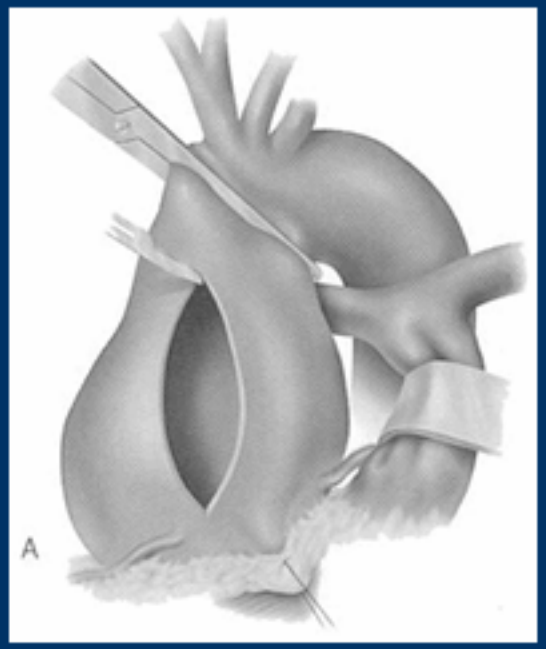
Indications for op.:

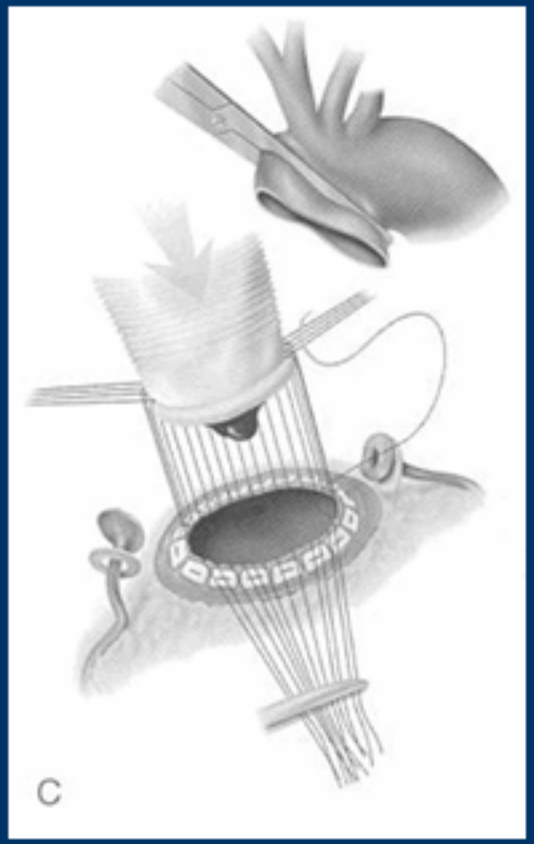
- **complaints**
- **signs of heart failure**
- **significant stenosis and/or regurgitation**
- **decreasing EF**
- **progressive LV dilation**

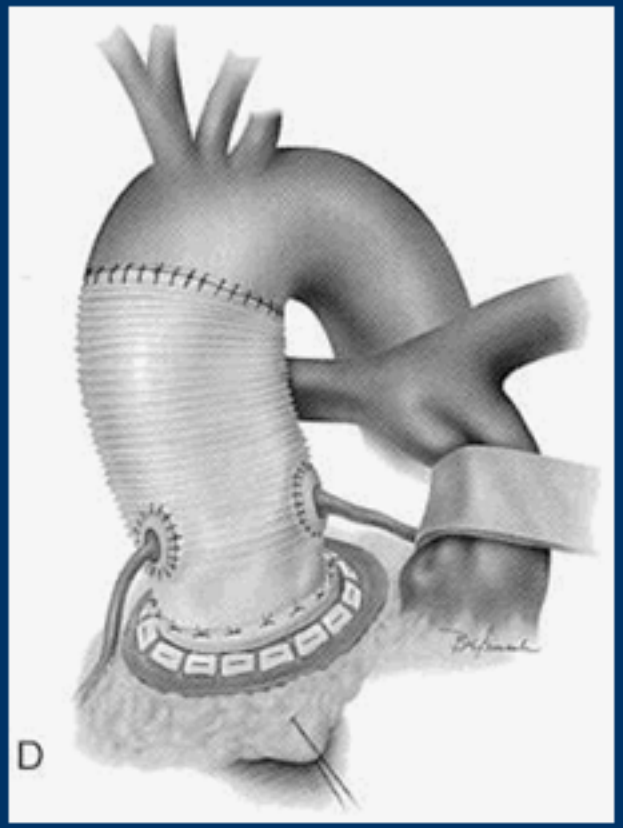
Bentall operation

Billentyűs érprotézis

Billentyűs érprotézis felvarrt coronariákkal in situ







Diseases of the mitral valve

Stenosis:

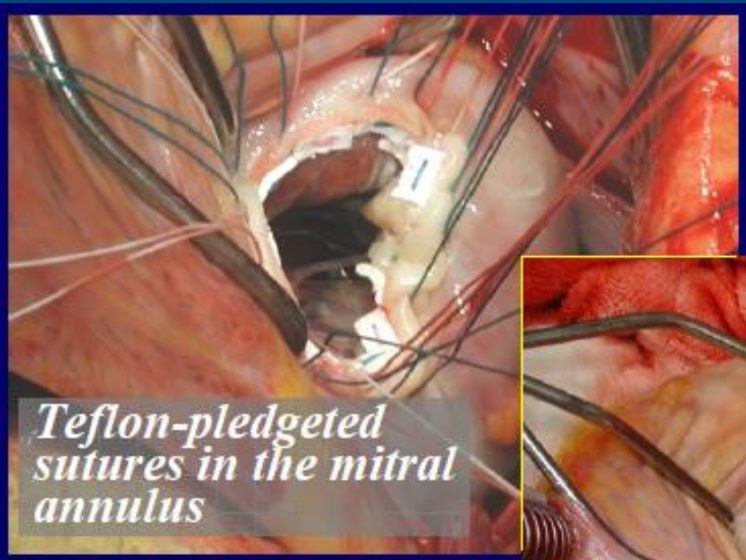
Average transvalvular pressure gradient >10Hgmm
Area<1.5cm^2 (n: 4.0-5.0 cm^2)

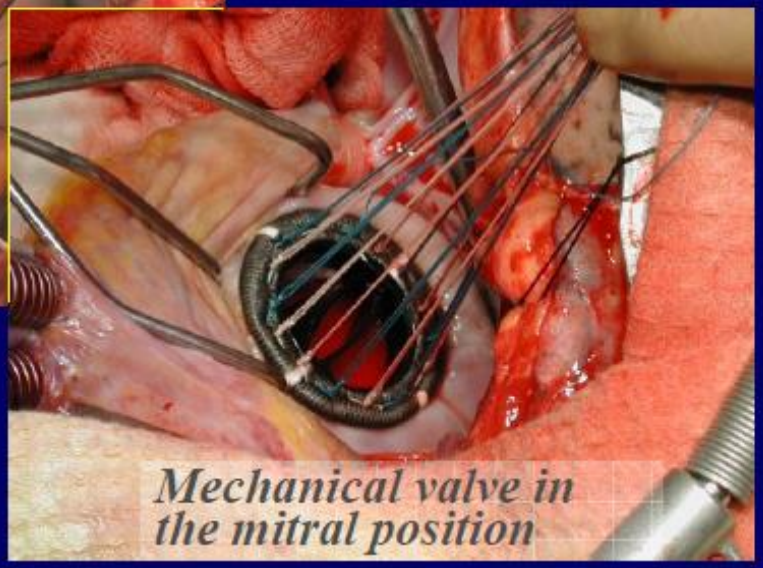
Regurgitation:
Grade I-IV (size of jet)

Indications for op.:

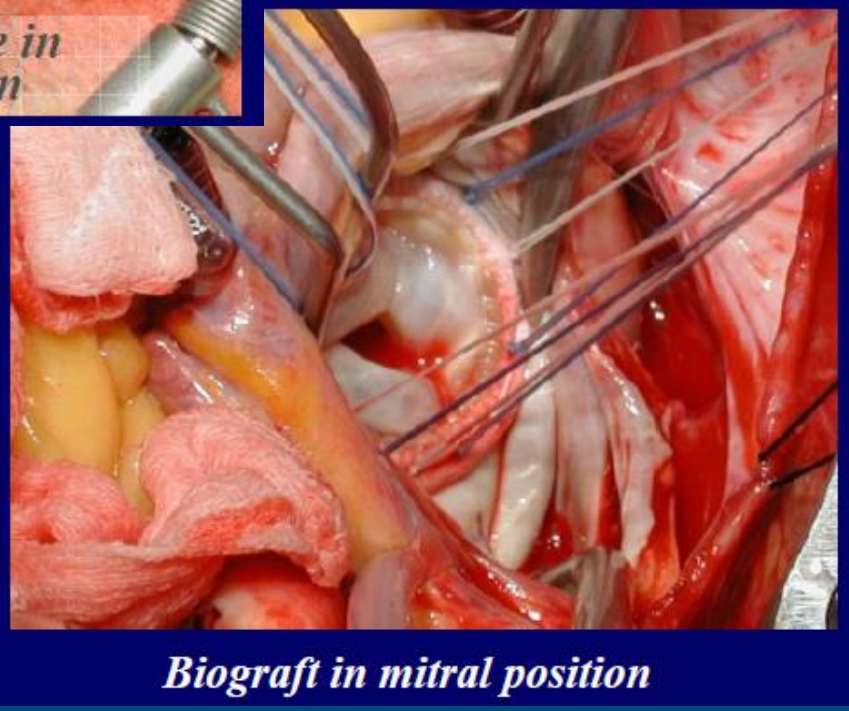
- **complaints**
- **signs of heart failure**
- **significant stenosis and/or regurgitation**
- **decreasing EF**
- **progressive LV dilatation**
- **pulmonary hypertension? (systolic > 60Hgmm)**

CABG can improve mild or moderate MR

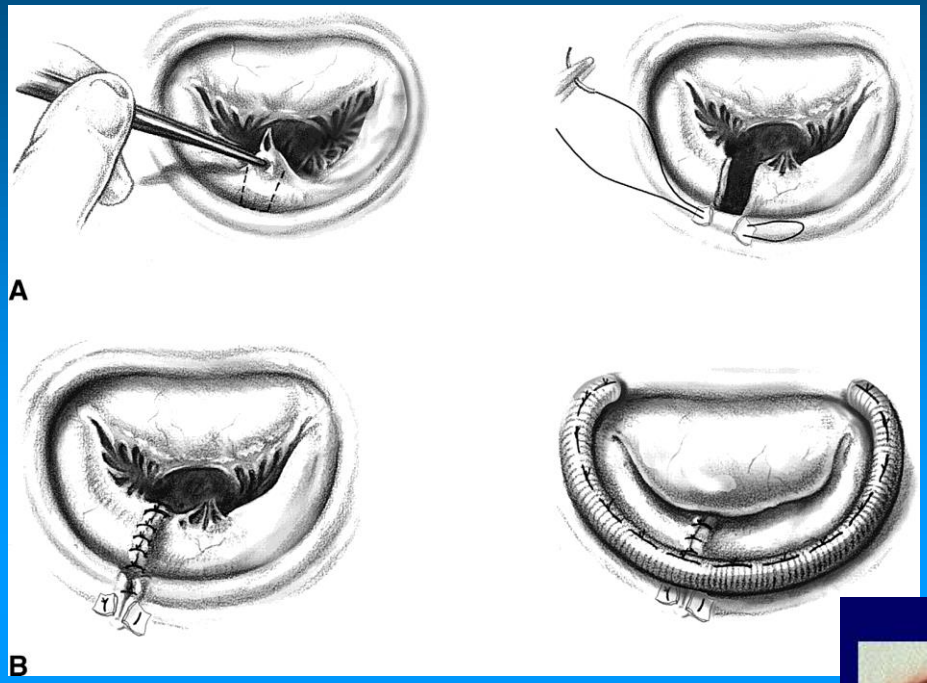




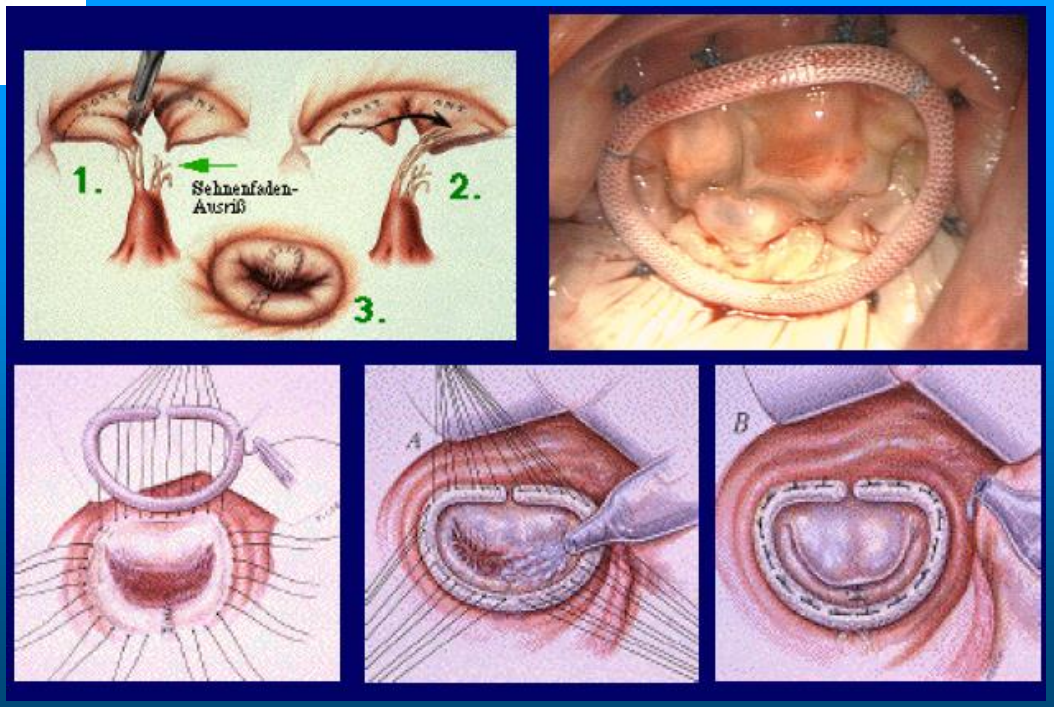
Mitral valve implantation



Repair of the mitral valve



Quadrangular resection
with annuloplasty ring



1. ***Valve Implantation***– teflon pledgeted U-stitches, or continuous stitches
   - *Mechanical valve*
   - *Biological valve*
2. ***Valvuloplasty*** (repair of the own valve):

   annuloplasty: tightening the annulus by a *ring* **(Carpentier)** or a double C-shaped annular suture **(DeVega),**

   comissurotomy, excision of the part of leaflet with ruptured chordae, decalcification, arteficial chorda implantation

   -Benefit: The own valve is the best valve: better flow-characteristics, only transient anticoagulation is needed

   -Disadvantage: result dependent on the surgeon's experience, possibility of recurrence

Valve surgery

Mechanical valve:

pyrolit carbon surface- hard, durable, antithrombogenic
but ***anticoagulation for lifetime***: cumarine or warfarin every day
Contraindication: serious gastric ulcus, pregnancy, hematol. disease
The most important: PTR – INR level control in every month!!!

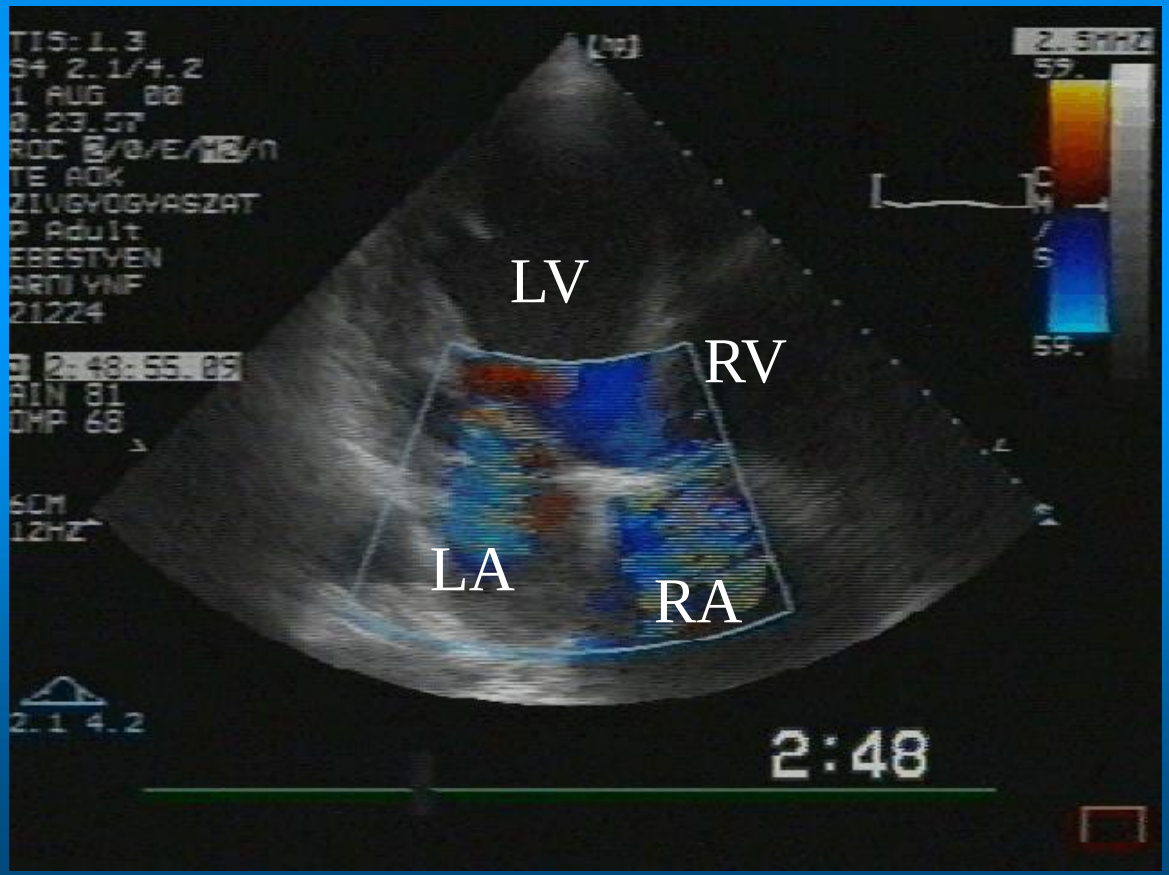
Biological valve:

anticoagulation only for 3 months
the lifetime of the valve is about 8-12 years
porcine, bovine (xenograft)
stentless (without sewing ring)
homograft
autograft (own pulmonary valve- Ross op.)

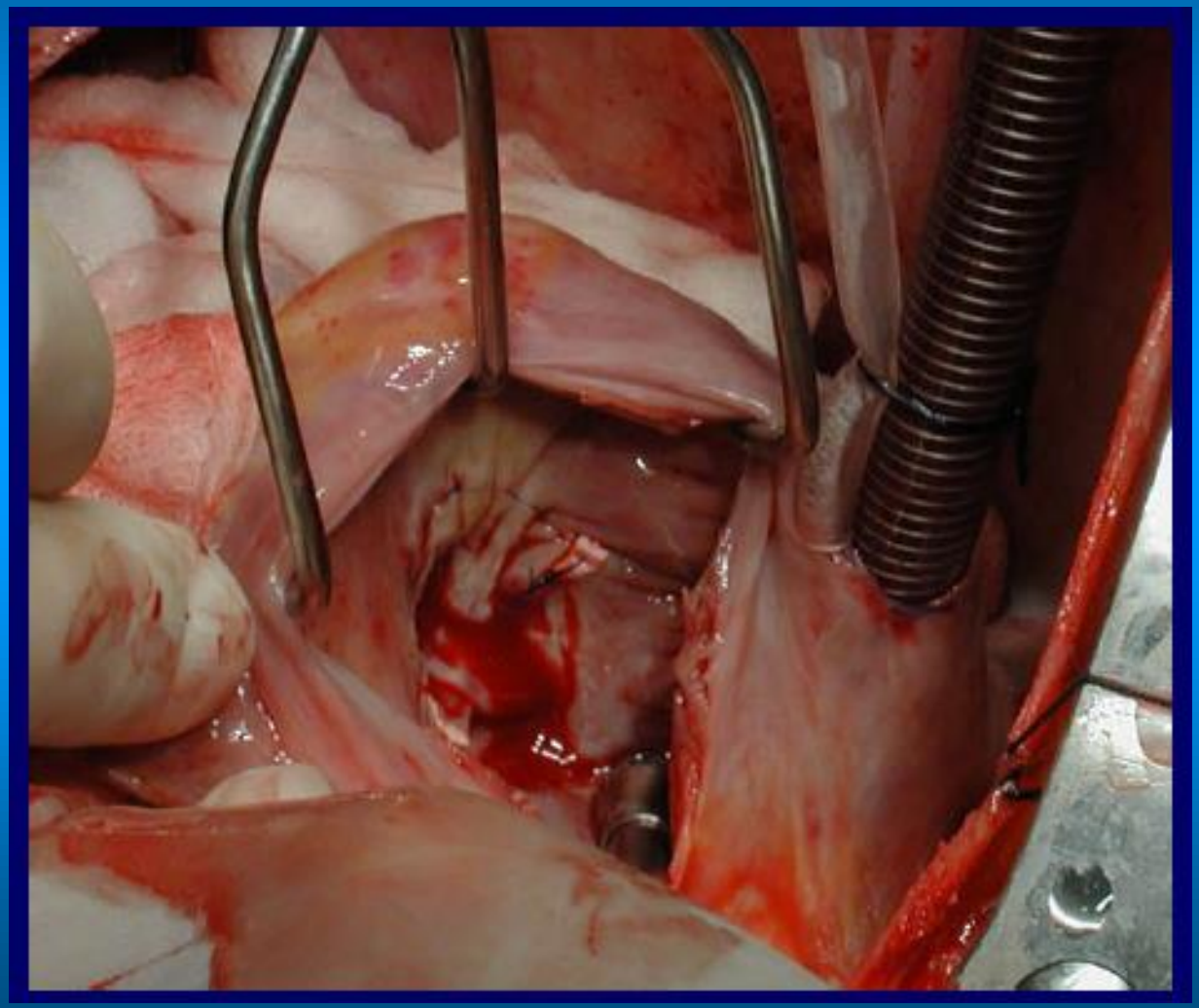
Diseases of the tricuspid valve

regurgitation: generally concomitant to mitral insuff., a result of annulus-dilation in CAD

IV. drug abusers: right sided endocarditis



DeVega plasty in tricuspidal position



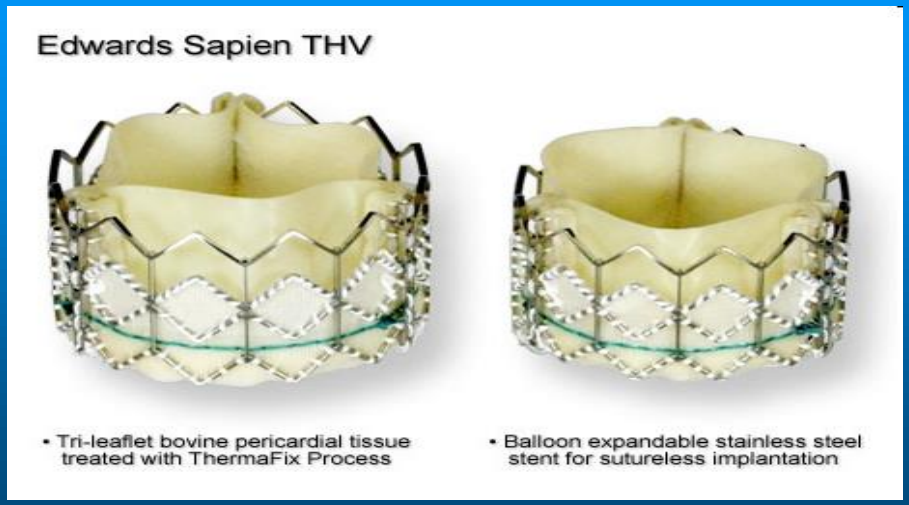
Complications after valve surgery

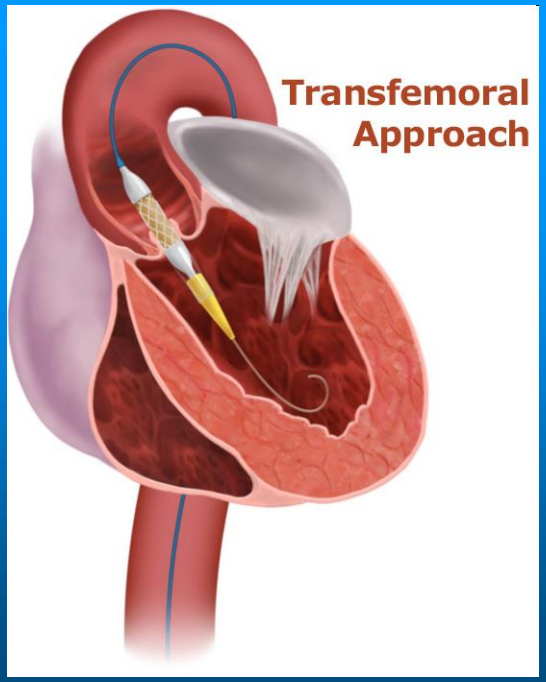
- Arrhytmias, atrial fibrillation
- Pericardial fluid accumulation, tamponad,
- Bleeding
- Wound healing infection, mediastinitis
- Neurological anomalies- due to embolisation, hypoperfusion
- Perioperative infarction, heart failure
- Late complications:
  - Thromboembolic complications, valve thrombosis
  - Bleeding complications (brain, joint, gastric bleeding – overdose of cumarin)
  - paravalvular leak (anaemia)
  - Endocarditis of the implanted valve
  - Degeneration of biological valve – need of reoperation

Minimally invasive valve implantation
TAVI procedure (Trans Aortic/Apical Valve Impl.)

Corevalve
(Medtronic)

For „High Risk” patients over 70y

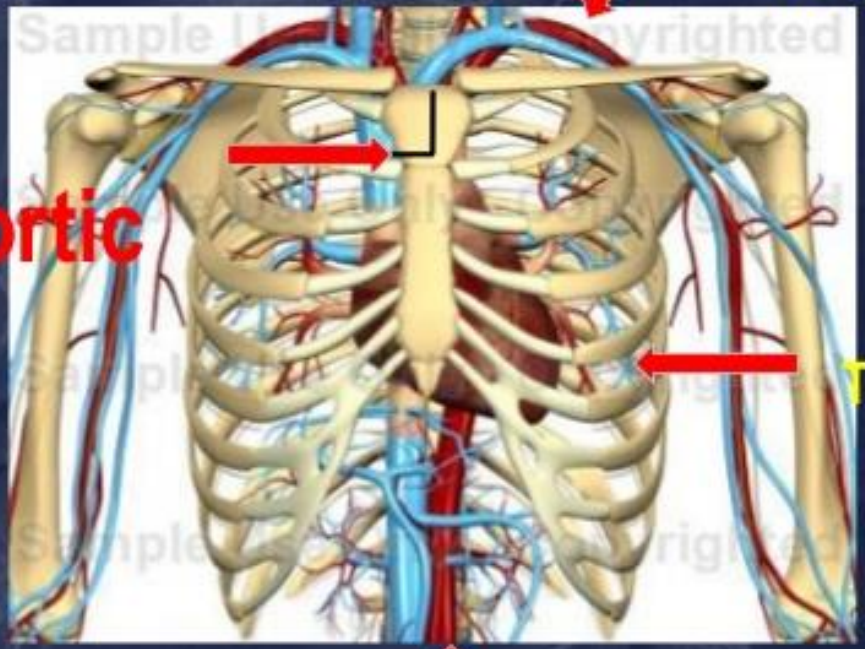




Results of Meta-analysis

	TAVI, ***1688 patients***	***AVR,*** ***1777 patients***	
Mortality	7.5%	6.9%	
Cardiovasc. mortality	3.7% (12.8%)	3.6% (11.9%)	
Stroke	2.6% (4.5%)	2.3% (3.4%)	
Stroke/TIA	4.6%	3.9%	
Vascular complications	13.8%	2%	*
Major bleeding	9.7%	20.5%	*
AMI	0.5%	0.5%	
Acute kidney insufficiency	6.5%	5.3%	
Postop. PM impl.	13.2%	3%	*
Postop. aortic regurgitation	7.8%	0.6%	*

VASCULAR ACCESS



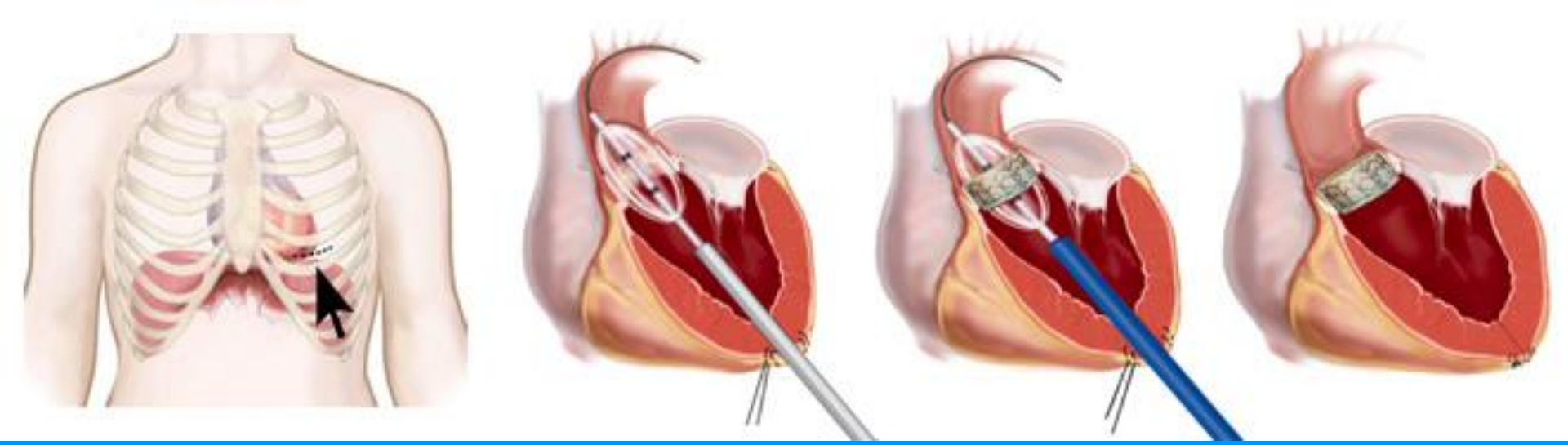
Transsubclavian

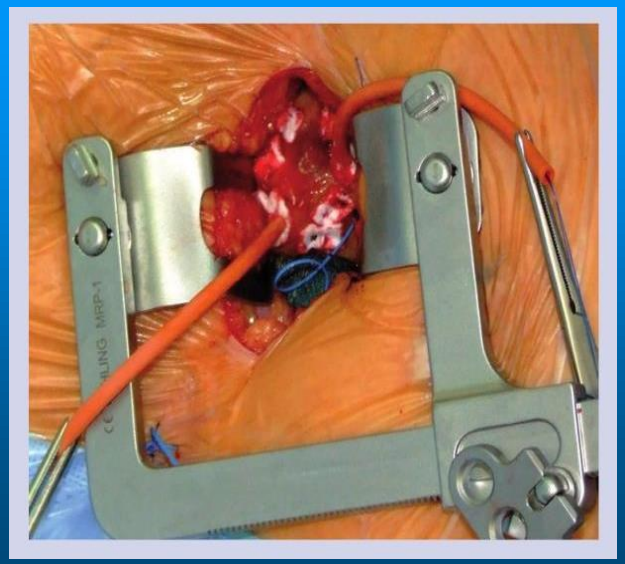
Transaortic

Transapical

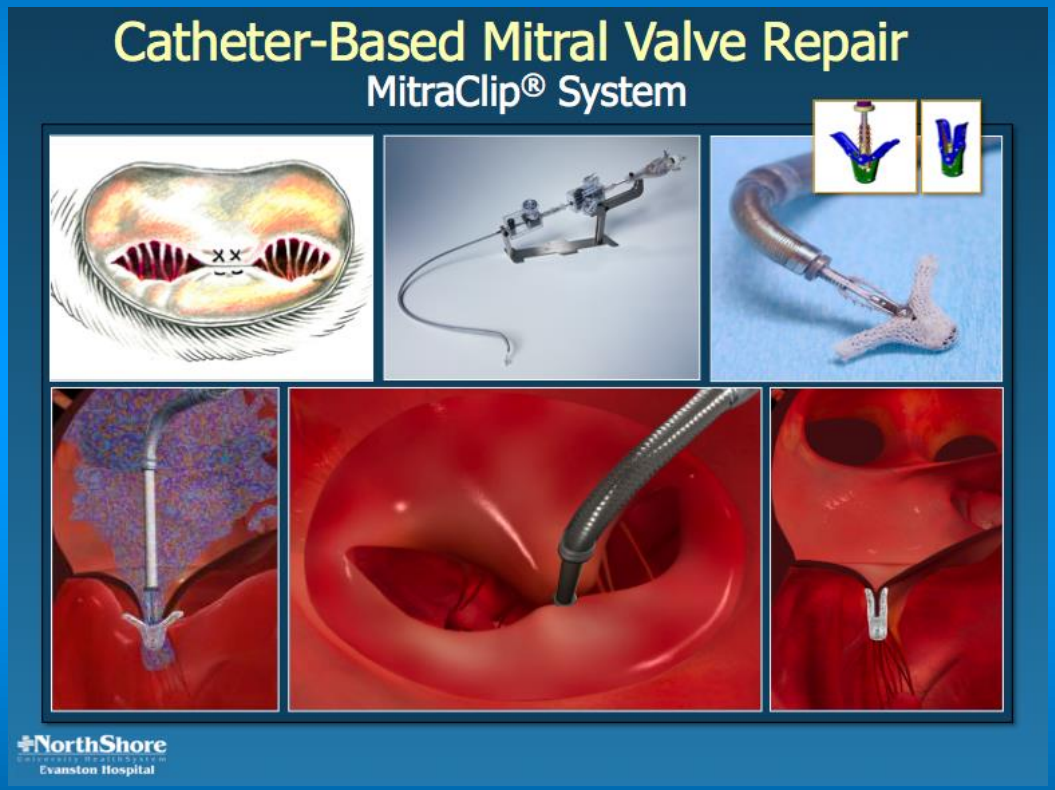
Transfemoral

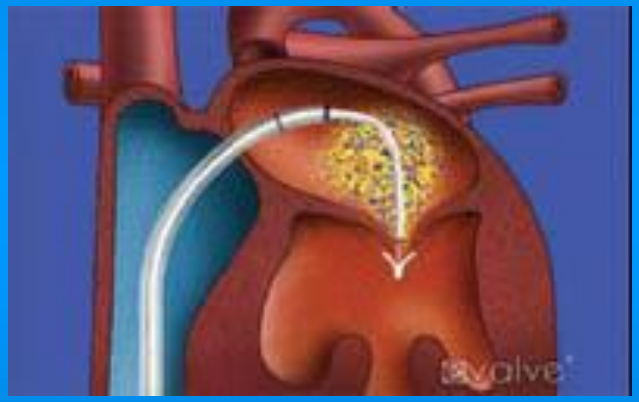
Trans-apical TAVI





Minimally invasive – catheter based mitral valve repair (MitraClip)





Patient follow-up after valve op.

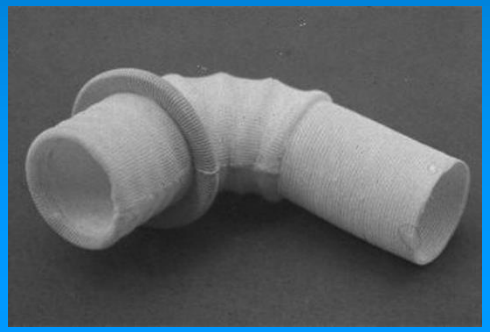
<u>Anticoagulation:</u> Syncumar/Cumadine to INR
Biograft: 3-6 months (INR 2.0-3.0), now ASA+clopi
Mechanical: life-long *(Ao: 2.0-3.0, M: 2.5-3.5)*
Tell it before any medical intervention !
1 week before any operation change to LMWH
postoperatively heparine for some days

<u>Endocarditis profilaxis:</u> antibiotics
In case of dental extraction (depuration) or before and after any invasive intervention
amoxicillin+clavulanic acid, erythromycin

Apico-aortic conduit valve

Valve

LV connector



Graft