



Pirogov

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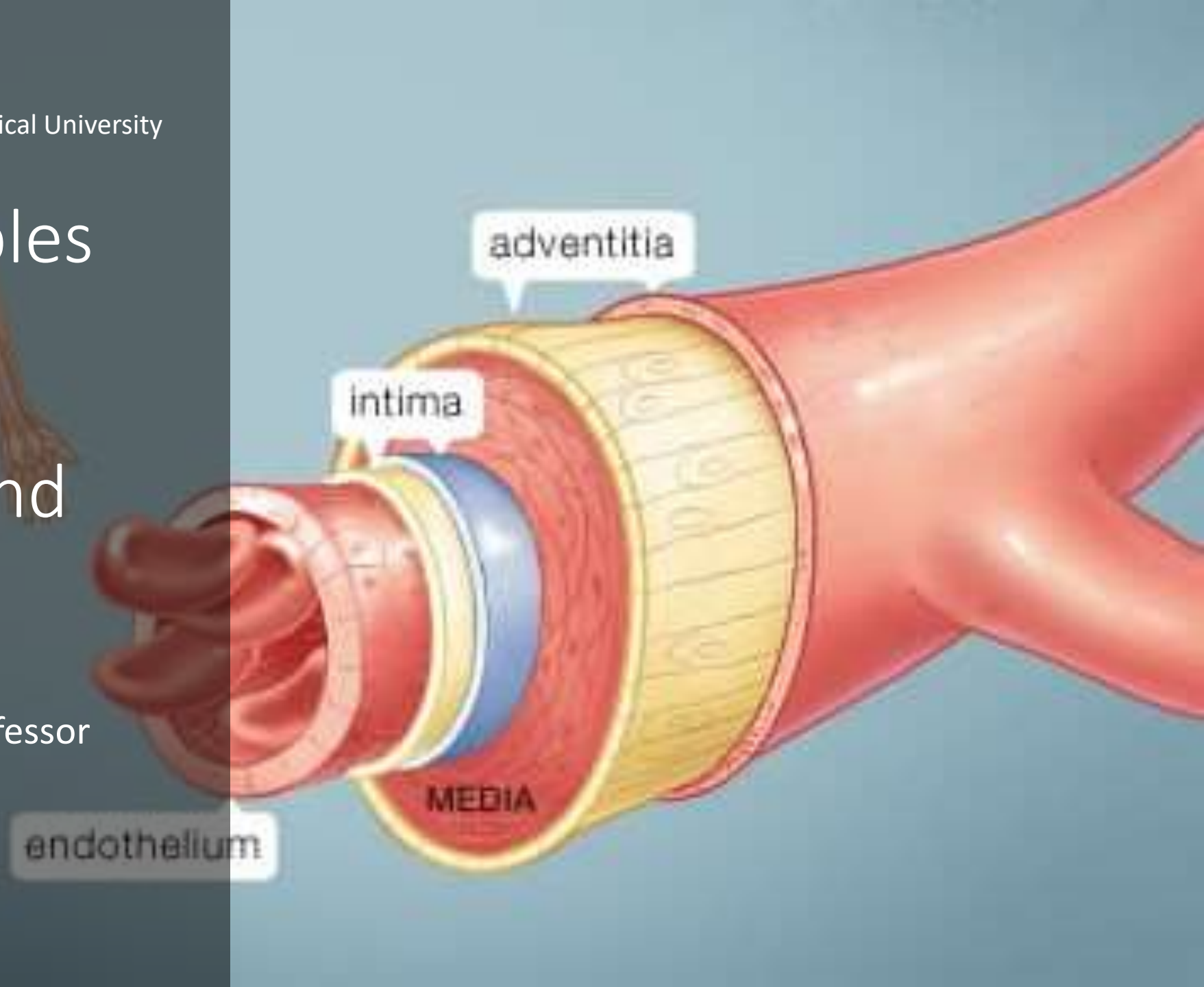
Department of General surgery

Basic principles of artery diseases diagnostic and treatment

Lecturer:

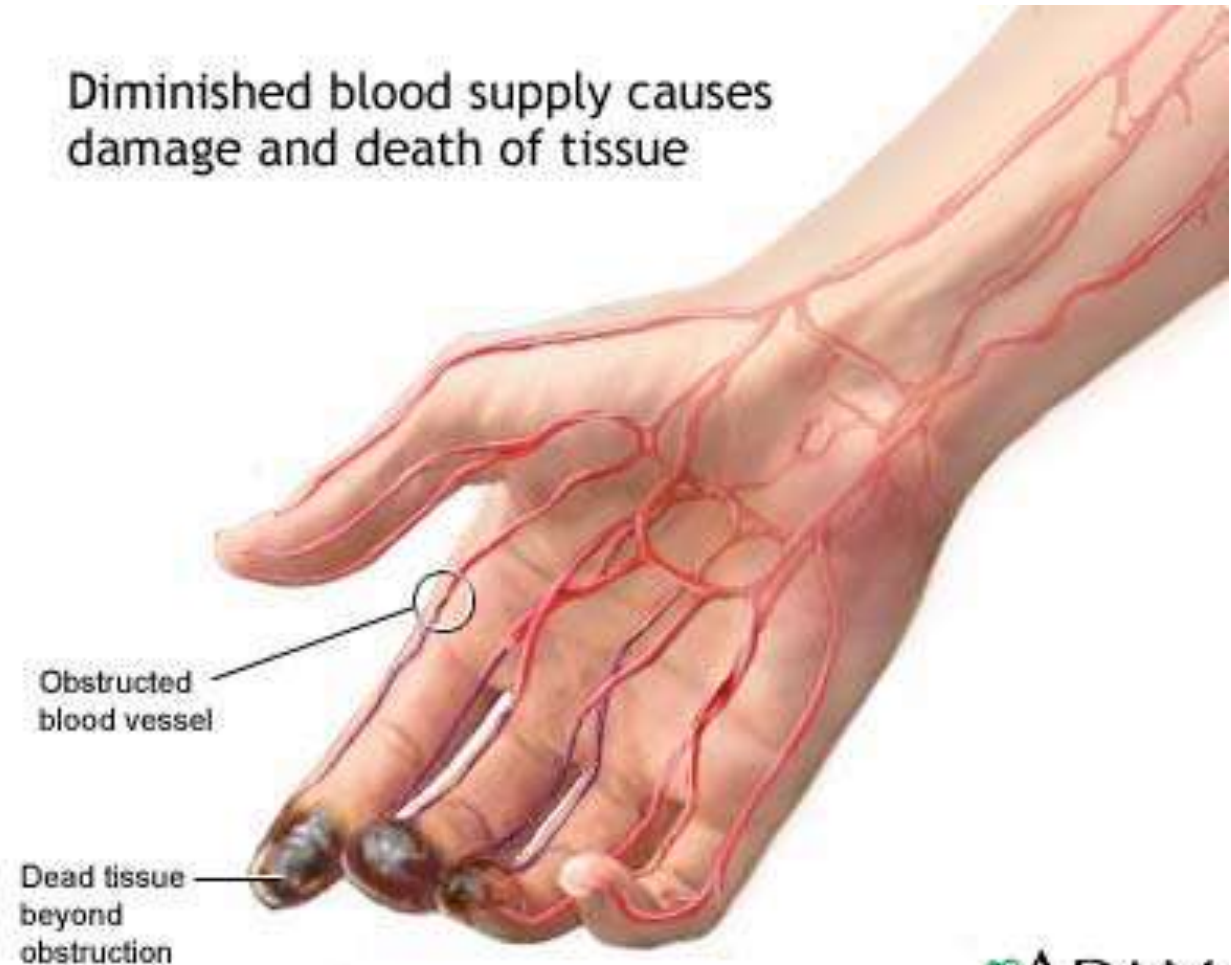
MD, PhD, Associate professor

Kirill Lobastov



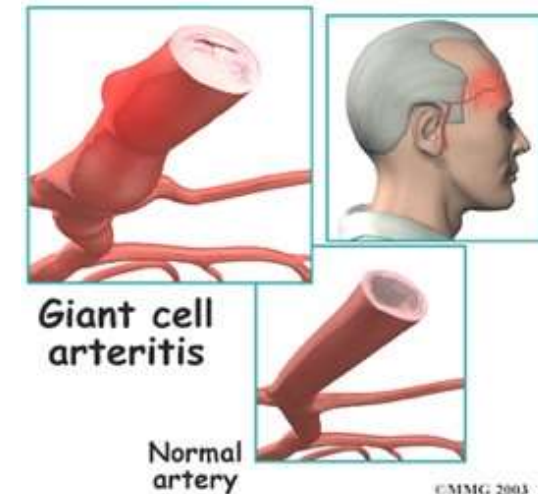
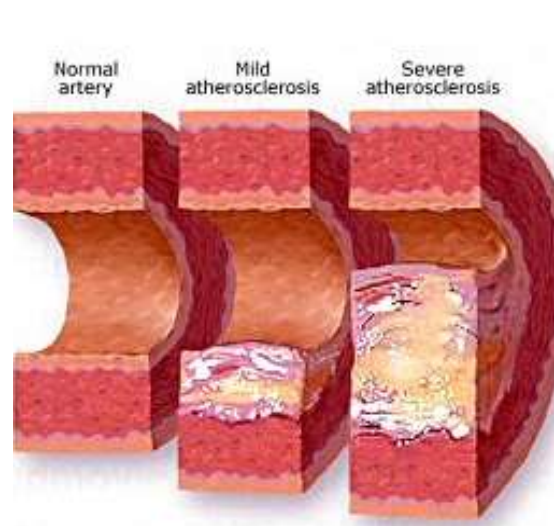
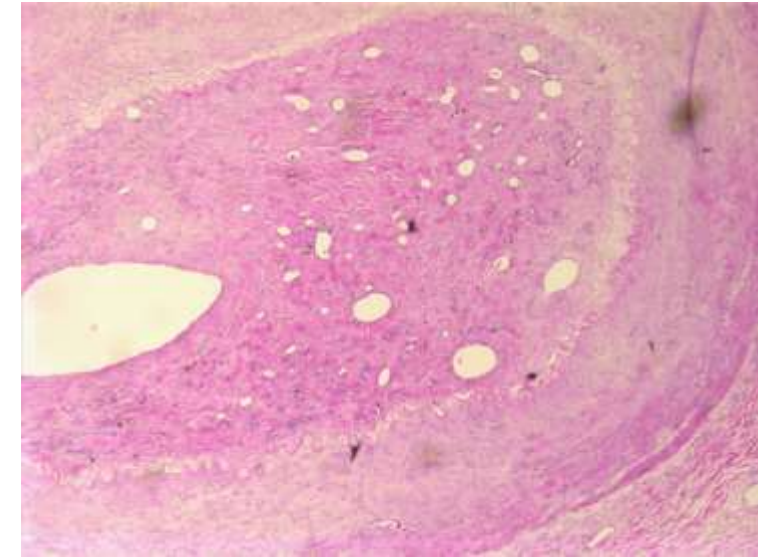
Arterial insufficiency

- Decrease of arterial blood inflow to any organ and limb, which lead to organ ischemia and dysfunction.

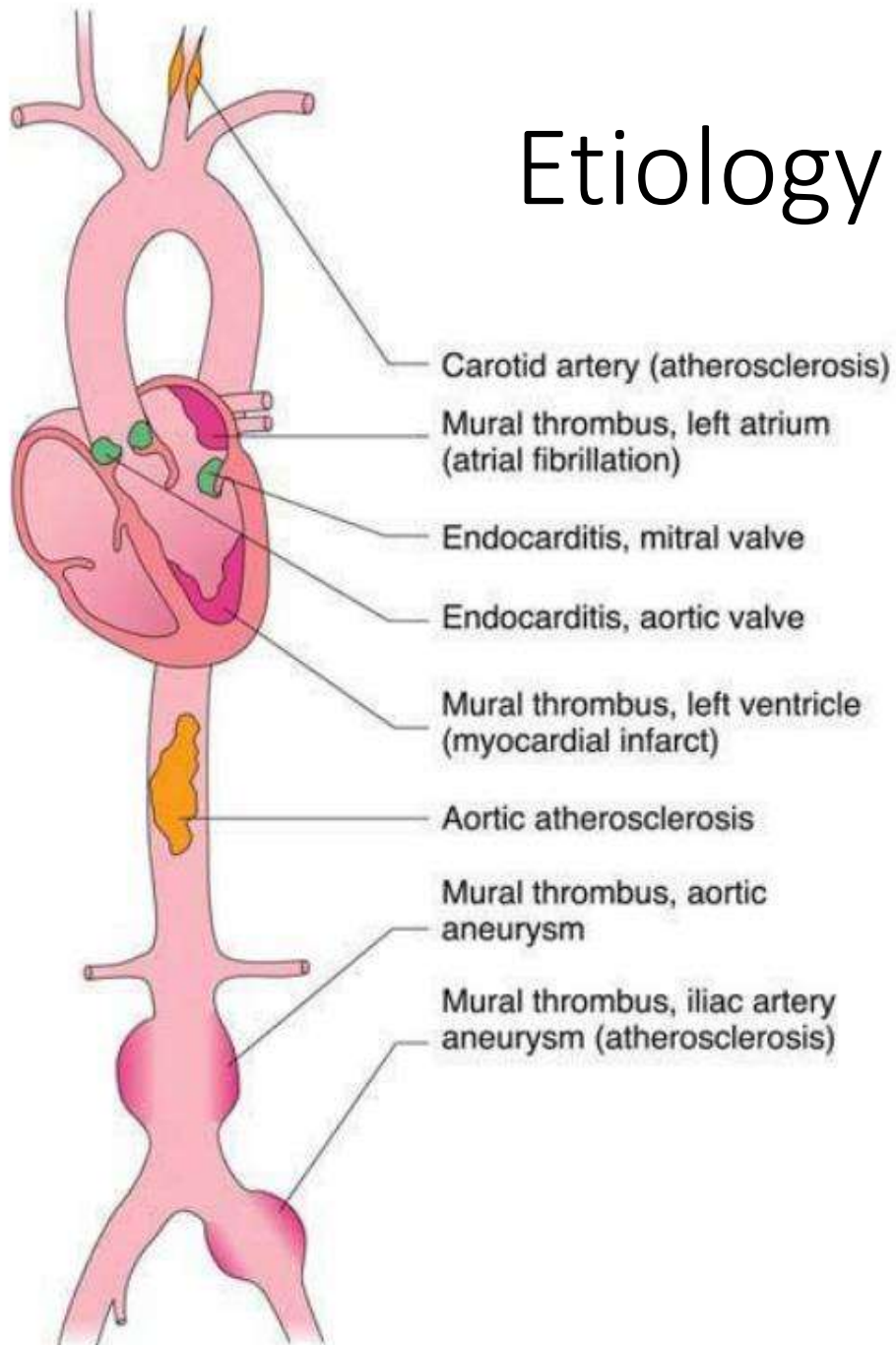


Etiology of arterial insufficiency

- Atherosclerosis
- Arteritis
 - Thromboangiitis obliterans
 - Obliterating endarteritis
 - Temporal arteritis
 - Takayasu's aorto-arteritis
- Fibromuscular dysplasia
- Complications:
 - Arterial thrombosis
 - Arterial emboli

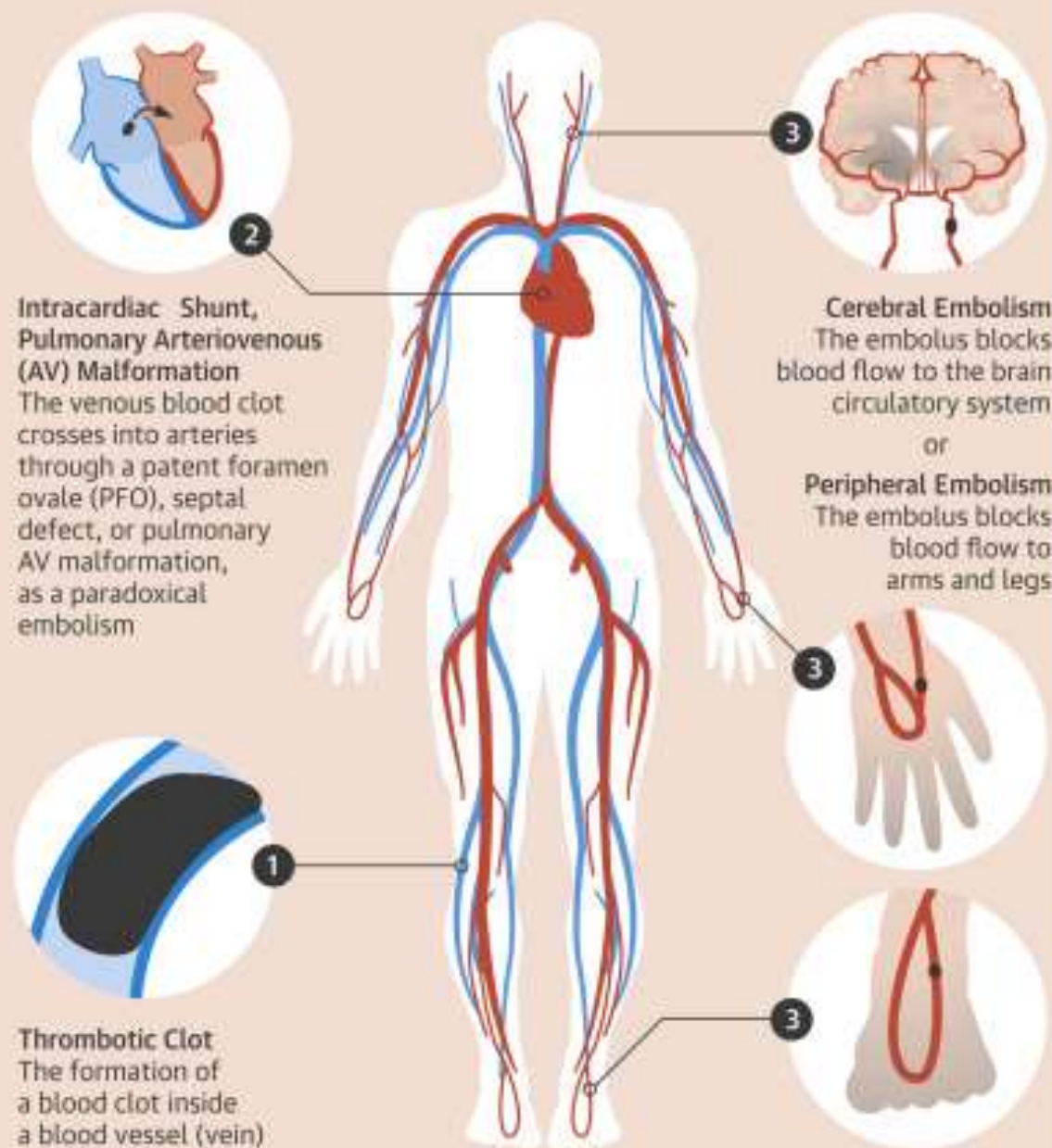


Etiology of arterial embolism



- Cardiac diseases – 90%
 - Atrial fibrillation
 - Myocardial infarction
 - Endocarditis (bacterial, rheumatic) with valve vegetations
 - Myocardial aneurysm
 - Valvular prosthesis
 - Paradoxical embolism
 - Cardiac tumor
- Pathology of vessels – 10%
 - Aneurysm
 - Atherosclerosis (ruptured plaque)

PATHWAY OF A PARADOXICAL EMBOLISM



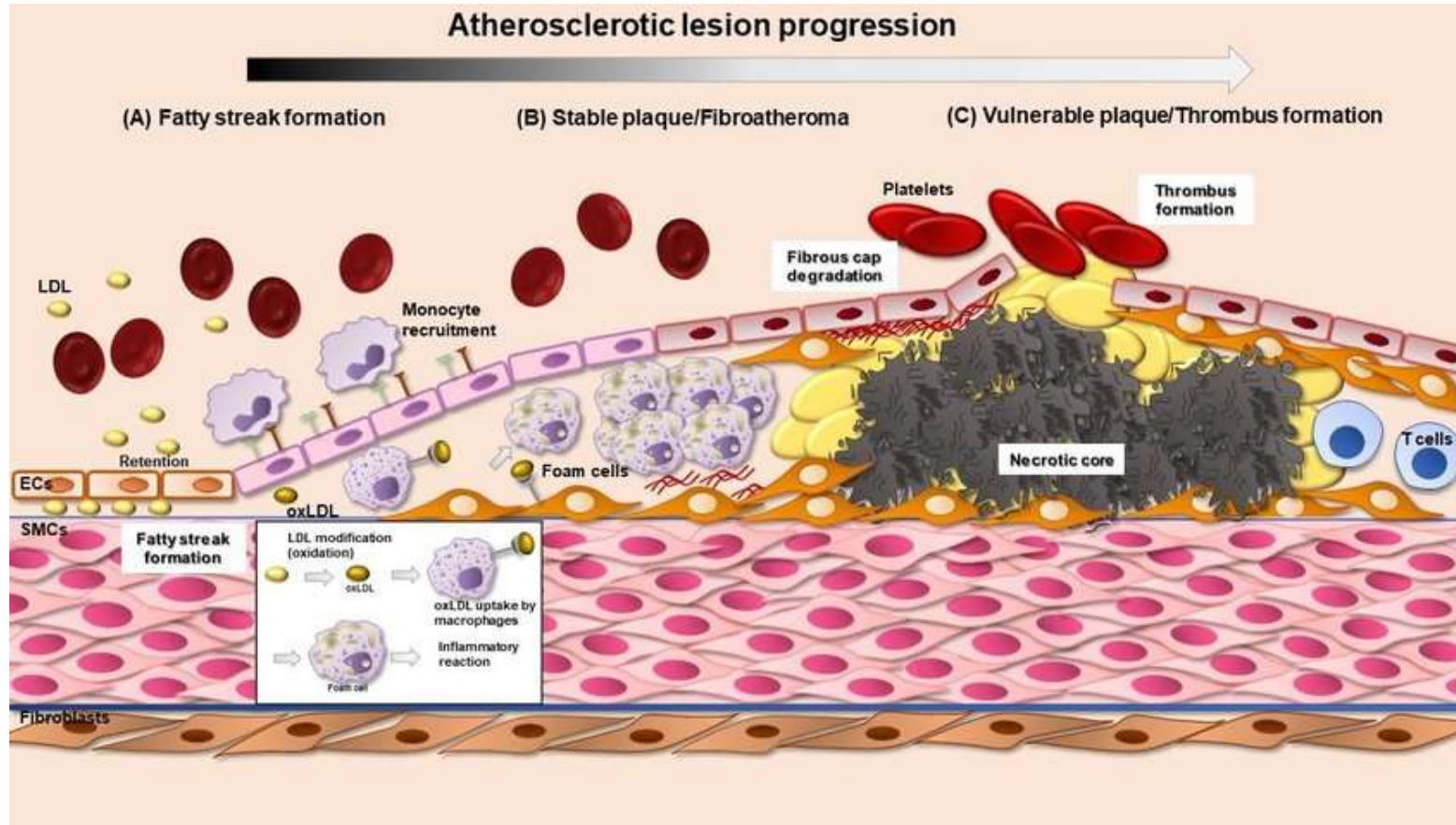
ASSOCIATED DIAGNOSTIC TOOLS

- Holter Electrocardiogram (ECG)**
Assessment for atrial fibrillation
- Transesophageal Echocardiography**
Evidence for intracardiac shunt or other source of thromboembolism
- Vascular Imaging**
Assessment for aortic arch atheroma and extracranial arterial disease
- Brain Imaging**
Assessment for location and size of stroke
- Laboratory Studies**
Assessment for increased risk of thrombosis (hypercoagulable state)

THERAPEUTIC PREVENTION

- Antithrombotic Therapy**
Administer drugs to reduce the risk for thrombotic clot formation: Acetylsalicylic acid or Clopidogrel as single therapy or in combination and Warfarin are considered
- Percutaneous Patent Foramen Ovale (PFO) Closure**
Percutaneous closure of PFO using a PFO occluder device

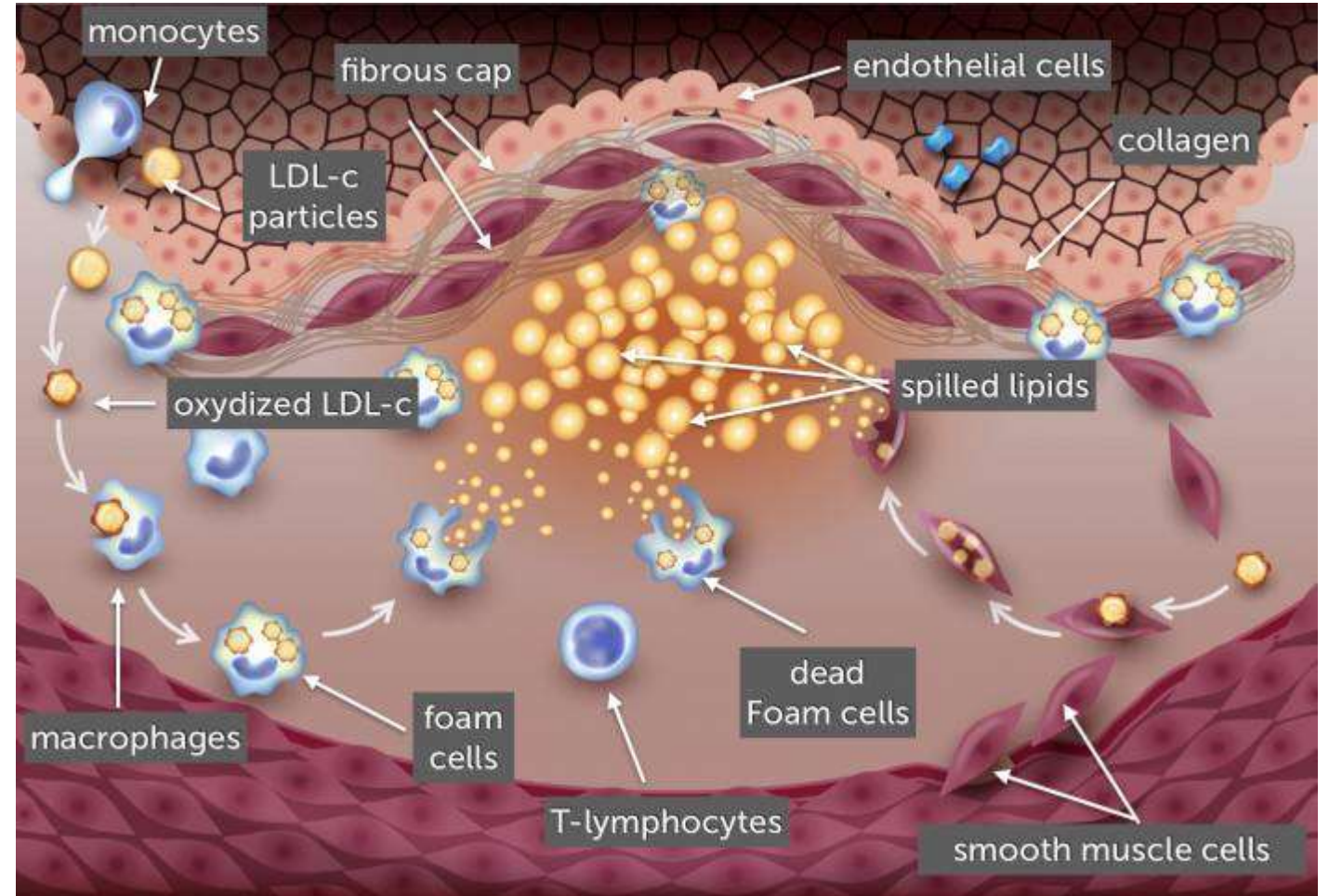
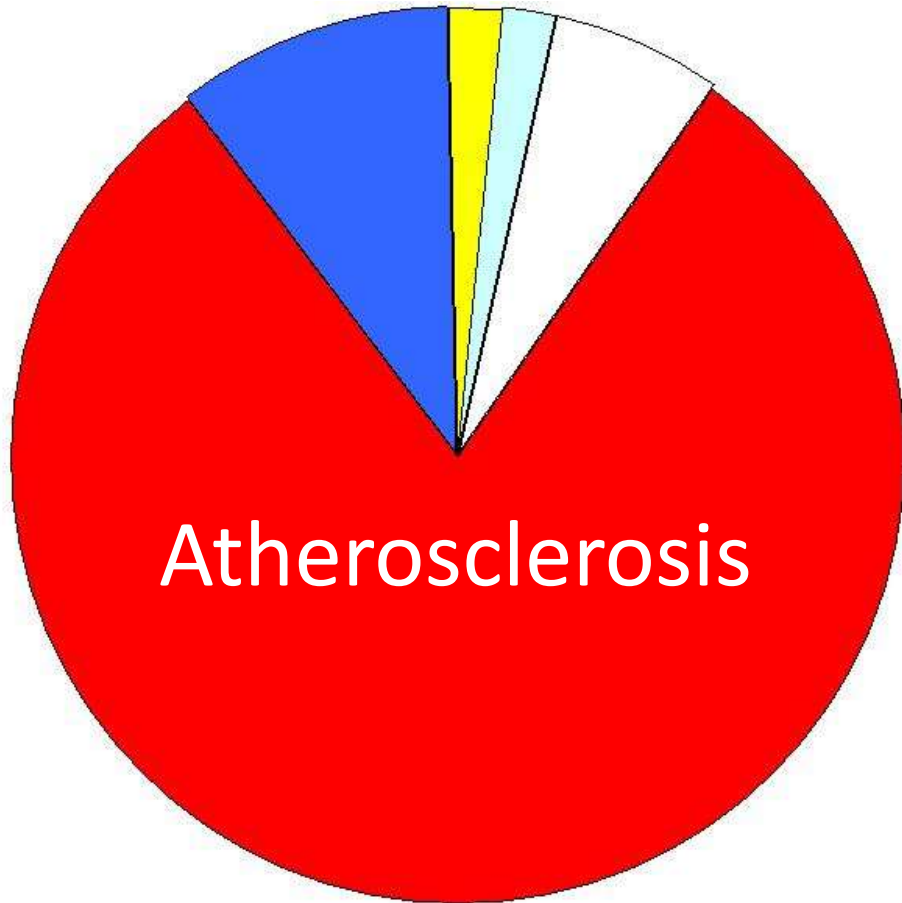
Etiology of arterial thrombosis



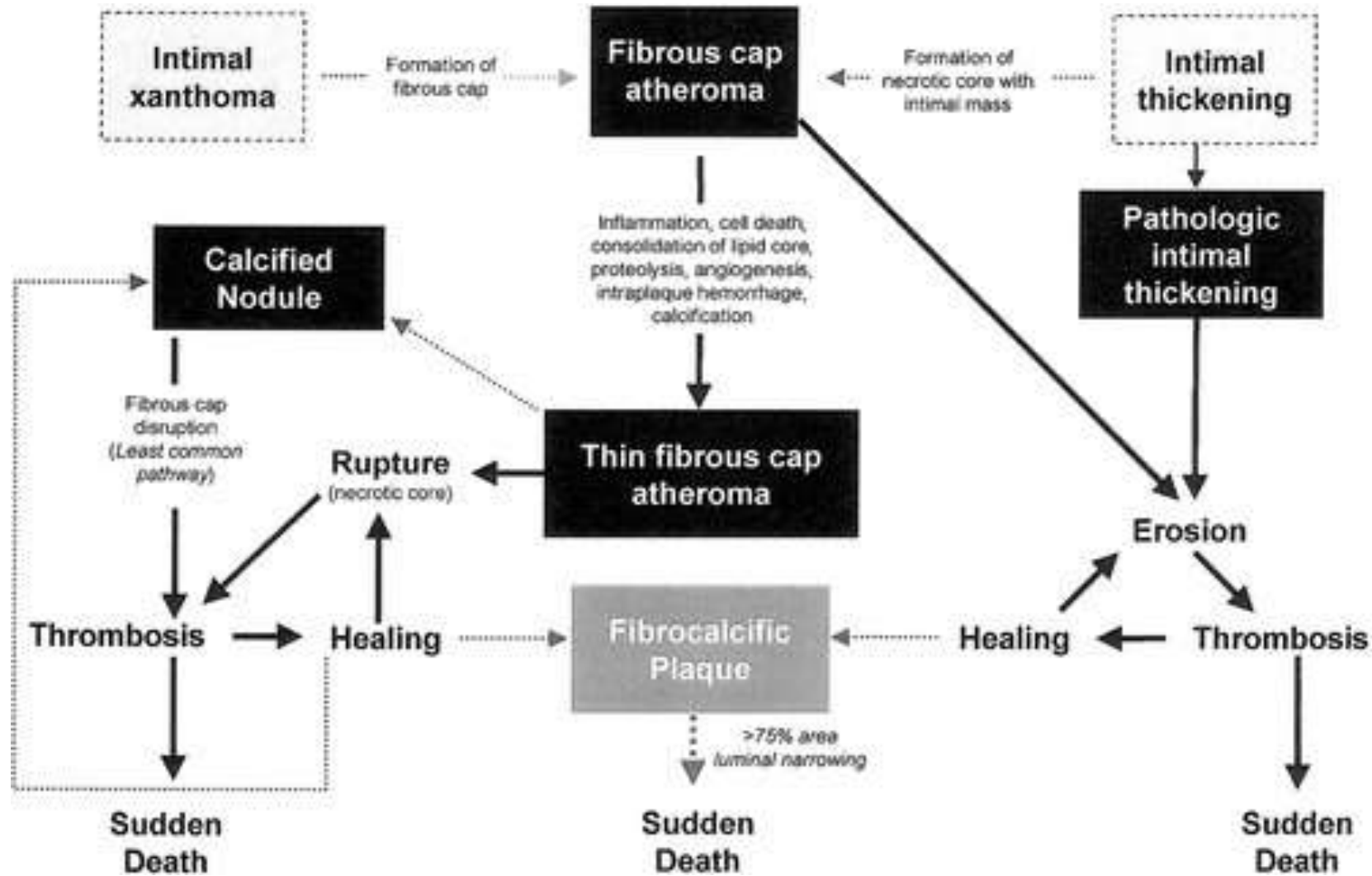
- Atherosclerosis
- Shock/low flow state
- Thrombophilia
 - Antiphospholipid syndrome
 - Protein C and S deficiency
 - Antithrombin deficiency
 - Heparin-induced thrombocytopenia
 - COVID-19

Clinical Condition		Defect of Blood, Protein and Platelet
Arterial Thrombosis	Venous Thrombosis	
Atherosclerosis	General surgery	Antiphospholipid syndrome
Cigarette smoking	Orthopaedic surgery	Sticky platelet syndrome
Hypertension	Arthroscopy	Cancer procoagulant (CP)
Diabetes Mellitus	Immobility	Protein S defects
Low-density lipoprotein cholesterol	Malignancy	Protein C defects
Hypertriglyceridemia	Sepsis	APC resistance (factor V Leiden)
Positive family history	Injury	Antithrombin defects
Left ventricular failure	Congestive Heart Failure	Heparin cofactor II defects
Oral contraceptives	Nephrotic syndrome	Plasminogen
Estrogens	Obesity	Tissue plasminogen activators defects
Lipoprotein(a)	Varicose veins	Plasminogen activator inhibitor defects
Polycythemia	Postphlebitic syndrome	Factors XII defects
Hyperviscosity syndromes	Oral contraceptives	Dysfibrinogenemia
Leukostasis syndromes	Estrogens	Hyper Homocystinemia

Etiology of chronic arterial occlusion



Atherosclerosis



Arterial insufficiency

- Heart
- Brain
- **Limbs**
- Kidney
- Intestine

PERIPHERAL ARTERY DISEASE AWARENESS MONTH

PAD AT A GLANCE



>60%

The proportion of patients with PAD who also have coronary artery disease or cerebrovascular disease.

Source: Bhatt DL, Steg PG, Ohman EM, et al. JAMA 2006;295:180-9.



1 in 5

The prevalence of peripheral artery disease (PAD) in adults >60 years of age. In the U.S. >8.5 million adults have PAD and >200 million worldwide.

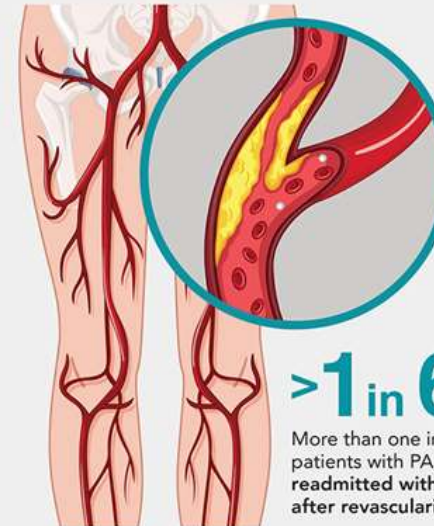
Source: Fowkes FG, Ruden D, Ruden I, et al. Lancet 2013;382:1329-40.



25%

Among patients with critical limb ischemia, at one year, 25 percent have an amputation and 25 percent cardiovascular mortality. Only fifty percent are alive with both limbs at one year.

Source: Hirsch AT, Haskal ZJ, Hertzer NR, et al. J Am Coll Cardiol 2006;47:1239-312.



>1 in 6

More than one in six patients with PAD are readmitted within 30 days after revascularization.



\$11,013

The median cost of a readmission after revascularization.



4.6%

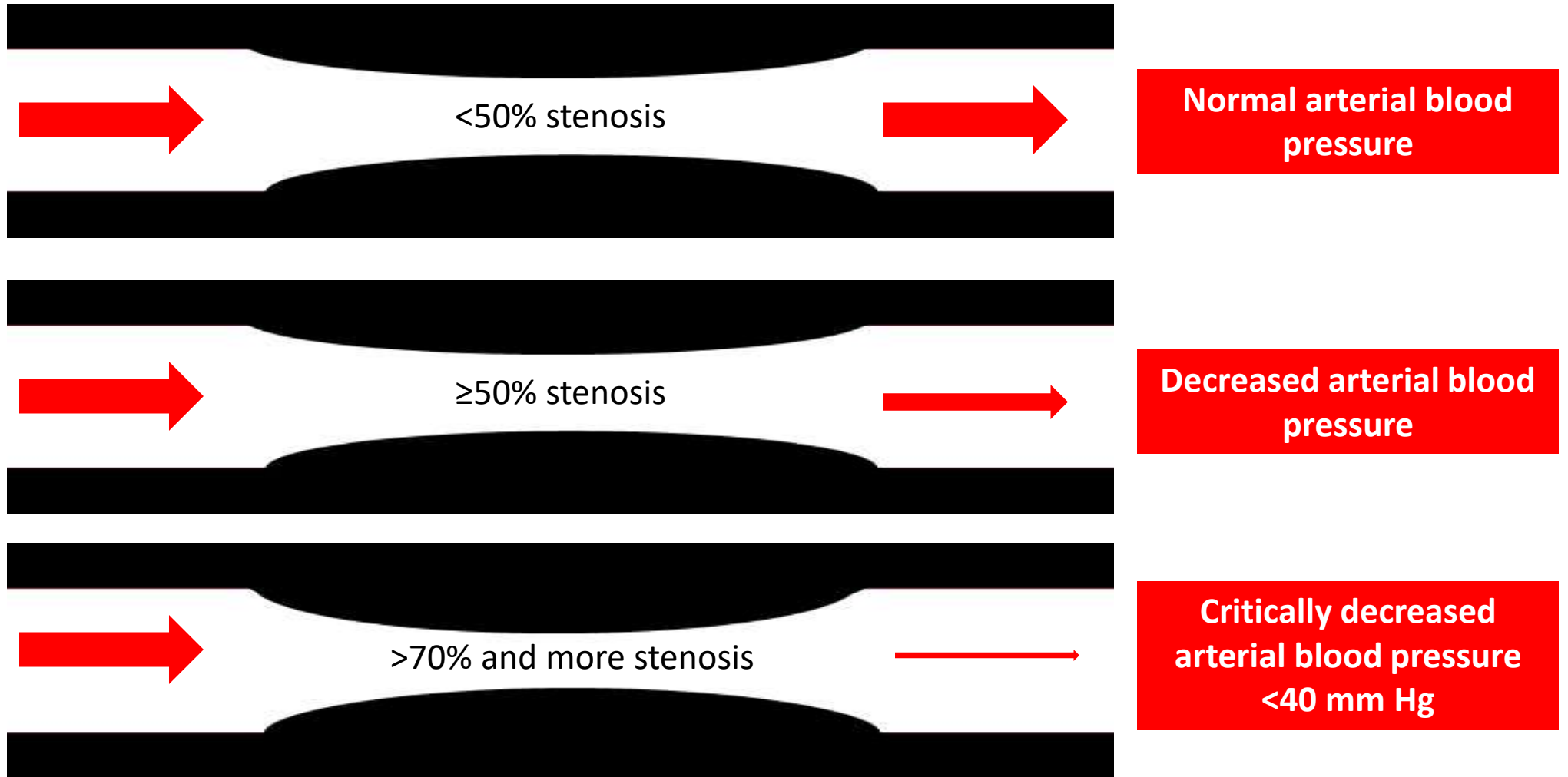
The proportion of patients who die during readmission after PAD revascularization.



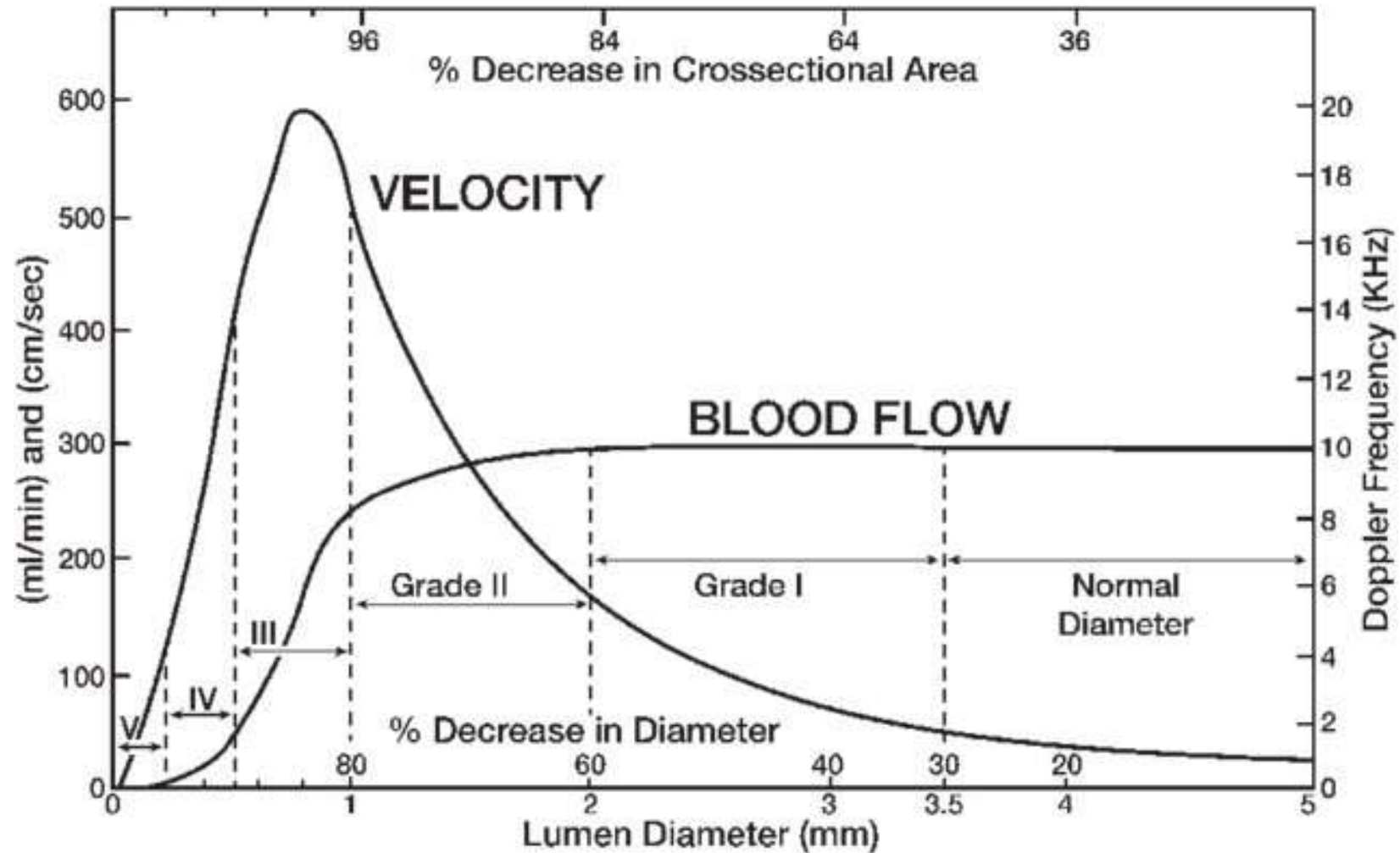
28%

Nearly one-third of all readmissions are due to complications.

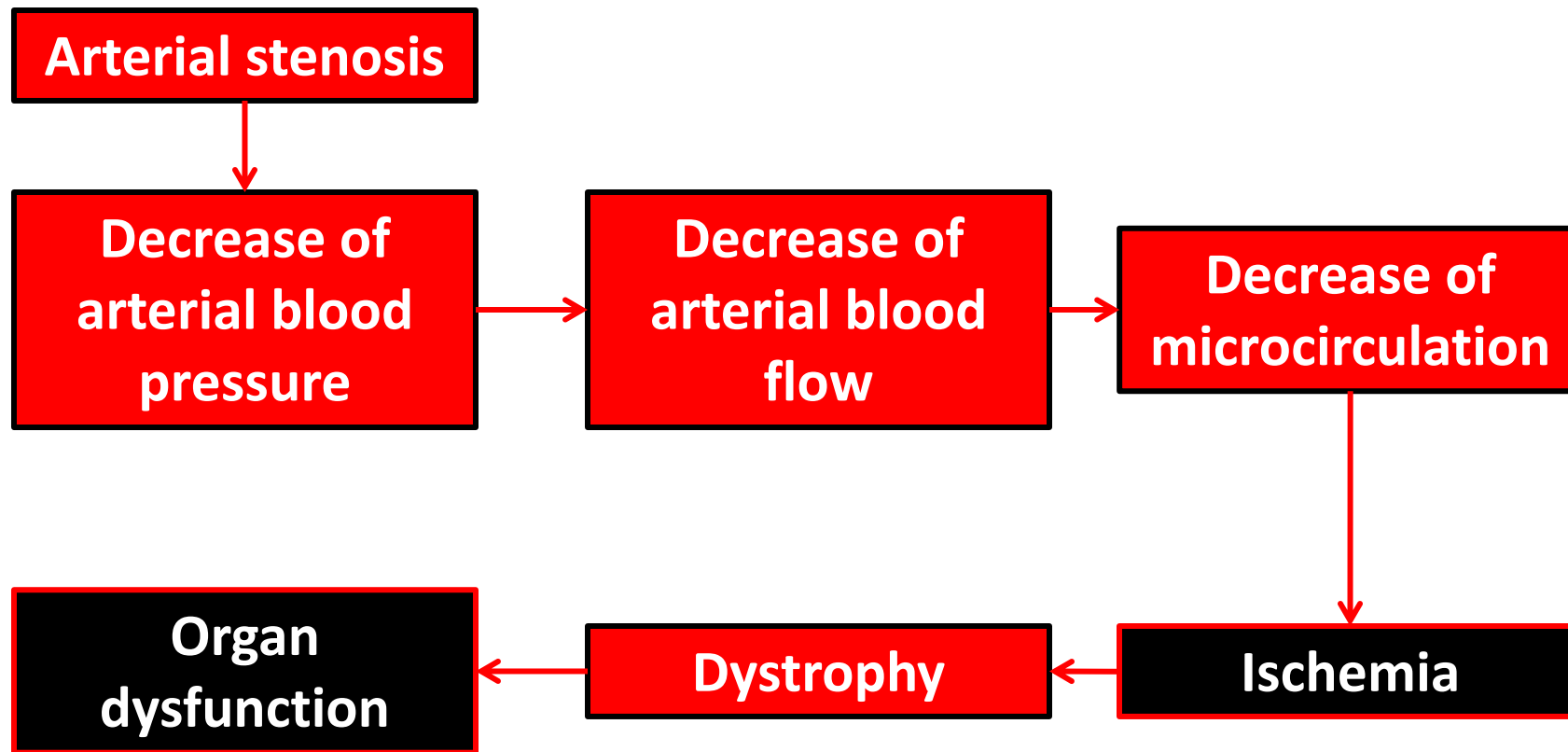
Pathogenesis of arterial insufficiency



Grade of stenosis and arterial blood supply

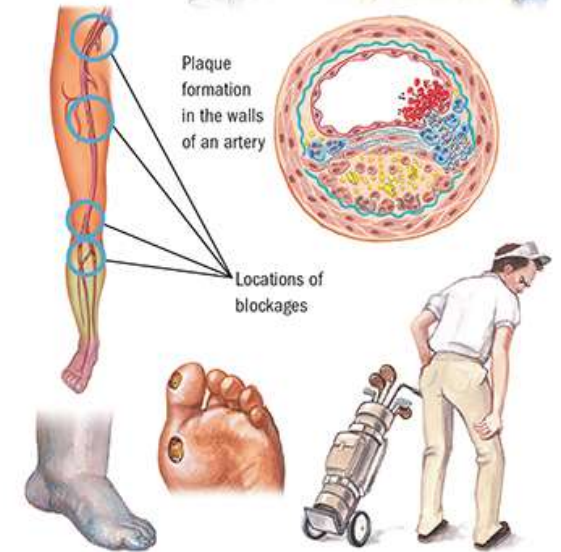
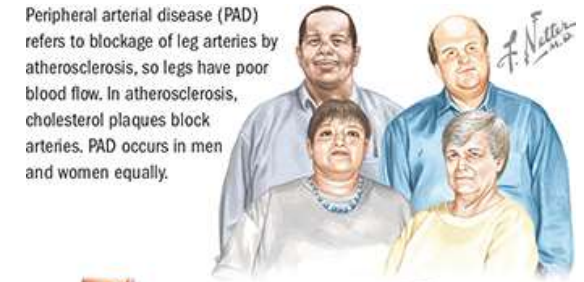


Pathogenesis of arterial insufficiency

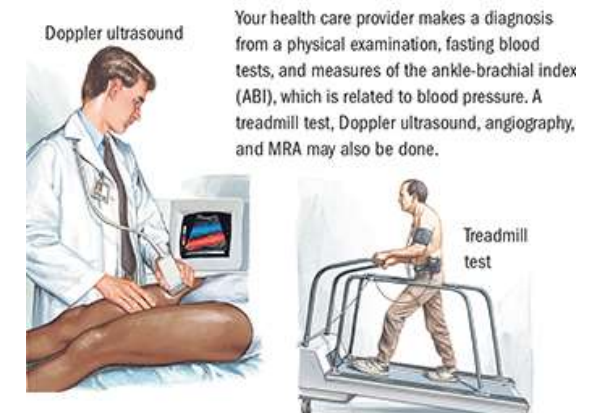


Diagnosis

- Clinical signs:
 - Pain during organ activity
 - Organ dysfunction
 - Systolic noise above artery
 - Decrease or absence of arterial pulsation
 - Dystrophy and necrosis



About half of people don't have symptoms, but the most common ones are pain, cramping, aching, and numbness. Others are heavy or tight feeling, cold skin, pale or bluish skin, and ulcers that don't heal.



Arterial insufficiency of lower limbs

- Acute arterial occlusion
 - Embolism
 - Thrombosis
- Chronic arterial occlusion
 - Atherosclerosis
 - Arteritis

Acute arterial occlusion

- The sudden decrease of arterial blood inflow without the possibility of collateral inflow development
- Acute leg ischemia
- Acute leg pain (ischemic pain)
- Acute leg dysfunction (paralysis because of nerves and muscle necrosis)
- Acute leg edema (subfascial edema because of muscle necrosis)
- Reduction of movements in joints (contracture)
- Leg necrosis - gangrene

Grades of acute limb ischemia

Grade	Pain	Sensitivity	Movement	Edema	Skin
1a	During contraction	Paresthesia	Not affected	no	Pale, cold
1b	Constant	Hypoesthesia	Not affected	no	Pale, cold
2a	Constant	No skin sensitivity	Reduced	no	Pale, cold
2b	Constant or absent	No skin sensitivity	Absent (paralysis)	no	Pale, cold
3a	Constant or absent	No skin sensitivity	Absent (paralysis)	Subfascial	Pale, cold
3b	Constant or absent	No skin sensitivity	Absent (paralysis)	Subfascial with joint contracture	Pale, cold
3c	Constant or absent	No skin sensitivity	Absent (paralysis)	Subfascial with total leg contracture	Pale, cold
4	Constant or absent	No skin sensitivity	Absent (paralysis)	Subfascial with total leg contracture	Necrotic

Grades of acute limb ischemia by Rutherford

Table 2. Clinical categories of acute limb ischaemia according to Rutherford²

Grade	Category	Sensory loss	Motor deficit	Prognosis	Doppler signals	
					Arterial	Venous
I	Viable	None	None	No immediate threat	Audible	Audible
IIA	Marginally threatened	None or minimal (toes)	None	Salvageable if promptly treated	Inaudible*	Audible
IIB	Immediately threatened	More than toes	Mild/moderate	Salvageable if promptly revascularised	Inaudible	Audible
III	Irreversible	Profound, anaesthetic	Profound, paralysis (rigor*)	Major tissue loss amputation. Permanent nerve damage inevitable	Inaudible	Inaudible

This is an identical replica of the table in the 1997 publication by Rutherford *et al.*,² with the exception of the asterisks (*).

* In the original 1997 classification it was stated that arterial Doppler sounds are never present in Stage IIA, and that rigor (mortis) is always present in Stage III. However, it is the opinion of the Writing Committee that exceptions to these rules do exist, and a slight modification of the Rutherford classification from 1997 may be appropriate in the future.

I



IIa



III



IIb

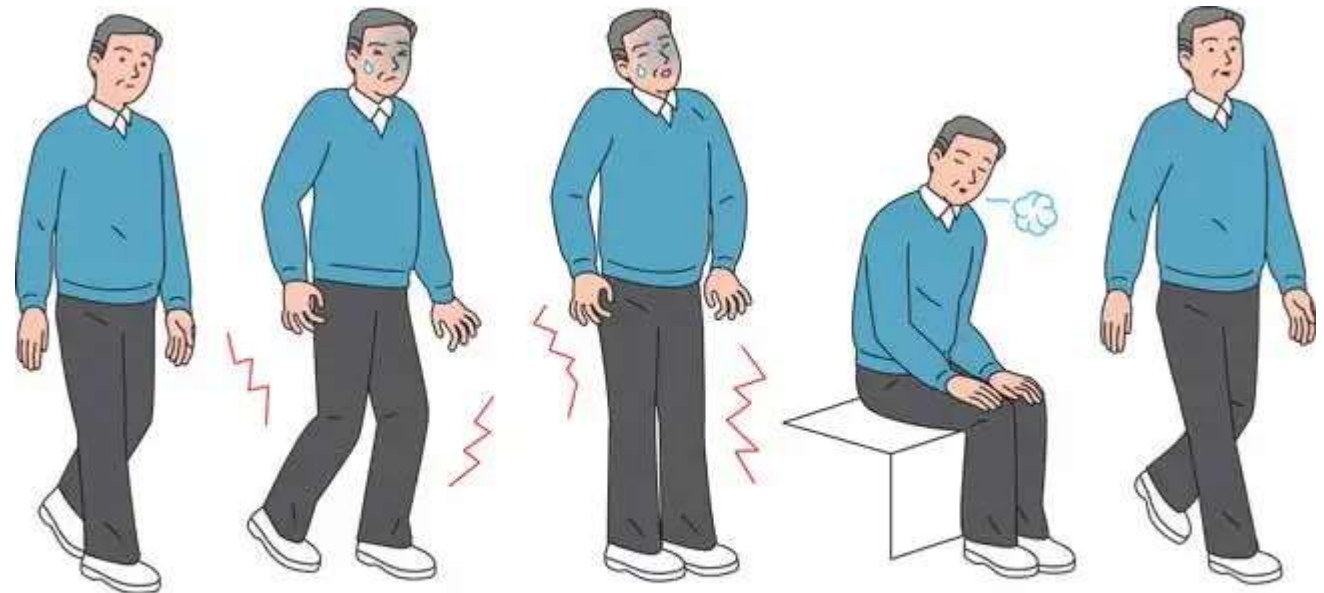


Leg gangrene



Chronic artery occlusion

- Slow development of arterial insufficiency and ischemia
- Development of collateral blood inflow
- Prevalence of skin and muscle dystrophy
- The main symptom – **intermittent claudication**: patient can walk some distance according to severity of arterial insufficiency without pain and then have pain in leg, which compels him to stop walking, after rest pain disappear and patient can continue walking again
- Leg gangrene develop slowly at the end of disorder



The first noticeable symptom of PAD may be intermittent claudication. This is leg discomfort, pain or cramping that develops with activity, is relieved with rest, and recurs upon resuming activity. The pain is most often noticed in the calf, but may also be felt in the buttocks or thighs.

Chronic artery insufficiency stages

- **Stage 1** – no soft tissues dystrophy, patient can walk >1000 meters without pain
- **Stage 2a** – first signs of skin and soft tissue dystrophy (decrease of skin hair amount), patient can walk without pain >250 meters
- **Stage 2b** – patient can walk without pain >50 meters
- **Stage 3** – severe skin and soft tissues dystrophy (decrease of muscle mass, skin pallor and coldness, thin legs), patient can walk without pain <50 m, suffer from pain in rest, to reduce pain need to make low position of leg
- **Stage 4** – skin ulceration and gangrene



Laboratory diagnostic of etiology

Laboratory marker	Pathology
Cholesterol	Atherosclerosis
Lipoproteins of high and low density	
C-reactive protein	Arteritis
Immunoglobulin IgM, IgG	
Circulating immune complex	

Laboratory diagnostic of ischemia

- Alanin amino transferase
- Aspartat amino transferase
- Lactate dehydrogenase
- Creatine Phospho Kinase
- Troponin



Instrumental diagnostic

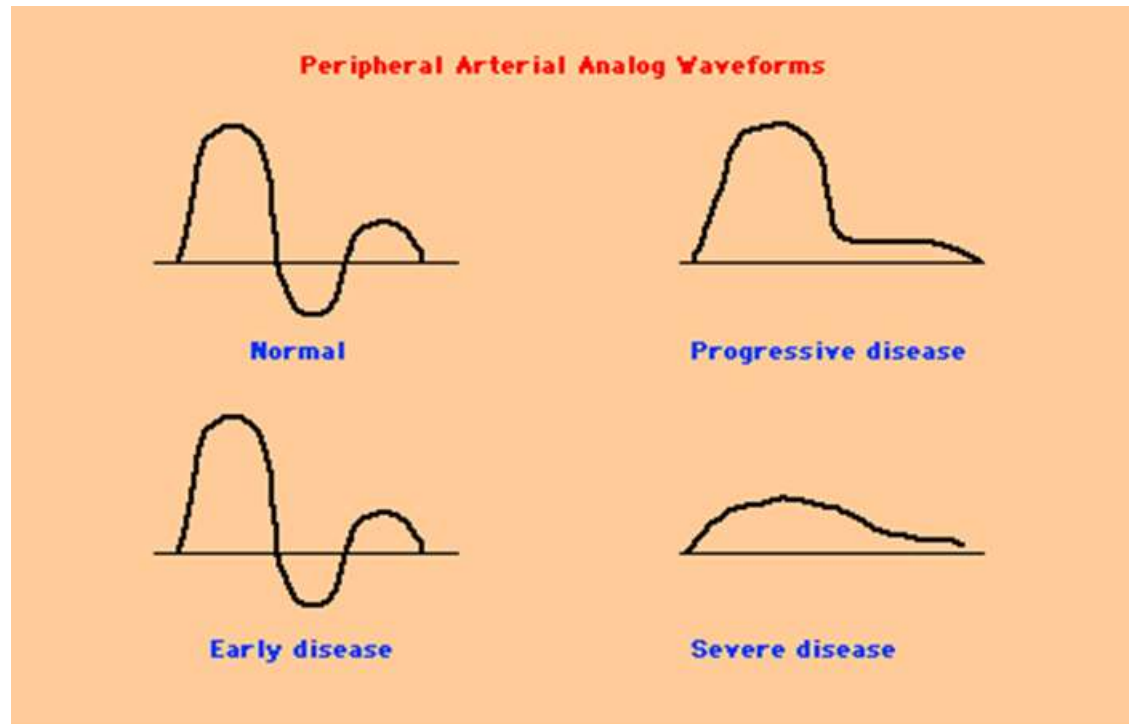
- Ultrasound doppler
- Ankle-brachial index
- Ultrasound duplex scanning
- Thermometry
- Angiography
- CT and MRT angiography
- Endovascular ultrasound scanning
- pO₂ evaluation methods
- Functional tests

Ultrasound doppler

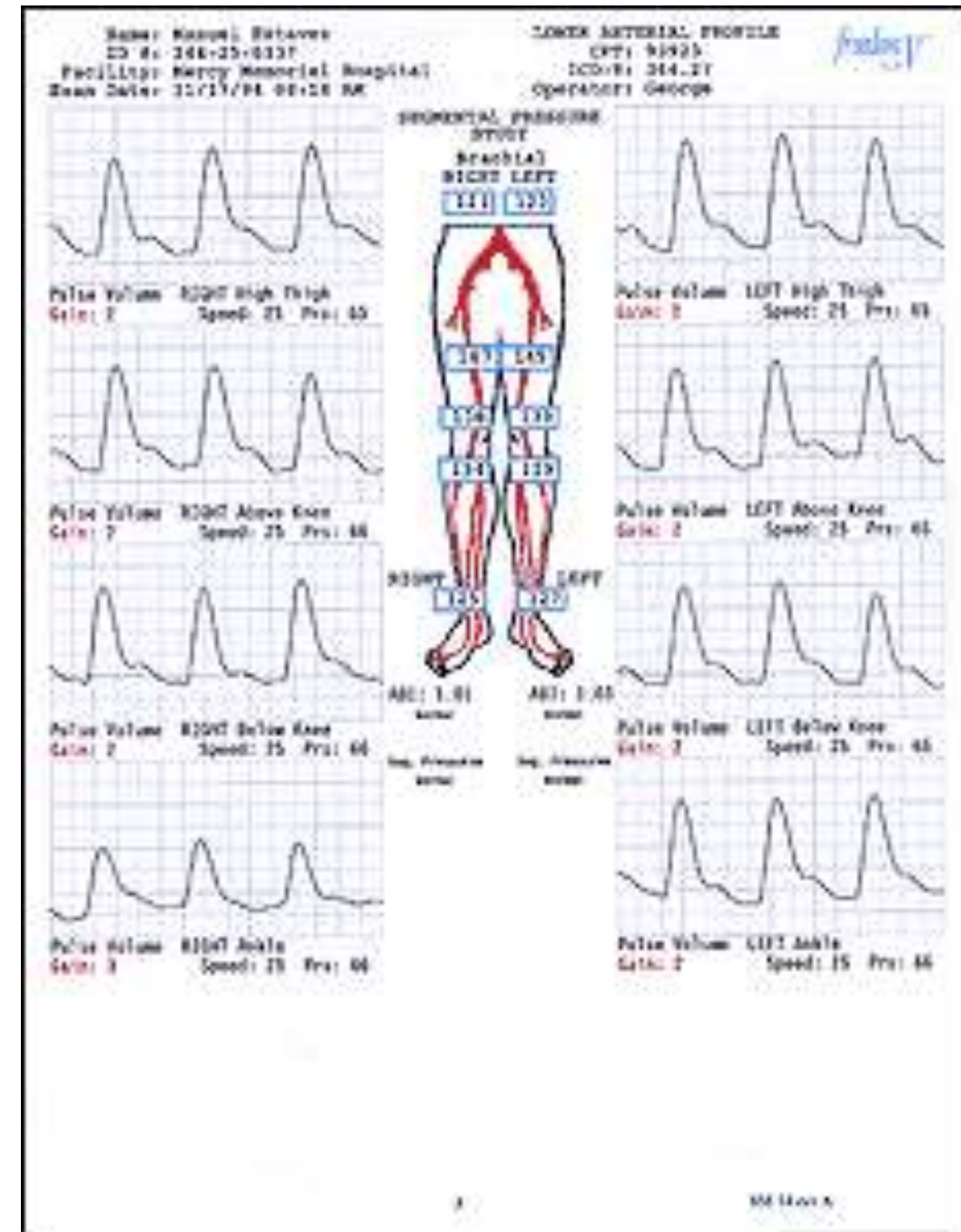
- Evaluation of arterial blood inflow without structural changes
- Functional test
- Indirect signs of arterial stenosis and occlusion
- Type of blood flow:
 - Normal triphasic
 - Stenotic and poststenotic (increased triphasic, turbulent)
 - Monophasic (occlusion)
 - Biphasic (postocclusion)



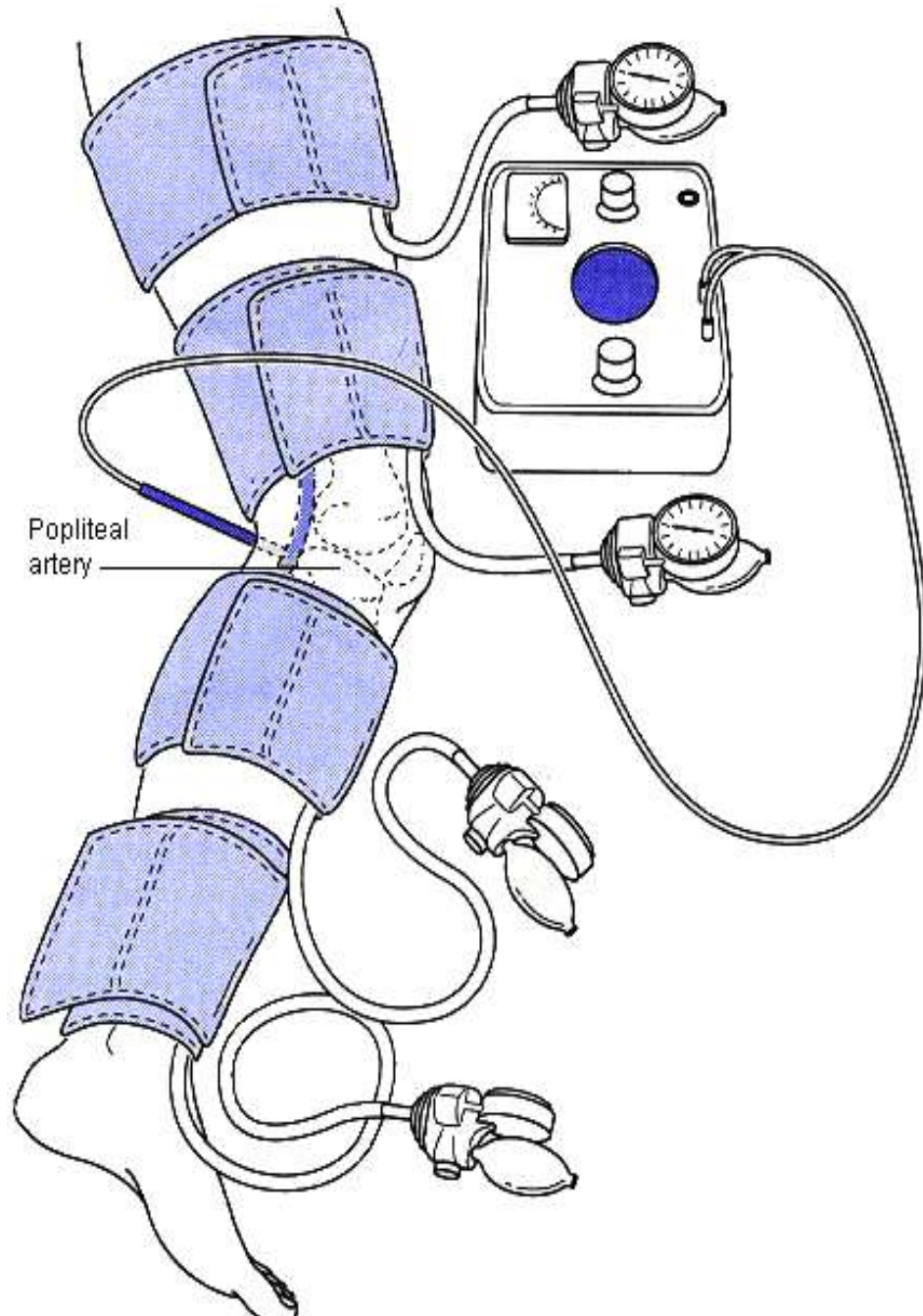
Ultrasound doppler



Ultrasonography in peripheral arterial disease Schematic representation of peripheral arterial waveforms in duplex Doppler ultrasonography in peripheral vascular disease. The normal peripheral arterial velocity waveform is triphasic and consists of a forward flow systolic peak, reversal of flow in early diastole, and forward flow in late diastole (top left). With progressive peripheral vascular disease, there is elimination of the reverse flow (top right), a decrease in systolic peak and an increase in flow in diastole (bottom left), and a decrease in flow in diastole (bottom right).



Ankle-brachial index



$$\text{ABI} = \frac{\text{(Systolic arterial blood pressure on ankle)*}}{\text{(Systolic arterial blood pressure on shoulder)**}}$$

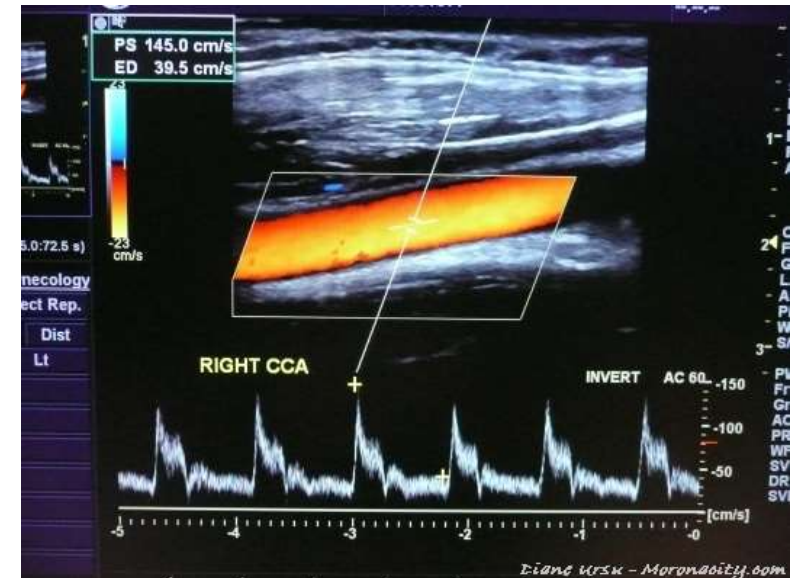
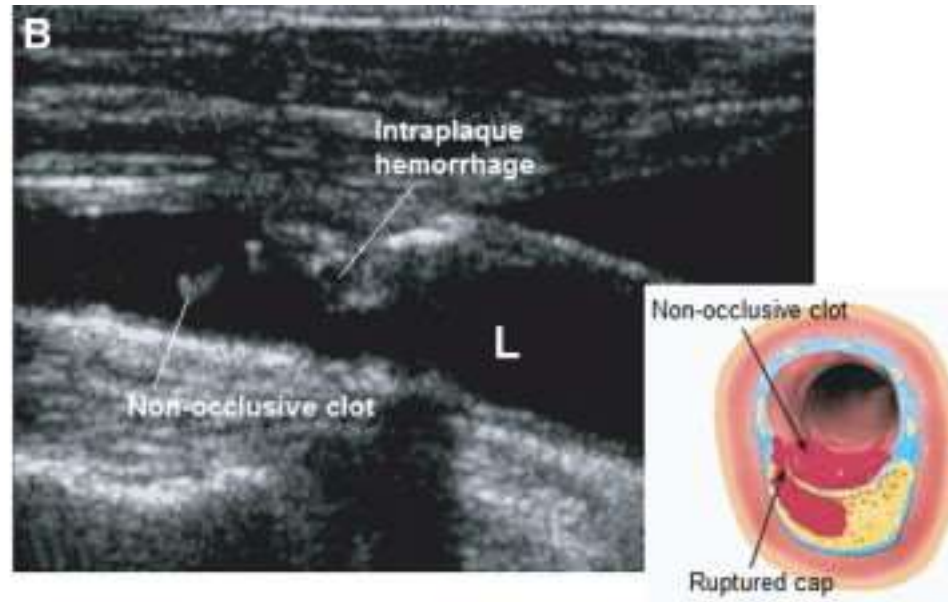
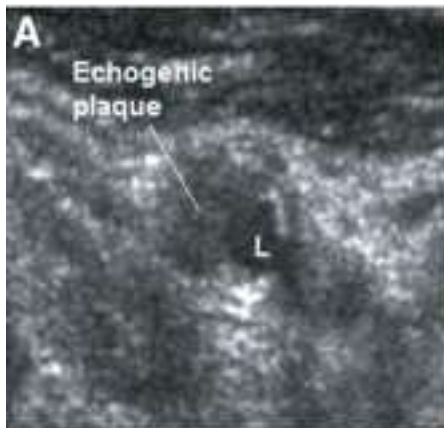
Normal:	0.9-1.2	(120/120 = 1)
Ischemia:	0.9-0.5	(60/120 = 0.5)
Critical ischemia:	<0.5	(50/120 = 0.4)
Arterial sclerosis	>1/2	(160/120 = 1/3)

* a.tibialis posterior

** a.brachialis

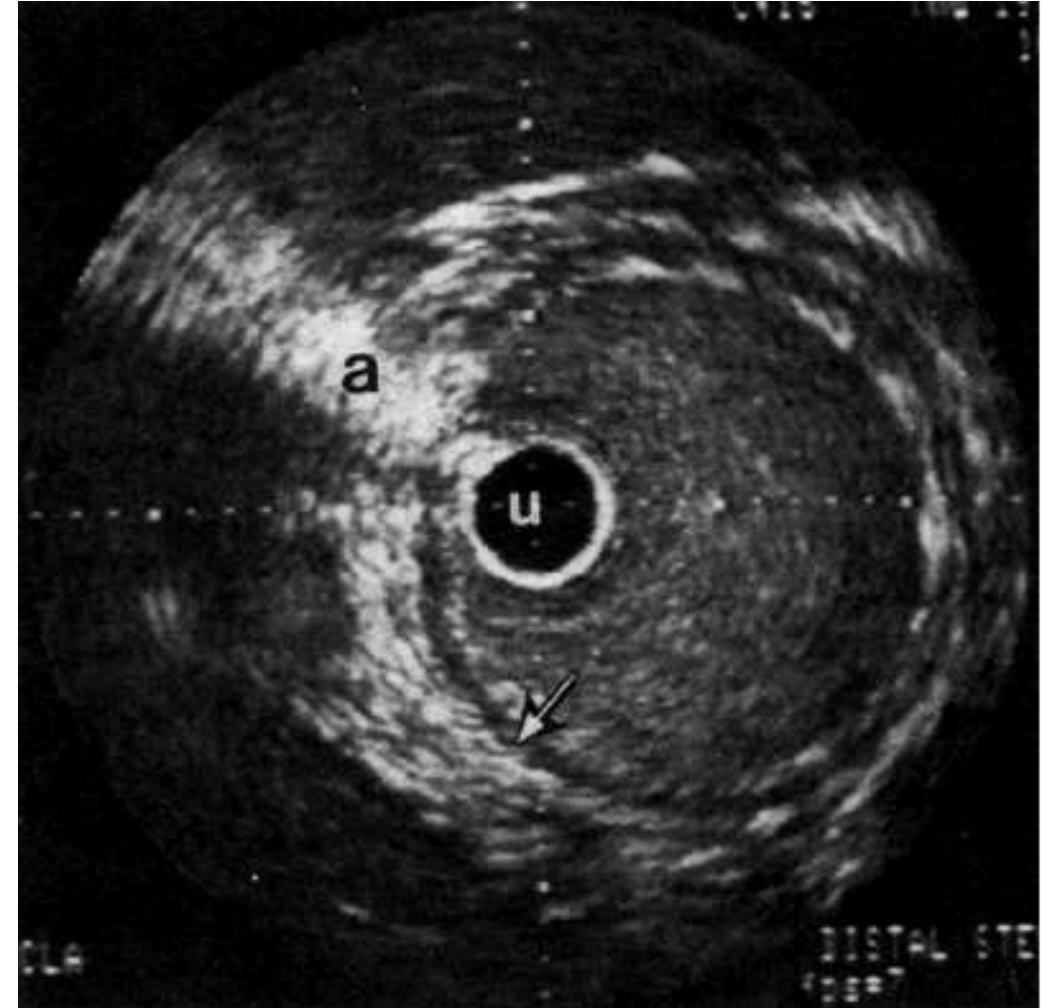
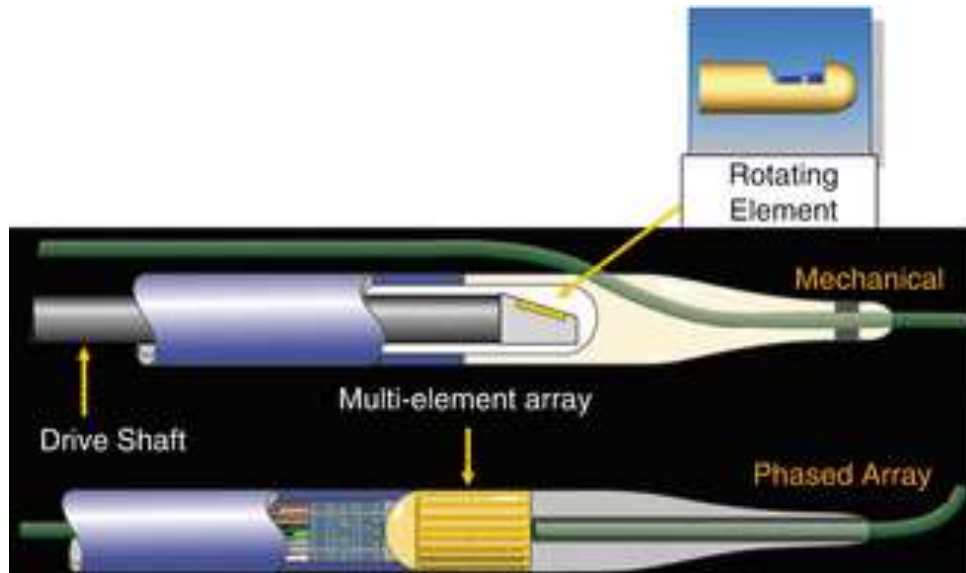
Duplex ultrasound

- Evaluation of structure changes in arteries (plaque, stenosis, occlusion)
- Evaluation of arterial blood inflow
- Localization, extension of changes
- Dynamics of changes, efficiency of treatment

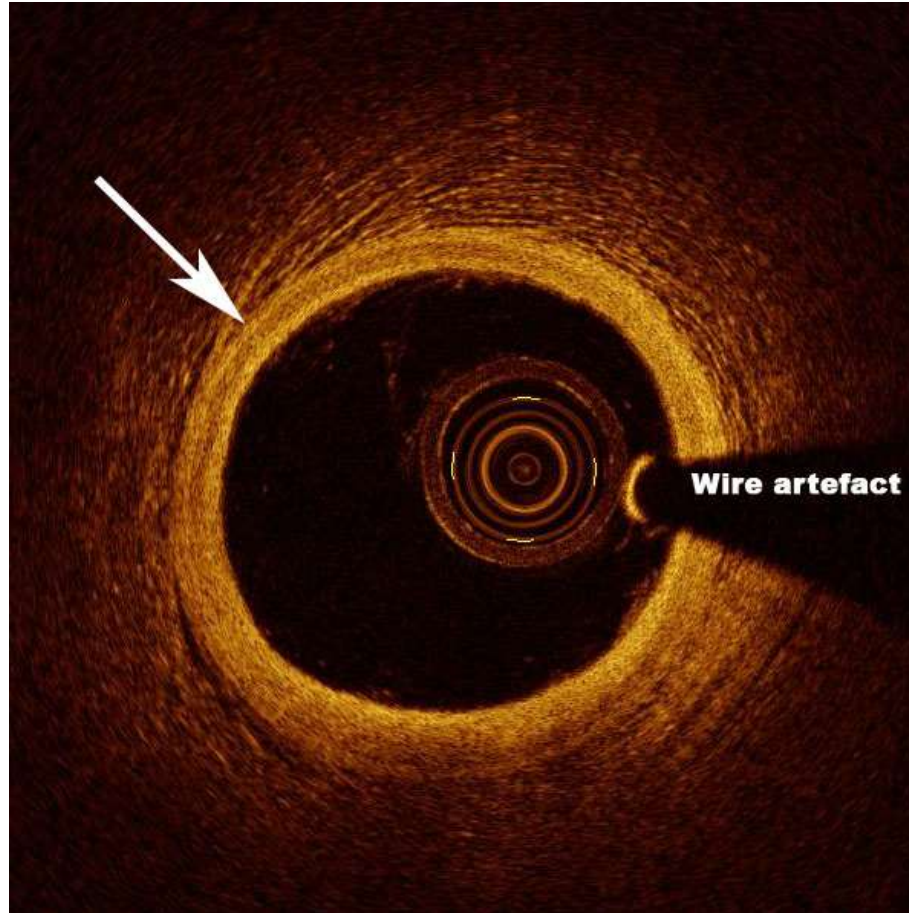


Endovascular ultrasound

- Evaluation of artery wall structure
- Structure of atherosclerotic plaque
- A special ultrasound probe, which injected into artery lumen



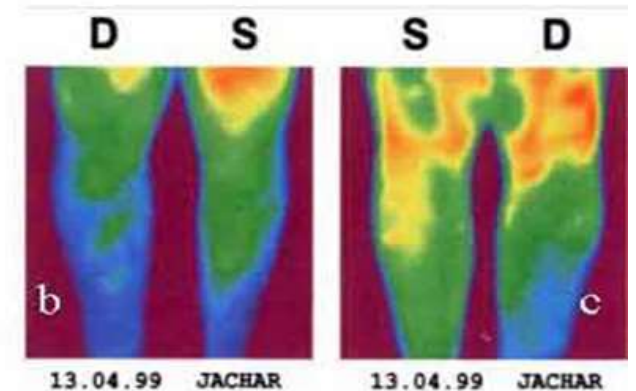
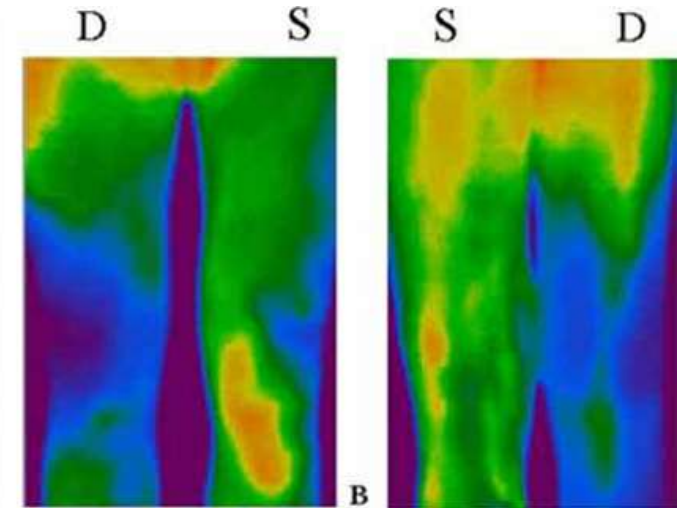
Endovascular optical coherent tomography



- Optical coherence tomography is an intravascular imaging modality like intravascular ultrasound.
- It utilizes light waves instead of sound waves for image acquisition and consequently provides a quantum leap in coaxial resolution.
- Light waves near infrared range (1,300 nm wavelength) are projected around the imaged structure and the reflected backscattered light signals form the images for analysis.
- High resolution image of all layers of vessel wall, plaque, stent, intima/neointima

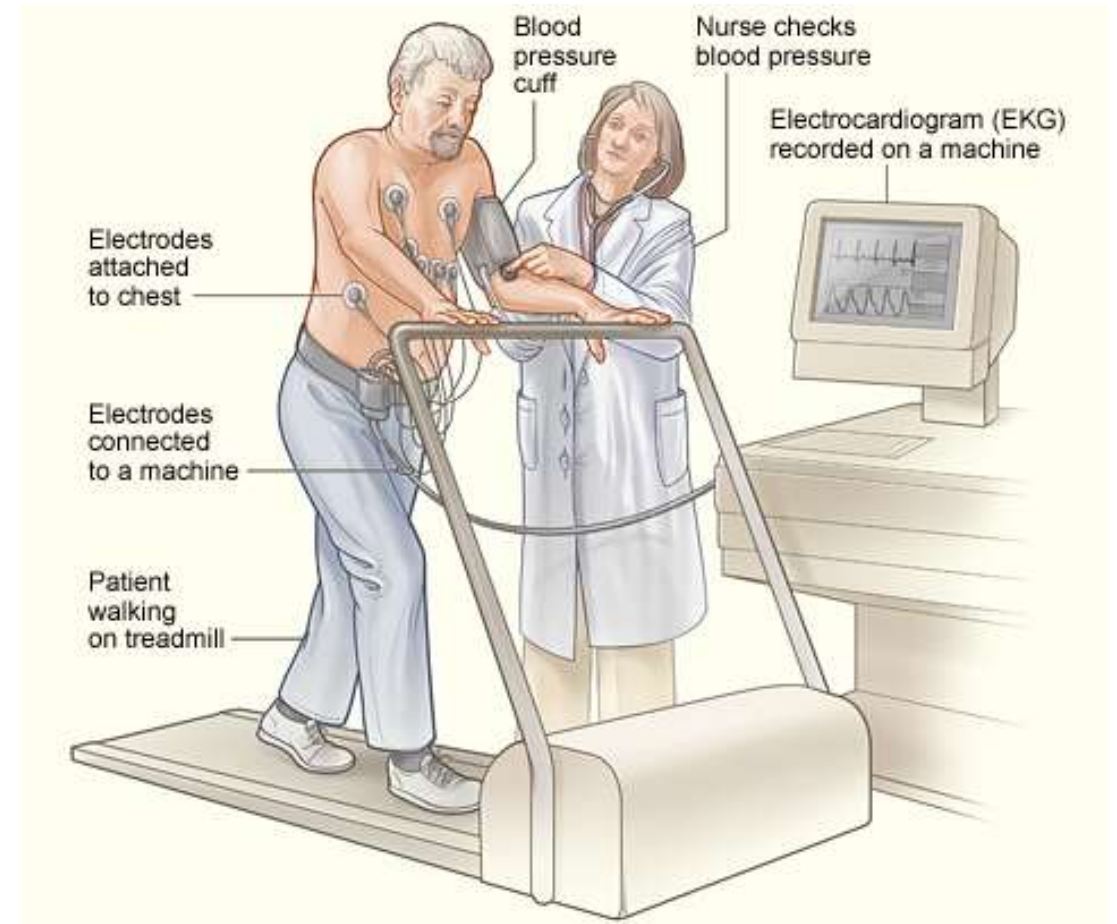
Thermography

- Registration of skin temperature due to infrared radiation
- Decrease of skin temperature and radiation in case of artery insufficiency



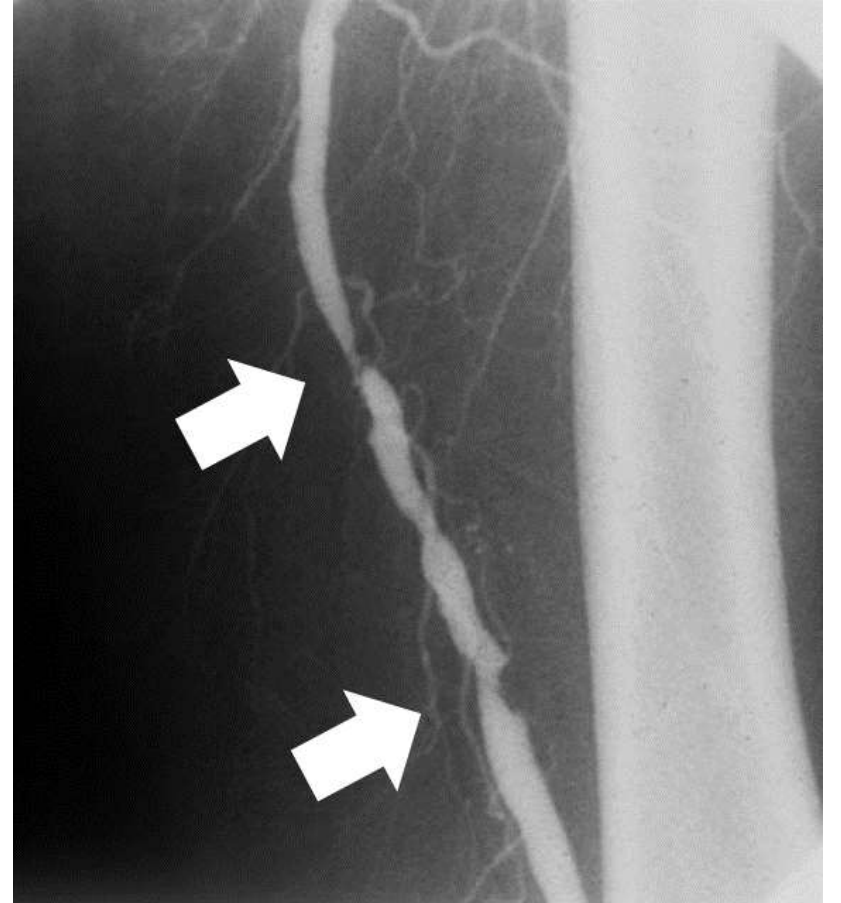
Functional (stress) tests

- Veloergometry, treadmill test
- Registration of ECG, ultrasound examination during physical activity
- Test for non overt insufficiency
- Tolerance for physical activity
- Evaluation of degree for arterial insufficiency



Angiography

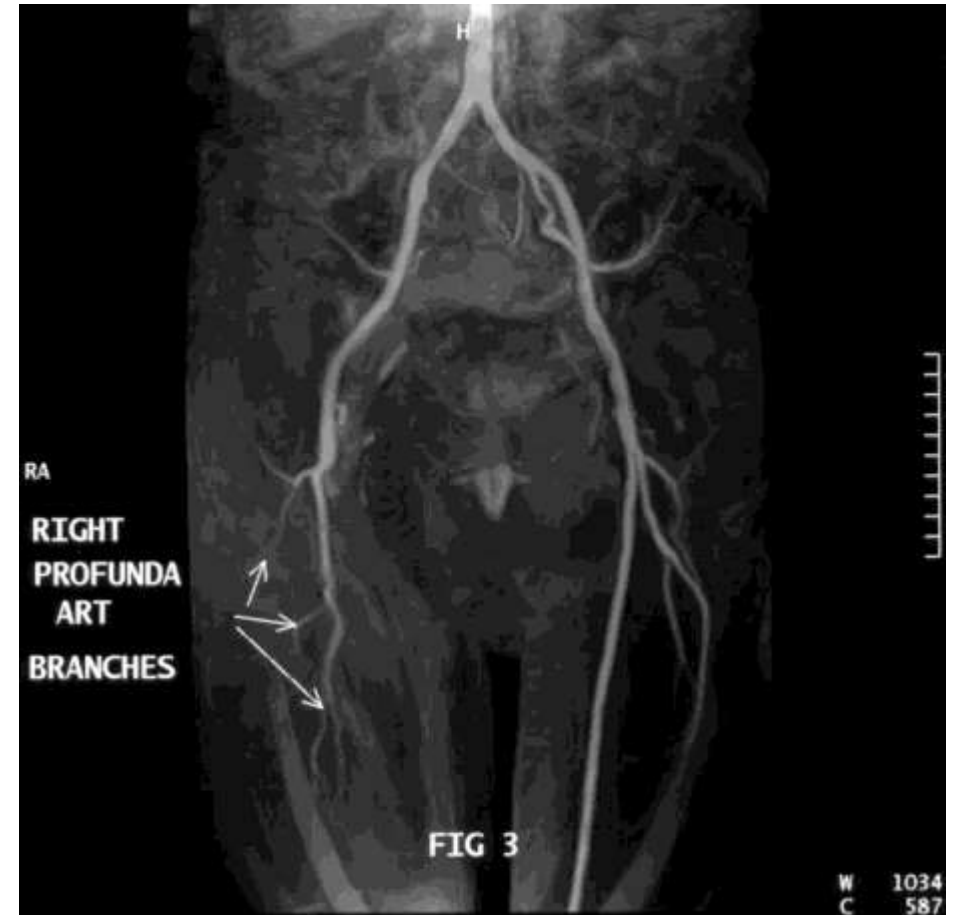
- Evaluation of arterial structure by X-Ray.
- Contrast injected direct into the artery (selective angiography) or into the vein with special X-ray technique (subtractive angiography)
- Visualization of stenosis and occlusion, evaluation of distal arteries, collateral flow



Atherosclerotic plaque stenosis in femoral artery (contrast selective arteriography)

Angiography

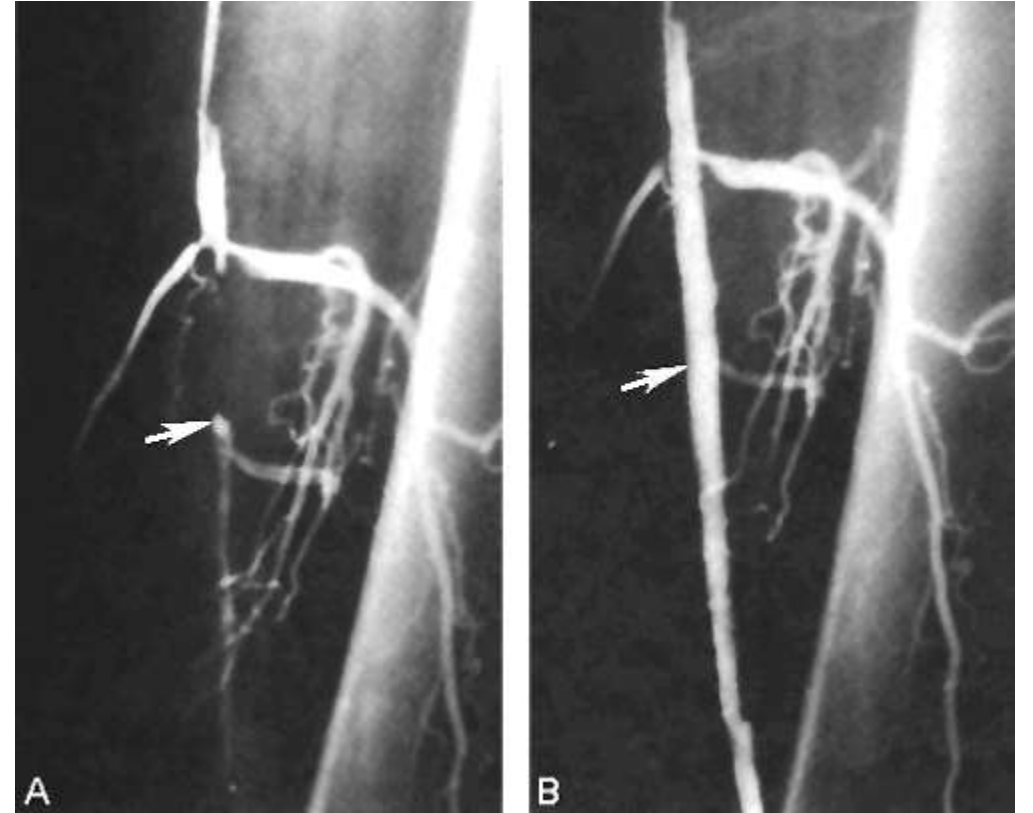
- Verification of etiology
- Evaluation of possibility for revascularization
- Performing of endovascular recanalization (balloon angioplasty, stenting, thrombectomy)



Occlusion of right femoral artery with collateral flow through profunda artery

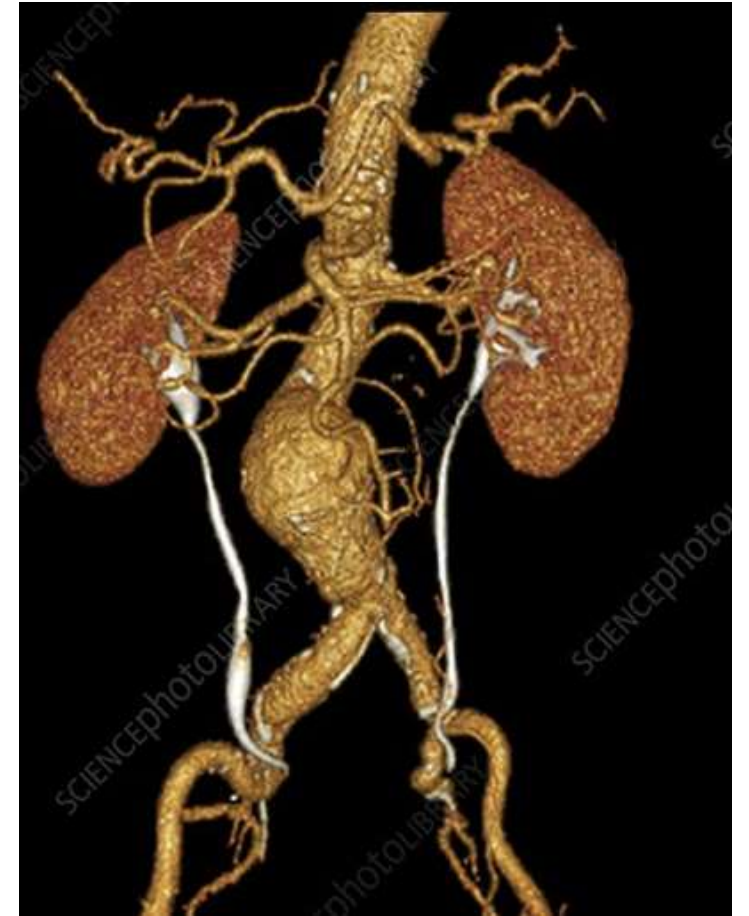
Angiography

- Occlusion of right femoral artery before and after recanalization



CT angiography

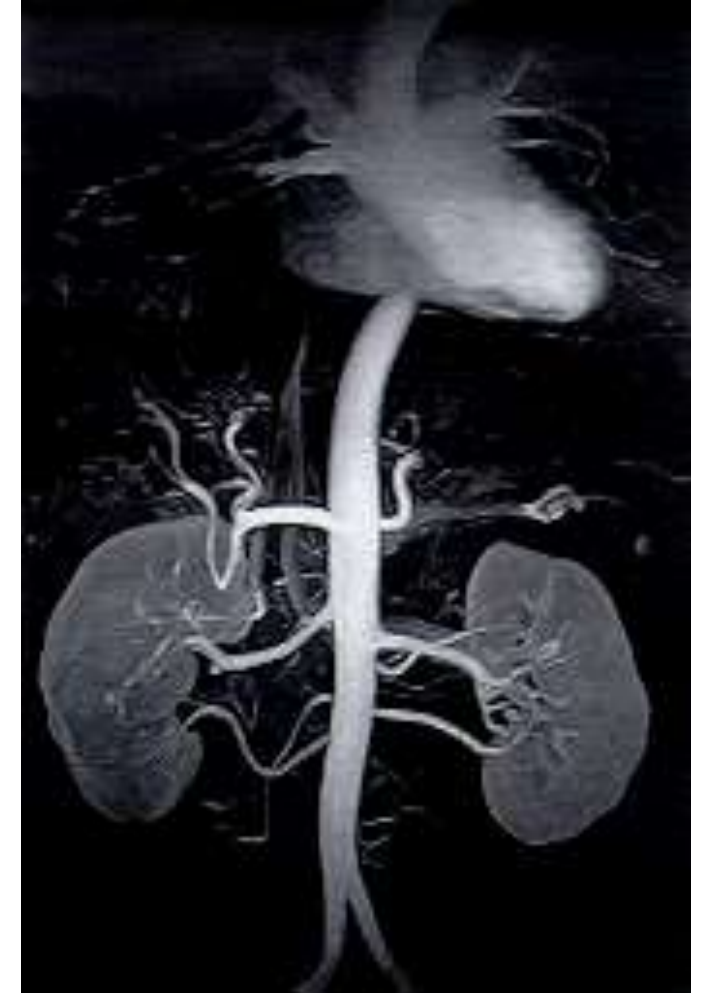
- Visualization of all arterial system structure after injecting contrast substance into peripheral vein
- Possibility of 3D reconstruction of all arterial system



Infrarenal aneurism of aorta in 3D CT reconstruction

MRI angiography

- Visualization of all arterial system structure after injecting magnetic contrast (gadolinium) substance into peripheral vein
- Possibility of 3D reconstruction of all arterial system
- Absence of radiological loading



Basic principles of artery diseases treatment

Stop progression of the main disease (atherosclerosis, arteriitis)

Increase of microcirculation

Increase of metabolic function

Increase of collateral blood inflow

Prophylaxis of thrombosis

Treatment of arterial diseases



Cessation of smoking is strongly indicated for ALL PATIENTS with arterial disease irrespective of etiology

Etiological treatment

No Tobacco
Positive attitude

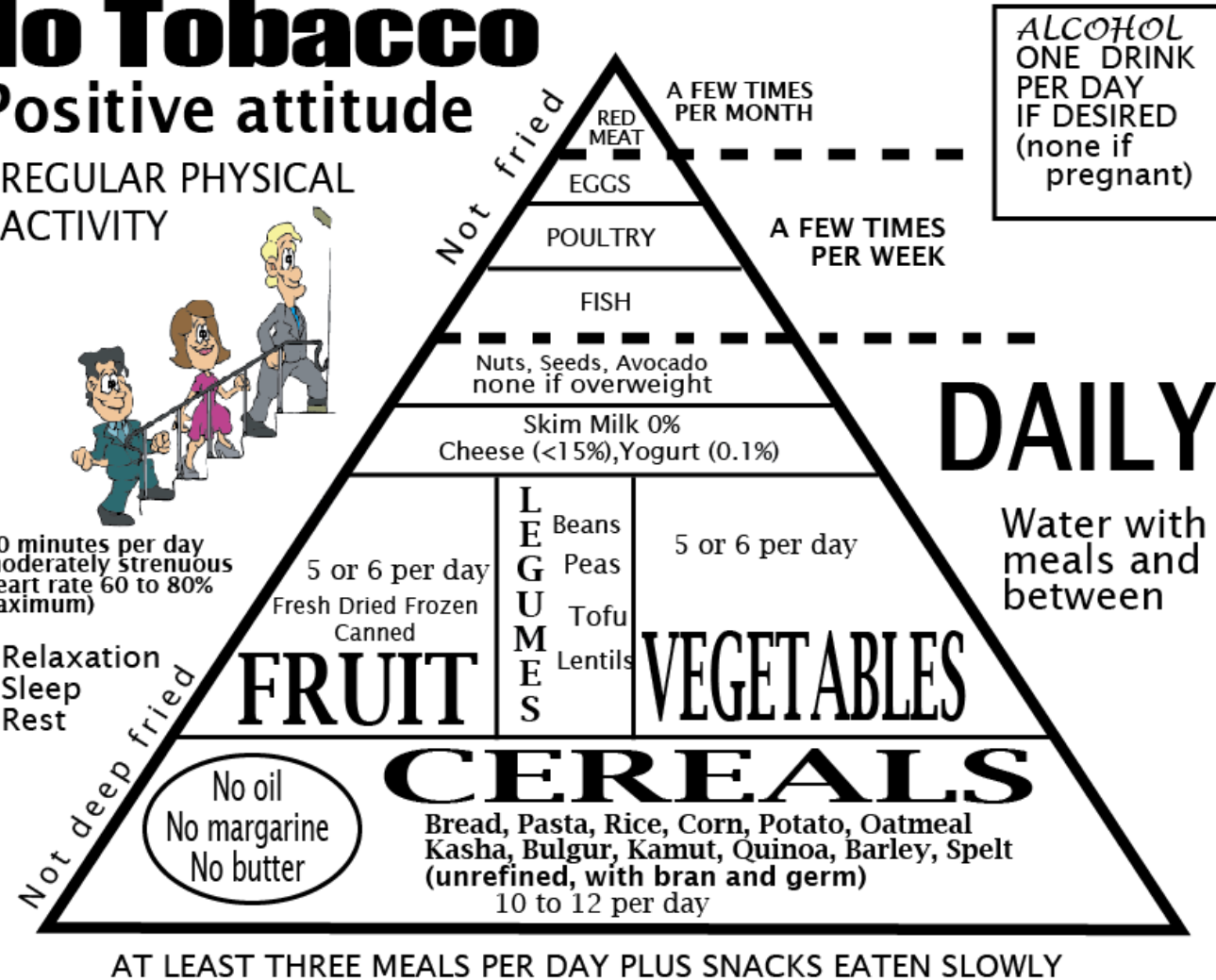
REGULAR PHYSICAL
ACTIVITY



(30 minutes per day
moderately strenuous
-heart rate 60 to 80%
maximum)

Relaxation
Sleep
Rest

ALCOHOL
ONE DRINK
PER DAY
IF DESIRED
(none if
pregnant)



• Atherosclerosis:

- Diet with restriction of (fats) and carbohydrates
- Statins - reduction of cholesterol production
- Polyunsaturated fat acids (omega-3, omega-6)

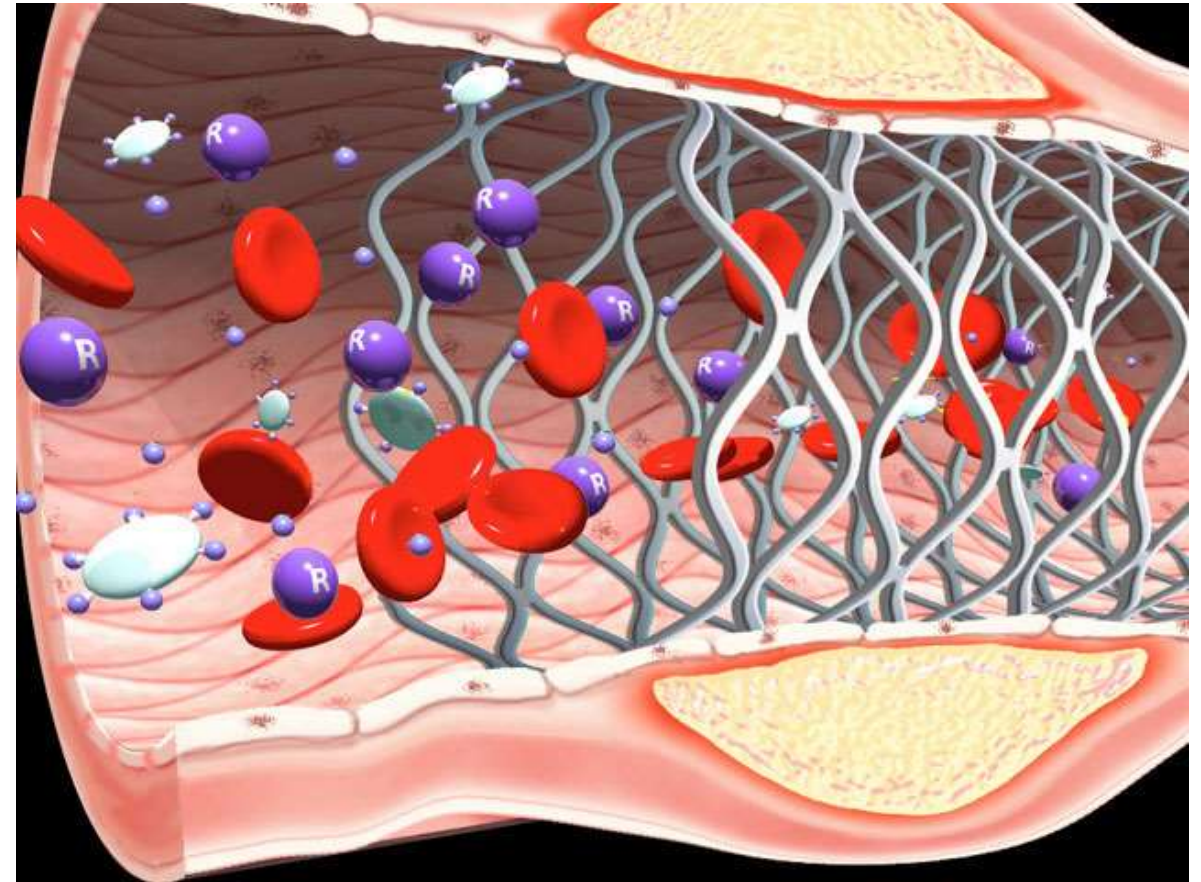
Etiological treatment

- Arteritis – autoimmune disease:
 - Steroid hormones
 - Cytostatic drugs
 - Antivirus drugs
 - Antibiotics



Improvement of collateral blood inflow

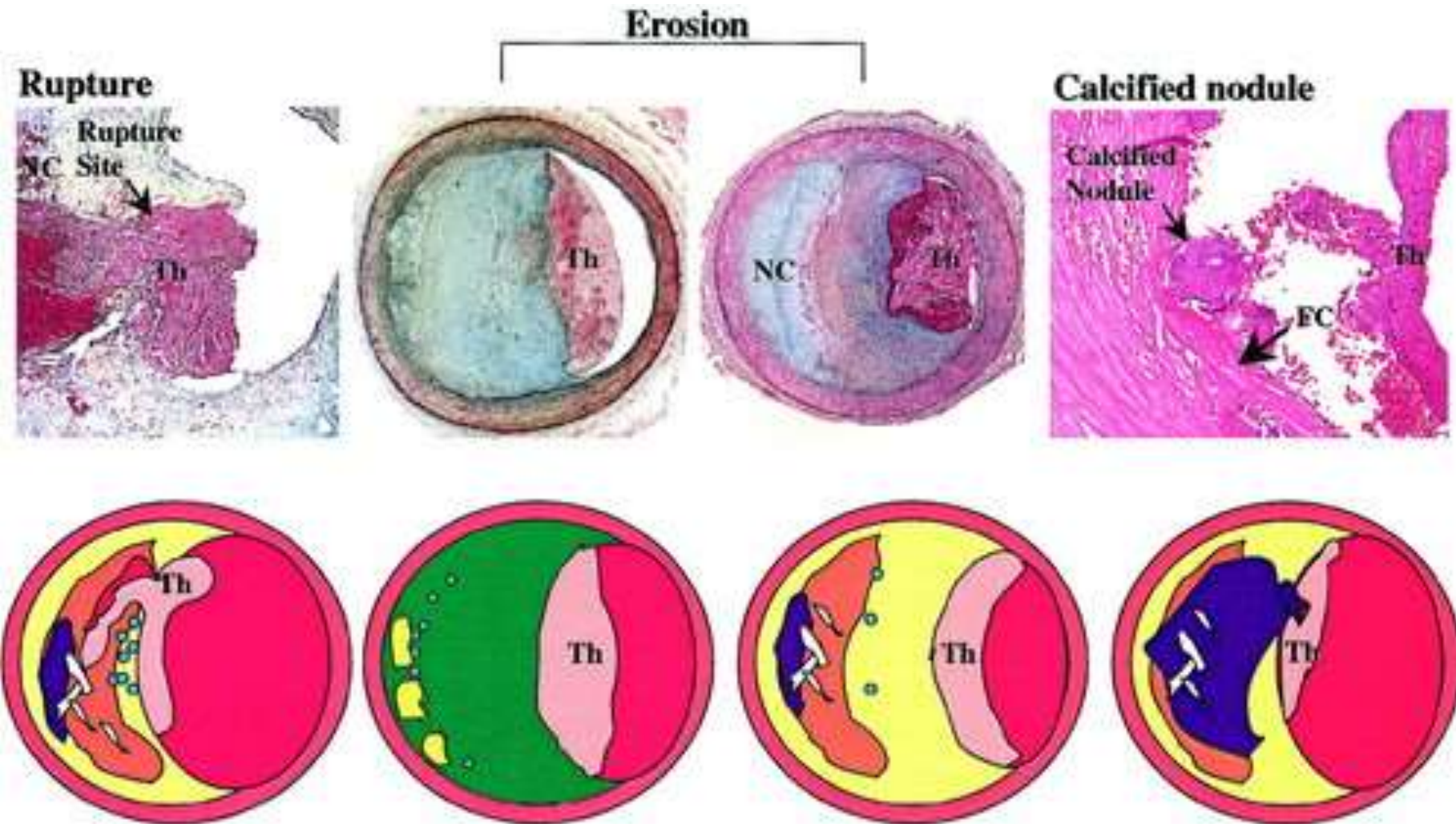
- Training walking
- Physiotherapy procedures (magnetic, electric calf stimulation)
- Spasmolytic and vasodilating drugs (carefull!)
- Decrease of blood viscosity
- Sympathetic nodes destruction and removing



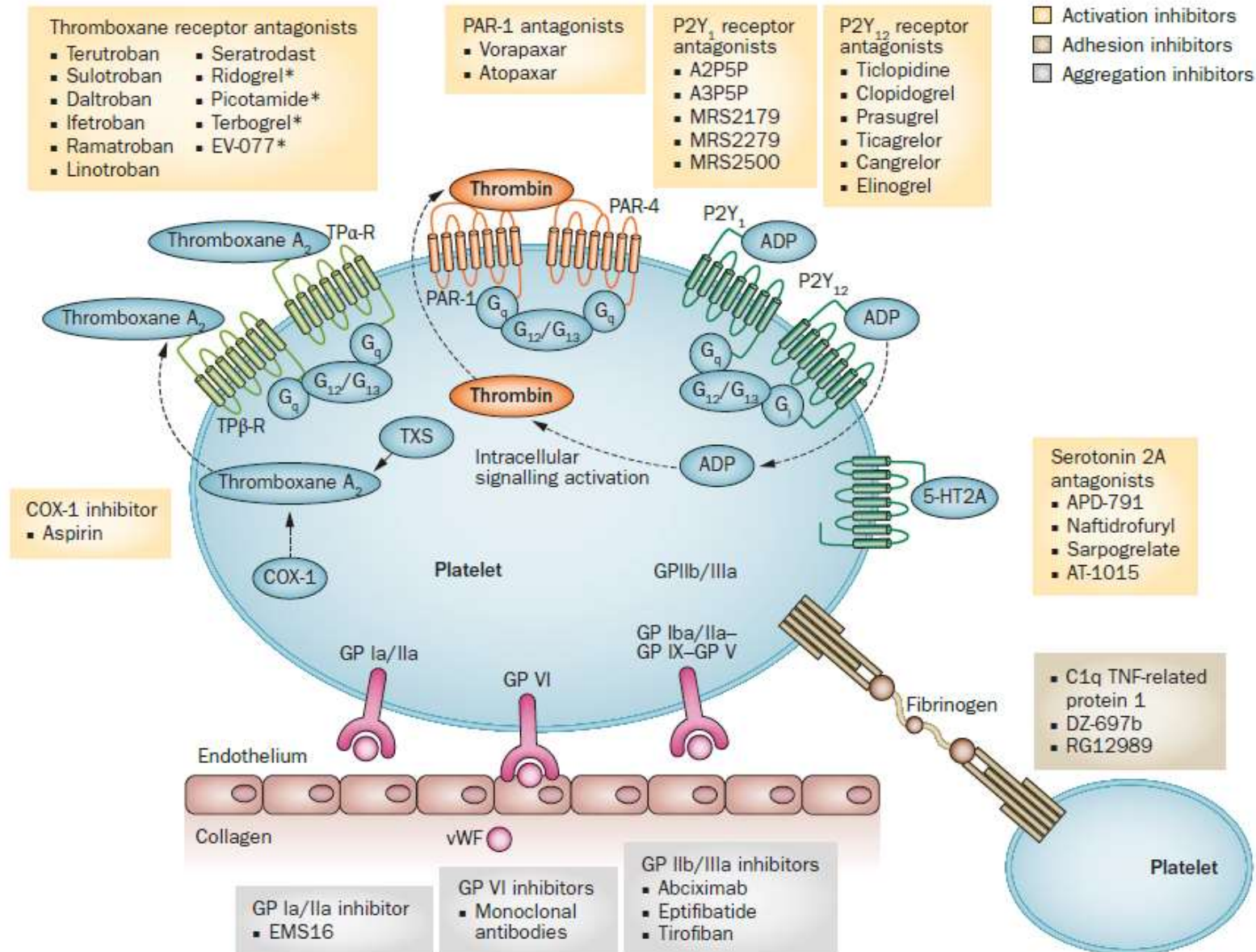
Pharmacological vasodilation

- Myothropic spasmolytic drugs: papaverini, drotaverine, dusodril
- Ca-blockers: nifedipine
- Alfa-adrenoblockers: - dihydroergotaminum, prazosinum
- **Prostaglandin drugs (PgE1): alprostadi**
- Complex: duvadilan, trentali
- Increase arterial blood inflow in not damaged vessels
- Because of system vessel dilation can reduce blood inflow in compromised region
- Syndrome of “blood steeling”

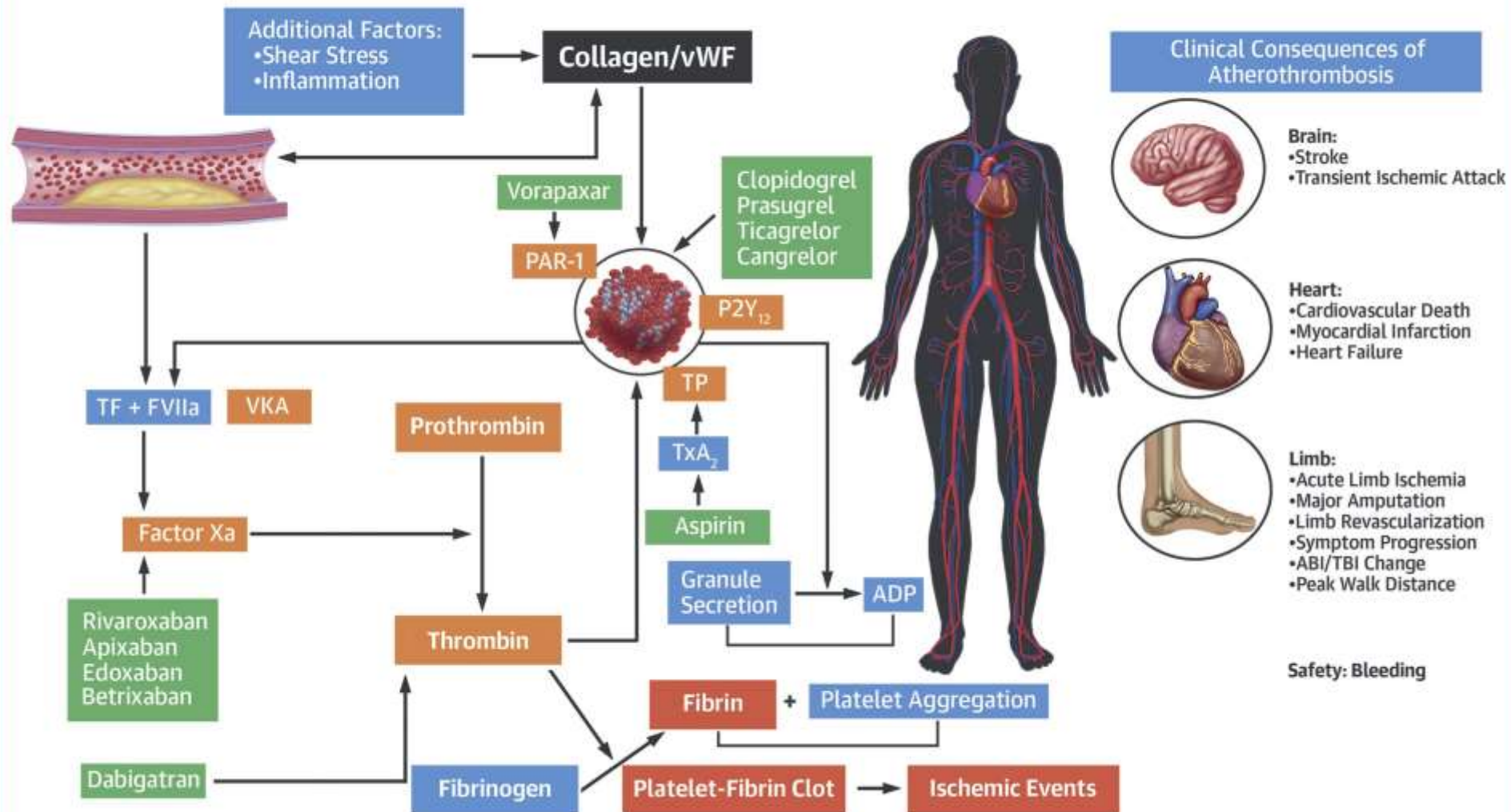
Rupture, erosion and healing



Decrease of platelet aggregation

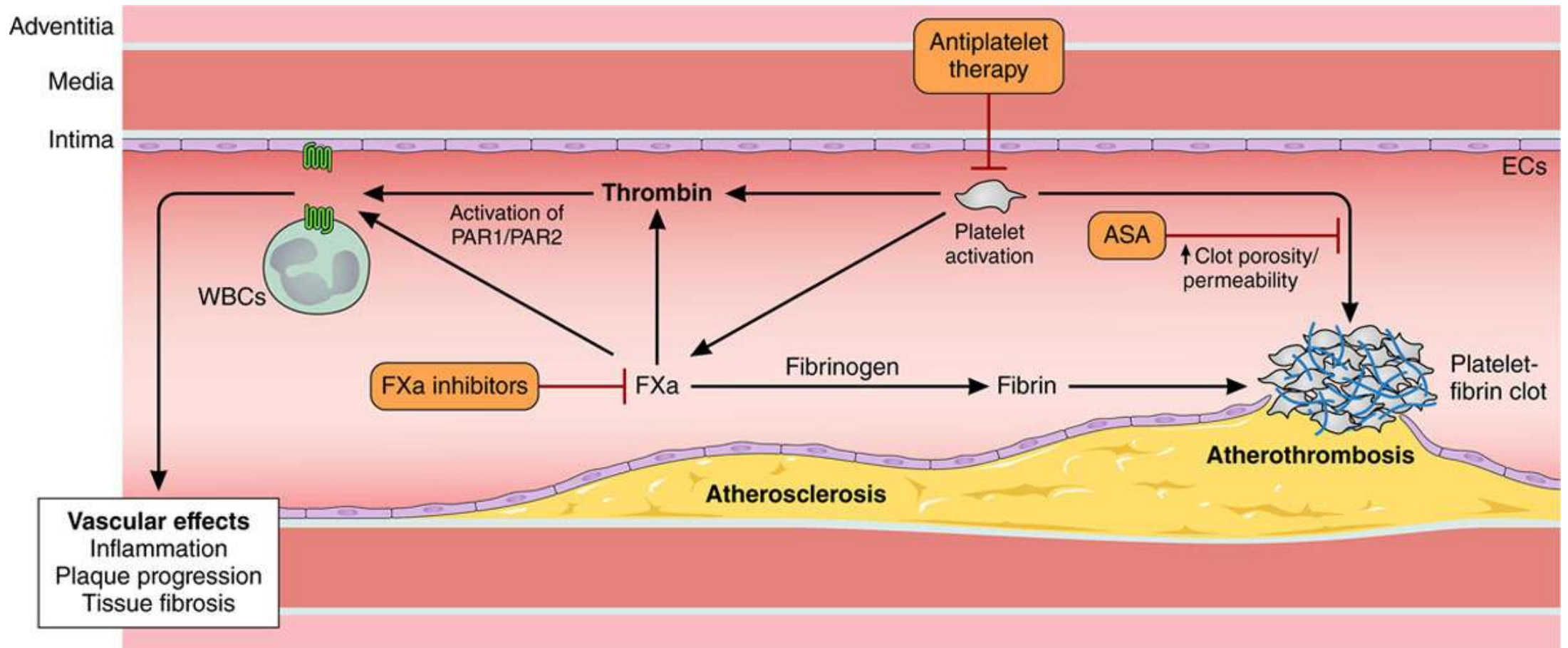


CENTRAL ILLUSTRATION: Mechanisms of Antithrombotic Medications and Clinical Endpoints Important to Patients With Peripheral Artery Disease



Jones, W.S. et al. J Am Coll Cardiol. 2018;71(3):352-62.

Dual antithrombotic therapy: rivaroxaban 2.5 mg bid + ASA 100 mg



Decrease of blood viscosity

- **ASA** (aspirin: platelet COG inhibition, reduction of thromboxane A₂ synthesis)
- **p2Y₁₂ inhibitors** (clopidogrel, prasugrel, ticagrelor: inhibition of ADP/fibrine receptors on platelet)
- **Pentoxifylline** (increase of cAMP, decrease of intracellular Ca concentration and improvement of platelet and red blood cells elasticity)
- **Anticoagulants** (rivaroxaban: reduction of thrombin level and decrease PAR-1 activation)
- **Heparinoids** (sulodexide: decrease synthesis of procoagulant factors by endothelium and platelets, restoring of GAGs on the surface of endothelium)
- **Nicotinic acid** (nicospan – nicotinic acid + drotaverine) (inductor for fibrinolytic system)

Increase of metabolic function and hypoxia tolerance

- Actovegine
- Solcoserile
- Riboxine
- Perindopril
- Alfa-lipoic acid, tioctic acid (Berlition)
- Vit. A, E, C
- Hyperbaric oxygen therapy



Hyperbaric oxygen therapy

- The patient put in the environment of high pressure with increased concentration of O₂ in special boxes
- This increase the amount of O₂ physically dissolved in blood
- Decrease ischemia and improve metabolism



Surgical treatment of chronic artery insufficiency

Open surgery

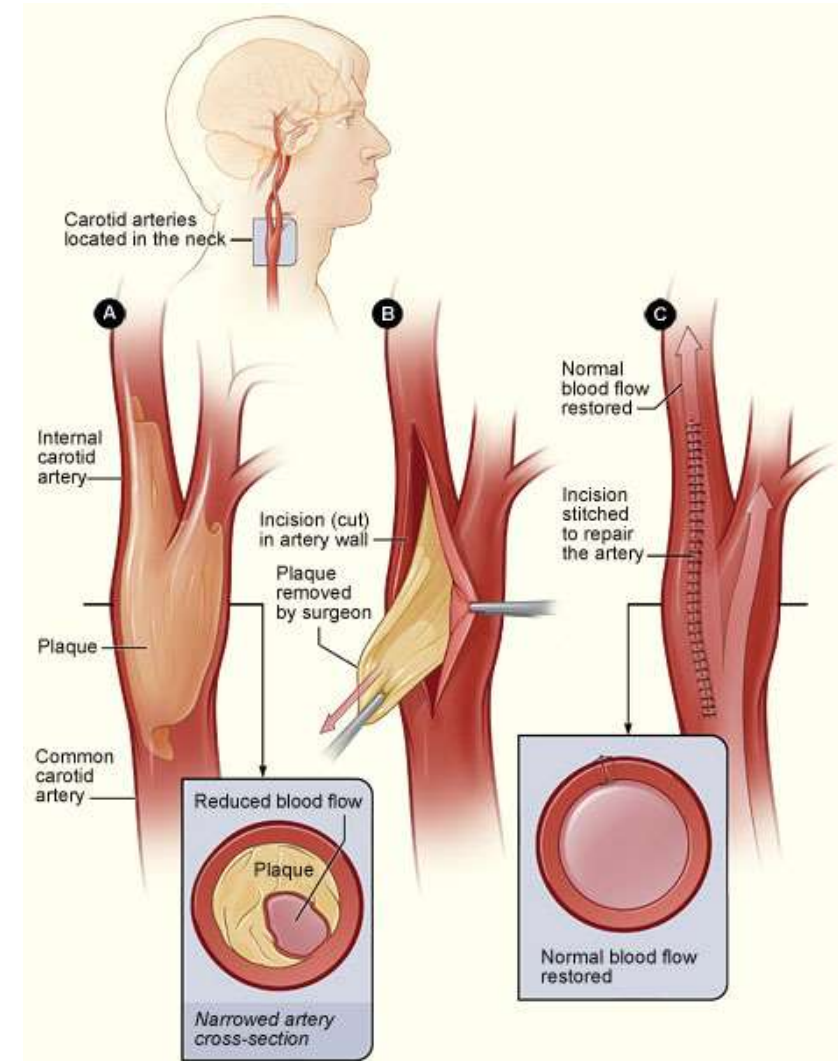
- Endarterectomy
- Arterial plastic
- Arterial bypass:
 - Venous graft
 - Arterial graft
 - Prosthetic graft

• Endovascular:

- Balloon angioplasty
- Stenting
- Mechanical recanalization (debulking)

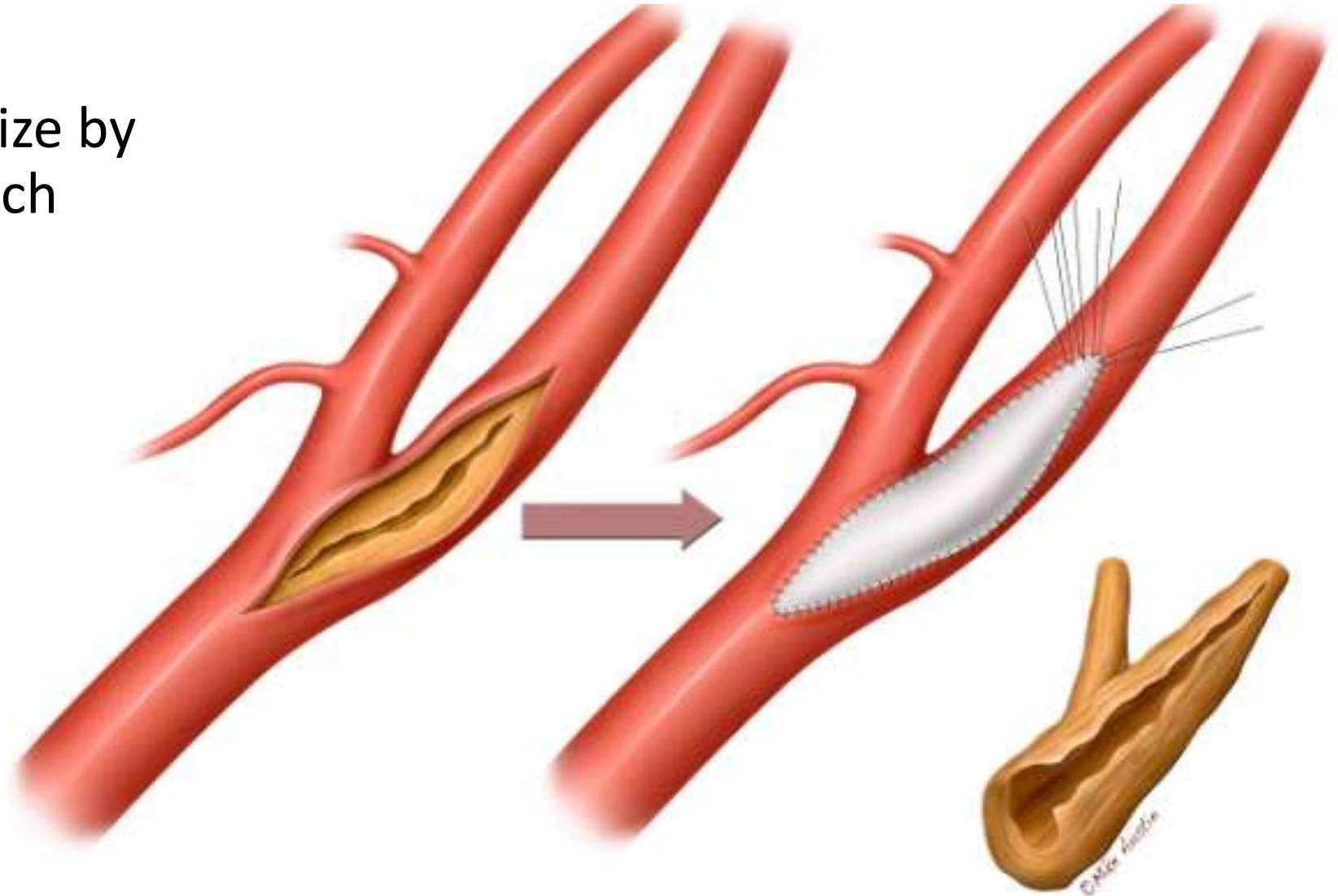
Endarterectomy

- Removing of atherosclerotic plaque with inner part of arterial wall through the incision in artery
- Good for large arteries with local stenosis and occlusion
- Femoral, carotid artery

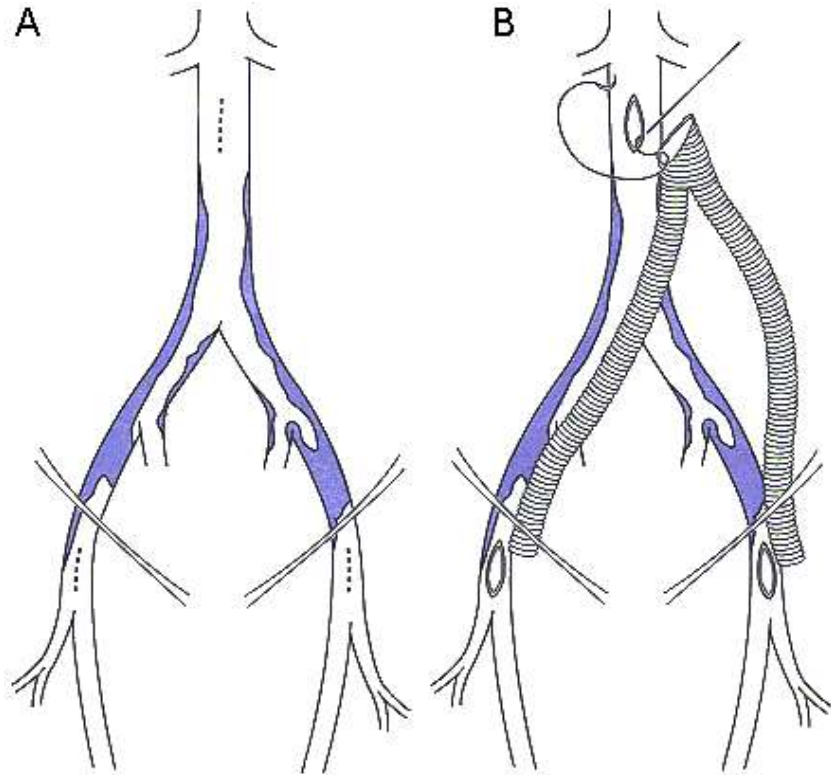


Arterial plastic

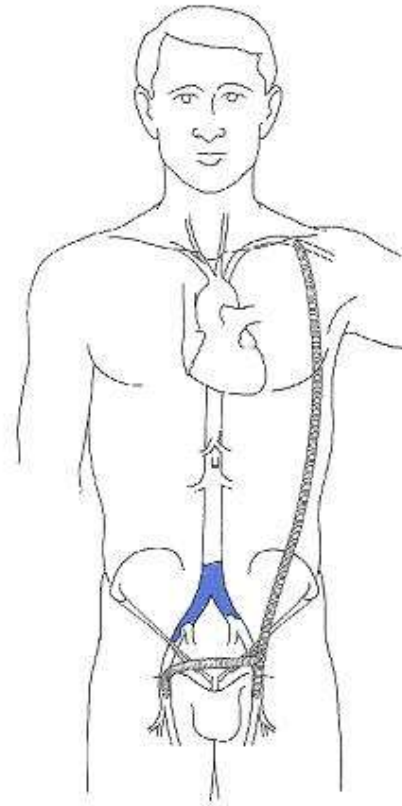
- Increase of arterial size by means of special patch
- Usually use after endarterectomy



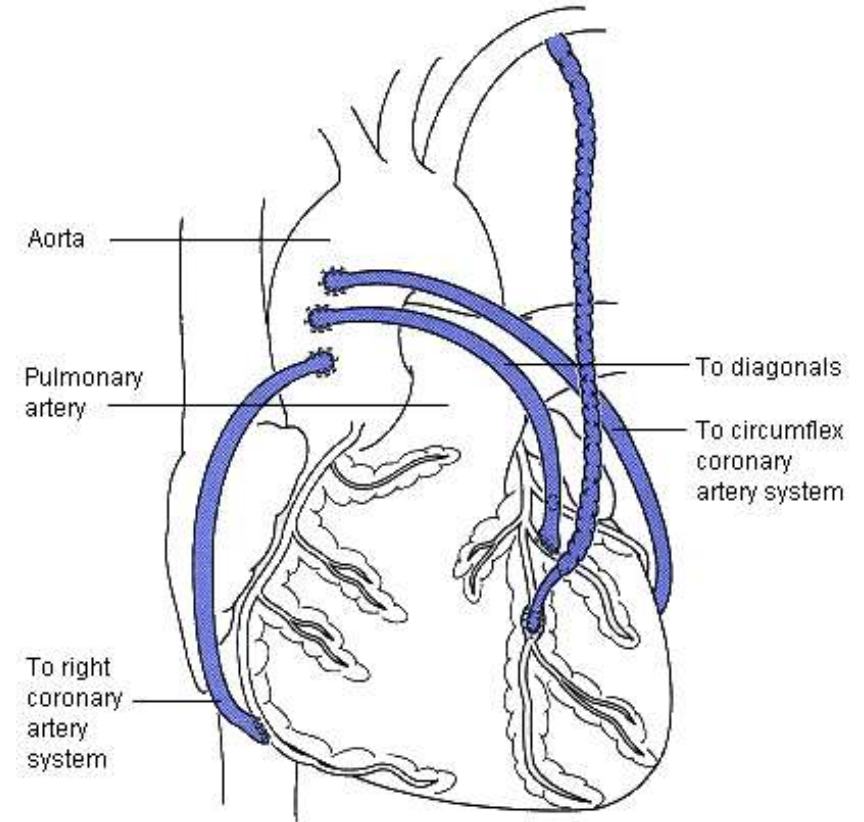
Arterial bypass



Aorto-femoral bifunctional
bypass



Extra-anatomical
bypass



Aorto-coronary bypass

Arterial bypass

- Open surgery
- Only in local occlusion, need free distal vessels
- Need stop of blood inflow during surgery
- Long term outcomes depend on graft quality
- Optimal – synthetic grafts
- After some time, grafts also may become occluded
- Complications:
 - Thrombosis
 - Re-occlusion
 - Aneurism
 - Bleeding
 - Infection

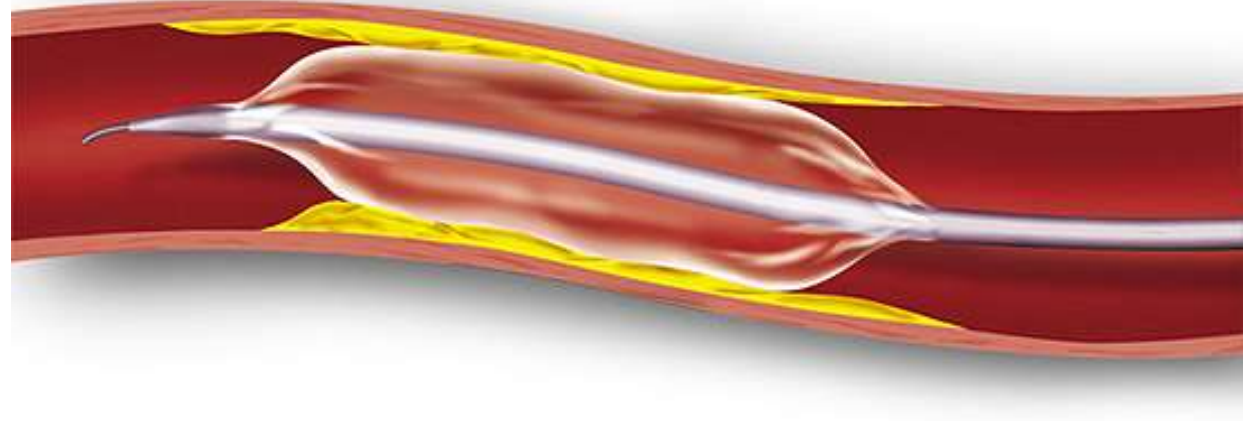
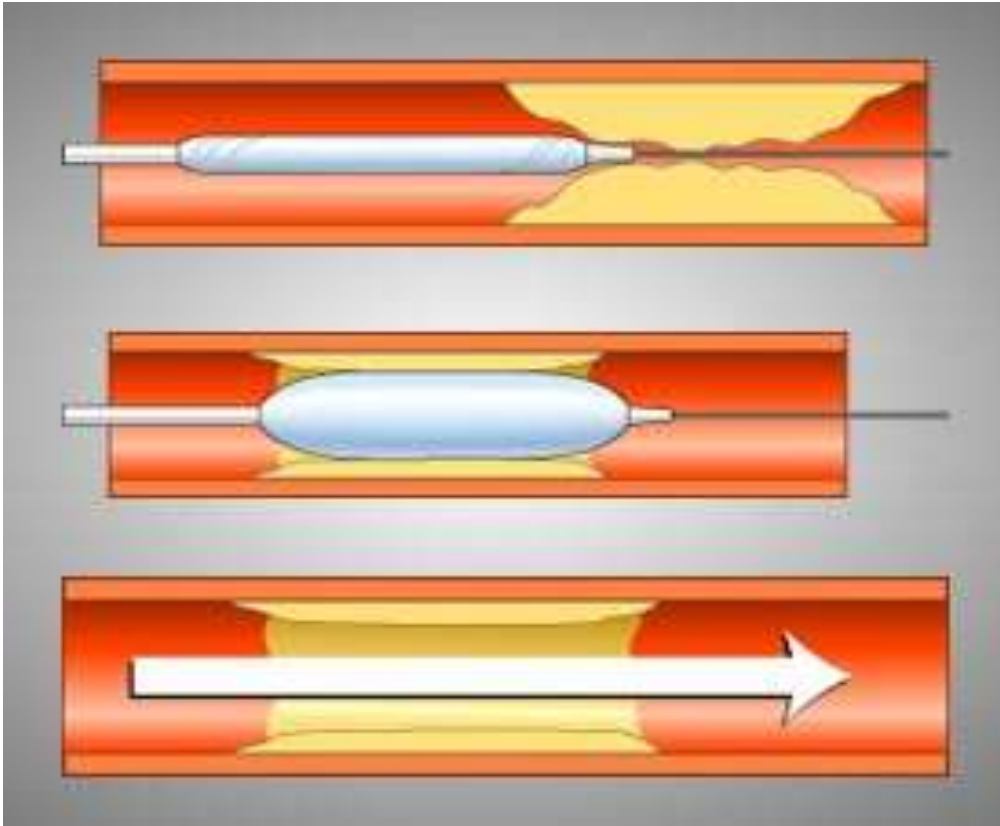


Endovascular procedures

- Under contrast X-ray navigation
- Access via peripheral artery (usually femoral or radial)
- By means of special endovascular catheters, which inserted to the zone of stenosis or occlusion
- Catheters allow to deliver drugs, instruments and grafts for intraluminal procedures

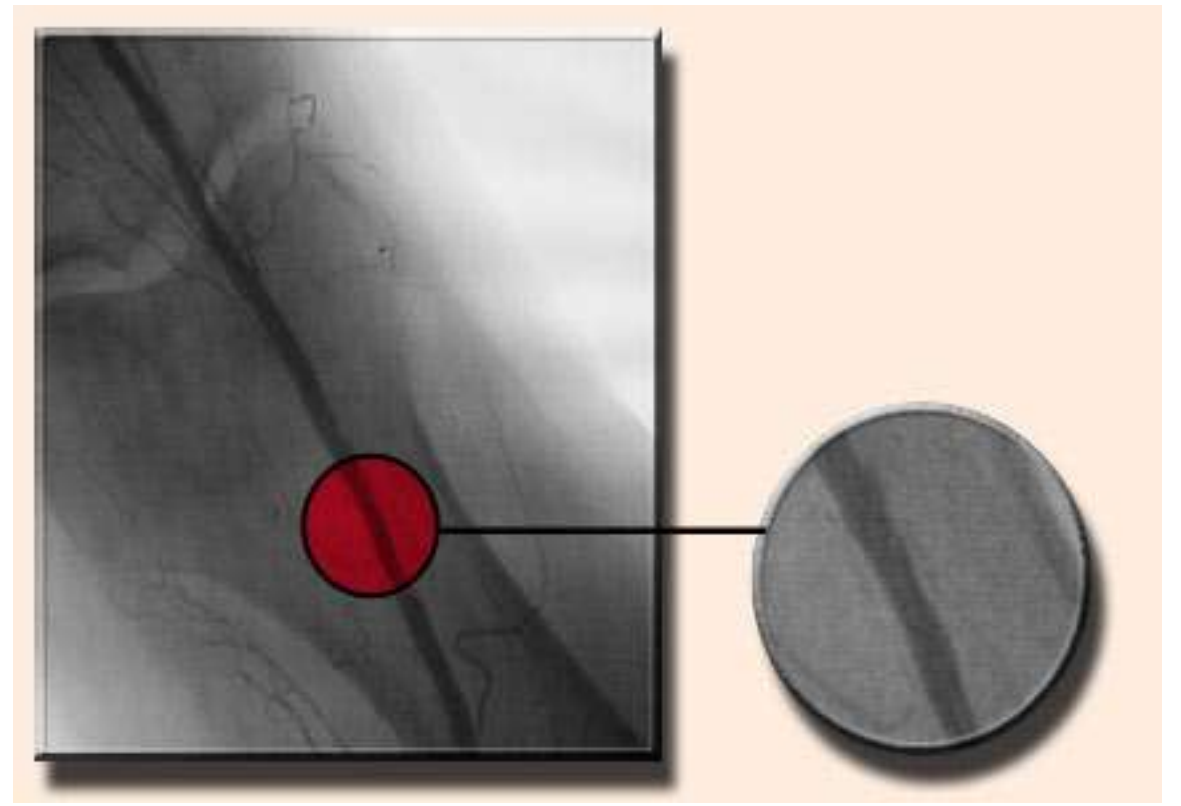
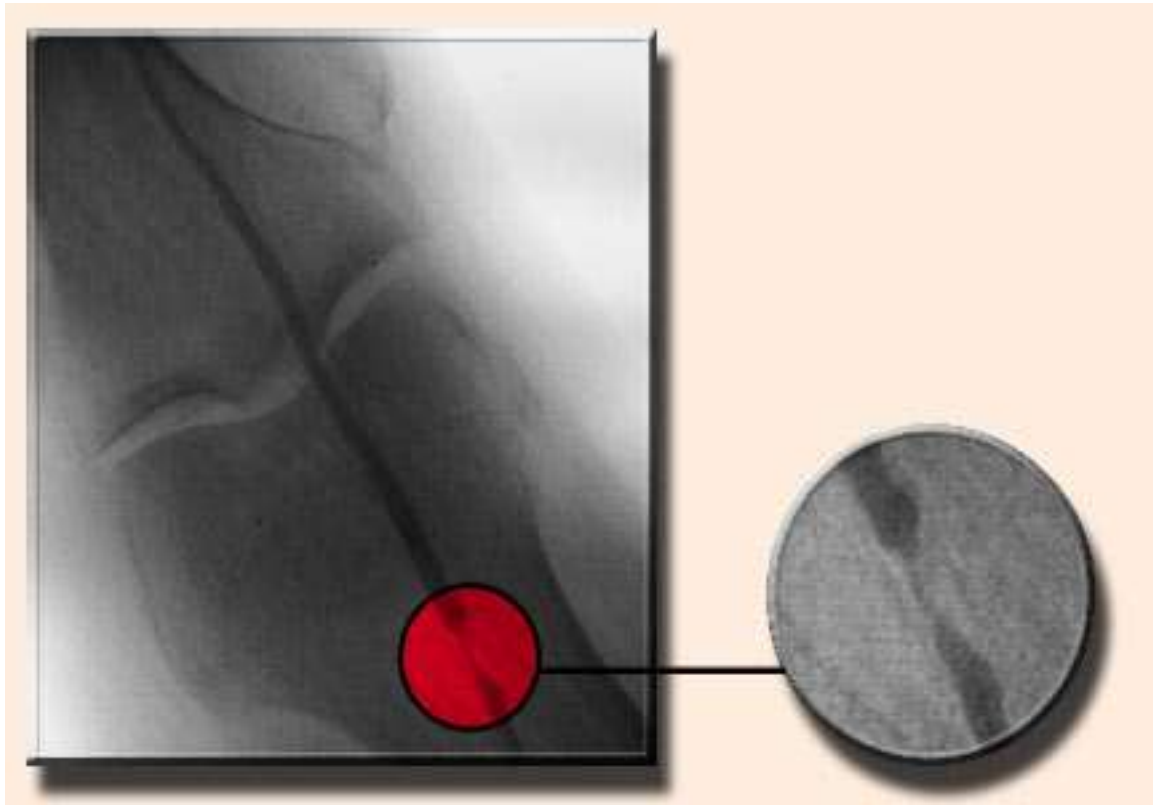


Balloon angioplasty



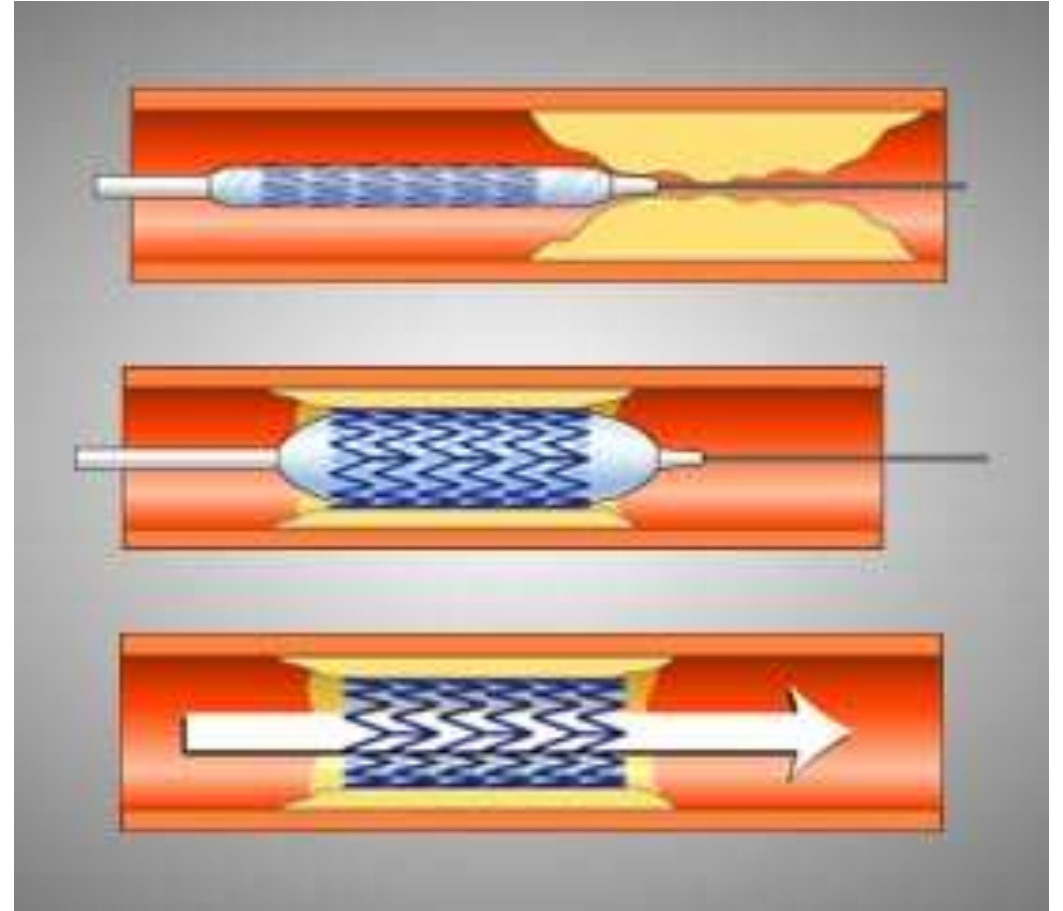
Mechanical dilatation of stenosis zone and plaque destruction

Angioplasty with balloon

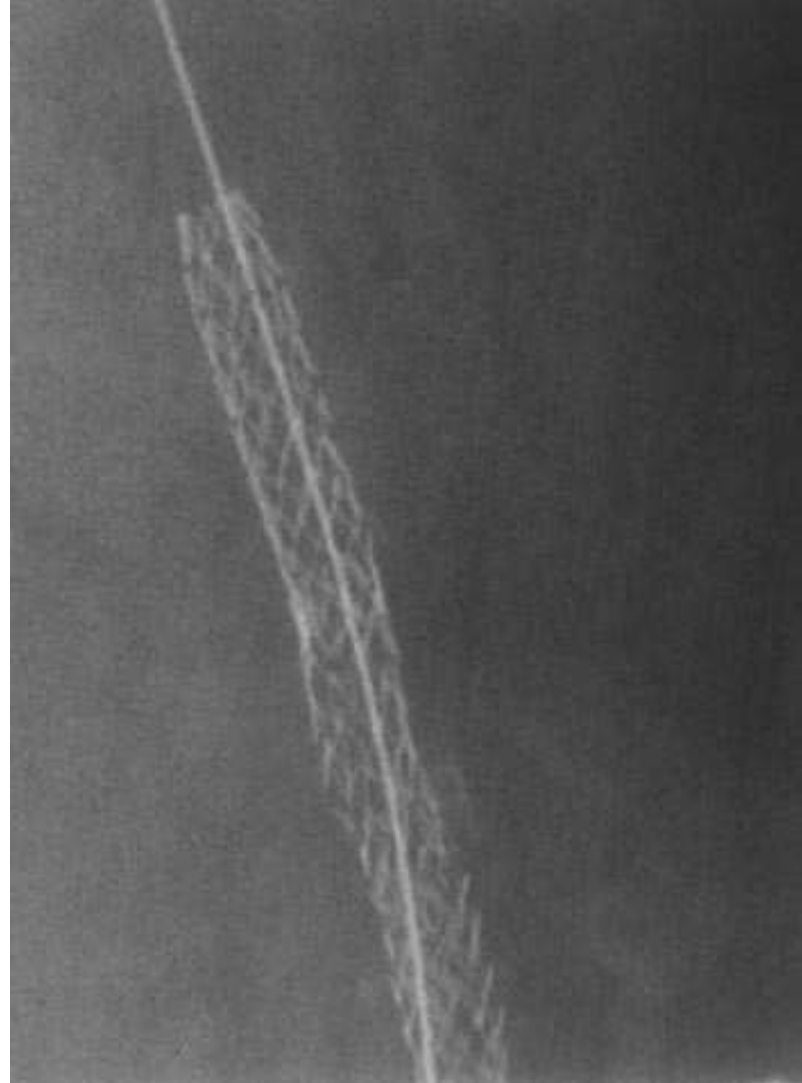
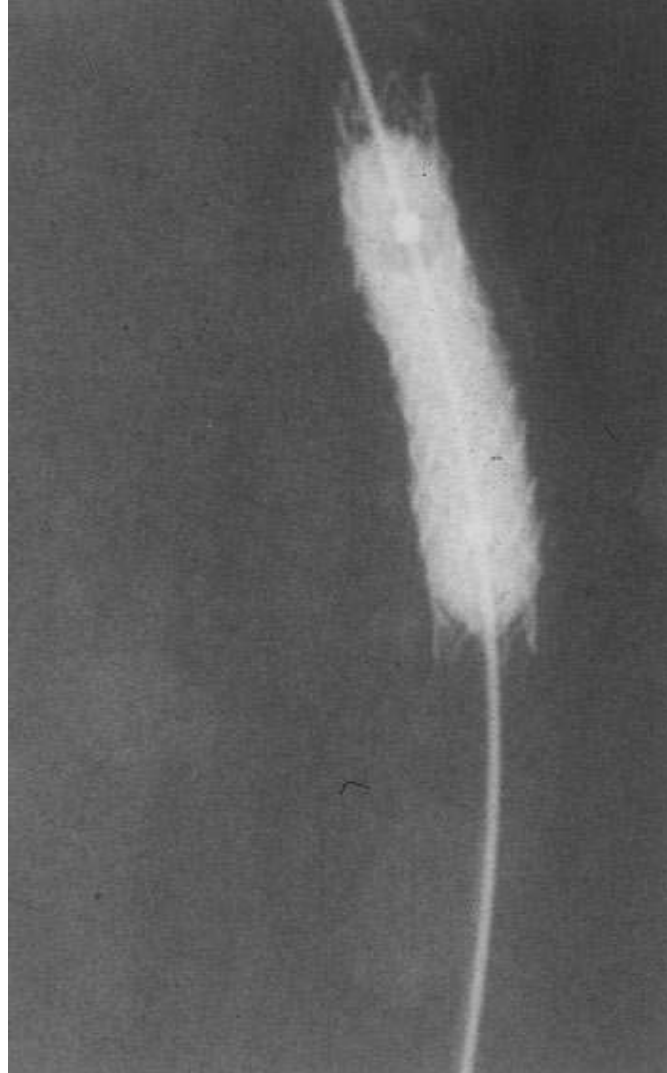
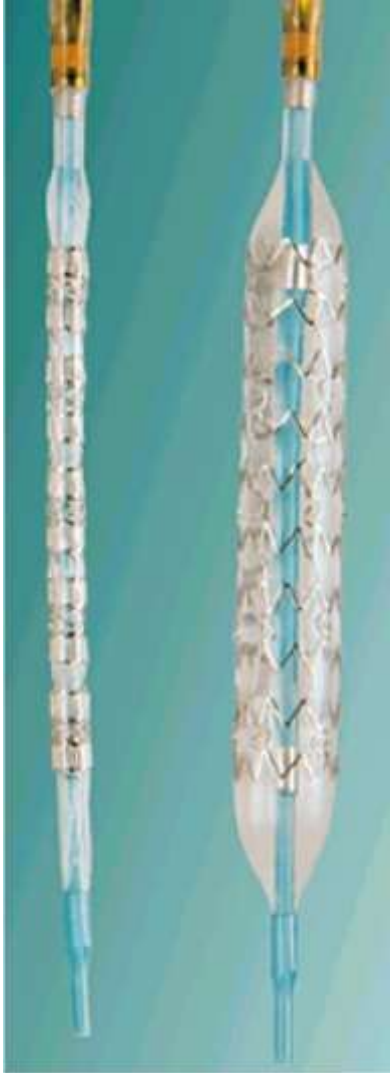


Stenting

- Self-expanding stent use after dilatation to save the result
- Stents made of nickel and titan alloy
- Insertion through the catheter in minimized form and then expanding with heating or balloon dilation
- Some stents contained drugs to prevent thrombosis and stenosis



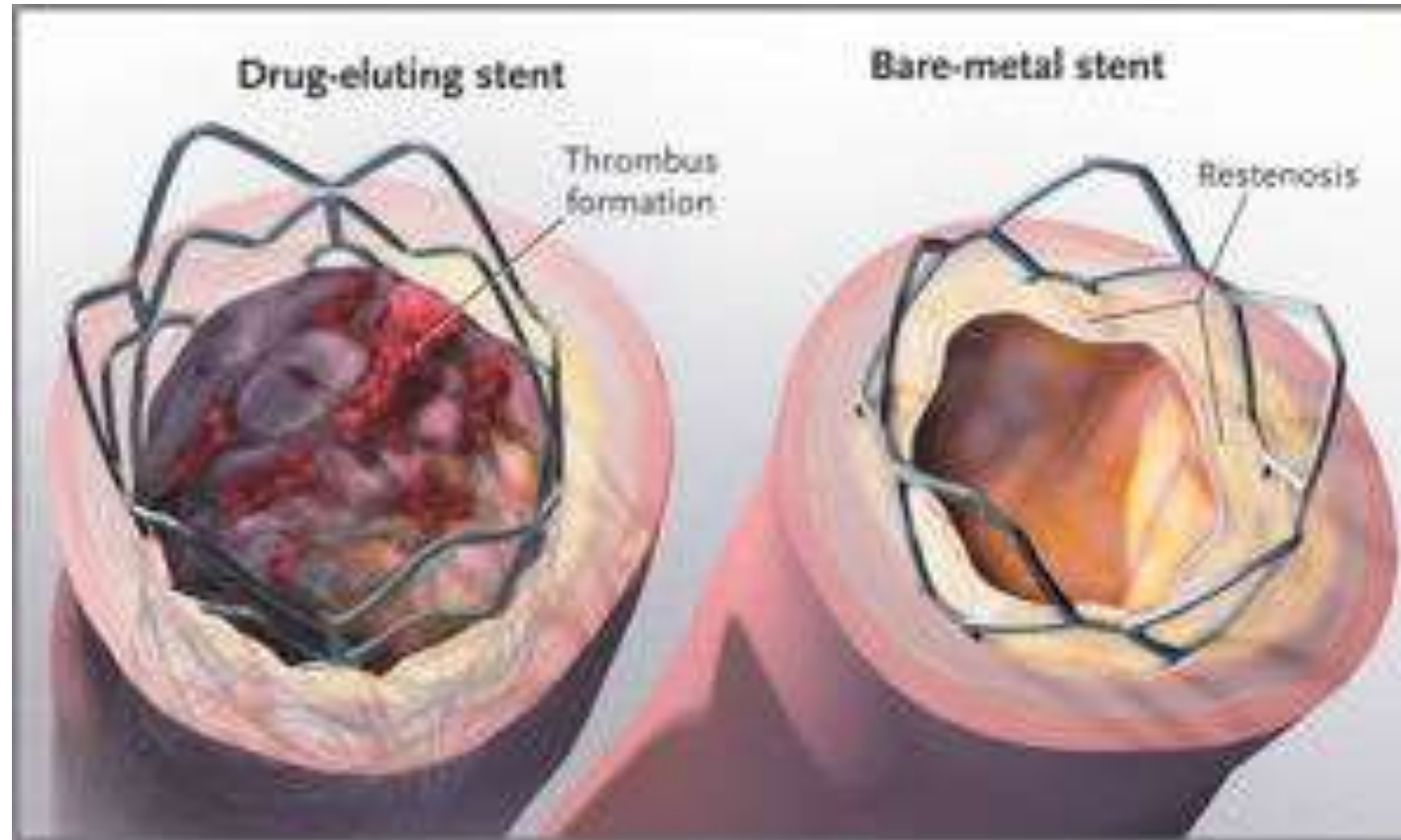
Stenting



Types of stents

- Bare-metal stents
 - Balloon-expanded
 - Stainless steel
 - Cobalt chromium alloy
 - Self-expanded (no balloon)
 - Nickel titanium (nitinol) stents with shape
- Drug-eluting stents
 - Coated with antifibrotic polymer that stops proliferation (paclitaxel [antiproliferative], rapamycin [immunosuppression])
- Bioresorbable Polymer Stents (poly-L lactide)

The difference



Bad endothelization
Endothelium irritation

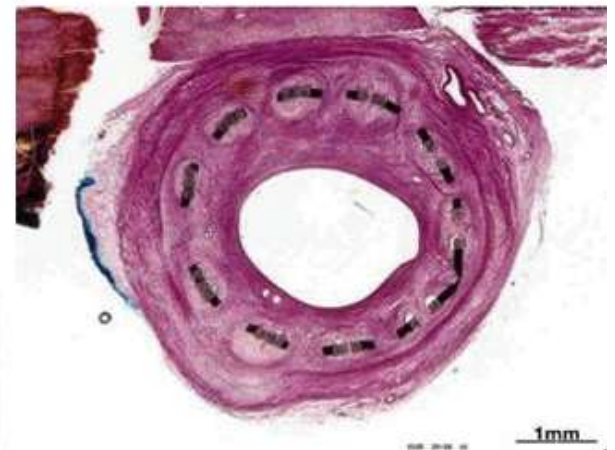
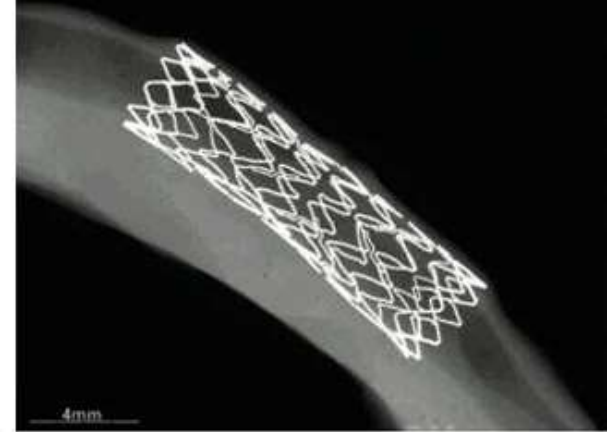
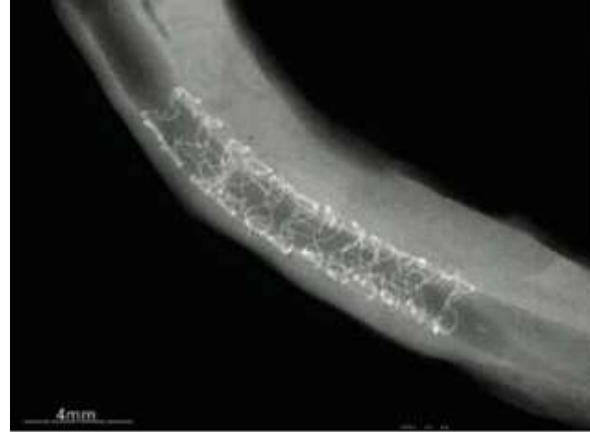
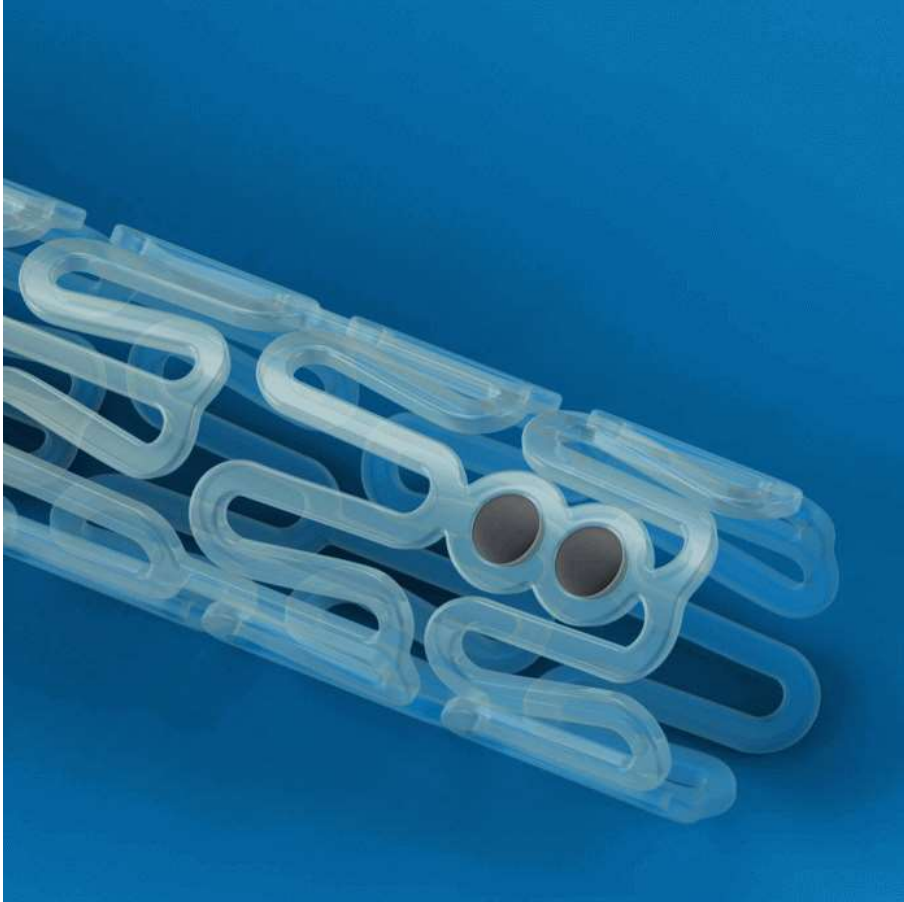
↓
Stent thrombosis

↓
Require long-term
anticoagulation

Vessel wall fibrosis

↓
Restenosis

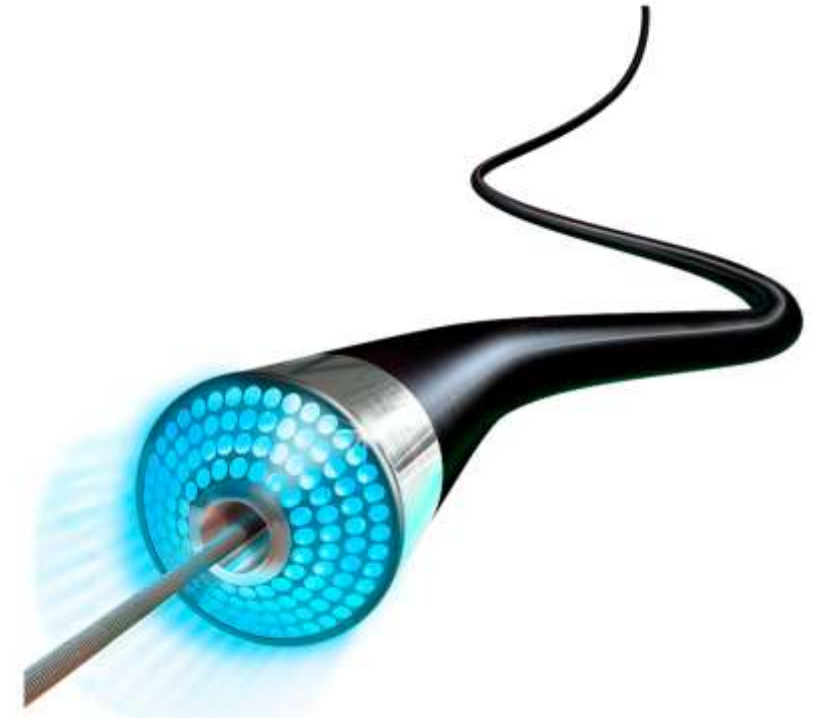
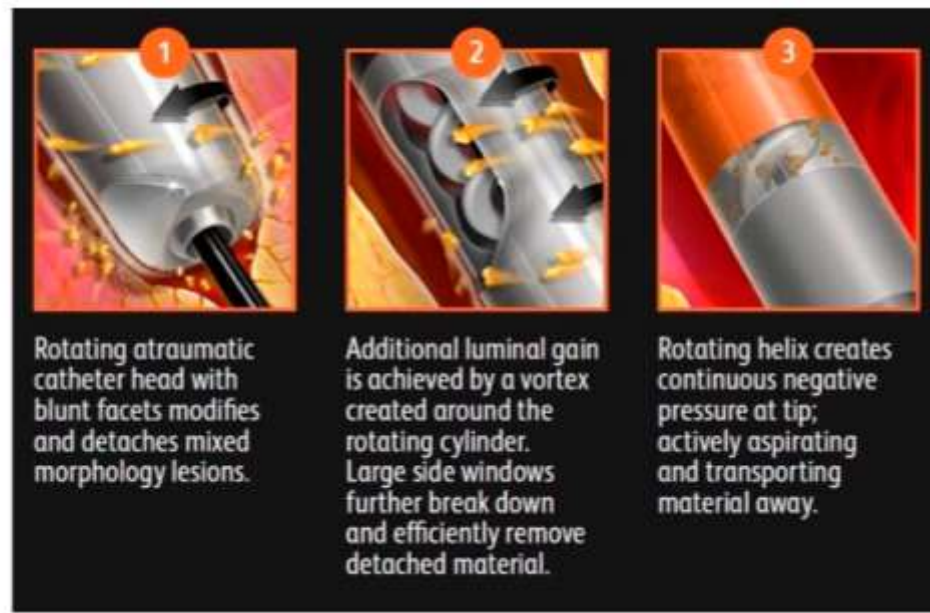
Bioresorbable polymer stents



Debulking (atherectomy)



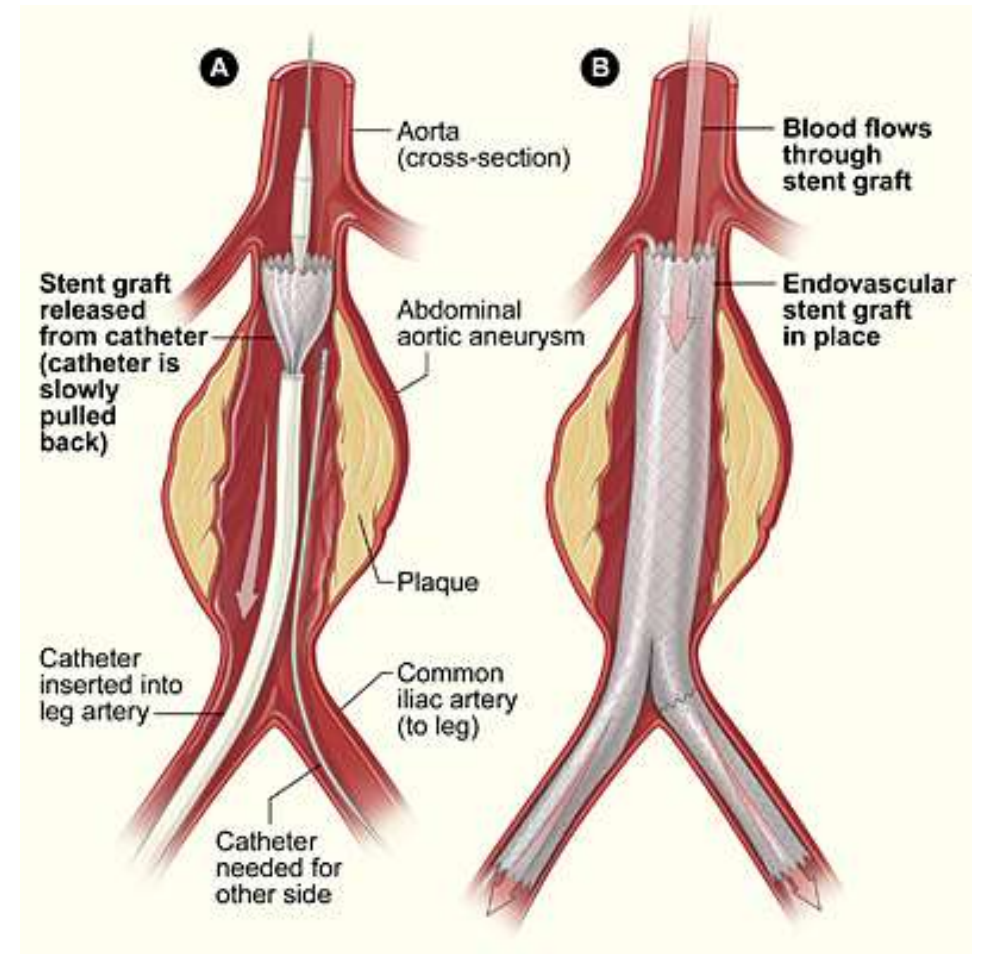
Mechanical rotational atherectomy



Laser atherectomy

Stent-grafts

- Stenting can be use for aneurism endovascular treatment
- Stent in this case can off the aneurism cavity from circulation



Acute arterial occlusion surgery

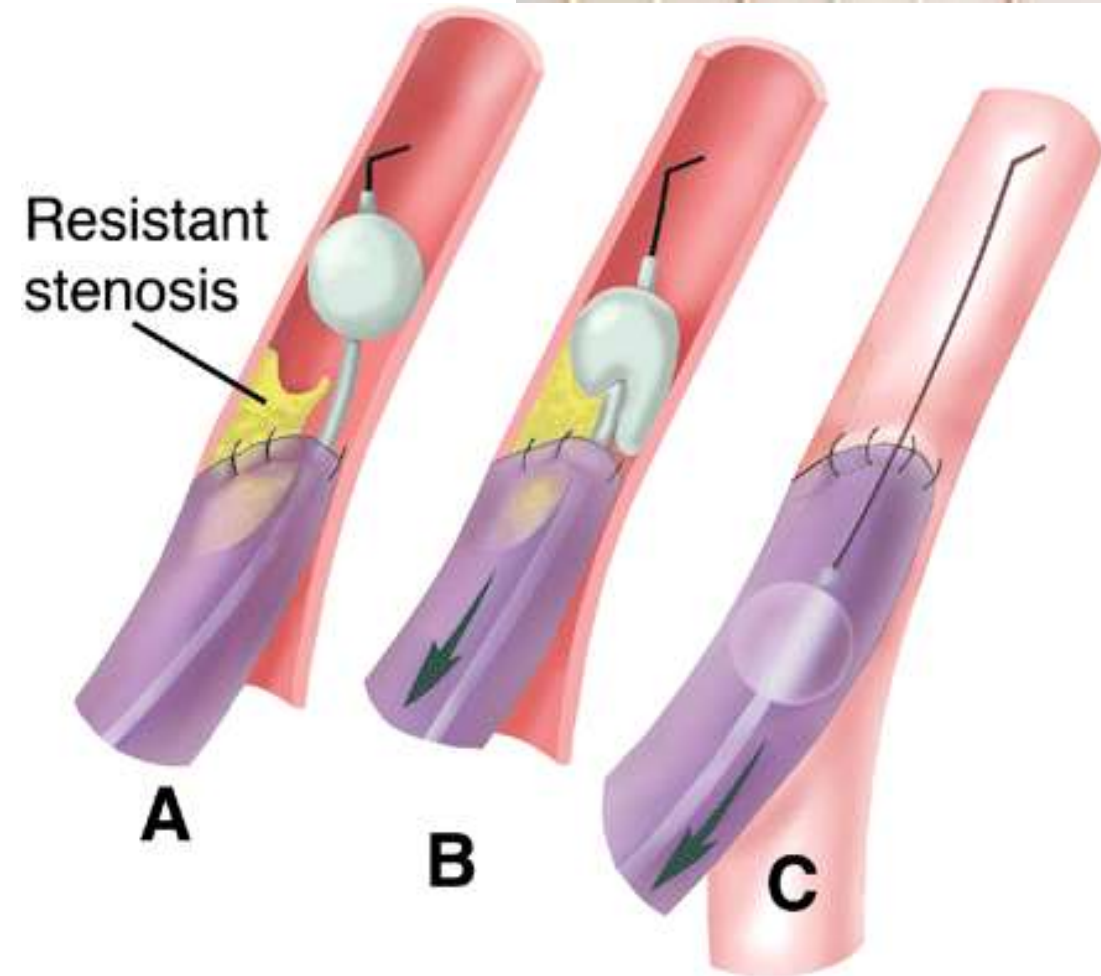
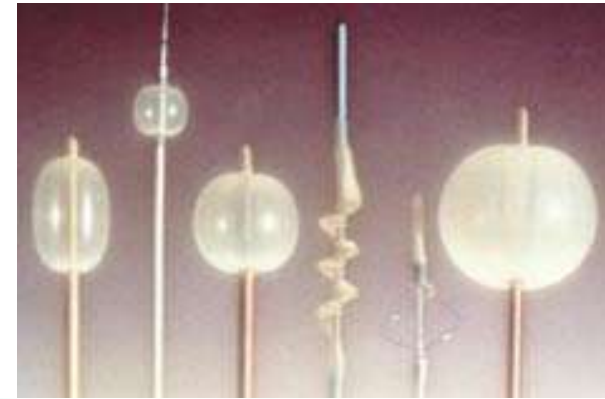
- Thrombectomy
 - Direct
 - Indirect
- Recanalization
 - Mechanical
 - Pharmacological (thrombolysis)
 - Pharmaco-mechanical

Direct thrombectomy

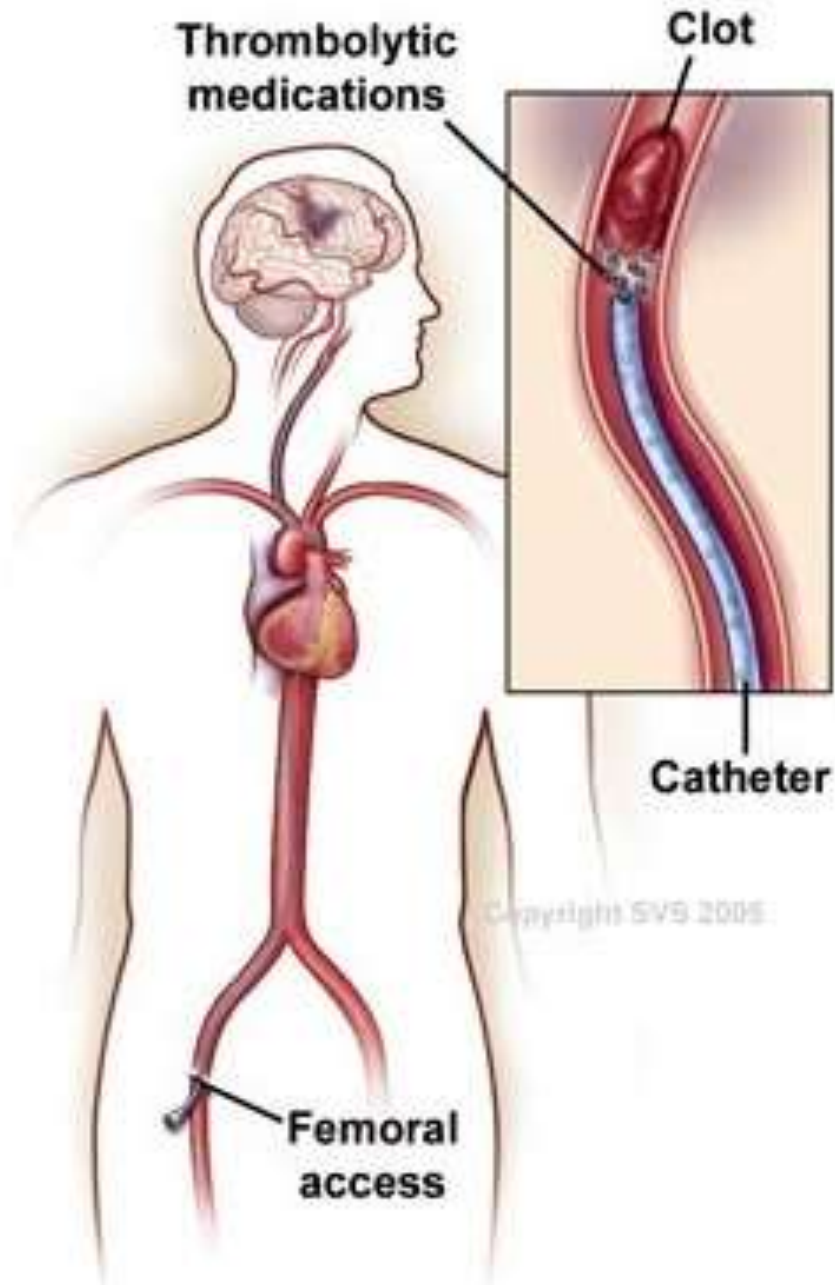


Indirect thrombectomy

- Thrombectomy by means of special catheter, that provides through the zone of thrombosis and remove thrombi by traction
- Usually use balloon catheter – Fogarty's



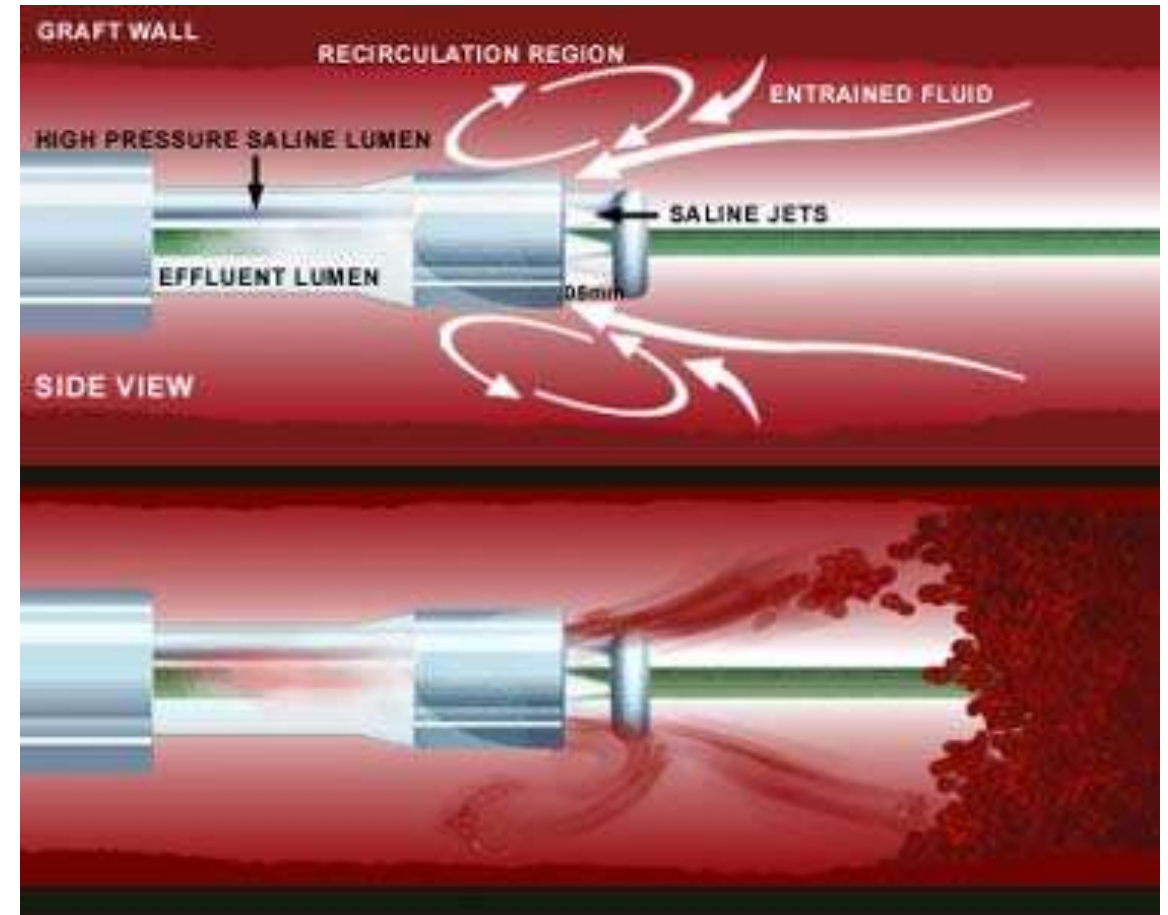
Thrombolysis



- Systemic (iv): MI, stroke
 - Risk of systemic bleeding
- Local (catheter-directed): acute limb ischemia, stroke, mesenteric ischemia
 - Less thrombolytic agent
 - Low bleeding rate
 - Higher efficacy

Pharmaco-mechanical recanalization

- Removing of thrombi by means of high-speed pulse flow with special moving catheter
- This flow create s vortex that fragments the thrombus and aspirate the masses
- At the end fibrinolytic drug can be injected in this zone



AngioJet system