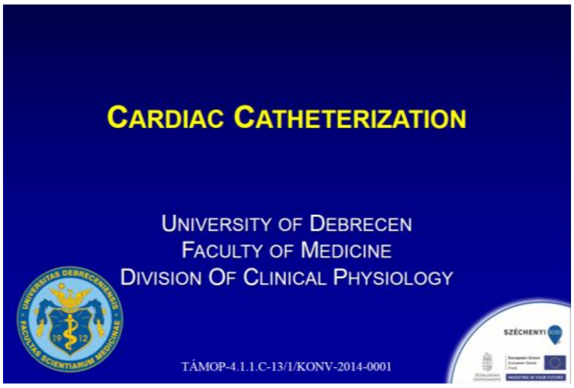
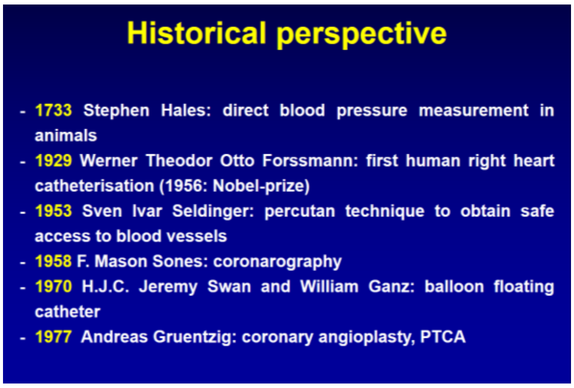
CARDIAC CATHETERIZATION

(PROF. DR. ZOLTÁN PAPP)



Slide 1

Cardiac catheterization



Slide 2

Historical perspective

In 1727 Stephen Hales (England) determined arterial blood pressure by measuring the rise in a column of blood in a glass tube bound into the carotid artery of a horse.

In 1929 Werner Theodor Otto Forssmann (Germany) shared the 1956 Nobel Prize in Medicine (with Andre Cournand and Dickinson Richards) for developing a procedure that allowed for cardiac catheterization.

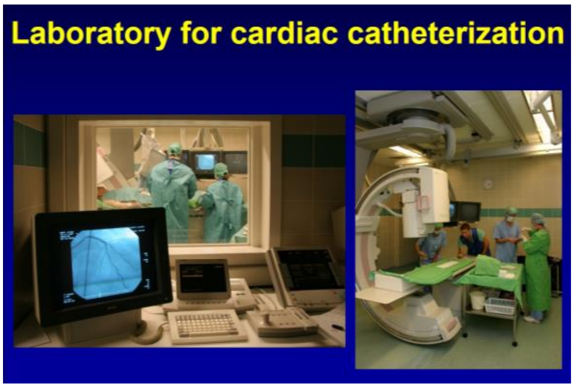
In 1953 Sven Ivar Seldinger (Sweden) developed the so called Seldinger technique, which is a medical procedure to obtain safe access to blood vessels and other hollow organs.

In 1958 F. Mason Sones (USA) performed the first coronaroangiography.

In 1970 H.J.C. Jeremy Swan and William Ganz (USA) developed pulmonary artery catheterization by including an inflatable balloon at the tip of the cardiac catheter.

In 1977 Andreas Gruentzig (Switzerland) performed the first coronaro-angioplasty.

A tananyag elkészítését "Az élettudományi- klinikai felsőoktatás gyakorlatorientált és hallgatóbarát korszerűsítése a vidéki képzőhelyek nemzetközi versenyképességének erősítésére" TÁMOP 4.1.1.C-13/1/KONV-2014-0001 számú projekt támogatta. A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósult meg.

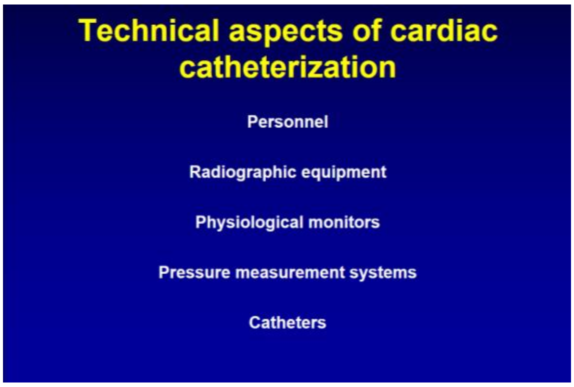


Slide 3

Laboratory for cardiac catheterization

Cardiac catheterization laboratory or cath lab is a medical examination room with diagnostic imaging equipment used to visualize the arteries of the heart and the chambers of the heart and to treat potential abnormalities.

"Cath Labs" typically consist of: patient couch, a floor or ceiling mounted image intensifier, set of viewing monitors, real-time ECG/Blood pressure/oxygen saturation measurements with software to record and measure these when needed, contrast injector pump, X-ray software for the recording and playback of the fluoroscopy runs acquired during the procedure, diagnostic catheters, guide catheters, guidewires, angioplasty balloons, stents (drug eluting and bare metal), sheaths, closure devices, general nursing supplies, defibrillator, drugs, reporting station, scrub area.



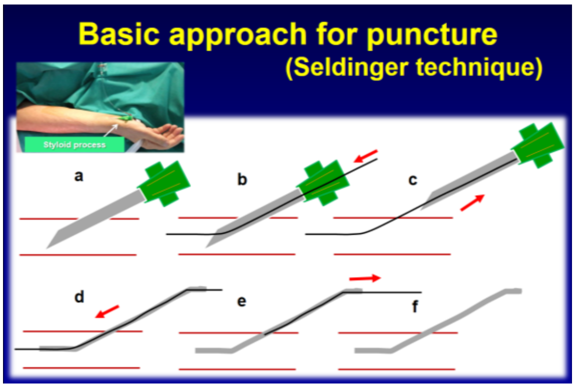
Slide 4

Technical requirements for cardiac catheterization

Cardiac catheterization relies on the following technical components:

- Well-trained invasive cardiologist specialist and assistants.
- Radiographic equipment for fluoroscopy, which is an imaging technique that uses X-rays for real-time moving images of the interior of a patient. This is useful for both diagnosis and therapy of the heart and of the coronary vessels during invasive cardiologic procedures. A fluoroscope consists of an X-ray source and a fluorescent screen, between which a patient is positioned. Most fluoroscopes include X-ray image intensifiers and cameras, to enhance the visibility of images and to provide signals for a remote display screen. Live pictures produced by fluoroscopy are conventionally recorded allowing off-line /repeated analyses independent of the catheter-assisted invasive investigation.
- Physiologic monitors allow the control of cardiac electrical activity through continuous electrocardiography, heart rate is also displayed.

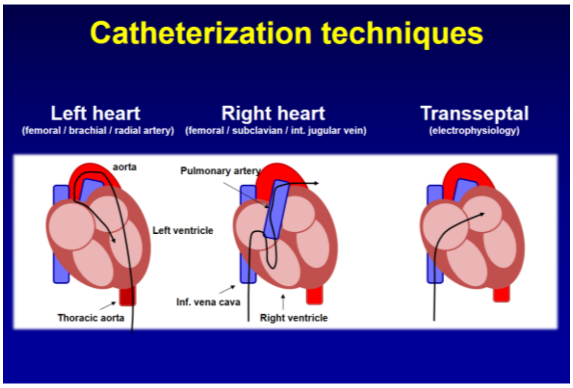
- Pressure measurement systems report on systemic and intracardiac blood pressures (indirect and direct methods for blood pressure measurements are both available).
- Cardiac catheters are relatively long, thin, flexible tubes that are put into a peripheral artery (most frequently a femoral or a radial artery).



Slide 5

Basic approach for puncture (Seldinger technigue)

The Seldinger technique is a medical procedure allowing safe access to blood vessels for intraluminal manipulations. During cardiac catheterization the selected peripheral vessel is punctured with a sharp needle. A round-tipped guidewire is then advanced through the lumen of the needle, and thereafter the neddle is removed. A "sheath" which is a blunt cannula is then advanced over the guidewire into the lumen of the vessel. Following the introduction of the sheath the guidewire is withdrawn. The sheath will thereafter allow the introduction of catheters to perform endoluminal procedures, e.g. angioplasty.



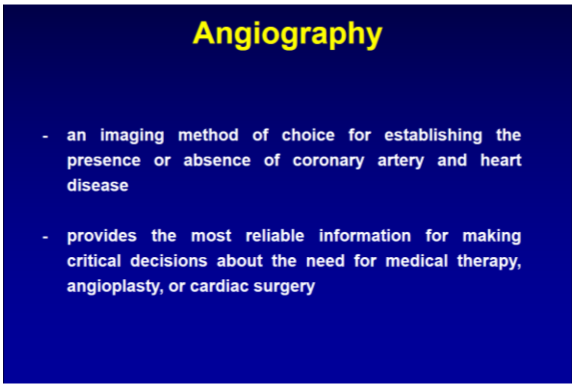
Slide 6

Catheterization techniques

During **left heart catheterization** cardiac catheters are advanced through the ascending aorta from either the femoral artery or the radial artery. From the ascending aorta the catheter can be maneuvered into the coronary ostia and into the coronary arteries. This approach serves both diagnostic (i.e. coronaro-angiography) and therapeutic purposes (i.e. coronary intervention/angioplasty).

During **right heart catheterization** cardiac catheters most frequently are advanced through the femoral vein, then the cardiac catheter can be forwarded through the right atrium into the right ventricle and further to the pulmonary artery. Right heart catheterization allows the determination of intracardiac pressures in the: right atrium, right ventricle, pulmonary arteries. Pulmonary capillary "wedge" pressure can be also determined to approximate the pressure values in the left side (more precisely in the left atrium) of the heart. Determination of the cardiac output and cardiac index also includes right heart catheterization. Cardiac output can be estimated by releasing a small amount of normal saline in one location of the heart and measuring temperature changes over time in another location of the heart (thermodilution method).

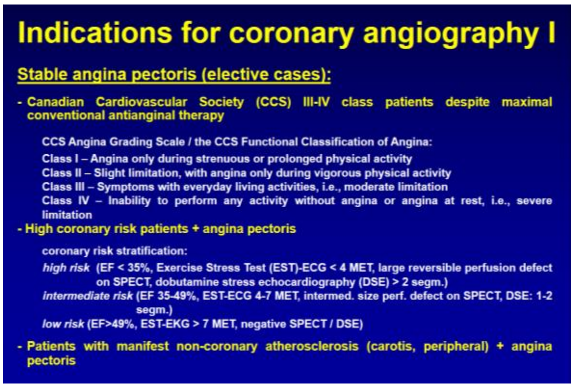
During **transseptal cardiac catheterization** a catheter is ascended to the heart through a peripheral big vein (e.g. v. femoralis) and the catheter is then forwarded from the right atrium to the left atrium through the interatrial septum. This method can be considered to measure the left atrial and left ventricular pressures, for percutaneous mitral balloon valvoplasty, catheter ablation of accessory electrical pathways on the left side of the heart, isolation of pulmonary veins, ablation of atrial fibrillation, and for evaluation of complex hemodynamics.



Slide 7

Angiography

Coronary angiography allows the evaluation of the function of the arteries of the heart and of heart chambers using contrast material and X-rays. Coronary angiography is conventionally performed during cardiac catheterization.



Slide 8

Indications for coronary angiography I

Coronary angiography can be considered in patients with stable angina pectoris (elective cases) when despite maximal conventional antianginal therapy the patients can be classified according to the Canadian Cardiovascular Society (CCS) in CCS III-IV classes (ie. patients with moderate to severe angina limitation).

The Canadian Cardiovascular Society grading of angina pectoris (sometimes referred to as the CCS Angina Grading Scale or the CCS Functional Classification of Angina) is commonly used for the classification of severity of angina:

Class I – Angina only during strenuous or prolonged physical activity

Class II – Slight limitation, with angina only during vigorous physical activity

Class III – Symptoms with everyday living activities, i.e., moderate limitation

Class IV – Inability to perform any activity without angina or angina at rest, i.e., severe limitation

Class 0 has also been proposed as an asymptomatic category.

Coronary angiography can be also considered for high risk coronary patients if angina pectoris is present.

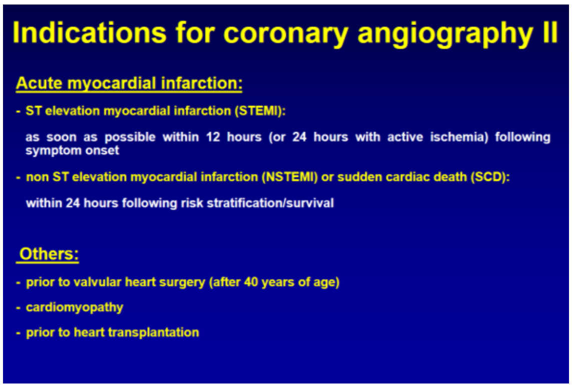
Coronary risk stratification:

high risk (EF < 35%, Exercise Stress Test (EST)-ECG < 4 MET, large reversible perfusion defect on SPECT, dobutamine stress echocardiography (DSE) > 2 segm.)

intermediate risk (EF 35-49%, EST-ECG 4-7 MET, intermed. size perf. defect on SPECT, DSE: 1-2 segm.)

low risk (EF>49%, EST-EKG > 7 MET, negative SPECT / DSE)

Coronary angiography can be also considered in Patients with manifest non-coronary atherosclerosis (carotis, peripheral) if angina pectoris is present.



Slide 9

Indications for coronary angiography II

Indications for coronary angiography include acute myocardial infarction.

ST elevation myocardial infarction (STEMI):

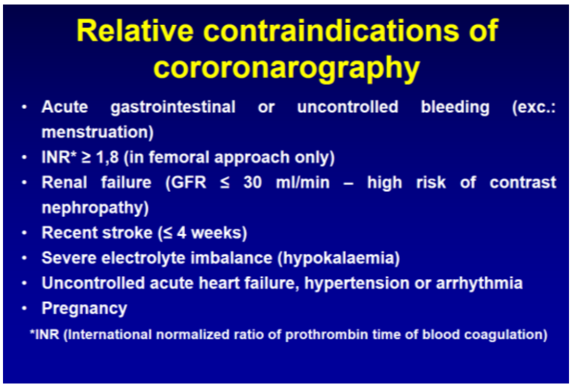
as soon as possible within 12 hours (or 24 hours with active ischemia) following symptom onset

Non ST elevation myocardial infarction (NSTEMI) or sudden cardiac death (SCD):

within 24 hours following risk stratification/survival

Finally, indications for coronary angiography include cases:

prior to valvular heart surgery (after 40 years of age)
cardiomyopathy
prior to heart transplantation



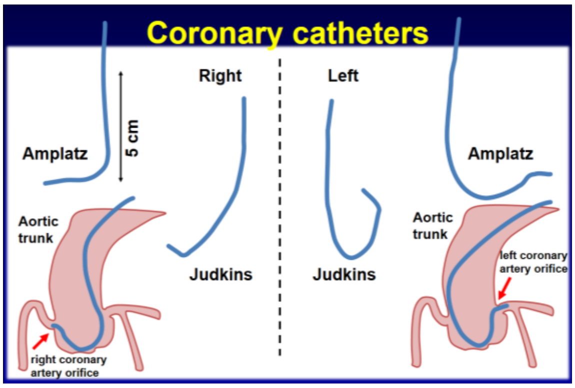
Slide 10

Relative contraindications for coronarography

There is only one abolsute contraindication for coronary angiography, i.e. when the patient refuses the investigation, all other conditions are considered as relative contraindications:

- acute gastrointestinal or uncontrolled bleeding (exc: menstruation)
- INR (International normalized ratio of prothrombin time of blood coagulation) ≥ 1,8 (in femoral approach only)
- Renal failure (GFR ≤ 30 – high risk of contrast nephropathy)
- Recent stroke (≤ 4 weeks)
- Severe electrolyte imbalance (hypokalaemia)
- Uncontrolled acute heart failure, hypertension or arrhythmia
- Pregnancy

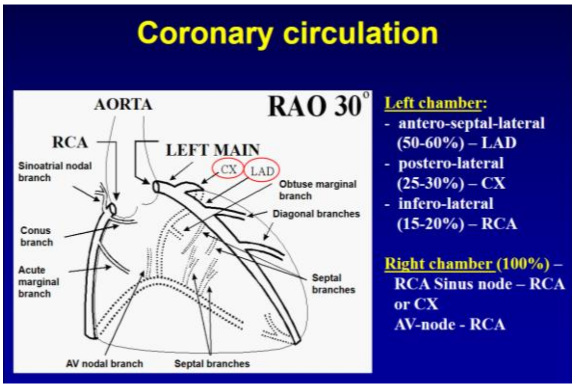
The high mortaliy rate of acute myocardial infarction is to be contrasted to each contraindication, and the decision is to be made on a personal basis taking into the consideration the potential risks and benefits. During elective coronary angiography relative contraindications are to be weighed higher than during acute coronary cases, because in the former cases advantages can be estimated only after the knwoledge of the anatomy of the coronary system.



Slide 11

Coronary catheters

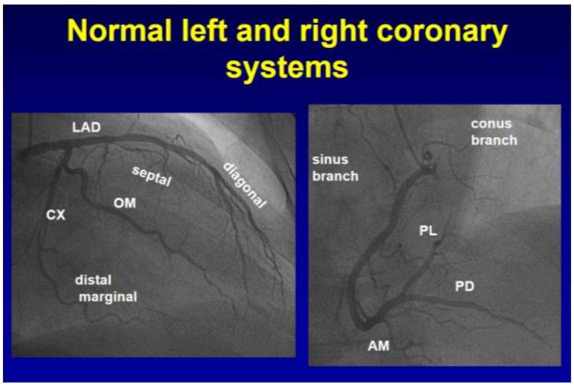
This slide represents typical coronary catheters that are most frequently employed during coronary angiography and coronary interventions. The different shapes and sizes of catheter tips allow cannulation of the coronary ostia in cases of various aortic trunk anatomies.



Slide 12

Coronary circulation

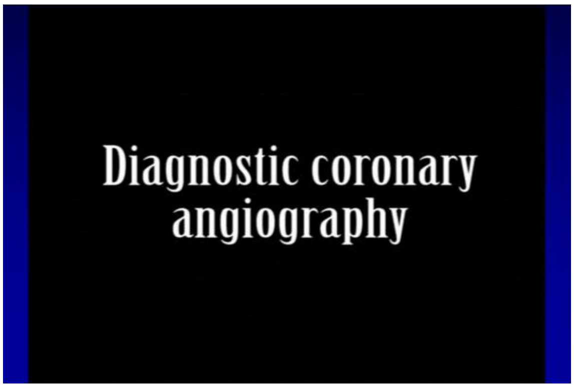
This slide demonstrates schematically the anatomy and the nomenclature of the coronary tree together with relative vascular contributions for some important anatomical structures. (RCA: right coronary artery, CX: circumflex branch, LAD: left anterior branch, RAO 30o: Right Anterior Oblique 30 degree projection)



Slide 13

Normal left and right coronary systems

This slide illustrates the left and the right coronary systems during coronary angiography from two typical projections. LAD: left anterior descending artery, CX: circumflex artery, OM: obtus marginal branch, AM: acute marginal branch, PL: posterolateral branch, PD: decendent posterior branch.



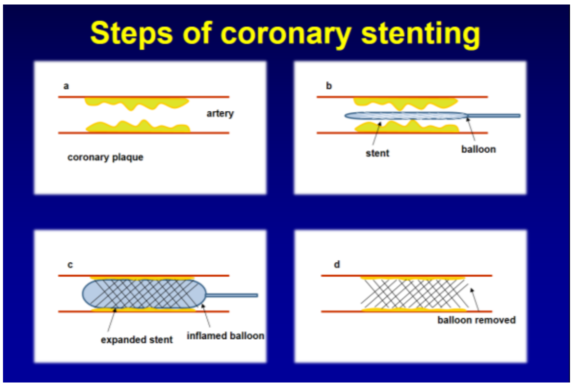
Slide 14

Diagnostic coronary angiography

This movie shows a coronary angiography with percutaneous radial artery approach. Following patient positioning in the cath lab the Allen's test is performed to determine the dominance between the radial and ulnar arteries supplying together the hand through arches of anastomoses (i.e. palmaris arches). During the Allen's test the hand is elevated and the patient is asked to make a fist for about 30 seconds. Then, both the ulnar and the radial arteries are composressed to the level of occlusion. The hand is then opened, and the color of the palm is inspected. The palm is normally blanched (i.e. the skin is pale and pallor can be observed) for this manoeuvre. Therafter, ulnar pressure is released and the color should return in a few seconds. The Allen's test is checking for abnormal circulation (defined as insufficient ulnar artery supply for the hand). If color returns as described above, the Allen's test is considered to be "Negative" (abnormal circulation is not present). If color fails to return, the test is considered "Positive" (abnormal circulation is present) and the ulnar artery supply to the hand is insufficient. The radial artery therefore cannot be safely cannulated.

The area of the wrist where the radial artrery is cannulated is cleaned and infiltrated with local anesthetic (lidocain).

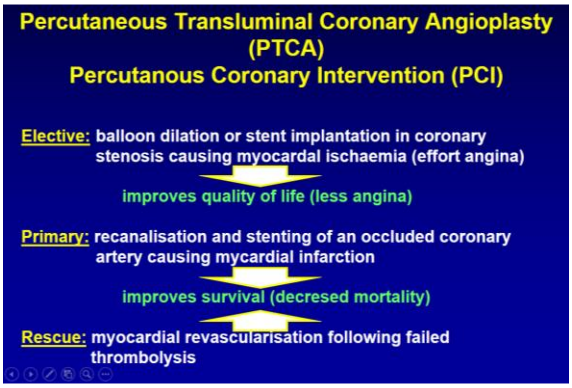
Prior to the radial coronary angiographic investigation heparin, nitrates and verapamil are administered into the radial artery. Heparin decresases the risks for catheter thrombosis and embolism, while the two other agents decrease the vasocosntrictive tendencies in the gracile (and therefore often spastic) radial artery. Puncture of the radial artery is performed according to the Seldinger technique as described previously. The cardiologist carefully moves the catheter up into the heart, while X-ray images help the doctor position the catheter. First aortography is performed by introducing a pig-tail catheter into the aortic trunk, then special catheters are employed to cannulate first the left and then the right coronary orificies. Cardiac catheters are ascended via guiding catheters having a bent and flexible tip to prevent the injuires/dissections of arteries. All catheters are ascended via guiding catheters, blind catheterization is prohibited. Following positioning of coronary catheters angiography is performed. This involves the injection os contrast material into the catheter, while X-ray images are taken to see how the dye moves through the artery. The contrast material helps to highlight any blockages in blood flow. Images are taken from various angles in order to visualize all segments in their entirety and without overlaps with other arteries. Each projection is specific for a different coronary segment. The procedure may last 30 to 60 minutes. At the end of the investigation the catheter and the sheat are removed, and compression is employed over the access site with a pressure around/above the systolic blood pressure for about an hour. Then the compressing pressure is gradually reduced till the appearance of distal radial pulse. Compression pressure at this reduced level is maintained for about 4-6 hours (in our institution till next morning).



Slide 15

Steps of coronary stenting

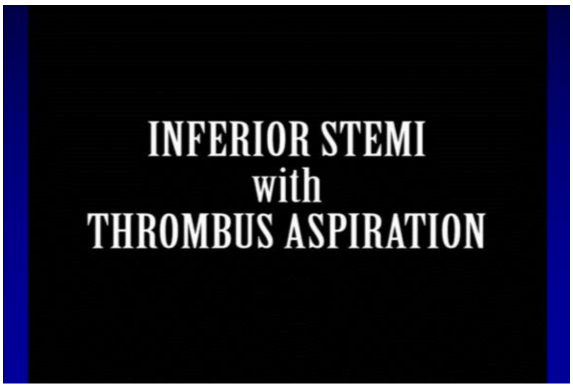
A coronary stent is a tube-shaped mesh made of metal which is placed in the coronary arteries to keep the arteries open. Stents are used in a procedure called percutaneous coronary intervention (PCI). Treating a blocked ("stenosed") coronary artery with a stent follows certain steps similarly to balloon angioplasty procedures without stent deployements with a few important differences. First, the interventional cardiologist uses coronary angiography to identify the location and to estimate the size of the blockage ("lesion/culprit lesion") by injecting a contrast material through the guide catheter and viewing the flow of blood through the downstream coronary arteries. The cardiologist then decides whether to treat the lesion with a stent, and if so, what kind and size. Drug eluting stents are most often sold as a unit, with the stent in its collapsed form attached onto the outside of a balloon catheter. Physicians may perform "direct stenting" where the stent is threaded through the lesion and expanded. The physician expands the balloon which deforms the metal stent to its expanded size. It is critically important that the framework of the stent be in direct contact with the walls of the vessel to minimize potential complications such as blood clot formation. Long lesions may require more than one stent—this result of this treatment is sometimes referred to as a "full metal jacket"



Slide 16

Percutaneous transluminal coronary angioplasty (PTCA) percutanous coronary intervention (PCI)

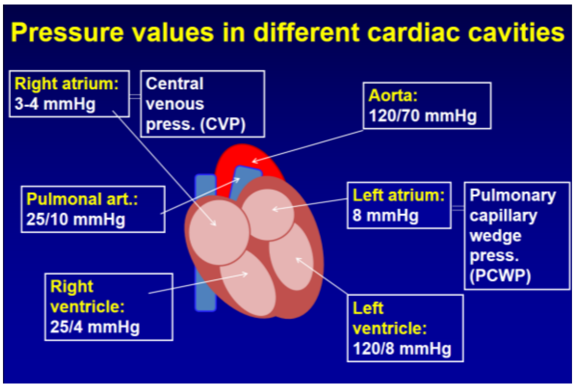
Elective PTCA is indicated only if the patient presents with typical chestpain and verified myocardial ischemia. In the above cases PTCA can improve teh quality of life (by eliminating angina attacks), but it cannot improve mortality and cannot prevent future myocardial infarction. However, primary PTCA during acute conditions or rescue PTCA following thrombolysis improves mortality. For the above reasons mortality of acute myocardial infarction could be reduced to about 4%.



Slide 17

Inferior STEMI with thrombus aspiration

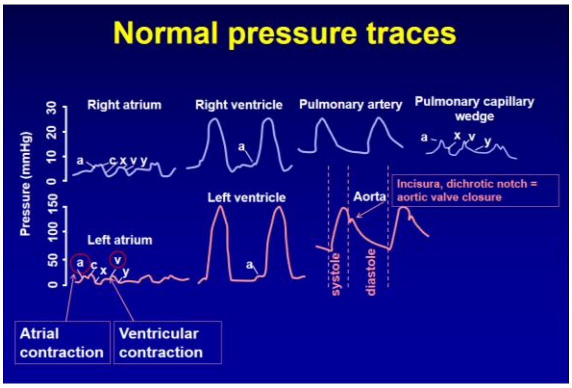
This video presents a case with inferior STEMI. The ECG recording revealed an inferior STEMI complicated by AV-block warranting urgent primary PTCA. The patient was trasnferred to the cath lab, where the coronary angiography illustrated proximal occlusion for the right coronary artery. A guide wire was ascended through the catheter crossing the occluding blod clot and thereby reaching distal coronary segments. Therafter, all manipulations were performed via the guide wire. A limited degree of reperfusion occured already during the introduction of the guide wire as indicated by the appearance of contrast material in the distal coronary segment and by the concomittant reperfusion arrhytmia (accelerated indioventricular rhythm and frequent extrasystoles). Significant thrombus mass was visible at the location of the occlusion, and therefore thrombus aspiration was attempted using a specific aspiration catheter. Nevertheless, the first attempt to remove the thrombus was not successful leading to distal embolization. As a next step, a stent has been implanted to correct for the coronary dissection limiting coronary perfusion at teh site of the lesion. The stent has been expanded and aligned to the vessel wall by inflating the balloon. This has been followed by ballon deflation and balloon removal. Next, a repated effort for thrombus aspiration has was attempted without major success (the thrombus was attached to the stent). Nevertheless, a subsequent thrombus aspiration attempt was successful allowing thrombus removal. The final coronary angiographic picture illustrated good distal perfusion with complete reperfusion of the right coronary artery.



Slide 18

Pressure values in different cardiac cavities

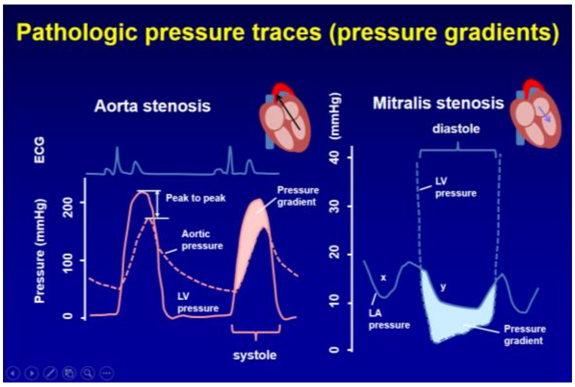
This slide represents mean pressure values for the different cardiac chambers. Pulmonary capillary wedge pressure (PCWP) can be measured using a balloon tipped catheter fed to the right side of the heart by ascending and wedging it to a peripheral pulmonary artery branch. The wedged balloon catheter blocks distal circulation in the cannulated pulmonary vessel, thereby allowing pressure equilibrtation with distal vascular segments, ultimately with the left atrium. This procedure allows for direct blood pressure recording in the left atrium avoiding the transseptal approach with potential unnecessary complications.



Slide 19

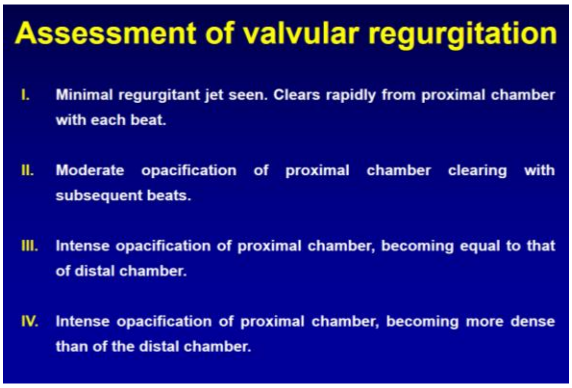
Normal pressure traces

The slide illustrates distinct pressure traces recorded in different cardiac chambers. Some points are particulary releavent: ‘a’ and ‘v’ waves, incisura, the identification and explanation of systolic and diastolic periods on the arterial pressure trace.



Slide 20	
Pathologic pressure traces (pressure gradients)	

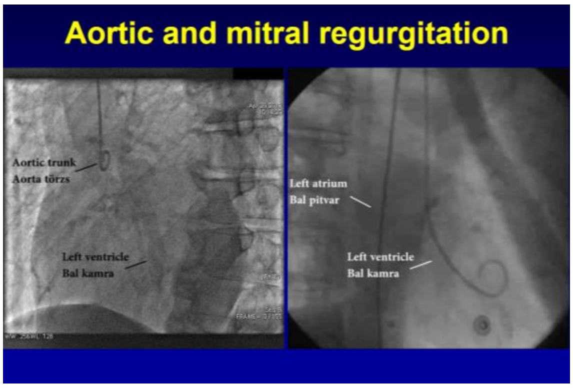
When cardiac valves are open pressure equilibrates between the proximal and distal heart chambers. In contrast, during valvular stenosis the pressure in the proximal chamber exceeds that of the distal chamber in the open state of the valve, hence a pressuer gradient develops. This pressure gradient characterizes the severity of valvular stenosis. In aortic stenois a systolic pressure gradients higher than 40 mmHg, in case of mitral stenosis a mean diastolic pressure gradients higher than 10 mmHg are considered to be significant.



Slide 21

Assessment of valvular regurgitation

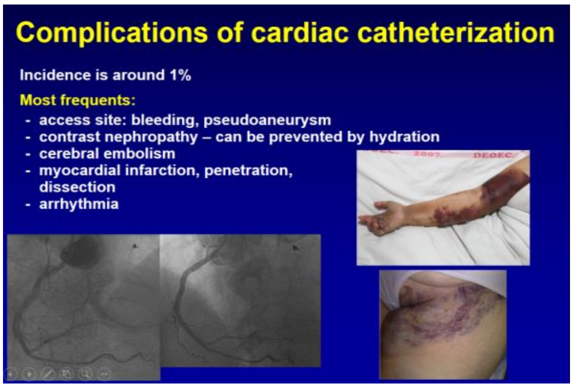
Valvular regurgitation can be graded during invasive cardiologic investigations by injecting contrast material to the distal cardiac chamber according to the presented scheme. Grade I illustrates mild severity, grade II-III relates to medium severity, grade IV is the most severe valvular regurgitation. Present day echocardiography allows the determination of more sophisticated parameters for valvular regurgitation, hence invasive cardiology methods are rarely employed for the assessement of valvular regurgitation.



Slide 22

Aortic and mitral regurgitation

During the valvulographic presentation on the left side of this slide the pig tail catheter has been positioned right above the aortic valve in the aortic trunk. Following the injection of contrast material significant regurgitation towards the left ventricle is visualized during systole. On the right side of this slide, severe mitral regurgitation is visible during a left side ventriculographic examination. The video reveals the regurgitation of a significant amount from the injected contrast material into the left atrium during systole.



Slide 23

Complications of cardiac catheterization

This slide illustrates the complications of cardiac catheterization with some demonstritive images. A catheterization evoked coronary dissection is shown on the left side. The elongated whitish line along the lumen of the right coronary artery together with the contrast material accumulation around the coronary ostium in the aortic wall reflects coronary dissection and aortic dissection. Following coronary stenting good distal coronary perfusion and closure of the aoritc dissection fissure were noticed. On the right side of this slide radial and femoral hematomas are shown as frequent comlications of cardiac catheterization, partly in response to combined antitrhombotic therapy.

QUESTIONS FOR SELFCONTROL

1. What are the differences for the clinical managaements in STEMI and NSTEMI?
2. How many different types of cardiac catheterizations techniques do you know?
3. What are the steps emloyed during the Seldinger technique?
4. What are the contraindications for coronary angiography?
5. What is the advantage of coronary stenting?
6. Which methods allow the direct determination of left atrial pressure?
7. Which are the most important differences between the pressure values for the left and the right hearts?
8. Which are the most frequent copmlications of cardiac catheterization?

TEST QUESTIONS

1. ***Choose the only <u>correct</u> response. Coronary angiography is considered in one of the following cases:***

a. patients with stable angina pectoris with Canadian Cardiovascular Society (CCS) class I
b. patients with stable angina pectoris with Canadian Cardiovascular Society (CCS) class II
c. patients with EF>49%, EST-EKG > 7 MET, negative SPECT / DSE
d. patients with STEMI 48 hours after the onset of chest pain
e. patients with older than 60 years prior to valvular heart surgery

2. ***Choose the only <u>correct</u> response. Coronary angiography is considered in one of the following cases:***

a. patients with no signs of non-coronary atherosclerosis + angina pectoris with Canadian Cardiovascular Society (CCS) class I
b. patients with EF > 45% without ischemia
c. patients with angina pectoris + EF < 35%, Exercise Stress Test (EST)-ECG < 4 MET, large reversible perfusion defect on SPECT, dobutamine stress echocardiography (DSE) > 2 segment wall motion abnormality)
d. 24 hours after heart transplantation
e. 48 hours after the survival of sudden cardiac death

3. ***Choose the only <u>correct</u> response. Coronary angiography is:***

a. a diagnostic method involving cardiac ultrasound investigation
b. a diagnostic method allowing the detection of ST segment elevation
c. a diagnostic method for establishing the presence or absence of coronary artery disease
d. a therapeutic method employed during heart transplantation
e. a therapeutic method involving cardiac pacemaker stimulation

4. ***Choose the only <u>correct</u> response. Percutaneous coronary interventions (PCI):***

a. do not include percutaneous transluminal coronary angioplasty (PTCA)
b. can be performed with or without stent insertion
c. are performed during open heart surgery
d. do not need the application of contrast materials
e. require deep anesthesia

5. ***Choose the only <u>correct</u> response. Percutaneous coronary interventions (PCI):***

a. involves catheter insertion to the heart through a peripheral large vein
b. conventionally require the transseptal approach
c. often involves the placement of intraluminal stents in the area of the culprit lesion
d. in elective cases inproves mortality for patients with effort angina
e. in primary cases has no effect on quality of life

6. ***Choose the only <u>correct</u> response. Left atrial pressure:***

a. can be determined by left heart cathteterization
b. can be determined by right heart cathteterization
c. is characteristically lower than the right atrial pressure

d. is characteristically higher than the pressure in pulmonary artery during systole
e. is clinically irrelevant

7. Choose the only <u>correct</u> response. Pulmonary capillary wedge pressure:

a. can be determined by left heart cathteterization
b. can be determined by inserting a balloon tiped catheter into a pulmory capilllary
c. can be determined by inserting a balloon tiped catheter into a pulmory artery
d. allows the determination of right atrial pressure
e. allows the determination of left ventricular pressure

8. Choose the only <u>correct</u> response. Relative contraindications of coronarogarphy includes:

a. INR < 1
b. GFR > 60 ml/min
c. pregnancy
d. STEMI
e. NSTEMI

9. Choose the only <u>correct</u> response. Percutaneous coronary interventions (PCI)* are considered as*:

a. “elective” when employed for patients with effort angina during emergency situations.
b. “elective” when employed for patients with effort angina together with STEMI.
c. “primary” when employed for patients with atrial fibrillation.
d. “rescue” when employed for patients with ventricular fibrillation.
e. “rescue” when employed for patients following failed thrombolyis.

10. Choose the only <u>correct</u> response. Diastolic pressure:

a. in the left ventricle is higher than in the aorta.
b. in the pulmonary arteryis higher than in the aorta.
c. in the right atrium is higher than in the left atrium.
d. in the right atrium equals to pulmonary capillary wedge pressure.
e. in the left atrium equals to the left ventrcle.

11. Choose the only <u>correct</u> response. Systolic duration:

a. is longer for the left ventricle than for the right ventricle.
b. ends with an incisura on the aortic pressure trace.
c. increases with heart rate.
d. cannot be followed by ECG.
e. correlates directly with the intensity of coronary circulation.

12. Choose the only <u>correct</u> response. Pathologic pressure traces include* significant pressure gradients between the left ventricle and the aorta for*:

a. aortic regurgitation.
b. mitral regurgitation.
c. aortic stenosis
d. mitral stenosis.
e. pulmonary regurgitation.

13. Choose the only <u>correct</u> response. Potential complications of cardiac catheterization during PCI may include all the followings except one:

a. acces site bleeding.
b. contrast nephropathy.
c. pulmonary embolism
d. myocardial infarction.
e. arrhythmia.

14. Choose the only <u>correct</u> response. Valvular regurgitation can be diagnosed by:

a. echocardiography.
b. ECG.
c. PCI.
d. PTCA.
e. .the Seldinger technique.

15. Choose the only <u>correct</u> response. One of the following coronary branches is involved in the blood supply of the AV-node:

a. RCA.
b. CX.
c. LAD.
d. diagonal branches of the LAD.
e. obtuse marginal branch of the CX.

16. Choose the only <u>correct</u> response. PCI can be considered for one of the following cases:

a. primary dilatative cardiomyopathy.
b. STEMI.
c. diastolic heart failure.
d. atrial fibrillation.
e. atrial flutter.

Key:

1	***E***	**6**	***B***	**11**	***B***	**16**	***B***
2	***C***	**7**	***C***	**12**	***C***		
3	***C***	**8**	***C***	**13**	***C***		
4	***B***	**9**	***E***	**14**	***A***		
5	***C***	**10**	***E***	**15**	***A***		

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