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# CroEcho 2011. — Sažeci edukacijskog tečaja

# CroEcho 2011 — Educative course abstracts

## 2D i M-prikaz ehokardiografija

## 2D & M-mode echocardiography

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Tematska cjelina donosi osnovna načela vizualizacije, mjerenja i integrirane ehokardiografske procjene korištenjem 2D i M-prikaza. Specifičnosti navedenih tehnika povezane su s njihovim ulogama u ehokardiografskom pregledu, a njihova komplementarnost osigurava pouzdanu procjenu i jamči potpunu reproducibilnost provedenih mjerenja. Dvodimenzionalna ehokardiografija (2D ili B-mod) prikazuje srčane strukture prolaskom ultrazvučnog snopa koji integrira višestruke linije skeniranja, dok M-prikaz (engl. M-mode, move mode ili pokretni prikaz) karakterizira visoka temporalna rezolucija s prikazom struktura u jednoj, odabranoj liniji prostiranja ultrazvučnog vala.

Optimalno vizualizirani prikaz srčanih struktura u 2D-tehnici, kroz standardne transtorakalne presjeke čiji pregled ova cjelina donosi, omogućit će pouzdanu procjenu većine srčanih struktura: uzlazne aorte i njenih specifičnih anatomskih segmenata, obje pretklijetke i klijetke, kao i korijena, početnog dijela te velikih grana plućne arterije. Pored istaknutih elemenata, tematska cjelina tečaja će posebnu pozornost usmjeriti optimalnoj vizualizaciji iz standardnih presjeka te uputiti slušače na nužnost i postupke trajne samokontrole pouzdanosti i reproducibilnosti učinjenih mjerenja.

Pored sagledavanja osnova ehokardiografske vizualizacije i mjerenja u M-prikazu te njihovih prednosti i ograničenja, u ovoj tematskoj cjelini se posebna pažnja usmjerava osiguravanju okomite perpendikularne pozicije snopa ultrazvučnih valova na dugu os srca, kao i na posljedične specifičnosti u interpretaciji provjedenih izmjera. Izvođenje postupka po Teichholzu i kritična interpretacija nalaza, kao i komparacija mjerenja s vrijednostima dobivenim u 2D-prikazu, uključeni su u tematsku cjelinu. Pored navedenog, posebnu pažnju usmjeravamo 2D procjeni srčanih struktura u standardnom algoritmu ehokardiografskog transtorakalnog pregleda: procjeni uzlazne aorte, aortnog bulbusa, lijeve pretklijetke i aortne valvule, mjerenju struktura lijeve klijetke, prikazu i izmjeru desne klijetke, analizi odjeka i procjeni funkcionalnih specifičnosti mitralnih kuspisa, kao i procjeni trikuspidne te plućne valvule.

Thematic section describes the basic principles of visualization, measurement and integrated echocardiographic evaluation by using 2D and M-image. Specific features of these techniques are associated with their roles in the echocardiographic examination, and their complementarity provides a reliable evaluation and guarantees full reproducibility of conducted measurements. Two-dimensional echocardiography (2D or B-mode) shows cardiac structures by passing the ultrasound beam which integrates multiple scan lines, while the M-mode (move mode) is characterized by high temporal resolution showing the structures in one selected line of propagation of ultrasonic wave.

Optimally visualized image of cardiac structures in the 2D technique through standard transthoracic views, whose overview is provided in this section, will provide a reliable evaluation of the most cardiac structures: ascending aorta and its specific anatomical segments, the both atria and ventricles, as well as root, initial part, and the large branches of pulmonary artery. In addition to the emphasized elements, the thematic section of the course will focus special attention on optimum visualization from the standard views and will draw listeners' attention to the necessity and procedures of permanent self-control of reliability and reproducibility of performed measurements.

In addition to overview of the basis of echocardiographic visualization and measurement in the M-image, and their advantages and limitations, in this thematic section, particular attention is drawn on ensuring vertical perpendicular position of the beam of ultrasonic waves on the cardiac long axis and consequential specific features in the interpretation of conducted measurements. Performing procedures according to Teichholz and critical interpretation of findings, as well as the comparison of measurements with the values obtained in 2D-image are included in the thematic section. In addition, special attention will be drawn on 2D evaluation of cardiac structures in the standard algorithm of echocardiographic transthoracic examination: evaluation of ascending aorta, aortic bulb, left atrium and aortic valves, measurement of the left ventricular structure, image and measurement the right ventricle, analysis of the echo and evaluation of functional specific features of mitral cuspis as well as the evaluation of tricuspid and pulmonary valves.

# Dopplerska ehokardiografija

# Doppler echocardiography

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Dopplerska ehokardiografija je nezamjenjiv dio potpunog ehokardiografskog pregleda. Kao što jednodimenzijska (M-prikaz) i dvodimenzijska (2D) ehokardiografija pružaju slikovne prikaze srčanih struktura, Dopplerska ehokardiografija pruža podatke o protoku krvi unutar srca i velikih krvnih žila. Navedeni uzorci protoka temelje se na promjeni frekvencije povratnog signala odbijenog od eritrocita kojeg prima ultrazvučna zraka. Osnivni fizikalni principi Dopplerske ehokardiografije temelje se na Dopplerskom učinku prema kojem se frekvencija zvuka povećava primicanjem izvora zvuka, a snizuje se udaljavanjem izvora. Razlika u frekvenciji odašiljanog i odbijenog zvuka definira Dopplerski pomak. Brzina protoka krvi se nadalje računa prema Dopplerskoj jednadžbi te je u odnosu s Dopplerskim pomakom, brzinom zvuka u krvi i kuta upada — kut između ultrazvučne zrake i strujanja krvi. Navedeni kut također predstavlja glavno ograničenje Dopplerske ehokardiografije. Naime, povećanje kuta upada (loša podešenost ultrazvučne zrake sa smijerom strujanja krvi) smanjuje izračunatu brzinu te onemogućuje precizni izračun vršnih brzina.

Modaliteti Dopplera koje se koriste u sklopu standardnog ehokardiografskog pregleda uključuju pulsni Doppler (PW), kontinuirajući Doppler (CW) i obojani Doppler (CD). Glavna obilježja PW-a su dubinska rezolucija, dobra kontrola postavljanja uzorkovanog volumena (engl. *sample volume*) te mali uzorkovani volumen, što ga čini povoljnim za mjerenja niskih brzina na specifičnim područjima, za mjerenja volumena, procjenu dijastoličke disfunkcije itd. Suprotno tome, CW omogućava mjerenje vršnih brzina (gradijenti tlakova na zaliscima, poluvrijeme pada tlaka itd.), manje je podložno poduzorkovanju (engl. *aliasing*) te ima višu senzitivnost. Oba ova modaliteta se koriste u hemodinamksim mjerenjima. Obojeni Doppler pruža podatke na 1D ili 2D podlozi tako da prikazani uzorci protoka pružaju kvantitative podatke o mjestu, smijeru i prirodi protoka (laminaran, turbulentan).

Navedene komplementarne ehokardiografske metode valjalo bi rutinski koristiti kako bismo proveli sveobuhvatni ehokardiografski pregled koji pruža sve podatke o morfologiji, funkciji i hemodinamici srca.

Doppler echocardiography is an irreplaceable segment of the complete echocardiographic examination. As 1D (M-mode) and 2D echocardiography provide images of the heart structures, Doppler echocardiography provides data on blood flow within the heart and great vessels. These flow patterns are based on the changes in frequency of the backscatter signal from red blood cells, which are then intercepted by the ultrasound beam. The basic physical principles of Doppler echocardiography are based on the Doppler effect according to which sound frequency increases as a sound source moves toward the observer and decreases as the sound moves away. This difference (change) in frequency of the transmitted and reflected sound defines the Doppler shift. Blood flow velocity is further calculated from the Doppler equation and is related to the Doppler shift by the speed of sound in blood and the angle of incidence — the angle between the ultrasound beam and blood flow. This angle also represents the main limitation of Doppler echocardiography. Namely, an increase in the angle of incidence (poor alignment of the ultrasound beam with the direction of blood flow) decreases the calculated velocity, thus disabling precise calculation of peak velocities.

Several Doppler modalities employed in the standard echocardiographic examination comprise Pulsed-wave Doppler (PW), Continuous-wave Doppler (CW) and Colour flow imaging. The main characteristics of PW are depth resolution, good control of sample volume placement and small sample volume, thus being optimal for the measurement of low velocities at particular locations, volume measurements, assessment of diastolic function etc. On the contrary, CW enables measurements of peak velocities (valvular pressure gradients, pressure half time, etc), has less aliasing issues and a higher sensitivity. Both of these modalities are utilised in haemodynamic measurements. Colour Doppler provides data overlaid on a 2D or M-mode template where visualised flow patterns provide quantitative information on spatial location of the flow, direction and the nature of the flow (turbulence/laminar flow).

In order to obtain a comprehensive echocardiographic examination providing full data on the heart's morphology, function and haemodynamics, all of the aforementioned echocardiographic modalities should routinely be employed in a complimentary manner.

# Optimizacija ehokardiografskog prikaza

# Image optimization

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Optimizacija slike jedan je od najvažnijih preduvjeta za dobar ehokardiografski pregled. Da bismo dobili sve informacije koje trebamo, potrebno je znati što točno želimo prikazati, kako to postići i koje nam sve mogućnosti ehokardiografski uređaj pruža. Također, potrebno je znati i osnove fizike ultrazvuka što će nam pomoći u optimizaciji prikaza. Za početak, važno je omogućiti najbolje preduvjete za dobar posao. To znači da je potrebno zamračiti prostoriju u kojoj se odvija pregled, postaviti bolesnika u adekvatan položaj (ovisno o projekciji koju želimo snimiti), zauzeti udoban položaj tijekom snimanja, namjestiti monitor i postaviti EKG. Svaki od ehokardiografskih modaliteta (jednodimenzijski, dvodimenzijski, obojani, pulsni i kontinuirani Doppler) koji koristimo ima svoje posebne karakteristike te se tijekom ehokardiografskog pregleda slika mora kontinuirano optimizirati radi što bolje kvalitete prikaza, kako bismo izbjegli artefakte, a dobili što točniju i potpuniju informaciju. Tako se kod optimizacije dvodimenzijske slike, među ostalim, treba voditi računa o ukupnom (gain) i slojevitom osvjetljenju (time-gain compensation), dubini (depth), širini lepeze (sector with) te frekvenciji ultrazvučnog signala (ovisno o debljini bolesnika). Svi ovi parametri mogu nam pomoći u postizanju što bolje rezolucije slike. Za optimizaciju jednodimenzijskog ultrazvuka najvažniji je adekvatan položaj na kojem presijecamo dvodimenzijsku sliku (npr. ukoliko želimo mjeriti debljinu stijenki ventrikla, položaj jednodimenzijskog ultrazvuka mora biti okomit na navedene stijenke). U ovom modalitetu također je moguće namjestiti i jačinu signala te brzinu prolaza "vremenske trake" (tzv. horizontal sweep). Kod optimizacije obojanog Dopplera valja voditi računa o veličini područja interesa (color sector), pojačanju prikaza u boji (color gain) i skali boje (Niquist limit). Što se tiče pulsnog Dopplera, najvažniji je odabir mjesta uzorkovanja brzina krvi na koje postavljamo volumni uzorak (sample volume). Ispravni odabir mjesta osnova je točne interpretacije Dopplerskih krivulja. Općenito je za Dopplerski modalitet najvažnije to da smjer ultrazvučnog snopa bude paralelan sa smjerom strujanja krvi, jer samo u tom slučaju dobivamo točne podatke o brzini krvi, a to nam onda omogućuje precizne hemodinamske izračune (gradijenti, volumeni...). Kako kod pulsnog, tako i kod kontinuiranog Dopplera možemo optimizirati i položaj osnovne linije (baseline), raspon prikazanih brzina (scale) te jačinu signala (gain) i brzinu prolaza "vremenske trake" (tzv. horizontal sweep). Kod pulsnog Dopplera, ovisno o dubini na kojoj želimo mjeriti brzine krvi, mogu se koristiti različite frekvencije učestalosti impulsa (pulse repetition frequency — PRF).

Zaključno, za dobar rad ehokardiografičara važno je teoretsko znanje (o entitetima koje proučavamo, o mogućnostima ehokardiografskog uređaja, o fizici ultrazvuka), strpljenje, puno praktičnog rada i klinička integracija podataka koje nam ova dijagnostička metoda pruža.

Image optimization is one of the most important preconditions for good echocardiographic examination. To gain all the information we need, it is necessary to know what we want to show, how to accomplish that and what are the possibilities of the echo machine. For better understanding of this method, it is crucial to know something about physics of ultrasound. In the beginning of the examination, it is important to have good conditions such as low light in the room and adequate patient position (depending on which views we want to get). It is important to set an ECG and to adjust the monitor. Each echocardiographic modality (M-mode, 2D, color Doppler, pulsed and continuous-wave Doppler) has its own special characteristics and it is necessary to optimize the image throughout the whole echocardiographic examination in order to improve the image quality. This way we can avoid artefacts and get more accurate information. For 2D echocardiographic image optimization, several sistem settings are available, such as gain, time-gain compensation, sector depth, with and transducer frequency. All these elements can help us in obtaining the best image resolution. For M-mode image optimization, the most important is perpendicular position of the beam to the surface of the structure we want to measure (for example LV diameter). In this modality it is possible to adjust active gain and horizontal sweep. When we talk about Doppler color flow imaging, it is important to appropriately set color sector, gray scale gain, color gain and color scale (Niquist limit). As far as pulsed Doppler is concerned, the most important thing is correct selection of the sample volume position, because this is the basic condition for correct interpretation of Doppler tracings. In general, for the both pulsed and continuous Doppler recordings, a parallel intercept angle between the ultrasound beam and the direction of blood flow is crucial to obtain true velocities. In the both of these modalities we can adjust baseline position, velocity scale, horizontal sweep and active gain. When we use pulsed Doppler, depending on the depth of the structure, it is necessary to use different pulse repetition frequency (PRF).

To conclude, for optimal echocardiographic examination it is important to have good theoretical knowledge (about cardiology, echocardiography, ultrasound physics), lot of practical training, patience and clinical integration of all the data this method is offering.

# Kompletni ehokardiografski pregled

# Complete echocardiographic examination

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Cilj oslikavanja srčanih struktura metodom transtorakalne ehokardiografije (TTE) nije samo dobiti uvid u srčane šupljine i strukture, nego saznati i više informacija o funkciji. Pregled TTE započinje unosom demografskih i antropometrijskih podataka o pacijentu, razumijevanjem postavljenog kliničkog upita temeljem pregleda medicinske dokumentacije, a nastavlja se kliničkim pregledom i kontrolom vitalnih funkcija (arterijski tlak, kontinuirano praćenje elektrokardiograma) pa stoga ne čudi da optimalno vrijeme cjelokupnog trajanja pregleda koje uključuje i izdavanje nalaza iznosi 45-60 minuta. Neizostavni elementi koji su nužni za nastanak optimalnog rezultata pregleda TTE predstavljaju informiran i suradljiv pacijent, certificirano osoblje (individualnom europskom i/ili nacionalnom certifikacijom te recertifikacijom) uz akreditaciju ehokardiografskog laboratorija (uključujući postupnik pregleda i adekvatnu opremu) te kontinuirani nadzor i unaprjeđivanje svakodnevnog rada s ciljem postizanja što bolje kvalitete.

Kompletan TTE pregled ne uključuje samo pregled sistematskim pristupom u standardnim ehokardiografskim presjecima (transtorakalni, suprasternalni, subkostalni), nego i dodatni prikaz srčanih struktura modificiranim presjecima sa svrhom prikaza strukture ili morfologije, uz analize sistoličke (globalne, regionalne) i dijastoličke funkcije, protoka te uvida u hemodinamske karakteristike. Rezultate pretrage treba digitalno dokumentirati i potom arhivirati. Zaključke, odnosno odgovor na postavljen klinički upit, treba donositi intepretiranjem nalaza svih mjerenja, imajući u vidu da normalne vrijednosti rezultata ovise i o dobi i tjelesnoj površini.

Europsko udruženje za ehokardiografiju kontinuirano objavljuje preporuke za pregled koje su dostupne na web portalu www.escardio.org, kao i na web stranicama Radne skupine za ehokardiografiju Hrvatskog kardiološkog društva (http://croecho.kardio.hr/).

The aim of imaging cardiac structures by using the transthoracic echocardiography (TTE) is not only to obtain an insight into the cardiac chambers and structures, but to find out more information about the function. The TTE examination begins by entering demographic and anthropometric data on a patient thereby understanding the posed clinical query based on inspection of the medical records, and is continued by clinical examination and control of vital functions (blood pressure, continuous electrocardiogram monitoring) and therefore it is not surprising that the optimal time for the entire duration of the examination, which includes writing of examination report, is 45-60 minutes. Some essential elements that are necessary for the achievement of the optimal result of TTE examination are informed and cooperative patient, certified personnel (according to individual European and/or national certification and recertification) with the accreditation of echocardiography laboratory (including the examination procedure and appropriate equipment) and continuous monitoring and improvement of daily work with an aim to achieve better quality.

A complete TTE examination includes not only the examination by systematic approach in the standard views (transthoracic, suprasternal, subcostal), but also the additional image of cardiac structures by modified view in order to show the structure or morphology, along with analyses of systolic (global, regional) and diastolic function, flow and insight into the haemodynamic characteristics. The test results need to be documented and archived in digital format. The conclusions or the response to the clinical query needs to be reached by interpreting the results of all measurements, bearing in mind that normal result values depend on age and body surface.

European Association of Echocardiography continuously publicizes recommendations for examination that are available on the web portal www.escardio.org, and on the website of the Working Group for Echocardiography of the Croatian Cardiac Society (http://croecho.kardio.hr/)

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# Procjena volumena i sistoličke funkcije lijeve klijetke

# Assessment of volumes and systolic function of the left ventricule

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Transtorakalna ehokardiografija je neinvazivna, lako dostupna, jeftina dijagnostička metoda, bez potencijalno štetnog radioaktivnog zračenja, koja se danas široko primjenjuje u procjeni: veličine srčanih šupljina, oštećenja srčanih struktura, debljine miokarda, kontraktilnosti, bolesti perikarda, sistoličke i dijastoličke funkcije lijeve i desne klijetke te vaskularnoj i valvularnoj patologiji.

Jednodimenzionalnim prikazom u M modu uz istovremeni elektrokardiografski zapis moguće je procijeniti veličine srčanih šupljina, debljinu i motilitet stijenki, pokrete nekih valvularnih struktura u različitim dijelovima srčanog ciklusa te iz dobivenih rezultata procijeniti volumen i masu miokarda lijeve klijetke (LK), kao i sistoličku funkciju LK.

Prikazom dvodimenzionalne slike u stvarnom vremenu, 2D mod-u, također se mogu procijeniti volumen, segmentalna kontraktilnost i sistolička funkcija LK, kao i morfologija i funkcija valvularnih struktura. Primjenom spektralnog kontinuiranog ili pulsnog doplera mogu se dobiti dodatne informacije o brzinama protoka krvi u određenim srčanim strukturama tijekom različitih faza srčanog ciklusa i iz tih mjerenja izračunati tlakove u srčanim šupljinama, udarni i minutni volumen LK, procijeniti sistoličku i dijastoličku funkciju LK te funkciju valvularnih struktura.

Svaki od ovih modaliteta ima svoja ograničenja koja je potrebno poznavati da bi se njihovom pravilnom primjenom, kao i kombinacijom istih, postigla što objektivnija procjena morfologije i funkcije srčanih struktura.

Transthoracic echocardiography is a noninvasive, easily available, inexpensive diagnostic method, without potential harmful X-radiation that is today widely applied in evaluation of: the size of cardiac chambers, the damage of cardiac structures, thickness of the myocardium, contractility, pericardial disease, systolic and diastolic function of the left and right ventricle, vascular and valvular pathology.

One-dimensional image in M-mode with simultaneous electrocardiographic recording can assess the cardiac chambers size, wall thickness and motility, motions of certain valvular structures in different parts of the cardiac cycle, and from these results we may evaluate the volume and mass of the myocardium of the left ventricle (LV) as well as systolic function of the LV.

By using the two-dimensional image in real time (2D-mode), you can also evaluate the volume, segmental contractility and systolic function of the LV as well as the morphology and function of valvular structures. By applying spectral continuous or pulsed Doppler we can obtain additional information about the velocities of blood flow in certain cardiac structures during different phases of the cardiac cycle, and from these measurements we can calculate the pressure in cardiac chambers, stroke and minute volume of the LV, assess systolic and diastolic LV function and the function of valvular structures.

Each of these modalities has its limitations that we need to be familiar with as to obtain more objective evaluation of morphology and the function of cardiac structures provided that we use them properly and combine them.

# Procjena dijastoličke funkcije

# Assessment of diastolic function

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Dijastolička disfunkcija je stanje u kojem dolazi do smanjenog punjenja lijeve klijetke (LK) u ranoj i/ili kasnoj dijastoli. Izrazito smanjeno i/ili otežano dijastoličko punjenje smanjuje udarni volumen LK (i pored dobre sistoličke funkcije). Nužno se u tim stanjima razvijaju kompenzatorni mehanizmi kojim se udarni volumen održava porastom tlakova punjenja LK. Najvažniji je porast tlaka u lijevom atriju te retrogradno i porast tlaka u plućima. Povišen tlak u plućnoj cirkulaciji iznad 12mmHg dovodi do kliničke slike kongestivnog zatajivanja srca (ZS). Stoga je procjena dijastoličke funkcije LK i procjena tlakova punjenja važan

Diastolic dysfunction is a condition where reduced left ventricular (LV) filling occurs in early and/or late diastole. Extremely reduced and/or difficult diastolic filling reduces LV stroke volume (despite good systolic function). In these situations it is necessary to develop compensatory mechanisms to maintain stroke volume by elevation of LV filling pressure. The most important is the elevation of the pressure in the left atrium, and retrogradely the elevation of pressure in the lungs. Elevated pressure in the pulmonary circulation over 12mmHg leads to the clinical image of congestive heart failure. Therefore, the assessment of the dio ehokardiografskog pregleda. Za dijagnozu dijastoličkog ZS u bolesnika sa znacima i simptomima kongestivnog ZS moraju biti zadovoljeni sljedeći kriteriji: a) normalne ili tek blago oštećene sistoličke funkcije LK; b) postojanje oštećene relaksacije LK, punjenja ili oštećene rastežljivosti (dijastolička krutost). Metoda izbora za dokazivanje ovih kriterija je ehokardiografija.

Ehokardiografski dijagnostički parametri za dijastoličku disfunkciju su: produženo vrijeme izovolumne relaksacije miokarda (vrijeme izovolumne relaksacije — IVRT>105 msec i/ili vršak pada tlaka LK — LVdP/dt<1100 mmHgs-1) i sporo punjenje LK u ranoj dijastoli ( E/A omjer< 0.5 i/ili vrijeme usporavanja ranog mitralnog protoka — DT>220 msec i/ili omjer brzine protoka u plućnim venama u sistoli i dijastoli — S/D>2.5) i/ili smanjena dijastolička rastežljivost LK (brzina retrogradnog protoka u plućnim venama — PVA Flow >35cms-1 i/ili dulje trajanje retrogradnog protoka u plućnim venama u odnosu na trajanje A vala transmitralnog protoka — PVAt>MVAt za 30 ms).

Obzirom na ehokardiografske parametre transmitralnog protoka težinu dijastoličke disfunkcije klasificiramo u četiri stupnja: 1) smanjena relaksacija miokarda, 2) "pseudonormalizacija" kada već dolazi do porasta dijastoličkog tlaka na kraju dijastole, 3) reverzibilno restriktivno punjenje LK uz Valsalvin postupak gdje postoje i smetnje u rastežljivosti miokarda uz visok dijastolički tlak te 4) stupanj s ireverzibilnim restriktivnim punjenjem na Valsalvin postupak, značajne smetnje rastežljivosti miokarda. Najveći izazov je razlikovanje normalnog transmitralnog protoka od drugog stupnja dijastoličke disfunkcije tzv. "pseudonormalizacije". U otkrivanju patologije pored transimtralnog protoka koristimo dodatna mjerenja. I to, gore naveden odnos trajanja A vala i retrogradnog protoka u plućnim venama te brzinu mitralnog prstena u ranoj dijastoli Doplerom miokarda, gdje je brzina E′ manja od brzine u kasnoj dijastoli A′ i tako demaskira pseudonormalizaciju transmitralnog protoka.

LV diastolic function and assessment of filling pressures is an important part of echocardiographic examination. For the diagnosis of diastolic HF in patients with signs and symptoms of congestive HF, the following criteria must be satisfied: a) normal or only slightly impaired LV systolic function, and b) existence of the impaired LV relaxation, filling or impaired elasticity (diastolic stiffness). The method of choice for evidencing these criteria is echocardiography.

Echocardiographic diagnostic parameters for diastolic dysfunction are: prolonged isovolumetric myocardial relaxation time (isovolumetric relaxation time — IVRT>105 msec and/or peak of fall in LV pressure — LVdP/dt <1100 mmHgs-1) and slow LV filling in early diastole (E/A ratio <0.5 and/or early mitral flow deceleration time — DT> 220 msec and/or the ratio of the flow velocity in the pulmonary veins in systole and diastole — S/D>2.5) and/or reduced diastolic elasticity of the LV (velocity of retrograde flow in the pulmonary veins — PVA Flow> 35cms-1 and/or longer duration of retrograde flow in the pulmonary veins compared to the duration of A wave of transmitral flow — PVAt> MVAt in 30 ms).

Considering the echocardiographic parameters of transmitral flow, the severity of diastolic dysfunction is classified into four degrees: 1) decreased myocardial relaxation, 2) "pseudonormalisation" when it comes to an elevation of diastolic pressure at the end of diastole, 3) reversible restrictive filling of the LV by applying the Valsalva's manuever where there are disorders in myocardial elasticity with a high diastolic pressure, and 4) degree with an irreversible restrictive filling on the Valsalva's manuever, significant disorders of myocardial elasticity. The biggest challenge is to distinguish between normal transmitral flow of the second degree diastolic dysfunction, the so-called "pseudonormalisation". In detecting pathology, we use additional measurements besides the transimtral flow, namely the aforementioned relation of duration of A wave and retrograde flow in the pulmonary veins and the velocity of mitral ring in the early diastole by imaging myocardium by Doppler, where the velocity E′ is less than the velocity of the late diastole A′ and thus unmasks pseudonormalisation of transmitral flow.

# Mitralni zalistak — morfologija i procjena stenoze

# Mitral valve — morphology and assessment of stenosis

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Tehnološki razvoj transtorakalne i transezofagusne ehokardiografije posljednjih godina omogućio nam je uvid u sve anatomske i funkcionalne promjene mitralne valvule i mitralnog aparata. Standardni ehokardiografski pregled mitralne valvule uključuje jednodimenzijsku (M-mode), dvodimenzijsku i doplersku (obojani, pulsni i kontinuirani dopler) analizu. U posljednjih nekoliko godina transezofagusna ehokardiografija predstavlja rutinsku metodu tijekom kardiokirurških operacija na mitralnoj valvuli. De-

Technological development of transthoracic and transesophageal echocardiography has in recent years allowed us to obtain an insight into all the anatomical and functional changes in mitral valve and the mitral apparatus. Standard echocardiographic examination of mitral valve includes a one-dimensional (M-mode), two-dimensional and Doppler (color, pulsed and continuous Doppler) analysis. During the past few years, transesophageal echocardiography has been a routine method during cardiac opertaljne ehokardiografske analize mitralnog aparata (miokarda lijeve klijetke, papilarnih mišića, korda tendineja, mitralnog prstena, segmenata prednjeg i stražnjeg mitralnog listića i lijeve predklijetke) dovele su do razvoja novijih kardiokirurških tehnika reparacije valvule čime se uvelike poboljšao ishod kirurškog liječenja kao i kvaliteta života bolesnika.

Mitralna stenoza predstavlja opstrukciju dijastoličkom protoku krvi iz lijeve predklijetke u lijevu klijetku. Posljedica je zadebljanja i slabije pokretljivosti mitralnih listića, najčešće zbog reumatskih promjena. Prema studiji s Mayo klinike u 99% kardiokirurški liječenih bolesnika s mitralnom stenozom nađene su promjene povezane s reumatskom bolesti. Promjene koje upućuju na reumatsku etiologiju obuhvaćaju zadebljavanje i sljepljivanje listića po komisurama te skraćivanje korda tendineja. Često se nađu i kacifikacije kuspisa. U rijetke uzroke mitralne stenoze ubrajaju se infektivni endokarditis, kacifikacije mitralnog anulusa, prirođene malformacije mitralnog zalistka i sistemski lupus. Široka primjena antibiotske profilakse streptokoknih infekcija u zapadnoeuropskim zemljama unazad nekoliko desetljeća dovela je do smanjenja incidencije mitralne stenoze, dok u zemljama “trećeg svijeta” još uvijek predstavlja značajnu valvularnu patologiju.

Transtorakalna i, rjeđe transezofagusna ehokardiografija, predstavlja metodu izbora u utvrđivanju patoloških promjena mitralnog zalistka kao i hemodinamskih, odnosno patofizioloških posljedica bolesti (promjene lijeve klijetke i predklijetke, procjena tlaka u plućnoj cirkulaciji, procjena funkcije desne klijetke). Nezamjenjiva je uloga ehokardiografske procjene mitralne stenoze u odluci o optimalnom izboru liječenja, bilo kardiokirurškim metodama, bilo perkutanom balonskom dilatacijom mitralne valvule. Europsko kardiološko društvo je 2007. godine izdalo smjernice za liječenje bolesti srčanih zalistaka u kojima je ehokardiografija istaknuta kao temeljna metoda za procjenu težine mitralne stenoze prema kojoj se donose i odluke o liječenju bolesnika. Prema navedenim smjernicama mitralna stenoza se dijeli u stenozu blagog, umjerenog i teškog stupnja. Teška mitralna stenoza ima slijedeća ehodoplerkardiografska obilježja: srednji transmitralni gradijent viši od 10 mmHg, površina mitralne valvule <1 $cm^2$ i tlak u plućnoj arteriji >50 mmHg.

ations on mitral valve. Detailed echocardiographic analyses of mitral apparatus (left ventricular myocardium, papillary muscles, chorda tendineae, mitral ring, segments of the anterior and posterior mitral leaflet and left atrium) have led to the development of more recent cardio-surgical techniques of valve reparation, whereas the outcome of surgical treatment and quality of life of patients have greatly improved.

Mitral stenosis is an obstruction to diastolic blood flow from the left atrium into the left ventricle. The consequence is thickening and lower mobility of mitral leaflets, mostly due to rheumatic changes. According to a study from the Mayo Clinic, in 99% of patients treated by cardio-surgical treatment with mitral stenosis, we found changes associated with rheumatic diseases. The changes that indicate a rheumatic etiology include thickening and sticking together of leaflets in the commissures, and shortening of the chorda tendineae. Calcification of cusp is often found. Rare causes of mitral stenosis include infective endocarditis, mitral anulus calcification, congenital malformations of the mitral valve and systemic lupus. Widespread application of antibiotic prophylaxis of streptococcal infections in western European countries during the last few decades has led to a reduction in the incidence of mitral stenosis, while in the “third world” countries is still represents a significant valvular pathology.

Transthoracic and, more rarely transesophageal echocardiography, is a method of choice in determining pathological changes of mitral valve and the hemodynamic or pathophysiological consequences of the disease (changes to the left ventricle and atrium, evaluation of the pressure in the pulmonary circulation, evaluation of the right ventricular function). The role of echocardiographic evaluation of mitral stenosis is irreplaceable when deciding on the optimal choice of treatment, either by cardio-surgical methods or percutaneous balloon mitral valve dilation. In 2007, the European Society of Cardiology issued guidelines for the treatment of valvular heart disease where echocardiography was highlighted as a fundamental method for estimating the weight of mitral stenosis according to which decisions on the treatment of patients are made. According to these guidelines, mitral stenosis is divided into mild, moderate and severe degree stenosis. Severe mitral stenosis shows the following echodopplercardiographic features: average transmitral gradient greater than 10 mmHg, mitral valve area <1 $cm^2$ and pulmonary artery pressure >50 mm Hg.

# Aortni zalistak — morfologija i procjena stenoze

# Aortic valve — morphology and assesement of stenosis

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Aortni zalistak je kompleksna trolisna struktura koja dijeli ventrikul i aortu. Crta pripajanja aortnih listića ima oblik trokrake krune koja se proteže od virtualnog prstena bazalnog pripoja listića do sinotubularnog spoja. U nekoliko zadnjih dekada ova struktura je postala najčešća valvu-

The aortic valve is a complex three-leaflet structure that divides the ventricle and the aorta. The attachment line of aortic leaflets is three-arm crown shaped that extends from the virtual ring of the basal attachment of the leaflet to sinotubular junction. In the past few decades, this struclarna patologija, raste sa starošću i produljenjem životnog vijeka populacije. Kod mlađih osoba radi se češće o prirođenom dvolisnom zalisku, a kod starijih dobnih skupina o degenerativnom kalcificirajućem procesu koji je sličan aterosklerotskom procesu. Aortna skleroza predstavlja pretklinički stadij, s blagim hemodinamskim promjenama i prethodi aortnoj stenozi, s kojom čini jedinstveni kontinuum u progresiji bolesti. Prevalencija aortne stenoze u starijih od 65 godina nalazi se u oko 4% europske populacije, dok točnih podataka za Hrvatsku nemamo. Klinička sumnja za postojanje aortne stenoze zasniva se, s obzirom na dugu asimptomatsku fazu, na postojanju auskultacijskog nalaza s karakterističnim sistoličkim šumom, a dijagnoza se potvrđuje ehokardiografijom, kojom se procjenjuje stupanj promjena, odnosno težina bolesti. Dvodimenzionalnom ehokardiografijom uočavaju se promjene na zaliscima i promjene geometrije i funkcije lijevog ventrikula te promjene na ascendentnoj aorti, koje su posljedica hemodinamskih promjena na zalisku. U kvantifikaciji bolesti ključna je doplerska ehokardiografija kojom se određuje maksimalna brzina protoka i iz nje izvodi maksimalni i srednji gradijent između lijevog ventrikula i ascendentne aorte. U slučajevima u kojima lijevi ventrikul zbog slabosti ne može proizvesti gradijent koji bi bio adekvatan odraz težine stenoze, mora se mjeriti površina aortnog zaliska jednadžbom kontinuiteta, kako bi dobili pravu sliku težine stenozirajućeg procesa. To je ključno u situacijama aortne stenoze malog protoka i malog gradijenta i paradoksne aortne stenoze malog protoka i malog gradijenta. S druge strane, vrijednosti povišenog arterijskog tlaka (AT) utječu na parametre gradijenta što nalaže potrebu mjerenja vrijednosti AT za vrijeme rutinske ehokardiografske evaluacije i reevaluaciju ehokardiografskih parametara nakon normalizacije AT.

ture has become the most common valvular pathology; it rises with age and prolonged life of the population. In younger people, it is more about the congenital biscupid valve, and in older age groups it is the degenerative calcification process in question that is similar to the atherosclerotic process. Aortic sclerosis represents a preclinical stage, with mild hemodynamic changes and it precedes aortic stenosis, with which it makes a unique continuum in disease progression. The prevalence of aortic stenosis in persons over 65 years is represented in about 4% of the European population, while we still do not have accurate data available for Croatia. Clinical suspicion for the presence of aortic stenosis is based, considering the long asymptomatic phase, on the existence of auscultation findings with characteristic systolic murmur, and the diagnosis is confirmed by echocardiography, which assesses the degree of changes and severity of the disease. Two-dimensional echocardiography detects changes in the valves, changes in the geometry and left ventricular function as well as changes in ascending aorta, which are the consequence of hemodynamic changes in the valve. In quantification of the disease, Doppler echocardiography is fundamental which is used to determine the maximum flow rate, while the mean gradient between the left ventricle and ascending aorta is derived from it. In cases when the left ventricle may not, due to its weakness, produce a gradient that would be an adequate reflection of the severity of stenosis, then the aortic valve area must be calculated by the continuity equation, in order to obtain a true insight into the severity of the stenosis. This is crucial in situations of low flow aortic stenosis and low gradient aortic stenosis and paradoxical low flow aortic stenosis and low gradient aortic stenosis. On the other hand, the values of elevated blood pressure (BP) affect the gradient parameters requiring the measurement of the BP values during a routine echocardiographic evaluation and reevaluation of echocardiographic parameters after normalization of BP.

# Ehokardiografija najčešćih prirođenih srčanih bolesti u odrasloj dobi

# Echocardiography of the most common congenital heart diseases in adults

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Ovo predavanje se fokusira na ulogu ehokardiografije u adolescentnoj i odrasloj dobi kod najčešćih oblicika prirođenih srčanih bolesti. Odrasli s prirođenom srčanom bolesti predstavljaju potpuno drugačiji izazov za ehokardiografa zbog raznolikosti i složenosti urođenih srčanih malformacija, kao i mogućih i vjerojatnih kirurških zahvata koji su se obavili tijekom djetinjstva. Ehokardiografski pristup bolesnicima s prirođenim srčanim lezijama se značajno razlikuje od pristupa koji se koristi za ocjenu ostalih oblika srčane bolesti. Anatomija srca, orijentacija komora i odnosi među velikim krvnim žilama se često drastično razlikuju od normalnog srca i zahtjevaju posebnu akviziciju i tumačenje slike.

This lecture focuses on the role of echocardiography in the adolescent and adult with most common forms congenital heart disease. Adults with congenital heart disease present an entirely different array of challenges for the echocardiographer due to the diversity and complexity of congenital cardiac malformations, as well as possible and probable surgical procedures performed during childhood. The echocardiographic approach to patients with congenital heart lesions differs substantially from that used to evaluate other forms of cardiac disease. Cardiac anatomy, chamber orientation and great vessel relationships are often drasticaly different than a normal heart and demand specific image acquisition and interpretation.

Početni ehokardiografski pregled bolesnika zahtjeva sekvencijalni pristup srčanoj anatomiji, prvo određivanju atrijskog situsa i ocjenjivanju obrazaca venskog utoka u pretklijetku. Nakon toga, trebamo definirati atrioventrikularne povezanosti koje se temelje na morfologiji klijetki i valvula te se potom određuje odnos između klijetki i glavnih arterija. Nakon što smo odredili sve anatomske odnose možemo pokušati odrediti vrstu malformacije: Ebsteinova anomalija, cor triatriatum, subvalvularna, valvularna i supravalvularna pulmonalna stenoza, ventrikulski i atrijski septalni defekt, bikuspidna aortna valvula, koarktacija aorte, defekti atrioventrikularnog kanala, konotrunkalne anomalije i anomalije u razvoju klijetki.

The initial echocardiographic examination of the patient requires a sequential approach to cardiac anatomy, first determining the atrial situs and assessing venous inflow patterns to the atria. Afterwards, we need to define atrioventricular connections based on ventricular and valvular morphology. Finaly, relationship between ventricles and major arteries are determined. Only after we have determined all of the anatomical relationships, can we try to ascertain the type of malformation. Ebstein's anomaly, cor triatriatum, subvalvular, valvular and supravalvular pulmonary stenosis, ventricular and atrial septal defects, bicuspid aortic valve, coarctation of the aorta, endocardial cushion defects, conotruncal abnormalities and abnormalities of ventricular development.

# Srce u volumnom opterećenju

# Heart in volume overload

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Volumno opterećenje srca označava sva ona stanja kod kojih je povećano punjenje klijetki tijekom dijastole (tzv. preload). Možemo govoriti o lijevostranom, desnostranom ili globalnom volumnom opterećenju, akutnom ili kroničnom, fiziološkom ili patološkom, kardijalnom ili ekstrakardijalnom. Patofiziološki mehanizam srčanog remodeliranja gotovo je jednak u svim navedenim stanjima. Primjer jednog od najčešćih uzroka volumnog opterećenja je mitralna regurgitacija (MR).

U slučaju kroničnog volumnog opterećenja kod kronične mitralne regurgitacije, povećani stres na stijenke lijevog ventrikla (LV) u dijastoli dovodi do serijskog umnažanja sarkomera te do dilatacije i ekscentrične hipertrofije ventrikla (uz održavanje normalne debljine stijenki). Navedeno dovodi do povećanja ukupnog udarnog volumena, ali udarni volumen u sistemsku cirkulaciju ostaje normalan. U početnoj fazi, sistolička funkcija miokarda je očuvana i ejekcija frakcija (EF) je održana, odnosno čak i povećana na račun regurgitirajućeg volumena u lijevi atrij (LA). Međutim, kako bolest napreduje dolazi do daljnje dilatacije i sferičnog remodeliranja LV, dodatnog povećanja stresa na stijenke ventrikla te do pada intrinzičkog kontraktiliteta miokarda. U početnoj fazi oštećenja kontraktilnosti LV, EF je još očuvana. Ali kako proces napreduje dolazi do daljnje dilatacije ventrikla te pada EF i udarnog volumena, a time i do porasta teledijastoličkog tlaka. Paralelno s navedenim procesom u bolesnika s MR dolazi i do postupne dilatacije LA zbog njegovog povećanog punjenja u sistoli. Dilatacija LA i njegova povećana rastezljivost omogućuju duži period održavanja nižeg tlaka u LA. Tek kada teledijastolički tlak u LV značajnije poraste dolazi i do porasta tlaka u LA kao i u plućnoj cirkulaciji što onda dovodi do razvoja simptoma kroničnog srčanog popuštanja.

U akutnom volumnom opterećenju (npr. akutnoj mitralnoj regurgitaciji uslijed rupture papilarnog mišića) dolazi do brzog rasta teledijastoličkog tlaka, bez dilatacije ventrikla te do brzog rasta tlaka u LA budući da je atrij sma-

Volume overload signifies all those conditions in which diastolic ventricular filling (preload) is increased. It can be divided into left-sided, right-sided or global volume overload, acute or chronic, physiologic or pathologic, cardiac or extracardiac in origin. Pathophysiologic mechanism of heart remodeling is almost the same in all these aforementioned conditions. An example of one of the most common causes of volume overload is mitral regurgitation (MR).

In a case of chronic mitral regurgitation, an elevated left ventricular (LV) wall stress during diastole is present. It causes serial sarcomere assembly which leads to LV eccentric hypertrophy (with normal wall thickness). This leads to increased total stroke volume, but forward stroke volume remains normal. During the first phase of this process, LV systolic function is preserved and ejection fraction (EF) is normal or even increased due to regurgitant volume into left atrium (LA). However, as disease progresses, further LV dilatation and spherical remodeling occur and wall stress increases. This leads to fall in intrinsic myocardial contractility. In early phases of impaired myocardial contractility, LV EF is still preserved. With progressive LV remodeling, contractile dysfunction impairs ejection, resulting in a reduction of forward cardiac output and elevation of LV end-diastolic pressure. Concommitantly with this process in patients with MR, there is gradual dilatation of LA because of the increased systolic atrial filing. LA dilatation and increased compliance lead to prolonged maintaining of low intraatrial pressure. Only when LV end-diastolic pressure rises significantly, LA and pulmonary artery pressure rise, which leads to chronic heart failure symptoms.

In acute volume overload (e.g. acute mitral regurgitation caused by papillary muscle rupture) there is a sudden increase in LV end-diastolic pressure without LV dilatation. LA pressure also rises because LA is small and noncompliant. This leads to prompt elevation of pulmonary wedge and pulmonary artery pressure, which causes RV pressure njene rastezljivosti što dovodi i do brzog povišenja plućnog kapilarnog tlaka i posljedično plućne hipertenzije te tlačnog opterećenja desnog ventrikla. Klinički se navedeno stanje manifestira akutnim plućnim edemom.

Od ostalih uzroka volumnog opterećenja srca valja spomenuti ostale regurgitirajuće greške (aortnu, triksupidnu i pulmonalnu regurgitaciju), septalne defekte (ASD, VSD), ekstrakardijalne uzroke poput arteriovenskih fistula, hipertireoze, kao i neka fiziološka stanja poput trudnoće i bavljenja sportom (treninzi izdržljivosti).

Ehokardiografija je, uz dobru anamnezu i klinički status, vrlo važna i dragocjena za dijagnosticiranje i razlikovanje akutnog od kroničnog, odnosno patološkog od fiziološkog volumnog opterećenja. Isto tako, važna je za procjenu učinka takvog opterećenja na cjelokupno srce odnosno za procjenu stupnja bolesti pri čemu može biti iznimno korisna u donošenju odluka o terapijskim mogućnostima u pojedinog bolesnika. Iako su danas još uvijek u smjernicama za operativno liječenje regurgititrajućih grešaka u upotrebi standardni ehokardiografski pokazatelji sistoličke funkcije, kao što su EF, teledijastolički odnosno telesistolički promjer LV, oni u volumnom opterećenju imaju svoja ograničenja te nisu najbolji pokazatelji globalnog kontraktiliteta. Navedeni parametri mogu biti lažno dobri unatoč već oštećenoj kontraktilnosti miokarda. Stoga je važno imati to na umu kod procjene sistoličke funkcije u bolesnika s volumnim opterećenjem.

overload. Clinically this is manifested with acute pulmonary oedema.

Other causes of volume overload are other regurgitant valve lesions (aortic, tricuspid or pulmonary valve regurgitation), septal defects (ASD, VSD), extracardiac diseases such as arterio-venous fistula, thyreotoxicosis or some physiologic conditions like pregnancy or endurance training.

Echocardiography is, besides good history and physical examination, very important and valuable diagnostic tool in differentiating acute from chronic or pathologic from physiologic volume overload. It is also very important for serial evaluation of echocardiographic indices that can be important in clinical judgment for every patient with volume overload. Currently, standard ultrasound parameters reflecting global systolic function such as LV EF, end-systolic diameter, or end-diastolic diameter are still used in guidelines for operative treatment of valvular regurgitation, although these volume based parameters have important limitations in assessing global myocardial contractile function in patients with volume overload. These parameters can be falsly preserved despite the already impaired myocardial contractility. It is important to keep it in mind when assessing systolic function in patients with volume overload.

# Aortni zalistak — morfologija i procjena insuficijencije

# Aortic valve — morphology and assessment of regurgitation

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Ehokardiografija predstavlja metodu izbora u procjeni morfologije i funkcije srčanih zalistaka. Jednodimenzijska (M-mode), dvodimenzijska ehokardiografija, kao i doplerska mjerenja protoka svakodnevno se rutinski obavljaju u većini ehokardiografskih laboratorija čime se unatrag posljednjih nekoliko desetljeća stekao uvid u hemodinamske i patofiziološke procese poglavito valvularne, ali i šire srčanožilne patologije. Ehokardiografijom, kao neinvazivnom, za bolesnika bezopasnom dijagnostičkom metodom, mogu se prikazati svi anatomski i funkcionalni segmenti normalne i patološki promijenjene aortne valvule (polumjesečasti listići, korijen aorte i uzlazna aorta).

Aortna insuficijencija (regurgitacija) predstavlja povrat krvi iz aorte u šupljinu lijeve klijetke zbog nepotpunog zatvaranja polumjesečastih listića aortne valvule. Široka primjena ehokardiografije omogućila nam je češće prepoznavanje kao i procjenu težine aortne insuficijencije što je temelj za odluku o daljnjem liječenju. Populacijske studije, kao što je Framinghamska studija procjenjuju učestalost aortne insuficijencije u općoj populaciji 13% u muškaraca i 8,5 % u žena. Uzroci akutne i kronične aortne insuficijencije okvirno bi se mogli podijeliti u dvije grupe: bolest polumjesečastih zalistaka (bikuspidna aortna valvula, en-

Echocardiography is a method of choice in evaluation of morphology and function of heart valves. One-dimensional (M-mode), two-dimensional echocardiography and Doppler flow measurements are routinely performed on a daily basis in most echocardiography laboratories whereas during the past few decades, we gained an insight into the hemodynamic and pathophysiological processes, particularly valvular and wider cardiovascular pathologies. Echocardiography, as a non-invasive, diagnostic method harmless to a patient can be used to show all the anatomical and functional segments of normal and pathological aortic valves (semilunar leaflets, aortic root and ascending aorta).

Aortic insufficiency (regurgitation) represents the return of blood from the aorta into the left ventricular cavity due to incomplete closure of semilunar leaves of aortic valve. Widespread application of echocardiography has enabled more frequent recognition and evaluation of the severity of aortic insufficiency which is the basis for making a decision on further treatment. Population studies, such as the Framingham Heart Study estimate the frequency of aortic insufficiency in the general population, 13% in men and 8.5% in women. Causes of acute and chronic aortic insufficiency could be divided into two groups: semilunar valdokarditis, miksomatozna bolest, reumatska bolest, trauma i dr.) i bolesti aortnog korijena i uzlazne aorte (arterijska hipertenzija, disekcija, Marfanov sindrom, trauma i dr.).

Transtorakalna i transezofagusna ehokardiografija metoda je izbora u procjeni, bilo primarne valvularne, bilo patologije korijena ili uzlazne aorte. Stoga su i Europsko kardiološko društvo, kao i Europsko udruženje za ehokardiografiju donijeli smjernice za ehokardiografsku procjenu težine aortne regurgitacije, kao i preporuke za liječenje. Prema navedenim smjernicama aortna regurgitacija može biti blaga, umjerena i teška. Parametri teške aortne insuficijencije su sljedeći: regurgitacijski mlaz ≥65% izlaznog dijela lijeve klijetke, vena kontrakta ≥6 mm, PHT (pressure half-time) <200 msec, izražen holodijastolički reverzni protok u silaznoj aorti, ekscentrična hipertrofija lijeve klijetke, regurgitacijski volumen ?60 ml, frakcija regurgitacije ≥50%, EROA (effective regurgitant orifice) ≥0,3 $cm^2$.

vular disease (bicuspid aortic valve, endocarditis, myxomatous disease, rheumatic disease, trauma, etc.) and diseases of the aortic root and ascending aorta (hypertension, dissection, Marfan syndrome, trauma, etc.).

Transesophageal and transthoracic echocardiography is the method of choice in the evaluation of primary valvular and pathology of root or ascending aorta. Therefore, the European Society of Cardiology and the European Association of Echocardiography have issued guidelines for echocardiographic evaluation of severity of aortic regurgitation as well as recommendations for its treatment. According to these guidelines, aortic regurgitation may be mild, moderate and severe. Parameters of severe aortic insufficiency are as follows: regurgitation jet ≥65% of the outflow part of the left ventricle, vena contracta ≥6 mm, PHT (pressure half-time) <200 msec, expressed holodiastolic reversal flow in the descending aorta, eccentric left ventricular hypertrophy, regurgitation volume ?60 ml, regurgitation fraction ≥50%, EROA (effective regurgitant orifice) ≥0,3 $cm^2$.

## Srce u tlačnom opterećenju

## Heart in volume overload

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Kronični porast napetosti stijenki uslijed tlačnog opterećenja, kao u arterijskoj hipertenziji i aortnoj stenozi, uzrokuje uvećanje mase miokarda s ili bez porasta relativne debljine stijenki. Prema Laplace-ovom zakonu, napetost stijenki lijeve klijetke (LK) je proporcionalna intraventrikulskom tlaku i polumjeru klijetke, a obrnuto proporcionalna debljini stijenki. Prilagodba na tlačno opterećenje je hipertrofija miokarda koja normalizira povećanu napetost stijenki.

Iz vrijednosti indeksa mase lijeve klijetke (LVMI) i relativne debljine stijenki (RWT), prema ehokardiografskim smjernicama iz 2005. godine, mogu se razlučiti četiri morfološka oblika lijeve klijetke: 1) normalna morfologija LK, označava LVMI ≤115 $g/m^2$ za muškarce, ≤95 $g/m^2$ za žene i RWT ≤0,42, 2) koncentrično remodeliranje LK, u kojem je relativna debljina stijenke povećana, a indeks mase normalan, 3) koncentrična hipertrofija LV, u kojoj su relativna debljina stijenke i indeks mase povećani, 4) ekscentrična hipertrofija LK, u kojoj je relativna debljina stijenke normalna, a indeks mase povećan.

Zadovoljavajuća hipertrofija, fiziološka ili u sklopu remodeliranja miokarda, omogućava nastajanje visokih sistoličkih tlakova uz normalizaciju napetosti stijenki. U značajnom opterećenju miokard ne hipertrofira dostatno da bi nadvladao povećane tlakove, ili ga u hipertrofiji onemoguće ishemija miokarda, nekroza miocita i reaktivna fibroza. Nesposobnost tlakom opterećenog miokarda da razvije dostatnu koncentričnu hipertrofiju klijetke označava premoć tlačnog opterećenja, smanjenje udarnog volumena i pad sistoličke funkcije LK. Uporedo sa slabljenjem sistoličke funkcije povećava se volumen LK, ali debljina stijenki ostaje podjednaka.

Chronic elevation of the wall tension due to volume overload, as in hypertension and aortic stenosis, causes enlargement of the myocardial mass, with or without an increase in relative wall thickness. According to Laplace's law, the tension of the walls of the left ventricle (LV) is proportional to intraventricular pressure and ventricular radius and inversely proportional to the wall thickness. Adjustment to the volume overload is the myocardial hypertrophy which normalizes the elevated wall tension.

From the values of the left ventricular mass index (LVMI) and relative wall thickness (RWT), according to the echocardiography guidelines of 2005, we can distinguish between the four left ventricular morphological forms: 1) LV normal morphology, marks LVMI ≤115 g/m2 for men, ≤95 $g/m^2$ for women and RWT ≤0,42, 2) concentric remodeling of LV, where the relative wall thickness is increased, and the mass index is normal, 3) concentric LV hypertrophy, where the relative wall thickness and mass index are increased, 4) eccentric hypertrophy of LV, where the relative wall thickness is normal and the mass index is increased.

Satisfactory hypertrophy, physiological hypertrophy or the one within remodeling of the myocardium allows the occurrence of high systolic pressures with normalization of the wall tension. In a significant overload, the myocardium does not hypertrophy enough to overcome elevated pressures, but it is prevented from hypertrophy by myocardial ischemia, myocyte necrosis and reactive fibrosis. The inability of the volume overloaded myocardium to develop sufficient concentric ventricular hypertrophy indicates superiority of volume overload, decrease in stroke volume and decreased LV systolic function. Along with weakening of the systolic function, the LV volume is increased, but the wall thickness remains equal.

Promjene LK uzrokovane tlačnim opterećenjem mogu se kvantificirati ehokardiografskim mjerenjima mase i volumena. Kod pravilno oblikovane LK, uz uporabu Teichholzove formule kubiranja, koriste se dijastolička linearna mjerenja u standardnim presjecima, najčešće prema ASE ili PENN konvenciji. Izbor mjerenja određuje oblik formule koja će se upotrijebiti, a temeljno je odabrati jasne prikaze i precizno razlučiti i označiti strukture miokarda. Kod izmijenjenog oblika LK najprikladnija je 2D metoda, koja pretpostavlja da je oblik LK nalik metku (*bullet-shaped*). Ovdje se sredinom LK, u kratkoj parasternalnoj osi ocrtaju epikardijalna i endokardijalna area, a daljnji izračuni mase miokarda mogu biti prema AL (*area-length*) ili TE (*truncated ellipse*) metodi.

Changes in LV caused by volume overload can be quantified by echocardiographic measurements of mass and volume. In the event of properly shaped LV, by using Teichholz cube formula, the linear diastolic measurements in standard cross-sections are used, mostly according to ASE or PENN convention. The choice of the measurement determines the shape of the formula that will be used, and it is fundamental to choose clear images and precisely distinguish and mark the myocardial structures. In the event of modified shape of LV, it is the 2D method that is the most appropriate method, which presumes that the LV is bullet-shaped. Here in mid-LV, in short parasternal axis, the epicardial and endocardial area are viewed, while further calculations of the myocardial mass may be done according to AL (area-length) or TE (truncated ellipse) method.

# Dilatacijska kardiomiopatija

# Dilated cardiomyopathy

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Etiološki heterogen entitet dilatacijske kardiomiopatije objedinjuje istaknute morfološke karakteristike koje ga svrstavaju u red najimpresivnijih, iznimno izazovnih i edukacijski posebno vrijednih ehokardiografskih područja. S ciljem objektivnog prikaza i naglašavanja značaja ehokardiografije u terapijskom pristupu i definiranju prognoze ovih bolesnika, prije isticanja ultrazvučnih specifičnosti, dilatacijsku kardiomiopatiju valja ukratko etiološki i klinički definirati, te istaći njenu poziciju u okvirima današnjih podjela kardiomiopatija.

Ehokardiografija dilatacijske kardiomiopatije obuhvaća u prvom redu procjenu veličina, volumena i oblika srčanih šupljina, analizu simetričnosti i definiranje tipa ev. ventrikularne asimetrije, kao i procjenu debljine, regionalne te globalne kinetike stijenki miokarda sa svim očekivanim specifičnostima.

Pored dijagnostičkih kriterija i temeljnih ehokardiografskih osobitosti dilatacijske kardiomiopatije koji čine okosnicu ove programske cjeline, njen poseban klinički i ehokardiografski karakter, kao i pozicija didaktičke cjeline unutar završnog dijela tečaja naglašavaju obavezu prikaza tipičnih nalaza pojedinih ehokardiografskih elemenata obrađenih tijekom tečaja u slučajevima dilatacijske kardiomiopatije. Stoga prezentacija teme pored navedenog obuhvaća prikaz trombotskih masa u dilatacijskoj kardiomiopatiji, pregled očekivanih obrazaca u procjeni dijastoličke funkcije s pratećom analizom uvjetovanosti i kliničkih implikacija, prikaz tipične pozicije mitralne valvule u značajnoj dilataciji lijeve klijetke, osobitosti gibanja njenih kuspisa, kao i procjenu karaktera te kvantifikaciju očekivane sekundarne mitralne regurgitacije. Nadalje, u integrativnom pristupu ovoj izazovnoj temi, prikazat će se i nužna analiza desne klijetke s njenim očekivanim specifičnostima, prikaz trikuspidne regurgitacije s procjenom tlaka u plućnom optoku, kao i analizu drugih, potencijalno po-

Etiologic heterogeneous entity of dilated cardiomyopathy includes distinguished morphological features that make it one of the most impressive, extremely challenging and educationally particularly valuable echocardiographic areas. For the purpose of fair presentation and highlighting the importance of echocardiography in therapeutic approach and defining the prognosis for these patients, before highlighting the specific features of the ultrasound, the dilated cardiomyopathy should briefly be etiologically and clinically defined and its position within the today's divisions of cardiomyopathies should be emphasized.

Echocardiography of dilated cardiomyopathy primarily includes the evaluation of the size, volume and shape of cardiac chambers, the analysis of symmetry and the definition of type of potential ventricular asymmetry, as well as the evaluationt of thickness, regional, and global kinetics of myocardial walls with all expected specific features.

In addition to the diagnostic criteria and basic echocardiographic characteristics of dilated cardiomyopathy representing the basis of this whole program, its special clinical and echocardiographic character, as well as the position of didactic section within the final part of the course emphasize the obligation of presentation of typical findings of specific echocardiographic elements processed during the course in cases of dilated cardiomyopathy. Therefore, the presentation of the topic in addition to the above mentioned includes the presentation of thrombotic masses in dilated cardiomyopathy, an overview of expected patterns in the evaluation of diastolic function with accompanying analysis of conditionality and clinical implications, the presentation of typical positions of mitral valve in significant dilation in the left ventricle, the particularity of its cuspis motions, as well as the evaluation of the nature and quantification of the expected secondary mitral regurgitation. Furthermore, the integrative approach to this challenging topic will also show the required analysis of the right ventricle with its expected specific features, presentation of tricuspid regurgitation with estimated pressure in the pulvezanih entiteta koje ehokardiografski možemo isključiti ili potvrditi.

Obzirom na značajan napredak koji je u liječenju kongestivnog srčanog zatajivanja i srodnih stanja postignut tijekom posljednjeg desetljeća, ali i zbog očekivane parcijalne reverzibilnosti koju susrećemo u nekim etiološkim skupinama dilatacijske kardiomiopatije, uloga ehokardiografije sve je naglašenije od dijagnostike i početne procjene usmjerena longitudinalnom praćenju ovih bolesnika s posebnom ulogom u vođenju terapijskog pristupa. Temeljna načela i primjeri iz ovog područja, uključeni su također u tematsku cjelinu.

monary circulation, as well as the analysis of other, potentially related entities which in terms of echocardiography can be ruled out or confirmed.

Considering a significant progress achieved in the treatment of congestive heart failure and related conditions over the last decade, but also due to the expected partial reversibility that we face in some etiological groups of dilated cardiomyopathy, the role of echocardiography is more and more emphasized by the diagnostics and initial evaluation focused on longitudinal monitoring of these patients with special role in conducting the therapeutic approach. Basic principles and examples from this area are also included in the thematic unit.

# Hipertrofijska i restrikcijska kardiomiopatija

# Hypertrophic and restrictive cardiomyopathy

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Hipertrofijska i restrikcijska kardiomiopatija pripadaju glavnim oblicima kardiomiopatija koje se mogu razlikovati ehokardiografijom.

Hipertrofijsku kardiomiopatiju (HCM) obilježava povećanje mase lijeve klijetke (LK) koja se rutinski mjeri M-prikazom. Kada je povećanje mase LK prisutno bez jasne etiologije, uzrok hipertrofije je u većini slučajeva mutacija gena za proteine srčane sarkomere. Nasuprot tome, hipertrofija LK se smatra sekundarnom kada je prisutan prepoznatljivi poremećaj poput tlačnog opterećenja (hipertenzija ili aortna stenoza) ili sistemska bolest (amiloidoza, bolesti odlaganja), neovisno o prisutnosti obstrukcije izgonskog trakta LK. Međutim, razlikovanje između HCM i hipertrofijskog remodeliranja u npr. hipertenziji često predstavlja dijagnostički izazov zbog opsežnog preklapanja ehokardiografskih znakova u ovim stanjima.

Hipertrofija u HCM najčešće obuhvaća interventrikulski septum što često dovodi do gradijenta u izgonskom traktu LK >30 mmHg u mirovanju. Međutim, obstrukcija također može biti dinamička te se izaziva vježbanjem ili Valsalvinim manevrom. Stoga, u procjeni hipertrofije LK uvijek valja upotrijebiti Dopplersku ehokardiografiju, mjereći vršne brzine izgonskog trakta LK i kavuma LK, kako tijekom mirovanja tako i uz provocirajuće manevre. Obstrukcija izgonskog trakta LK često se javlja uz sistolički anteriorni pomak mitralnog zalistka (SAM).

Restrikcijsku kardiomiopatiju (RCM) teže je ehokardiografski dijagnosticirati nego dilatacijsku ili HCM, a ponekad je izazovno razlučiti ju od konstrikcijskog perikarditisa. RCM karakterizira nizak ili normalan dijastolički volumen LK, inicijalno očuvana no kasnije u tijeku bolesti i reducirana sistolička funkcija, uvećanje atrija, normalan perikard i dijastolička disfunkcija. Dijastolička disfunkcija često je restrikcijska uz povećanje vršne brzine protoka nad mitralnim zalistkom, brzim vremenom deceleracije ranog mitralnog protoka i smanjenom ranom dijastoličkom brzinom na mitralnom anulusu prema Doppleru miokarda. Ti-

Hypertrophic and restrictive cardiomyopathy are among the major types of cardiomyopathies that can be differentiated by echocardiography.

Hypertrophic cardiomyopathy (HCM) is characterized by increased left ventricular (LV) mass, which is readily measured by M-mode echocardiography. When such an increase in LV mass is present without apparent etiology, the cause of hypertrophy in the majority of cases is mutation in a gene encoding cardiac sarcomeric proteins. Converesly, LV hypertrophy is considered secondary when an identifiable disorder such as pressure overload (hypertension or aortic stenosis) or systemic disease (amyloidosis or storage diseases) is present, regardless of the presence of LV outflow tract obstruction. However, differentiation between HCM and hypertrophic remodeling in e.g. arterial hypertension often presents a diagnostic challenge due to substantial overlap between echocardiographic findings in these entities.

The pattern of hypertrophy in HCM most often involves the interventricular septum, often inducing a resting LV outflow gradient > 30 mmHg. However, the obstruction can also be dynamic — provocable by exercise or the Valsalva maneuver. Thus, Doppler techniques must always be employed in the assessment of LV hypertrophy, measuring peak LV outflow and mid-cavity velocities, during rest and provoking maneuvers. LV outflow obstruction is often concomitant with systolic anterior motion of the mitral valve (SAM).

Restrictive cardiomyopathy (RCM) is more difficult to diagnose with echocardiography than dilated or hypertrophic cardiomyopathies, and may be challenging to distinguish from constrictive pericarditis. RCM is characterized by a low or normal diastolic volume, initially normal but later in the disease course reduced LV ejection fraction, atrial enlargement, normal pericardium and abnormal diastolic function. Diastolic dysfunction is frequently restrictive, with an elevated peak mitral inflow velocity, rapid early mitral inflow deceleration, and reduced Doppler tissue imaging early annular velocity. A typical example of pičan primjer RCM je amiloidna kardiomiopatija koja se može javiti u svim oblicima sistemskih amiloidoza. Ekstracelularno odlaganje amiloida u čitavom srcu ima za posljedicu biventrikulsko zadebljanje stijenki (ispravnije no hipertrofiju stijenki) udruženu s restriktivnim punjenjem LK.

RCM is amyloid cardiomyopathy which can occur in all forms of systemic amyloidoses. Extracellular deposition of amyloid throughout the heart results in biventricular wall thickening (rather than LV hypertrophy) associated with a restrictive filling pattern detected by Doppler echocardiography.

# Ehokardiografija u ishemijskoj bolesti srca

# Echocardiography in ischemic heart disease

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Posljednih desetak godina zahvaljujući tehnološkim novinama na polju ehokardiografije dijagnostika ishemijske bolesti srca (IBS) postala je neusporedivo egzaktnija. U praktičnom svijetu najčešće smo ograničeni na transtorakalnu ehokardiografiju. Procjenjujemo primarno segmentalnu i globalnu funkciju lijevog (desnog) ventrikula u miru, a što može u uvjetima stabilne angine pektoris (AP), bez poremećaja kinetike, tj. u razdoblju bez tegoba biti ograničavajući moment, značajno smanjujući specifičnost metode. Naravno, izuzeti su bolesnici s već preboljelim infarktom i ožiljnim promjenama mokarda. U okolnostima sumnje na stabilnu AP nezaobilazna je već dobro poznata "stress" ehokardiografija koja svakim danom poprima sve veće značenje provocirajući uvjete koji dovode do ishemije miokarda popraćene s karakterističnim mehaničkim, električnim i perfuzijskim poremećajima miokarda.

Dobro je poznato da postoji neposredna veza između koronarnog protoka i njemu odgovarajuće segmentalne kontraktilne funkcije miokarda. U osoba s uredno prohodnim koronarnim arterijama protok u uvjetima opterećenja ili inotropne stimulacije (dobutamin stress) može se više nego trostruko povisiti s ehokardiografski jasno vidljivim pojačanim sistoličkim zadebljanjem miokarda. U bolesnika sa stabilnom AP i signifikantnom stenozom koronarne arterije (>70%) koronarni protok u uvjetima mirovanja (bez tegoba) uobičajeno ostaje normalan budući da se kompenzacijski smanjuje rezistencija stijenke koronarne arterije i ovo je patofiziološki mehanizam odgovoran za uvjetno "lažno" urednu segmentalnu kinetiku.

S druge strane vrlo je zahtjevan pristup bolesniku s akutno nastalom boli u prsištu. Od krucijalnog značenja je isključenje neishemijske boli. Nužno je što ranije prepoznavanje ishemijske boli kako bi se bolesnicima s akutnim koronarnim sindromom (AKS) pružile sve mogućnosti hitne terapije i intervencije bazirane na kliničkim dokazima. U dijagnostici AKS koji obuhvaća akutni infarkt miokarda (AIM) s elevacijom ST-segmenta, bez elevacije ST-segmenta i nestabilnu AP dijagnostika se tradicionalno temelji na simptomatologiji, EKG promjenama i porastu troponina. Ne smijemo pri tome zaboraviti da se 20-45% bolesnika prezentira s tipičnom ili atipičnom boli u prsištu (npr. žene, dijabetičari, starije osobe) i dijagnostički nespecifičnim EKG promjenama, a srčani enzimi koji su izrazito senzitivni, postaju pozitivni tek 4-6 sati po pojavi boli. Da bi se

During the last ten years, owing to technological novelties in the field of echocardiography, the diagnostics of ischemic heart disease (IHD) has become incomparably more precise. In practical world, we are most frequently limited to transthoracic echocardiography. We estimate the primary segmental and global function of left (right) ventricle in rest, which can be in conditions of stable angina pectoris (AP) without disruption of kinetics, i.e. during the period without symptoms a limiting moment, significantly decreasing the specific features of the method. Of course, we exclude patients with a history of heart attack and fibrotic myocardial changes. In circumstances of suspected stable AP, we find unavoidable the already well known stress echocardiography, which has an increasing importance every day provoking conditions that lead to myocardial ischemia accompanied by the characteristic mechanical, electrical and myocardial perfusion disorders.

It is well known that there is a direct link between coronary flow and its corresponding segmental myocardial contractile function. In persons with normal coronary blood flow, the flow may in the conditions of load or inotropic stimulation (dobutamine stress) be more than threefold increased with the echocardiographically clearly visible increased myocardial systolic thickening. In patients with stable AP and significant coronary artery stenosis (>70%) the coronary blood flow in conditions of rest (without symptoms) usually remains normal since the resistance of the coronary artery wall is reduced in terms of compensation and this is the pathophysiological mechanism responsible for the conditional false orderly segmental kinetics.

On the other hand, the approach to a patient with occurred acute chest pain is very demanding. The exclusion of non-ischemic pain is of crucial importance. It is essential to detect the ischemic pain as early as possible as to provide the patients with acute coronary syndrome (ACS) with any emergency treatment options and interventions based on clinical evidence. In the diagnostics of ACS, which includes acute myocardial infarction (AMI) with ST-segment elevation, without ST-segment elevation and unstable angina pectoris, the diagnostics is traditionally based on symptomatology, ECG changes and increase in troponine. We must not forget the fact that 20-45% of patients is presented with typical or atypical chest pain (e.g. women, diabetics, elderly persons) and diagnostically non-specific ECG changes, while cardiac enzymes, which are extremeshvatila veličina problema vrijedno je istaći da se samo u SAD svake godine hospitalizira pod dijagnozom AKS čak 2 milijuna bolesnika, da se radi o dijagnozi odgovornoj za 30% sveukupne smrtnosti i da se 8% bolesnika s neprepoznatom dijagnozom AIM pogreškom upućuje kući.

Akutna ishemija dovodi do kaskade biokemijskih fizioloških promjena u miokardu. Posljedica ishemije su poremećaji dijastoličke, a zatim sistoličke funkcije koji rezultiraju segmentalnim (u slučaju trožilne koronarne bolesti globalnim) ispadima kinetike, a ehokardiografski su vidljivi već unutar nekoliko sekundi po okluziji koronarne arterije. U pravilu ovi poremećaji kinetike prethode EKG promjenama, štoviše i pojavi simptoma.

Iz potrebe da se korelira arterijska koronarna cirkulacija s funkcijom (kinetikom) miokarda lijevi ventrikul je uobičajeno podijeljen na 16, odnosno na 17 segmenata. Tradicijski ehokardiografski model (16 segmenata) neznatno se razlikuje od novijeg, usvojenog 2005. god. konsenzusom Američkog i Europskog udruženja za ehokardiografiju koje uvodi i 17 apikalni segment primarno namijenjen za druge niokardne perfuzijske metode (nuklearnu kardiologiju, kompjutoriziranu tomografiju i magnetsku rezonanciju). Iz ovoga slijedi da se u ehokardiografiji može koristiti 16 i 17 segmentalni model s posebnom napomenom da je apikalni segment u svim okolnostima nepomičan. Osnovna je zamjerka ovom 16 ili 17-tom segmentalnom modelu što ne uključuje niti jedan segment desne klijetke (DK). Desna je klijetka poglavito perfundirana ograncima desne koronarne arterije, a tek opsegom mala prednja strana desnog ventrikula može biti snabdijevena i prednjom silaznom lijevom koronarnom arterijom (LAD). Ova činjenica je izrazito važna s kliničkog aspekta jer u AKS s hipotenzijom do šokom trebamo uvijek isključiti ili dokazati mogućnost pridruženog infarkta DK, stoga ehokardiografičari uvijek trebaju komentirati i funkciju DK.

Ejekcijska frakcija (EF) je vrlo vrijedan pokazatelj ukupne sistoličke funkcije lijeve klijetke. Uobičajeno se određuje jednodimenzijskom tehnikom (M-mode) što je kod segmentalne IBS uzrok čestih pogrešaka. Upravo stoga mnogi liječnici smatraju da je M-mode u ishemijskoj bolesti, osim globalne hipo-akinezije (trožilne koronarne bolesti) nepodoban za određivanje EF. Dokazano je da je EF vjerodostojna ako se određuje 2D tehnikom, a putem razlika površine lijeve klijetke u dijastoli i sistoli koristeći formulu po Simpsonu iz apikalne projekcije dvaju i četiriju šupljina.

Osim segmentalnih poremećaja kinetike, EF lijeve klijetke, veličine srčanih šupljina, Dopplerom indirektnih pokazatelja dijastoličke disfunkcije miokarda, pokazatelja plućne hipertenzije vrijedna je informacija i o eventualnoj mitralnoj regurgitaciji, muralnom trombu te mehaničkim komplikacijama AIM (ruptura ventrikulskog septuma, ruptura papilarnog mišića, ruptura srca s formiranjem pseudoaneurizme).

U ovom prikazu naravno ne trebamo zaboraviti novije tehnike poput 3D prikaza, kontrastne miokardne ehokardiografije i tkivnog Dopplera, metode koje tek u većim kliničkim studijma trebaju pokazati svoju realnu kliničku vrijednost. Konačno u zaključku treba istaći, da bi se provelo ehokardiografiju kod IBS i da bi se nalaz zadovoljavajuće interpretirao neophodno je odgovarajuće iskustvo. Prema preporukama američke radne skupine *National*

ly sensitive become positive only after 4 to 6 hours after the occurrence of pain. In order to understand the problem, it is worth noting that only in the USA some 2 million of patients are hospitalized with ACS diagnosis every year, it is the diagnosis that is responsible for 30% of all deaths and 8% of patients with unrecognized AMI diagnosis are mistakenly sent home.

Acute ischemia leads to a cascade of biochemical physiological changes in the myocardium. The consequence of ischemia are the disorders of diastolic and systolic function resulting in segmental (in the case of three-vessel coronary disease in global) kinetic distortions, while echocardiographically, they are visible within a few seconds after the occlusion of coronary artery. Such kintetics distortions generally precede ECG changes and occurrence of symptoms as well.

For the requirement to correlate coronary artery circulation with the function (kinetics) of the myocardium, the left ventricle is usually divided into (16), 17 segments. Traditional echocardiographic model (16 segments) is slightly different from the more recent model, adopted in 2005 by consensus of the American and the European Society of Echocardiography, which also introduces 17 apical segment primarily intended for other myocardial perfusion methods (nuclear cardiology, computerized tomography and magnetic resonance). This makes us conclude that in echocardiography 16 and 17 segmental model can be used, thereby especially noting that the apical segment is in all circumstances fixed. The main objection to this 16 or 17 segmental model is that it involves no right ventricular segment. The right ventricle (RV) is particularly perfundated by branches of the right coronary artery, and only the small — in terms of volume — front side of the right ventricle can be supplied by the left anterior descending coronary artery (LAD). This fact is extremely important from the clinical point of view because in ACS with hypotension to shock, we should always exclude or prove the possibility of associated RV myocardial infarction, so echocardiography experts should always comment on the RV function.

Ejection fraction (EF) is always a valuable indicator of total left ventricular systolic function. It is usually determined by one-dimensional technique (M-mode) which is in case of segmental ischemic disease a cause of frequent mistakes. That is why many physians think that the M-mode in IHD, except for global hypo-akinesis (three-vessel coronary disease) is inadequate for the determination of EF. It has been proved that the EF is credible if it is determined by two-dimensional technique, by using the differences of the surface of the left ventricle in the diastole and systole according to Simpson's formula from apical projection of two and four cavities.

Besides segmental kinetics disorder, left ventricular EF, size of heart chambers, indirect indicators of diastolic myocardial dysfunction by Doppler, indicators of pulmonary hypertension, the information about potential regurgitation, mural thrombus and mechanical complications of AMI (ventricular septal rupture, rupture of papillary muscle, rupture of heart with the formation of pseudoaneurysm) is also valuable.

In this presentation, we of course should not forget about the more recent techniques such as 3D image, myocardial contrast echocardiography and tissue Doppler, the methods that in larger clinical studies should show their real clinical value.

*Heart Attack Alert Program* ehokardiografijom se smije koristiti samo onaj kardiolog koji se je tijekom najmanje tri mjeseca aktivno uključio u ovu dijagnostiku i učinio barem 150 pretraga pod budnom paskom iskusnog ehokardiografičara. U svakodnevnoj praksi neprepoznatim ostaje do 10% pozitivnih nalaza. Mogući su i lažno pozitivni nalazi kod kod bolesnika s blokom grane, volumskim opterećenjem desnog srca i nakon kardiokirurških zahvata. Znatno je bolje uočljiva ishemija koja zahvaća čitavu debljinu stijenke od netransmuralne ishemije.

Finally, to conclude, it should be noted, that echocardiography in IHD would be carried out and that relevant experience is required so that the result could be satisfactorily interpreted. According to the recommendations of the US Working Group National Heart Attack Alert Program, echocardiography may only be used by the cardiologist who has been actively involved in this diagnostics during the period of minimum three months and who has performed at least 150 tests under the vigilant supervision of echocardiography expert. In daily practice, some 10% of positive results remain unrecognized. False positive results are also possible in patients with bundle-branch block, volume load of the right heart even following cardiac surgeries. Ischemia, which affects the entire wall thickness of non-transmural ischemia is much better observable.

# Procjena umjetnih srčanih zalistaka

# Assessment of artificial heart valves

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U predavanju se govori o dijagnostičkim kriterijima procjene umjetnih zalistaka i prognostičkim implikacijama.U uvodu je naveden kratak pregled valvularnih proteza i njihove normalne funkcije, a zatim slijedi diskusija o načinu nastanka disfunkcije i podjeli disfunkcije umjetnih zalistaka. U poglavlju o stenozi umjetnih zalistaka naglaöava se važnost razlikovanja “lažne “ stenoze od pravih, naročito kod aortnih umjetnih zalistaka te se diskutira o najboljem izboru liječenja (fibrinoliza, klasična kardiokirurgija, TAVI). Kod valvularne i paravalvularne insuficijencije umjetnih zalistaka prikazani su razni klinički slučajevi uz obrazloženje etiologije i procjene stupnja insuficijencije te odluke o potrebi reoperacije. Posebna važnost pridana je poglavlju endokarditisa umjetnih valvula s brojnim komplikacijama (vegetacije, opstrukcije valvula vegetacijama ili destrukcija s insuficijencijom, izvoriöte embolija, valvularni ili paravalvularni abscesi, fistule, dehiscijencija valvule, prolaps valvule). Osim toga naglaöena je jedna od najvažnijih disfunkcija umjetnih valvula u smislu sklonosti trombozi valvule koja se može manifestirati samo kao embolija, značajna stenoza uz manje ili viöe izraženu insuficijenciju ili fibrinskih niti valvule, a prvenstveno je posljedica neadekvatne antikoagulante terapije. U predavanju se obrazlaže kada je neophodno napraviti transezofagusni ultrazvuk radi dodatne procjene umjetnih valvula (klinička sumnja na endokarditis bez potvrde na transtorakalnom ultrazvuku, sumnja na paravalvularni absces, itd). U zaključku se naglaöava važnost redovitog kliničkog i ehokardiografskog praćenja pacijenata s umjetnim srčanim zaliscima uz edukaciju istih u antikoagulacijskoj terapiji i profilaksi endokarditisa, čime se mogu spriječiti najvažnije disfunkcije umjetnih zalistaka u vidu tromboze i endokarditisa.

The lecture discusses the diagnostic criteria for evaluation of artificial valves and prognostic implications. The introduction shows a brief overview of valvular prostheses and their normal function followed by discussion of the manner of occurrence of dysfunction and classification†of artificial valves dysfunction. The chapter on stenosis of artificial valves emphasizes the importance of distinguishing between false and true stenoses, especially in aortic artificial valves, and discusses the best choice of treatment (fibrinolysis, classic cardiosurgery, TAVI). In case of valvular and paravalvular insufficiency of artificial valves, different clinical cases are shown with an explanation of etiology and evaluation of degree of insufficiency and decision on the need of re-operation. Particular importance is attached to a section of endocarditis of artificial valves with numerous complications (vegetation, valve obstruction by vegetation, destruction with insufficiency, source of embolism, valvular or paravalvular abscesses, fistulas, valve dehiscience, valve prolapse). In addition, emphasis is placed on one of the most important dysfunctions of artificial valves in terms of propensity to valve thrombosis, which can be manifested only as embolism, significant stenosis with a more or less pronounced insufficiency or fibrinic valve threads and it is primarily the consequence of inadequate anticoagulant therapy. The lecture explains when it is necessary to perform transesophageal ultrasound for additional evaluation of artificial valves (clinical suspicion of endocarditis without any verification by means of the transthoracic ultrasound, suspected paravalvular abscess, etc.). The conclusion emphasizes the importance of regular clinical and echocardiographic monitoring of patients with artificial heart valves providing them with education about anticoagulation therapy and prophylaxis of endocarditis, which can prevent the most important artificial valvular dysfunctions in the form of thrombosis and endocarditis.

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# Potraga za srčanim masama

# The search for cardiac masses

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Ehokardiografija je nezaobilazna dijagnostička metoda za otkrivanje srčanih masa. Srčane mase možemo naći u srčanim šupljinama i u velikim krvnim žilama koje ulaze u srce ili koje izlaze iz srca. U srčane mase ubrajamo tumore srca, trombe i vegetacije. Prema literaturnim podacima transtorakalna ehokardiografija (TTE) ima manju osjetljivost i specifičnost nego transezofagusna ehokardiografija (TEE) u otkrivanju srčanih masa. TEE omogućava detaljniji prikaz srčanih šupljnima i srčanih valvula te elektroda elektrostimulatora (ES) i implantabilnog kardioverter defibrilatora (ICD), nego što to omogućuje TTE.

Primarni tumori srca nalaze se u 0,001 — 0,28% slučajeva u patoanatomskim studijama. Sekundarni tumori srca otkrivaju se u 1,5 — 21% bolesnika s ekstrakardijalnim malignim tumorima. Tumori srca su u oko 75% slučajeva benigni. Tumore srca obično nalazimo u srčanim šupljinama ili na srčanim valvulama. Od benignih tumora najčešći su miksomi, fibroelastomi i lipomi. Na miksome otpada oko 30-50% svih primarnih tumora srca, a gotovo 90% miksoma nalazi se u atrijima, tri puta češće u lijevom nego u desnom atriju. U desnom ventriklu nalazi se miksom u oko 5% slučajeva, a oko 5% slučajeva nalazimo multiple lokalizacije miksoma.

Vegetacije u sklopu infekcijskog endokarditisa nalazimo na srčanim valvulama bilo nativnim ili umjetnim valvulama i na elektrodama ES ili ICD. Osjetljivost TTE za dijagnozu vegetacija je oko 60%, dok je osjetljivost TEE značajno viša i iznosi oko 85-90%. Međutim, osjetljivost ehokardiografije je niža u bolesnika s umjetnim srčanim valvulama ili ugrađenim drugim intrakardijalnim uređajima i u bolesnika s prolapsom mitralne valvule. Ehokardiografski je potrebno odrediti veličinu, ehogenost i mobilnost vegetacije. Ove informacije važne su nam za donošenje odluke o kirurškoj terapiji, a važne su i za procjenu embolijskog rizika i za prognozu bolesnika.

Prema novim smjernicama Europskog kardiološkog društva za profilaksu, dijagnozu i liječenje infekcijskog endokarditisa, TEE potrebno je učiniti u svih bolesnika sa suspektnim infekcijskim endokarditisom, osim u bolesnika u kojih je TTE nalaz negativan uz nisku kliničku suspektnost endokarditisa.

Trombe nalazimo u srčanim šupljinama, u gornjoj ili donjoj šupljoj veni i u početnom dijelu plućne arterije. Tromboembolijski događaji mogu biti teške komplikacije u bolesnika sa zatajivanjem srca ili s poremećajem koagulacije u smislu hiperkoagulabilnosti. Akutni infarkt miokarda (AIM) također može biti praćen nastankom tromba. U današnje vrijeme reperfuzijske terapije AIM pojavnost tromba u lijevoj klijetki znatno je rjeđa nego u godinama prije uvođenja rane reperfuzijske terapije. Međutim, u bolesnika s postinfarktom anurizmom lijeve klijetke pojavnost tromba je još uvijek visoka i iznosi oko 50%. Ehokardiografijom potrebno je odrediti lokalizaciju, veličinu, odnos

Echocardiography is an indispensable diagnostic tool for detecting cardiac masses. Cardiac masses can be found in the cardiac chambers and in large blood vessels entering and leaving the heart. The heart masses include heart tumors, thrombi and vegetation. According to literature data, transthoracic echocardiography (TTE) has a lower sensitivity and specificity than transesophageal echocardiography (TEE) in detecting cardiac masses. TEE provides a more detailed imaging of cardiac chambers, heart valves and pacing electrodes and implantable cardioverter defibrillator (ICD) than TTE.

Primary heart tumors are in 0.001 to 0.28% cases found in pathoanatomical studies. Secondary heart tumors are detected in 1.5 — 21% of patients with extracardiac malignant tumors. Heart tumors are in about 75% cases benign tumors. Heart tumors are usually found in the heart chambers or on the heart valves. Of benign tumors, the most common are myxoma, fibroelastoma and lipoma. Approximately 30-50% of all primary heart tumors are myxoma, and almost 90% myxoma are located in the atrium, three times more frequently in left than in the right atrium. In the right ventricle there is myxoma in about 5% of cases, while in around 5% of cases, we find multiple myxoma localization.

Vegetations in the infectious endocarditis are found on heart valves, either native or artificial valves and on pacing electrodes or ICD. The sensitivity of TTE for the diagnosis of vegetations is about 60%, while the sensitivity of TEE is significantly higher and is around 85-90%. However, the sensitivity of echocardiography is lower in patients with artificial heart valves or other implanted intracardiac devices in patients with mitral valve prolapse. Echocardiography is applied to determine the size, echogenicity and mobility of vegetation. This information is important for us to make a decision about surgical treatment, and it is also important for the evaluation of the patient's risk of embolism and prognosis.

According to the new guidelines of the European Society of Cardiology for prophylaxis, and treatment, diagnosis and treatment of infectious endocarditis, TEE should be performed in all patients with suspected infectious endocarditis except in patients in whom TTE result is negative with a low clinical suspectibility to endocarditis.

Thrombi are found in the heart cavities, the superior vena cava, inferior vena cava, and in the initial part of the pulmonary artery. Thromboembolic events can be serious complications in patients with heart failure or a coagulation disorder in terms of hypercoagulability. Acute myocardial infarction (AMI) can also be accompanied by the appearance of thrombi. Nowadays as reperfusion therapies in AMI are used, the incidence of thrombi in left ventricle is much rarer than in the years prior to the introduction of early reperfusion therapy. However, in patients with postinfarction aneurysm of the left ventricle, the incidence of thrombi is still high and it is approximately 50%. Echocardiography needs to determine the localization, size, relatromba prema okolnim strukturama i mobilnost tromba ili pojedinih dijelova tromba. Ove karakteristike važne su nam za procjenu rizika embolijskog događaja.

Ponekad nailazimo na poteškoće u potrazi za srčanim masama radi artefakata koji mogu biti uzrokovani sjenama kalcifikacija, sjenama dijelova umjetnih valvula ili elektroda ili kod spontanog eho kontrasta u lijevom atriju ili u lijevoj aurikuli. Zbog toga je potrebno uvijek u potragama za srčanim masama prikazati patološke promjene tj. srčane mase u više ravnina tj. presjeka. Na taj način izbjegavamo lažno pozitivne i lažno negativne rezultate. Uz dvodimenzijsku, veliki napredak u dijagnostici srčanih masa je trodimenzijska ehokardiografija. Live 3D ehokardiografija daje u realnom vremenu precizniji trodimenzijski prikaz srčanih masa i njihov odnos prema okolnim strukturama.

tion of thrombi to surrounding structures and mobility of thrombi or certain parts of the thrombi. These characteristics are important for us to assess the risk of embolic event.

Sometimes, we encounter difficulties while searching for heart masses due to artifacts that may be caused by calcification shadows, shadows of parts of artificial valves or electrodes or in case of spontaneous echo contrast in the left atrium or in the left auricle. Therefore it is always necessary while searching for cardiac masses to show pathological changes, i.e. cardiac mass in multiple views. In this way we avoid false positive and false negative results. With a two-dimensional echocardiography, a major breakthrough in the diagnosis of cardiac masses is the three-dimensional echocardiography. Live 3D echocardiography provides real-time accurate three-dimensional image of cardiac masses and their relation to surrounding structures.

# Osnove transezofagusne ehokardiografije

# The basics of transesophageal echocardiography

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Transezofagusna ehokardiografija (TEE) kao dijagnostička metoda koristi se od 1976. godine kao jednodimenzijski prikaz (1D), a godinu dana kasnije počinje primjena dvodimenzijskog prikaza (2D). U zadnjih desetak godina TEE je doživjela veliki napredak uz korištenje trodimenzijskog prikaza (3D) i “live” 3D prikaza u realnom vremenu.

TEE dijagnostička je metoda koja se izvodi sondom koja se stavlja u jednjak. Ultrazvučna sonda nalazi se u jednjaku, a presjeci srca prikazuju se iz gornjeg i srednjeg dijela jednjaka i transgastričnim pristupom. Dužina sonde je 100 cm, a promjer sonde je 7 ili 9 mm. Postoje i sonde manjih promjera za pregled djece s mogućnošću uvođenja nazogastričnim putem. Primjena TEE počela je s “monoplane” sondom, daljnji razvoj rezultirao je primjenom “biplane” sonde, a danas su na raspolaganju “multiplane” sonde koje stvaraju prikaz srca u više ravnina u kutu (angulaciji) od 0 st. do 180 st. u smjeru kazaljki na satu i kutu od 0 st. do 180 st. u smjeru suprotnom od kretanja kazaljki na satu.Činjenica je da se danas “monoplane” sonda smatra zastarjelom tehnologijom i gotovo se više i ne koristi. Kao kod TTE tako i kod TEE, anatomske odnose struktura srca i velikih kvnih žila određujemo uspoređivanjem s poznatim normalnim anatomskim odnosima, a u nekim kliničkim entitetima koristimo i kontrastnu TEE. Kontrastno sredstvo koristi se otopina glukoze ili fiziološka otopina NaCl.

Kod TEE razlikujemo standardne prikaze struktura srca u poprečnoj i u uzdužnoj ravnini. Poprečni prikazi su: prikaz u razini uzlazne aorte, prikaz u raznini pulmonalne valvule, prikaz u raznini aortne valvule, prikaz četiriju šupljina, prikaz luka aorte i prikaz silazne aorte. Uzduži prikazi su: prikaz u razini lijeve aurikule, prikaz u razini mitralne valvule, prikaz u razini pulmonalne valvule, prikaz u razini uzlazne aorte, prikaz u razini aortne valvule, prikaz u

Transesophageal echocardiography (TEE) as a diagnostic method has been used since 1976 as one-dimensional image (1D), and a year later, the two-dimensional image started to be used (2D). During the last ten years, TEE has seen a great progress by using three-dimensional image (3D) and live 3D real time image.

TEE is a diagnostic method that is performed by probe placed in the esophagus. An ultrasound probe is located in the esophagus, and heart sections are shown from the upper and middle portion of the esophagus and by transgastric approach. The length of the probe is 100 cm, while the diameter of the probe is 7 or 9 mm. There are smaller diameter probes for examination of children with a possibility of introducing them by nasogastric tube. The application of TEE started with “monoplane” probe, further development resulted in the application of “biplane” probe, and now there are “multiplane” probes available that produce the image of heart in multiple views of the heart in the angle (angulation) from 0 degree to 180 degree clockwise and in the angle from 0 degree to 180 degree anticlockwise. The fact is that today “monoplane” probe is considered to be outdated technology and it is almost no longer used. As in case of TTE and TEE, the anatomical relations of the heart structures and large blood vessels are determined by comparing them with the known, normal anatomic relations, and in some clinical entities, we also use a contrast TEE. The contrast agent that is used is glucose solution or saline solution.

In case of TEE, we distinguish between standard images of the heart structures in transversal and longitudinal views. The transversal views are: view at the level of ascending aorta, view at the level of pulmonary valve, view at the level of aortic valve, view of four chambers, view of aortic arch and view of descending aorta. Longitudinal views are: view at the level of the left auricle, view at the razini gornje šuplje vene, prikaz lijeve klijetke transgastričnim pristupom i prikaz u razini torakalne aorte. Komplikacije tijekom izvođenja TEE vrlo su rijetke, a učestalost je od 0,04 - 0,4%. U komplikacije ubrajamo nepostojanu VT, postojanu VT, zatajivanje srca, laringospazam, edem parotidne žlijezde, prolaznu hipotenziju, hipoksemiju i hipertenziju, a najrjeđa komplikacija je smrt u 0,04% slučajeva.

TEE zauzima vrlo važno mjesto u kliničkoj kardiologiji zbog prikaza struktura srca i u onih bolesnika u kojih se TTE ne može dobiti dobar prikaz zbog emfizema pluća, pretilosti ili deformiteta prsnog koša. TEE ima također veliku dijagnostičku vrijednost u vrlo teških bolesnika koji su u stanju šoka ili su na strojnoj ventilaciji, pa se u njih TTE ili drugim dijagnostičkim metodama ne mogu dobiti podaci o morfološkim ili funkcijskim promjenama srčanih struktura o kojima ovisi izbor terapijskih postupaka.

TEE ima važno mjesto u dijagnostici bolesti srčanih valvula poglavito kod bolesnika koji su na strojnoj ventilaciji ili imaju ozljedu prsišta.TEE jedina je ehokardiografska metoda za intraoperacijsku procjenu uspjeha mitralne ili trikuspidne valvuloplastike prije zatvaranja prsnog koša. TEE mjerimo brzinu protoka kroz srčane valvule i vršimo kvantifikaciju srčanih grešaka tj. stupnjeva stenoze ili regurgitacije. Moguće je mjeriti i protok kroz plućne vene i protok u lijevoj aurikuli. TEE je dijagnostička metoda prve razine za akutni aortni sindrom (AAS). U AAS spada akutna disekcija torakalne aorte, intramuralni hematom aorte i penetrantni aterosklerotični ulkus aorte.

TEE ima visoku osjetljivost i specifičnost u otkrivanju kardijalnih masa. Ova metoda nije skupa, minimalno je invazivna, može se izvoditi prijeoperacijski i intraoperacijski, a istodobno se u bolesnika mogu obavljati ostali potrebiti dijagnostički i terapijski postupci. TEE često određuje izbor medikamentne ili kardiokirurške terapije srčanih masa.

Transezofagusna ehokardiografija otvorila je novi prozor u srce uz velike dijagnostičke mogućnosti jedne neinvazivne dijagnostičke metode. Osim 2D TEE na raspolaganju je "live" 3D TEE kojom prikazujemo srčane strukture, morfološke i funkcijske promjene u realnom vremenu.

level of mitral valve, view at the level of pulmonary valve, view at the level of ascending aorta, ima view at the level of aortic valve, view at the level of the superior vena cava, view of the left ventricle by transgastric approach and view at the level of the thoracic aorta. Complications during performance of TEE are very rare, while the incidence is from 0.04 to 0.4%. The complications include non-sustained ventricular tachycardia, sustained ventricular tachycardia, heart failure, laryngospasm, edema of parotid gland, transient hypotension, hypoxemia and hypertension, while the rarest complication is death in 0.04% cases.

TEE plays a very important role in clinical cardiology because of imaging the cardiac structures in those patients in whom by TTE a good image cannot be obtained because of pulmonary emphysema, obesity, or chest deformities. TEE has also a great diagnostic value in very serious patients who are in the state of shock or are on mechanical ventilation, so in such patients it is impossible to obtain data on morphological or functional changes of cardiac structures by using TTE or other diagnostic methods, whereas the selection of therapeutic procedures depends on such data.

TEE plays an important role in the diagnostics of heart valves, especially in patients who are subject to mechanical ventilation or have chest injuries. TEE is one of the echocardiographic methods for intraoperative assessment of the success of mitral or tricuspid valvuloplastics prior to closing of the chest. TEE is measured by the speed of flow through heart valves and we quantify heart failures, i.e. the degrees of stenosis or regurgitation. It is possible to measure the flow through the pulmonary veins and the flow in the left auricle. TEE is the first-level diagnostic tool for acute aortic syndrome (AAS). The AAS includes acute thoracic aortic dissection, intramural hematoma of the aorta and penetrating atherosclerotic aortic ulcer.

TEE has a high sensitivity and specific feature in detecting cardiac masses. This method is inexpensive, it is minimally invasive, it can be done preoperatively and intraoperativelly, and at the same time other diagnostic and therapeutic procedures can be applied in patients. TEE frequently determines the selection of medicamentous and cardiosurgical treatment of cardiac masses.

Transesophageal echocardiography has opened a new window into the heart with great diagnostic option of a non-invasive diagnostic method. In addition to 2D TEE, live 3D TEE is available as well, which is used for imaging the heart structure, morphological and functional changes in real time.