VŠEOBECNÁ FAKULTNÍ NEMOCNICE V PRAZE

1. LÉKAŘSKÁ FAKULTA Univerzita Karlova

Mitral stenosis

Aleš Linhart

KOMPLEXNÍ KARDIO VASKULÁRNÍ CENTRUM VFN Praha

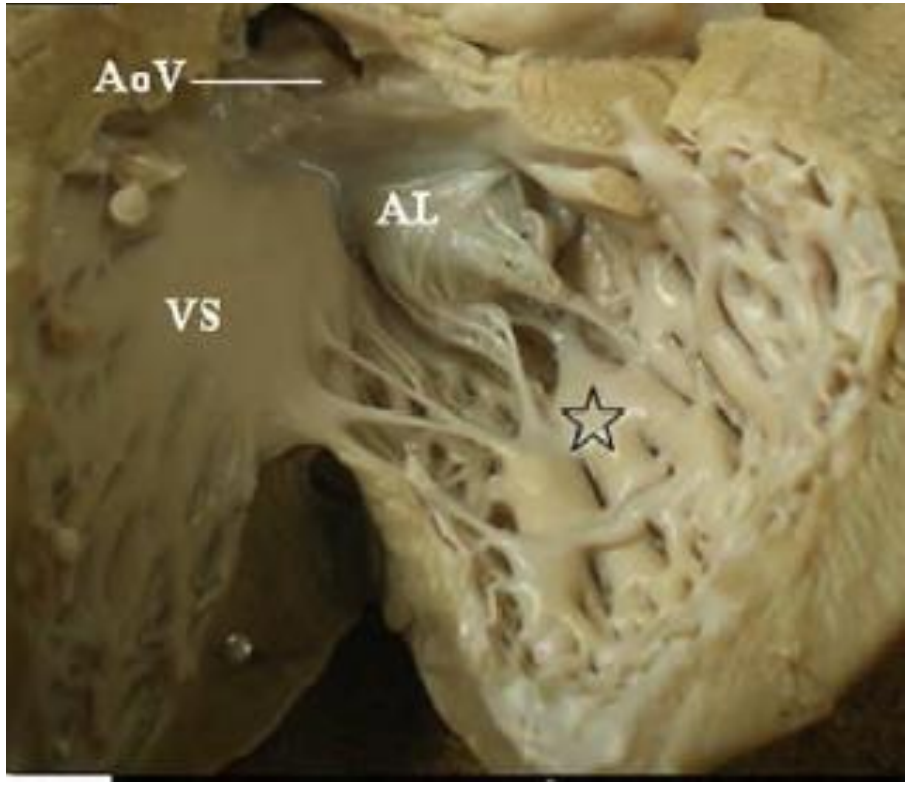
ETIOLOGY

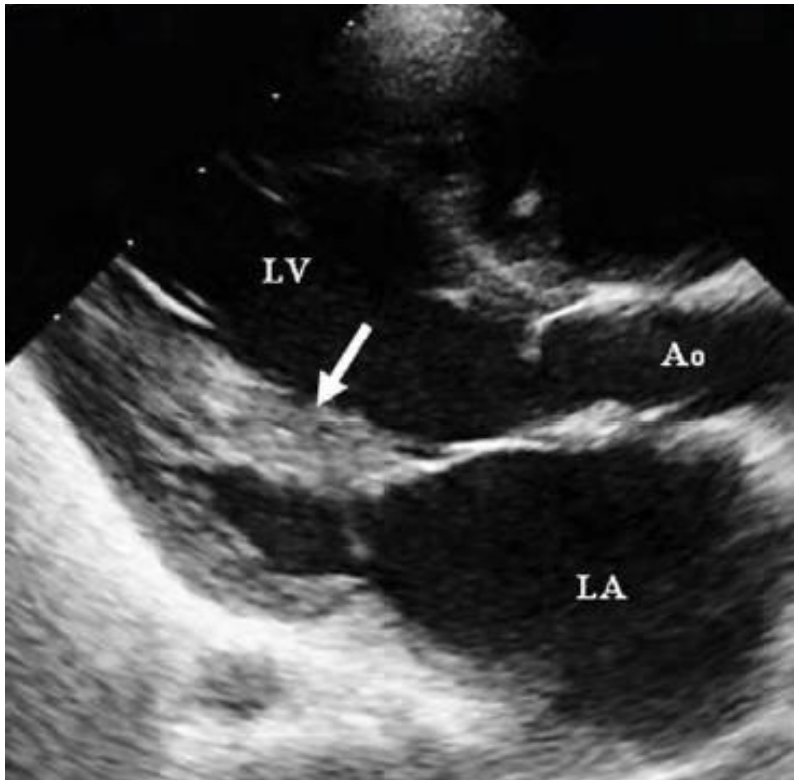
Mitral stenosis - etiology & pathogenesis

- **rheumatic !!!**
- congenital
- mitral annular calcification
- muccopolysaccharidosis

- **2/3 = females**
- **fusion of sommisures**
- **fibrosis, scaring and calcifications of the subvalvular apparatus**

Congenital mitral valve stenosis – parachute mitral valve

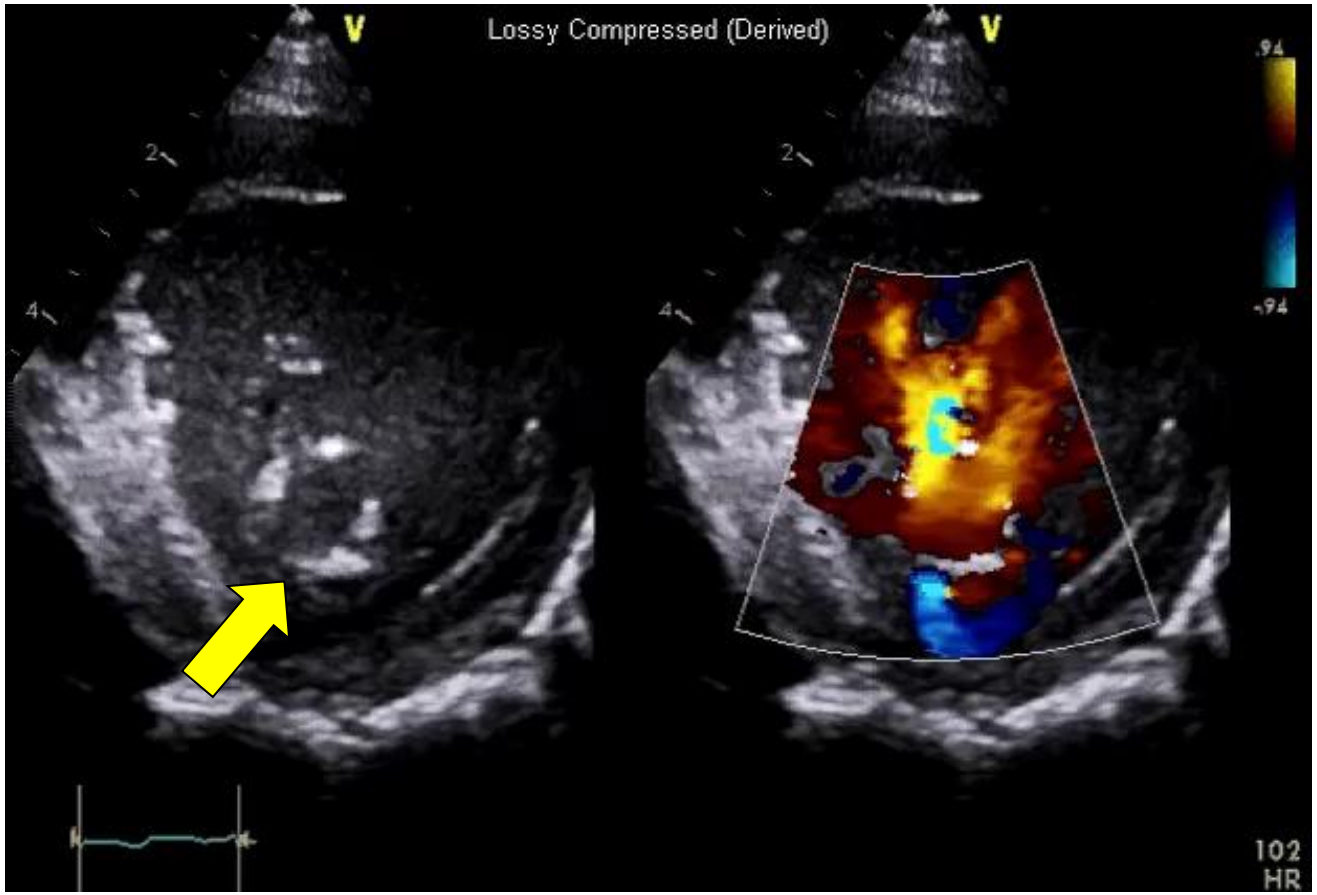




Single hypertrophied posteromedial papillary muscle.
Parachute-like asymmetric mitral valve – rudimentary lateral papillary muscle

Séguéla et al. Archives of Cardiovascular Disease (2011) 104, 465—479

Congenital mitral valve stenosis – parachute valve



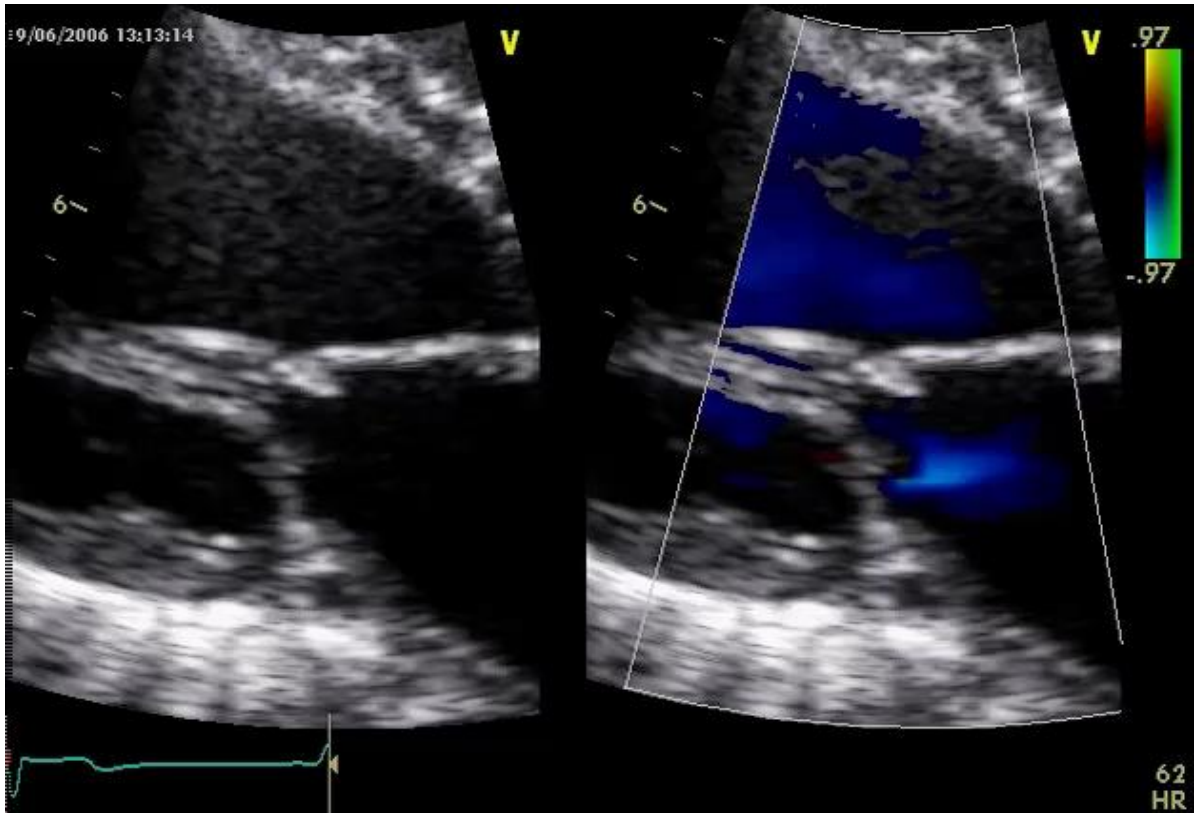
Single hypertrophied posteromedial papillary muscle. Note the eccentric opening of the mitral valve orifice

Courtesy Jan Marek, GOSH, London

Supravalvar stenosis – supramitral ring

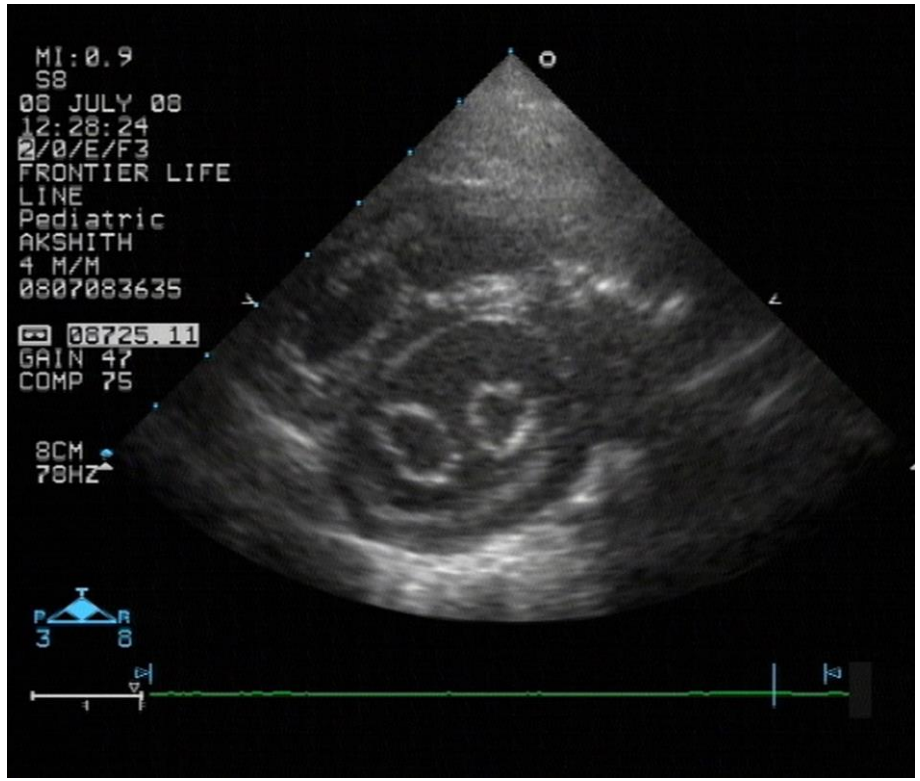
Shone syndrome :

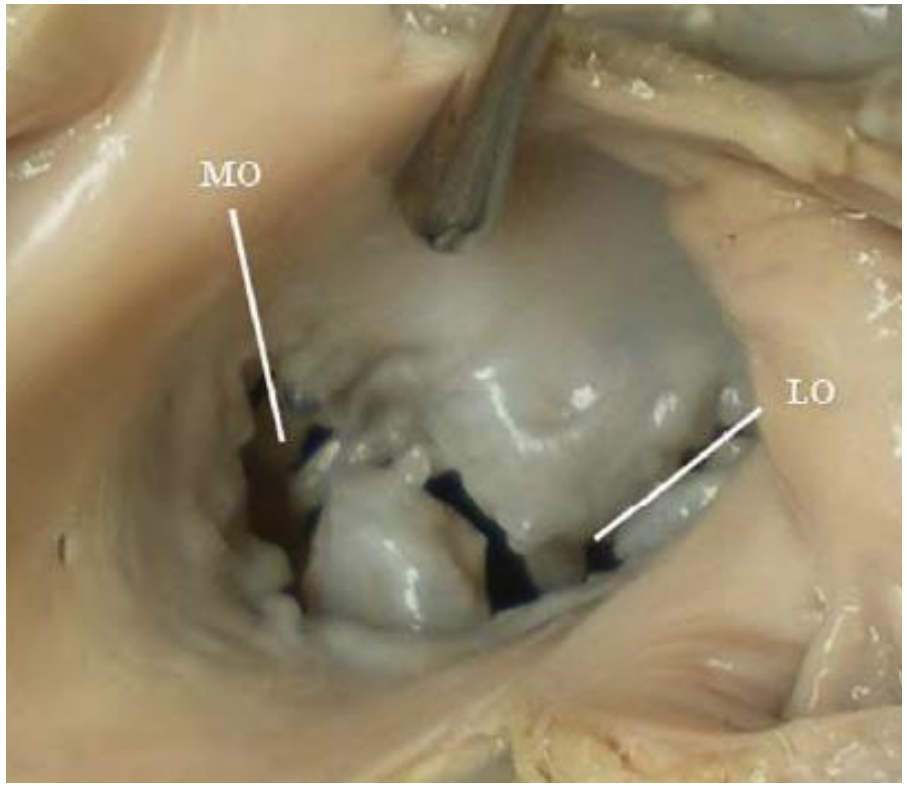
1. supravalvular mitral membrane (SVMM)
2. subaortic stenosis (membranous or muscular)
3. parachute mitral valve
4. coarctation of the aorta



Courtesy Jan Marek, GOSH, London

Double orifice mitral valve





Hartas et al., http://emedicine.medscape.com
Séguéla et al. Archives of Cardiovascular Disease (2011) 104, 465—479
Greenfield WS. Double mitral valve. Trans Pathol Soc. 1876. 27:128-129.

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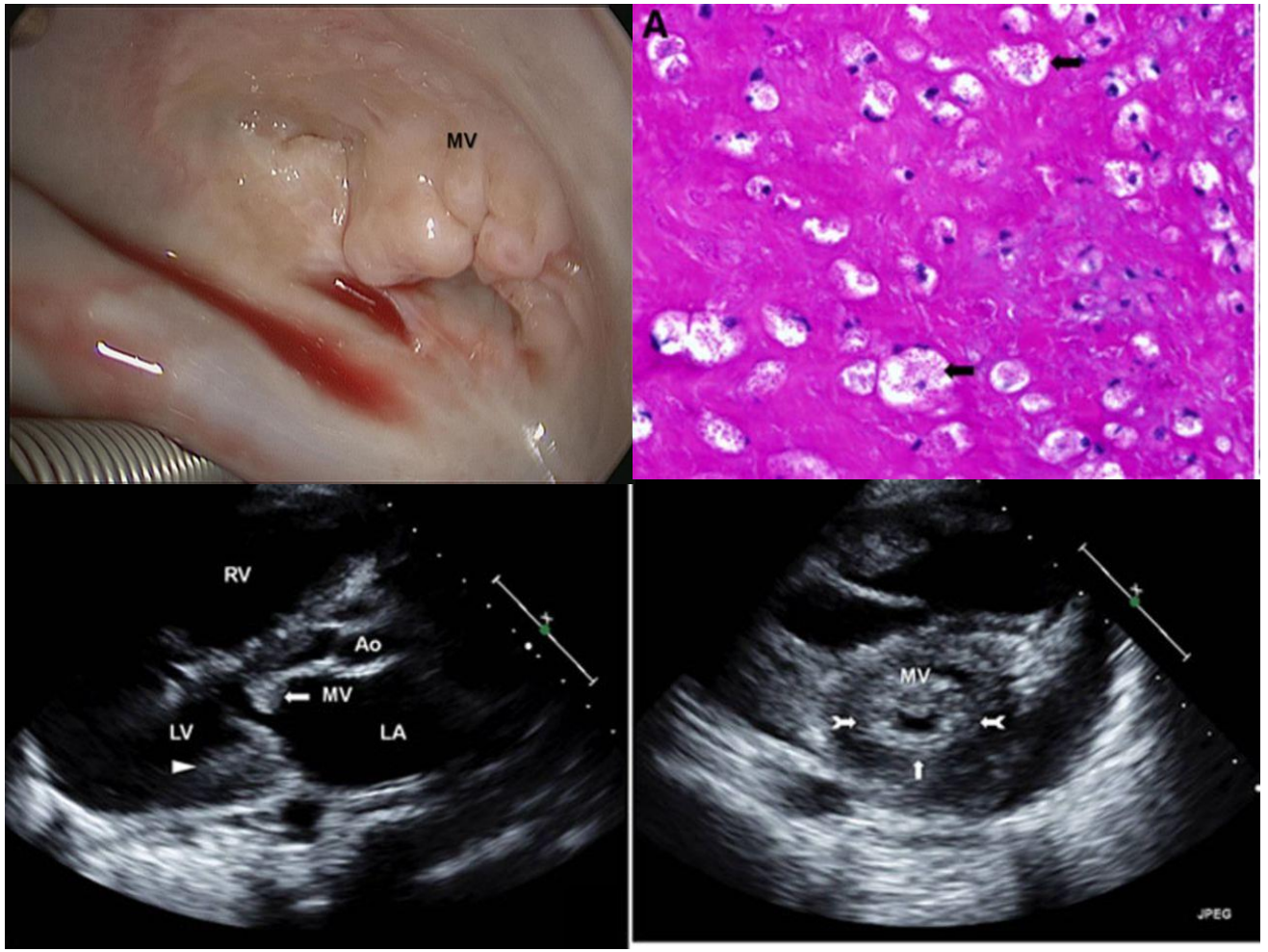
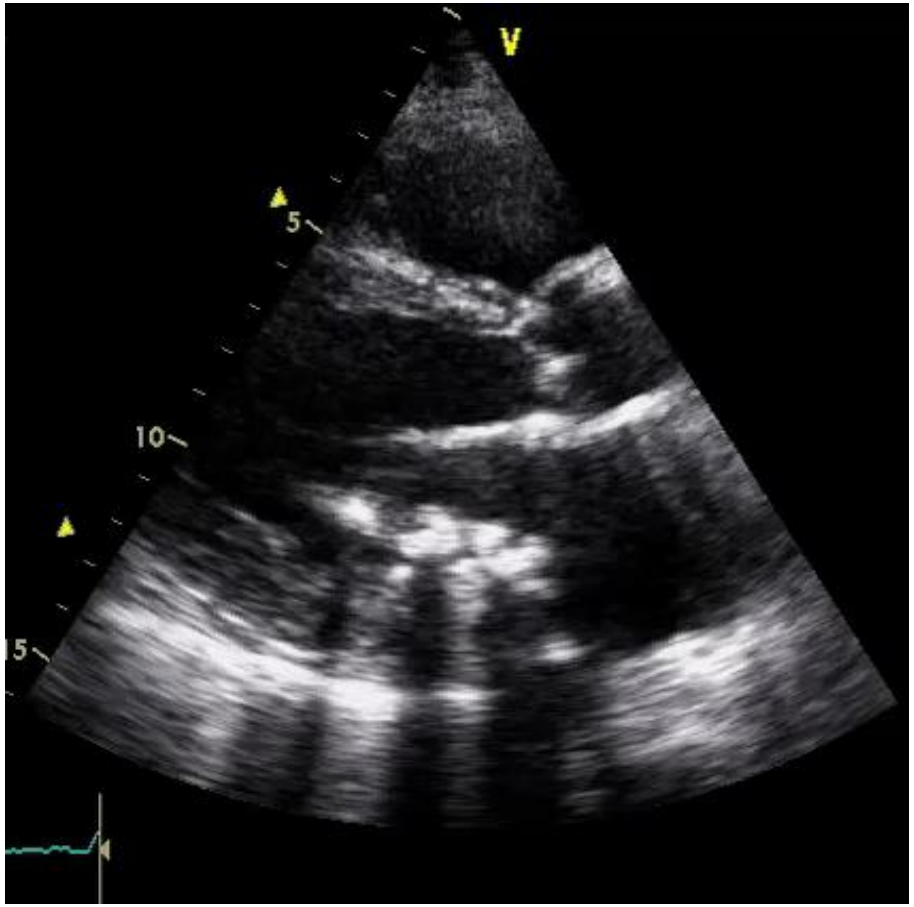
Muccopolysaccharidosis associated mitral valve stenosis

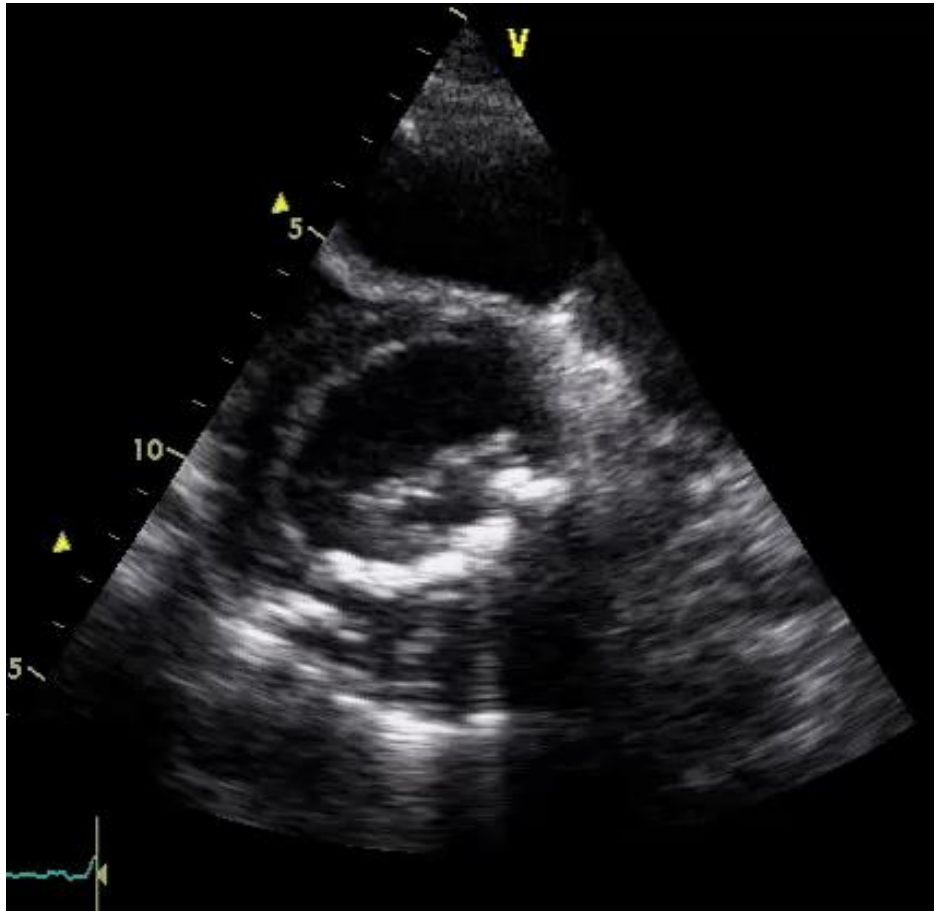
- Hunter’s syndrome
- X-linked disorder
- Defect in enzyme iduronate-2-sulfatase



Lee et al. Circulation. 2013;128:1269-1270

Mitral annular calcification





Cases and imaging: General University Hospital, Prague

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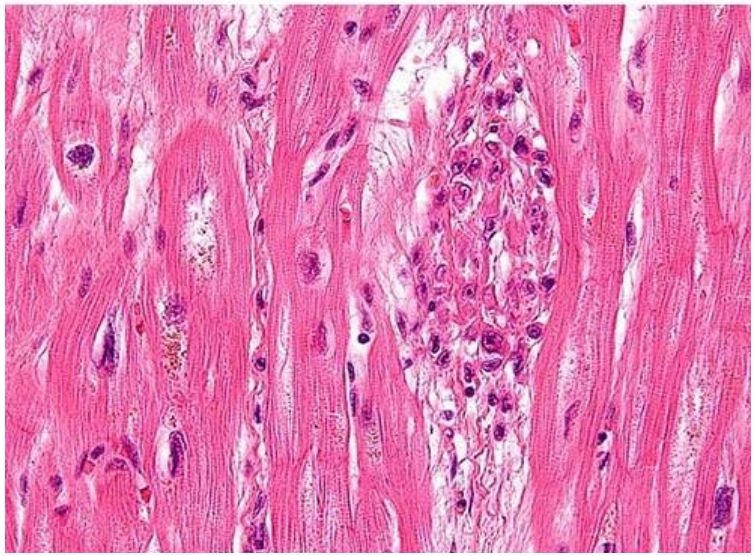
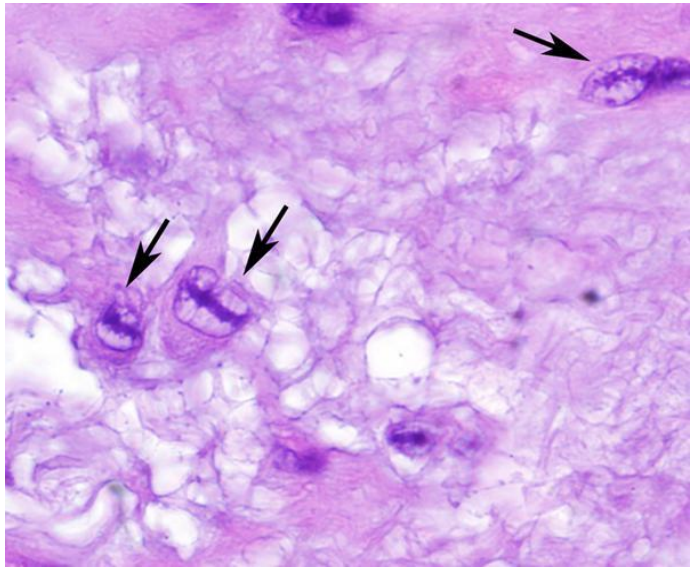
Rheumatic heart disease

- **Late inflammatory complication of pharyngitis caused by group A-hemolytic streptococci**
- **Humoral and cellular-mediated immune responses occurring 1-3 weeks after the onset of streptococcal pharyngitis.**
- **Immune cross-reactivity against bacterial M-proteins and myosine and valvular endothelial cells**
- **Acute: Rheumatic fever – pancarditis, pericarditis +/- multisystemic manifestations**
- **Chronic: valvular disease (up to 20-40 years later)**



Aschoff nodules (Hematoxyline-Eosin)[1]

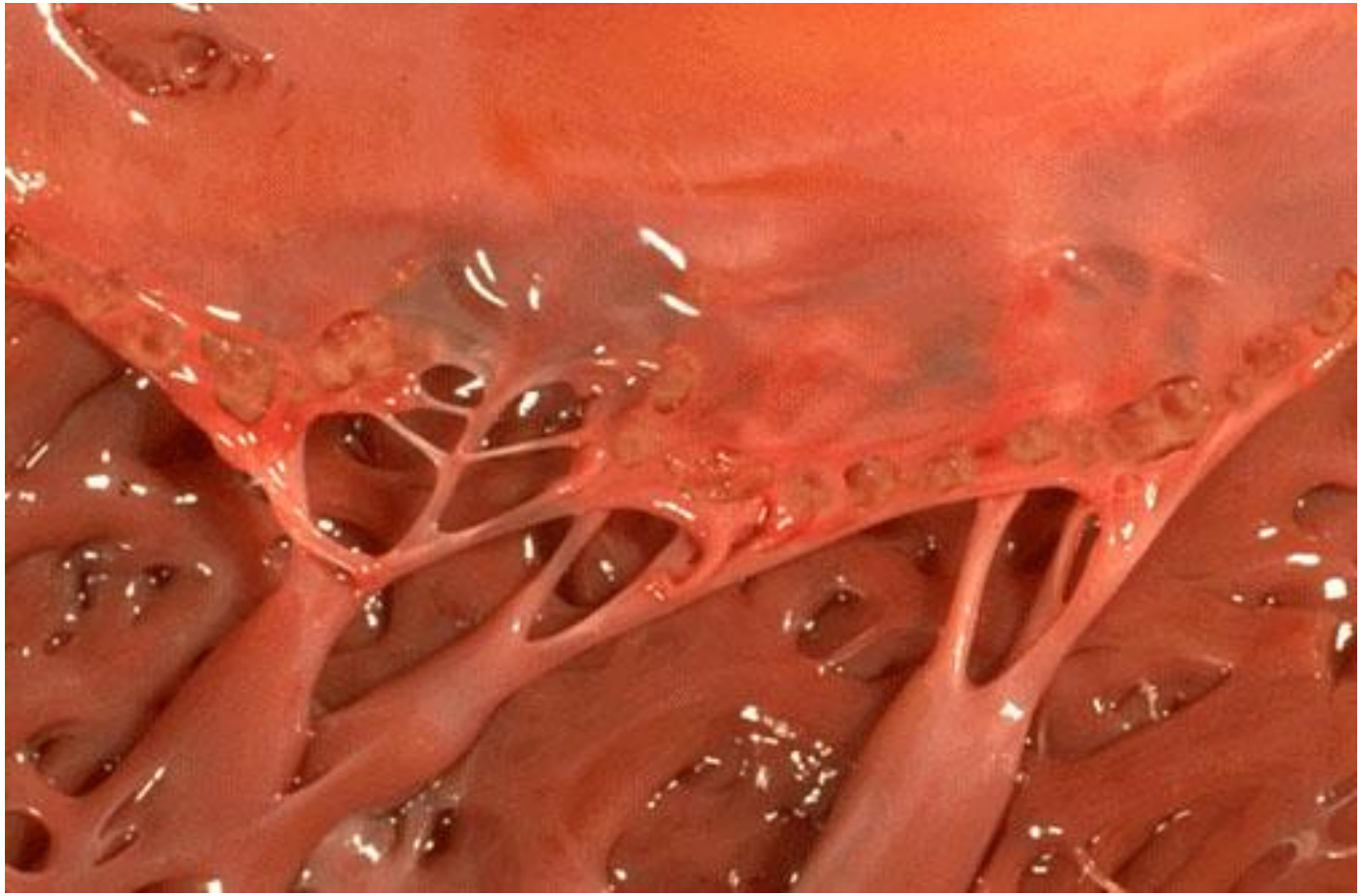
interstitial aggregate of macrophages and lymphocytes, with necrotic collagen, in an area of interstitial fibrosis.



Anistchkow (catterpillar) cells – Transformed macrophages[2]

1. Love and Restrepo Mod Pathol. 1988 Jul;1(4):256-61.
2. Burke AP. Medscape 2015.

Acute rheumatic mitral valve involvement



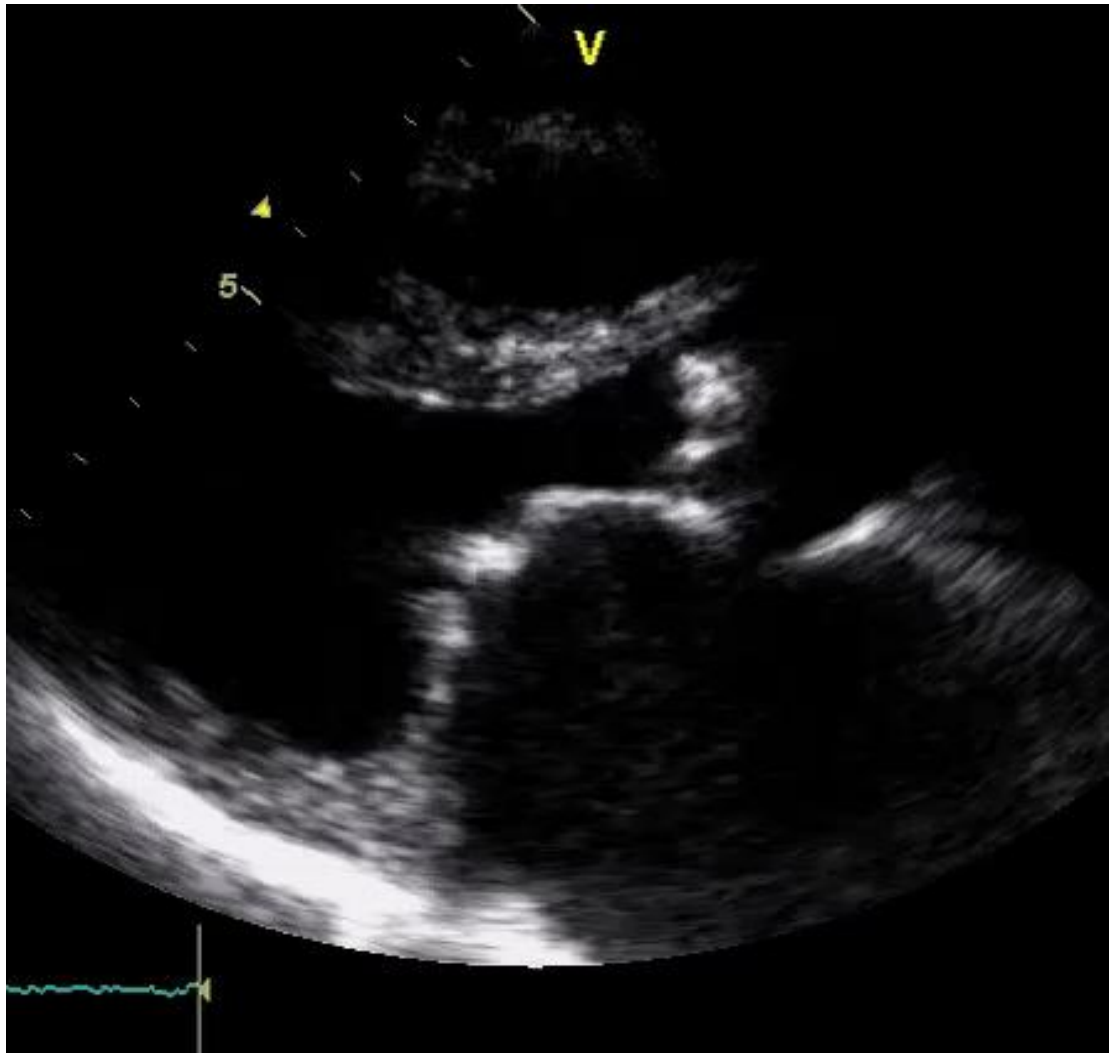
Small verrucous vegetations seen along the closure line of this mitral valve are associated with acute rheumatic fever.

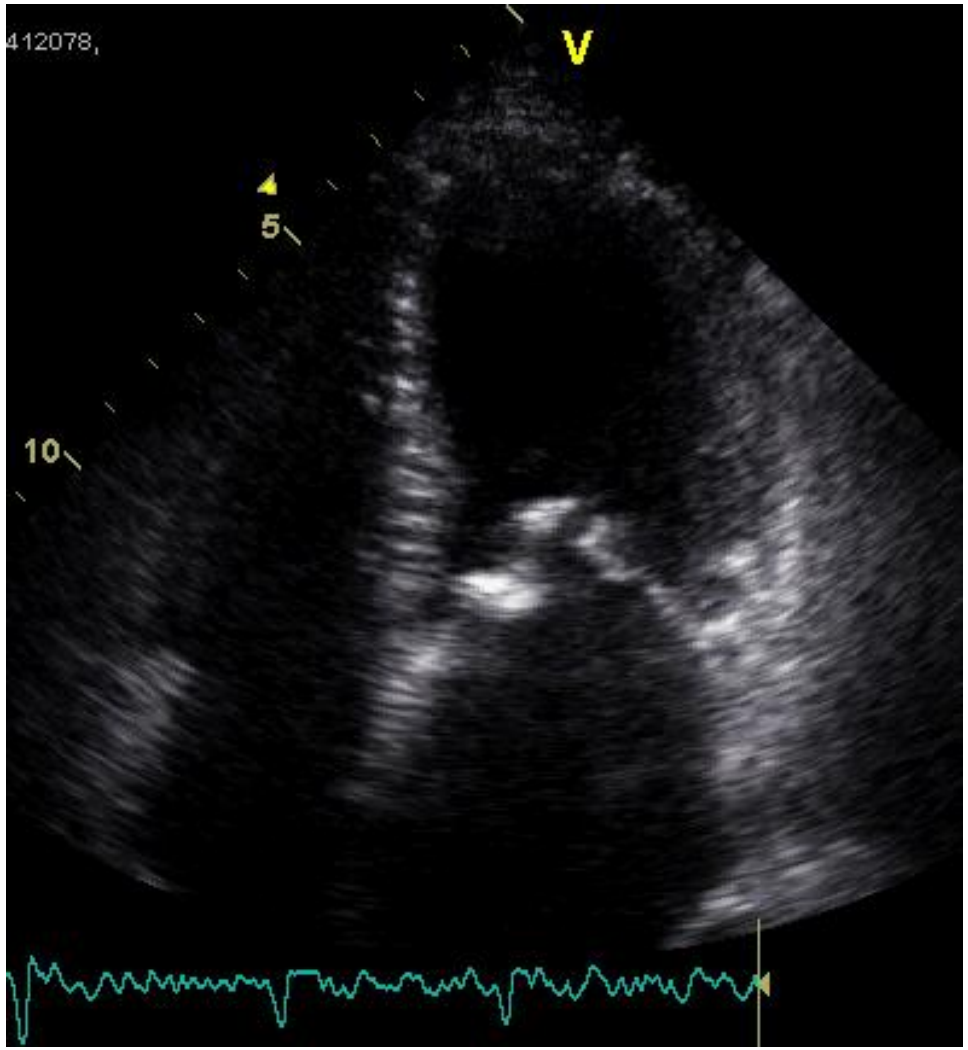
http://library.med.utah.edu

Chronic post-rheumatic changes

http://library.med.utah.edu

Rheumatic mitral valve disease





Cases and imaging: General University Hospital, Prague

PATHOPHYSIOLOGY

Mitral stenosis - Pathophysiology

Pressure gradient LA → LV

↓

↑ LA pressure → LA dilatation

→ **Atrial fibrillation**

→ **LA thrombi – systemic emboli**

↓

Postcapillary pulmonary hypertension

→ **Increased transudation**

expansion of lymphatic drainage

capillary and small vessels remodeling

↓

Combined pulmonary hypertension

(TPG = PAMP - PCWP > 12 mmHg

DPG = PAPD – PCWP > 7 mmHg)

→ **Arteriolar vasoconstriction**

→ **Arteriolar remodeling**

→ **Fixed Cpc-PH**

↓

RV overload

→ **RV failure**

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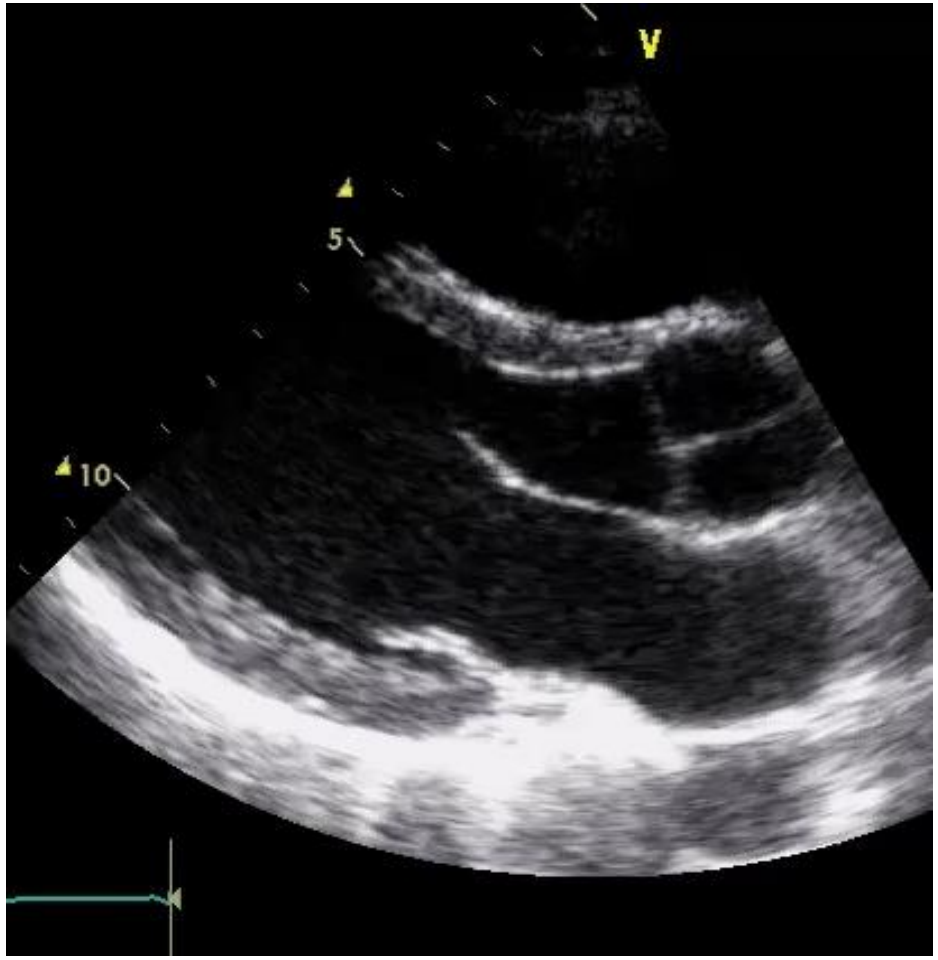
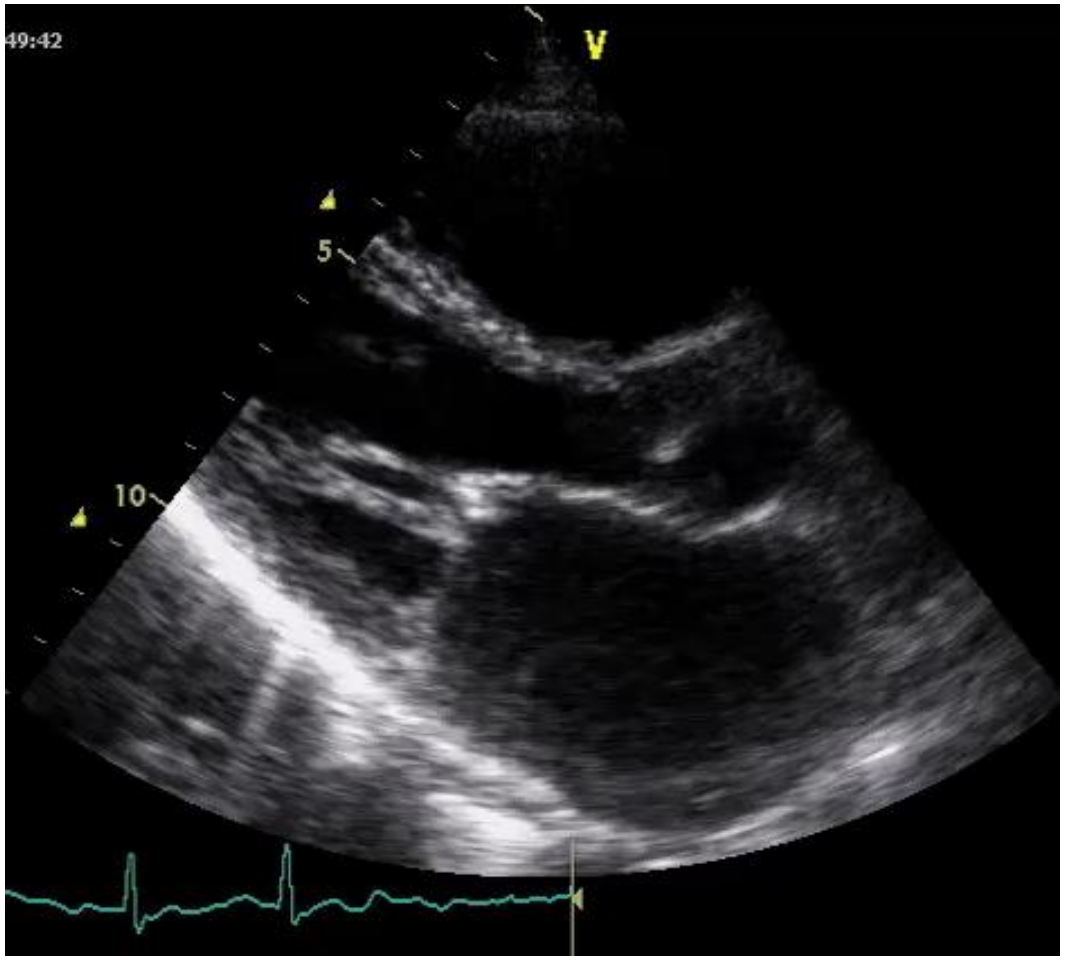
ECHOCARDIOGRAPHY

Key questions in echocardiography of mitral valve stenosis

- Is the stenosis present?
- How severe is the orifice narrowing?
- Would the stenosis be suitable for balloon valvuloplasty?
- Are there associated valvular lesions?
- What are hemodynamic consequences?
- Are there any other associated conditions?

Is mitral stenosis present?





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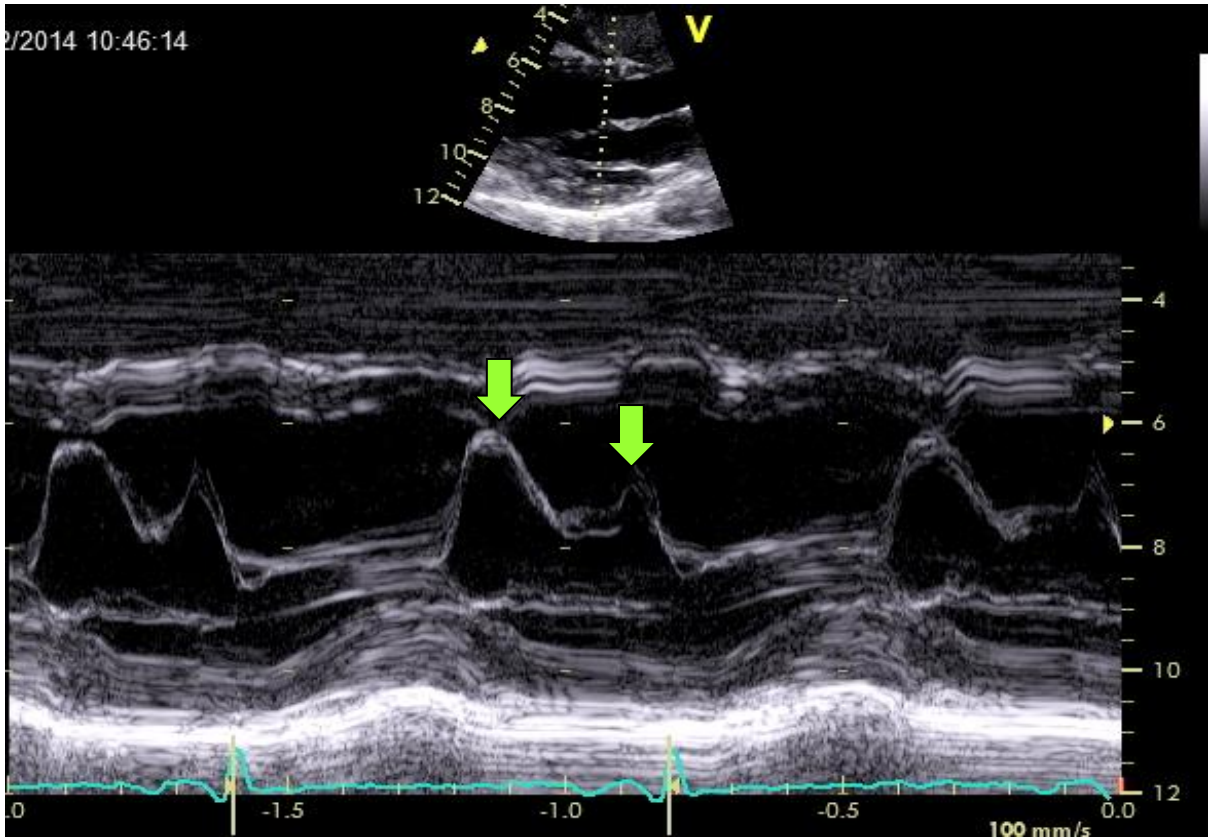
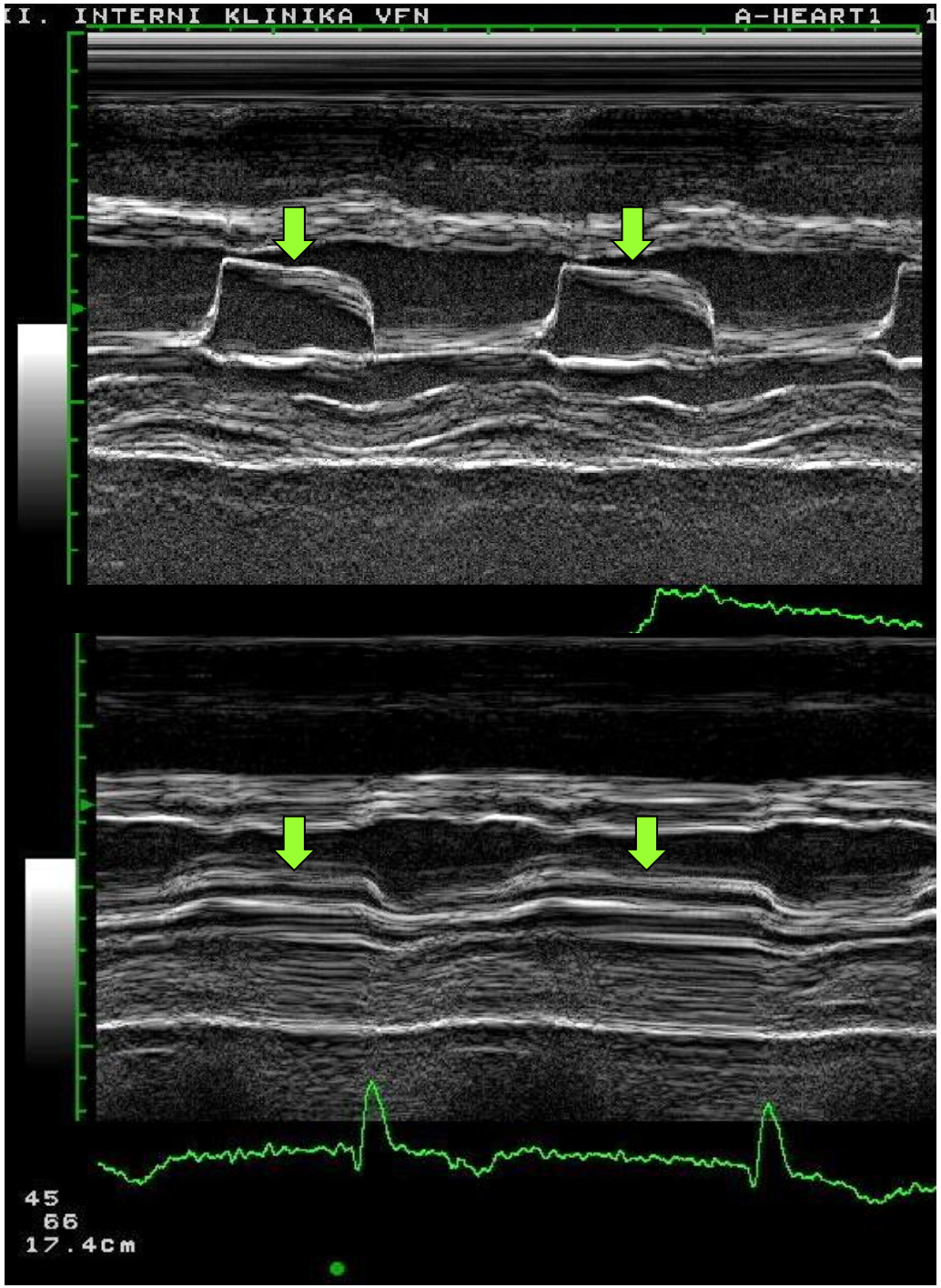
Mitral stenosis M-mode





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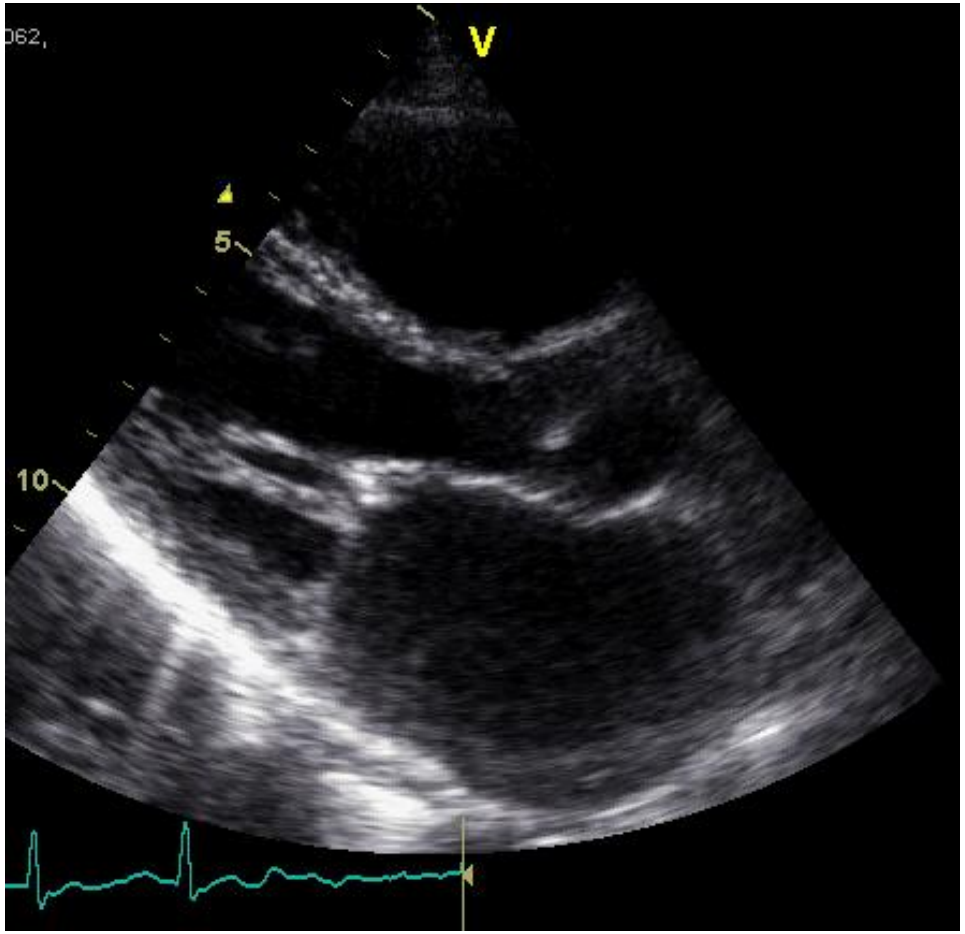
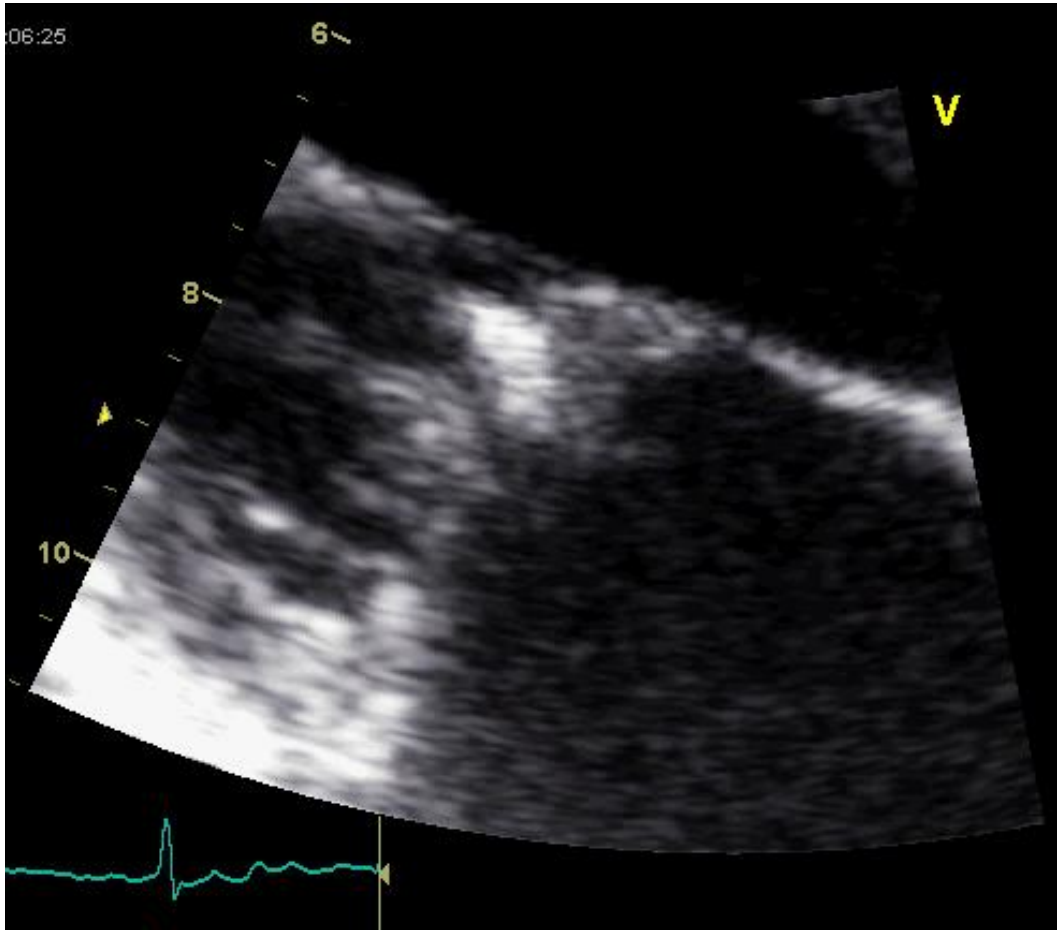
Mitral stenosis 2-D

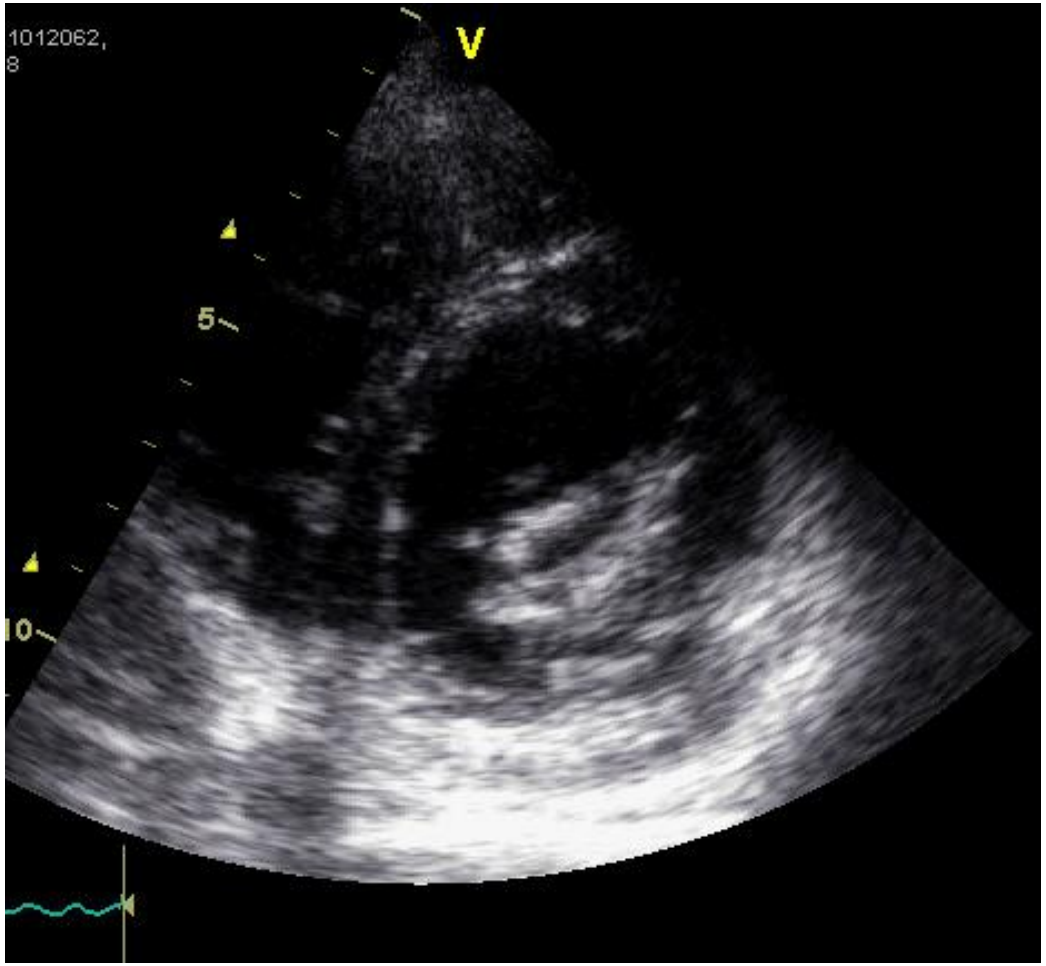


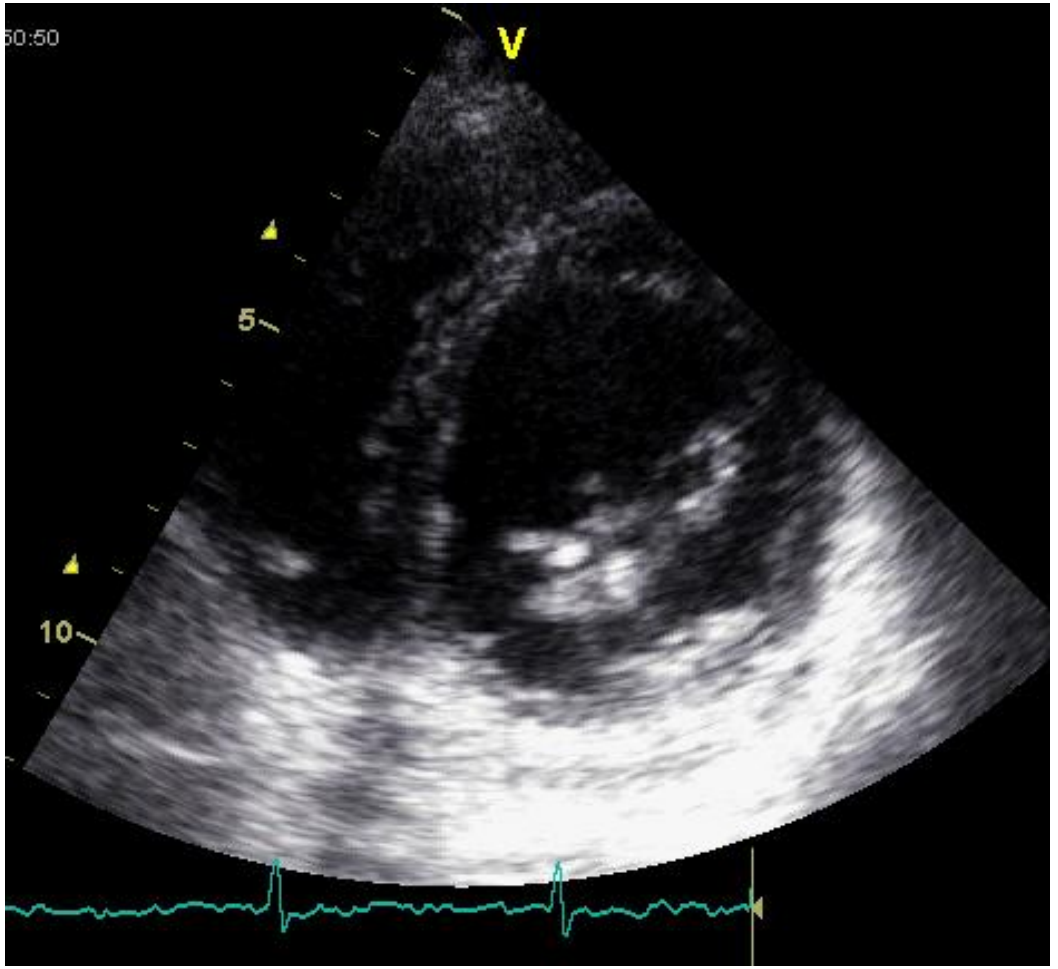


Fibrotic leaflet changes and calcifications
Commisural fusion – doming / hockey shape of the anterior leaflet

Cases and imaging: General University Hospital, Prague

Parasternal short axis view





Cases and imaging: General University Hospital, Prague

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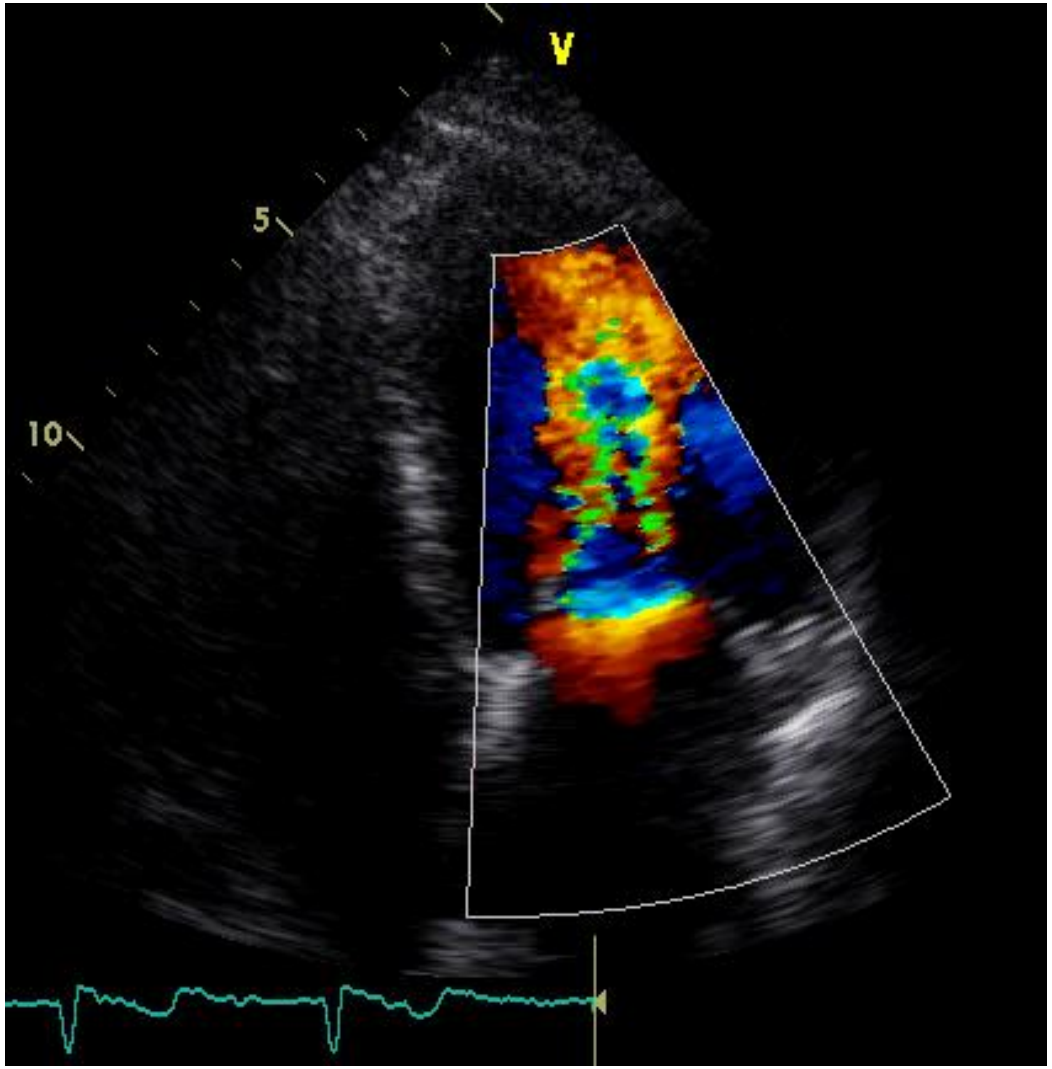
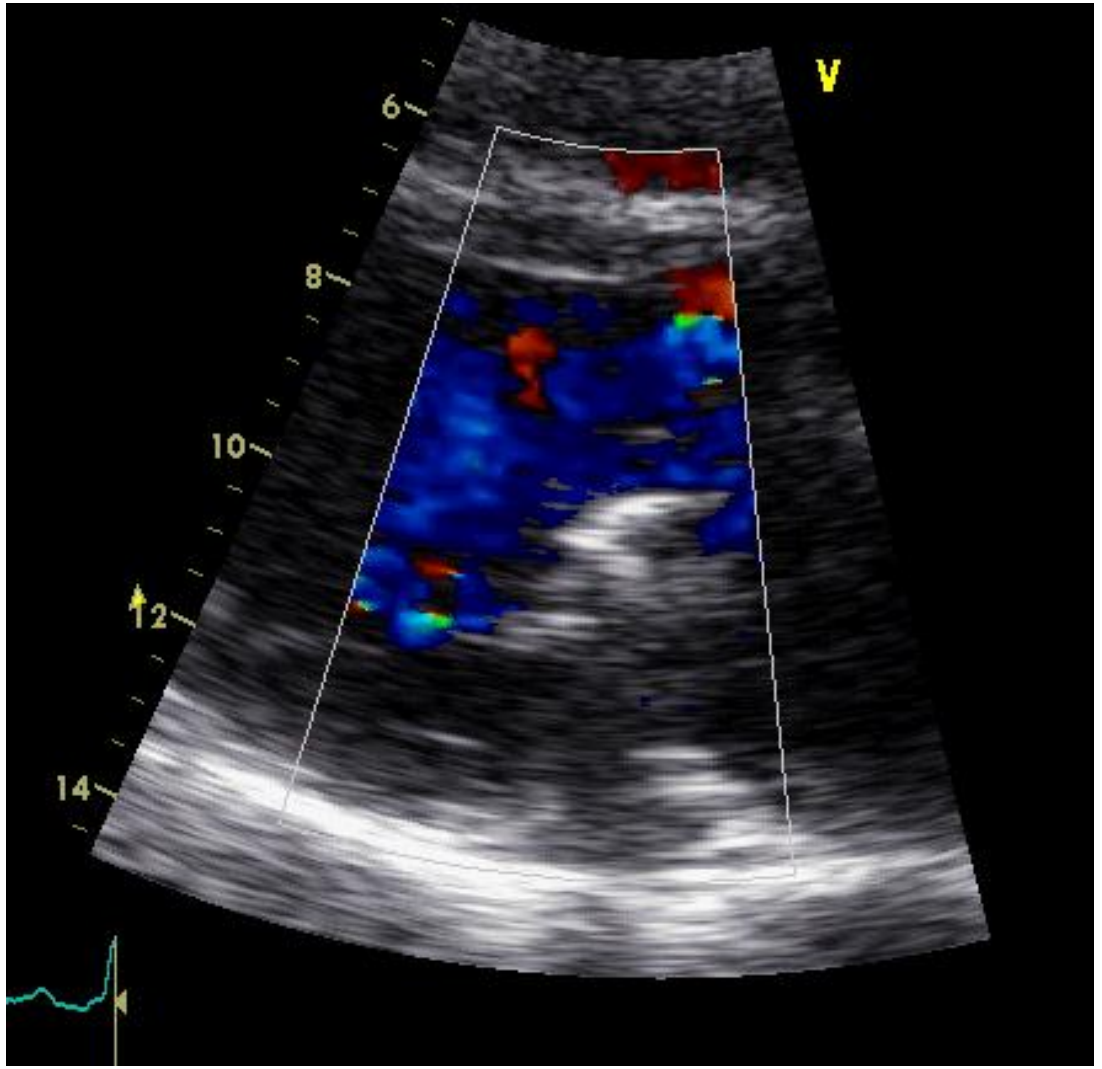
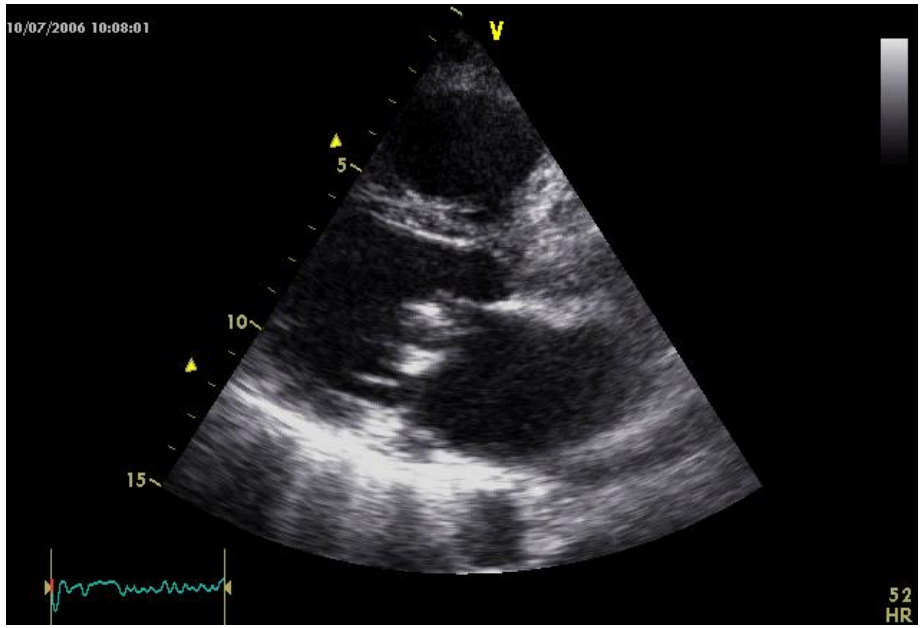
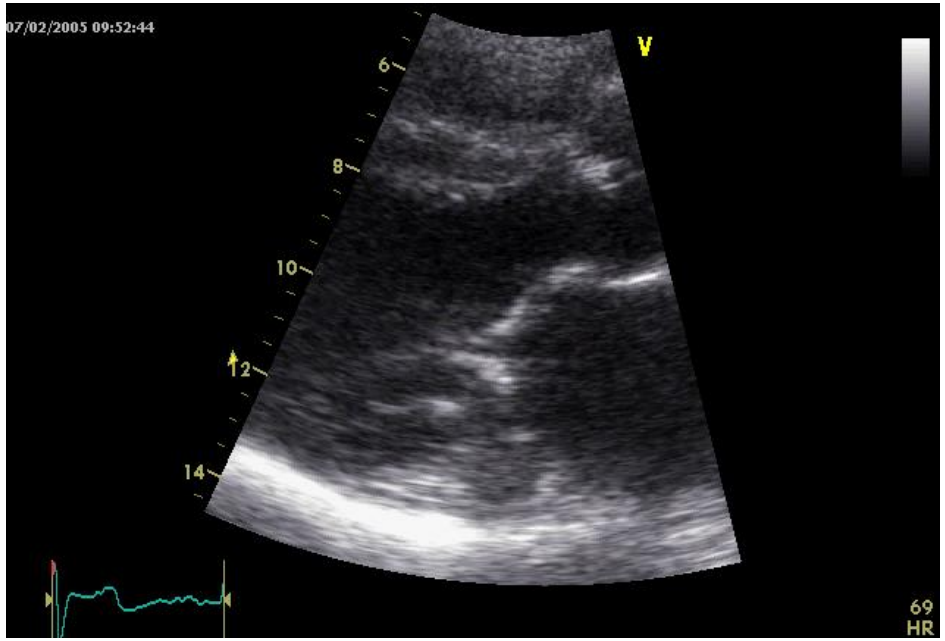
Color flow mapping

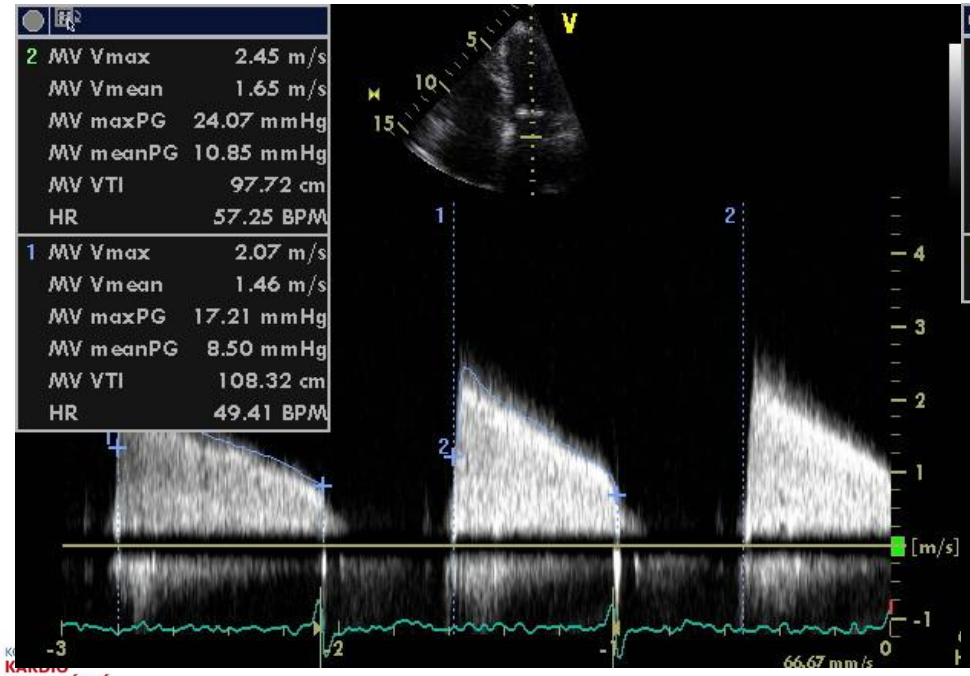


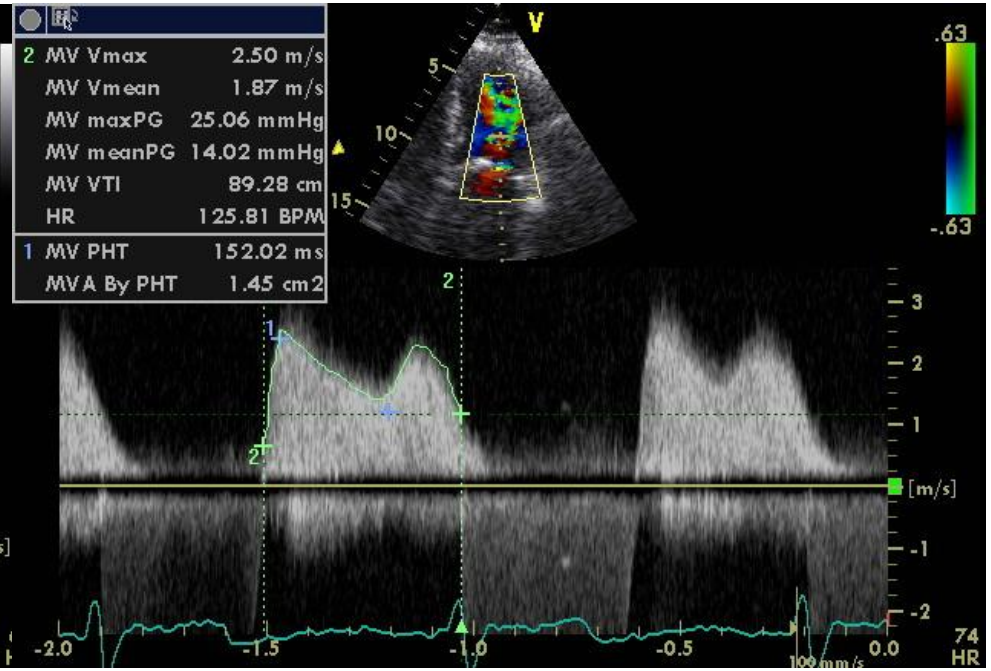


Cases and imaging: General University Hospital, Prague









Cases and imaging: General University Hospital, Prague

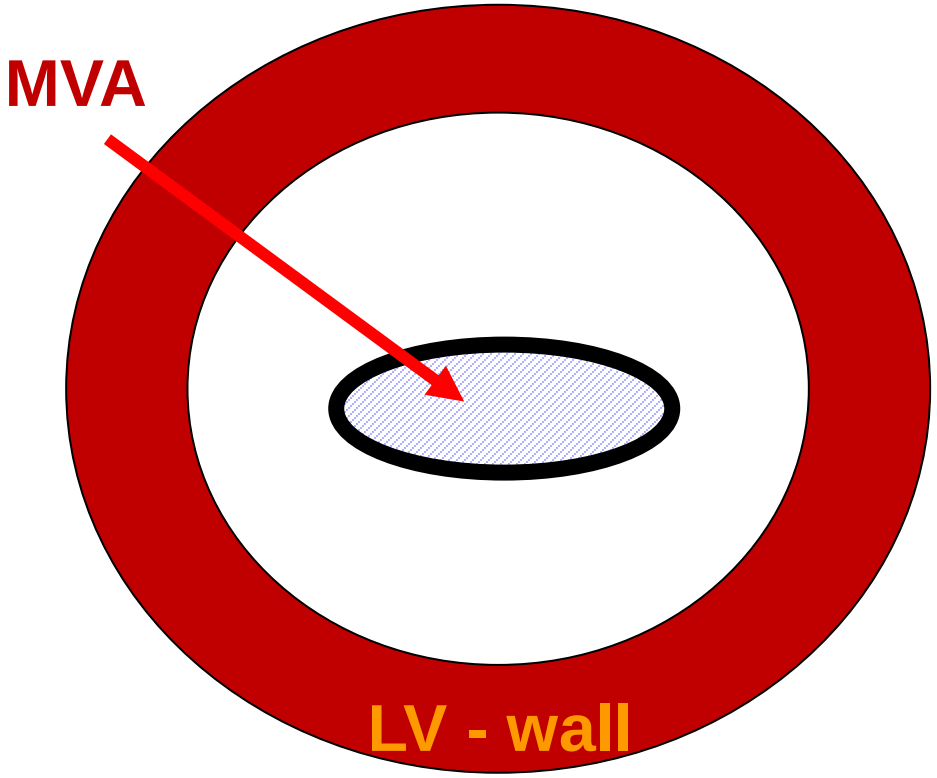
QUANTIFICATION

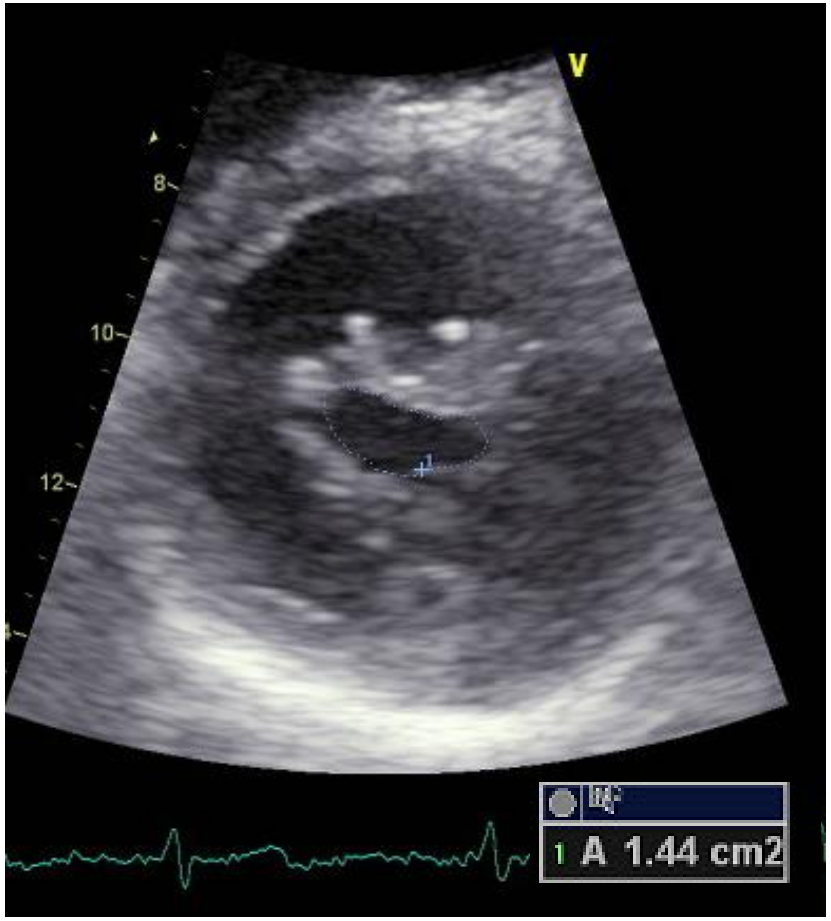
Mitral stenosis quantification

Severity[1]	Mild	Moderate	Severe
MVA planim. (cm^2)	>1,5	1,0-1,5	≤1
Supportive findings:			
Mean PG (mmHg)	< 5	5 – 10	> 10
PASP (mmHg)	< 30	30 – 50	> 50
MVAi (cm^2/m^2)[2]	1,0-1,5	0,6-1,0	< 0,6

1) Eur J Echocardiogr 2009;10:1-25
2) Cor Vasa 2007;49(7-8):Kardio

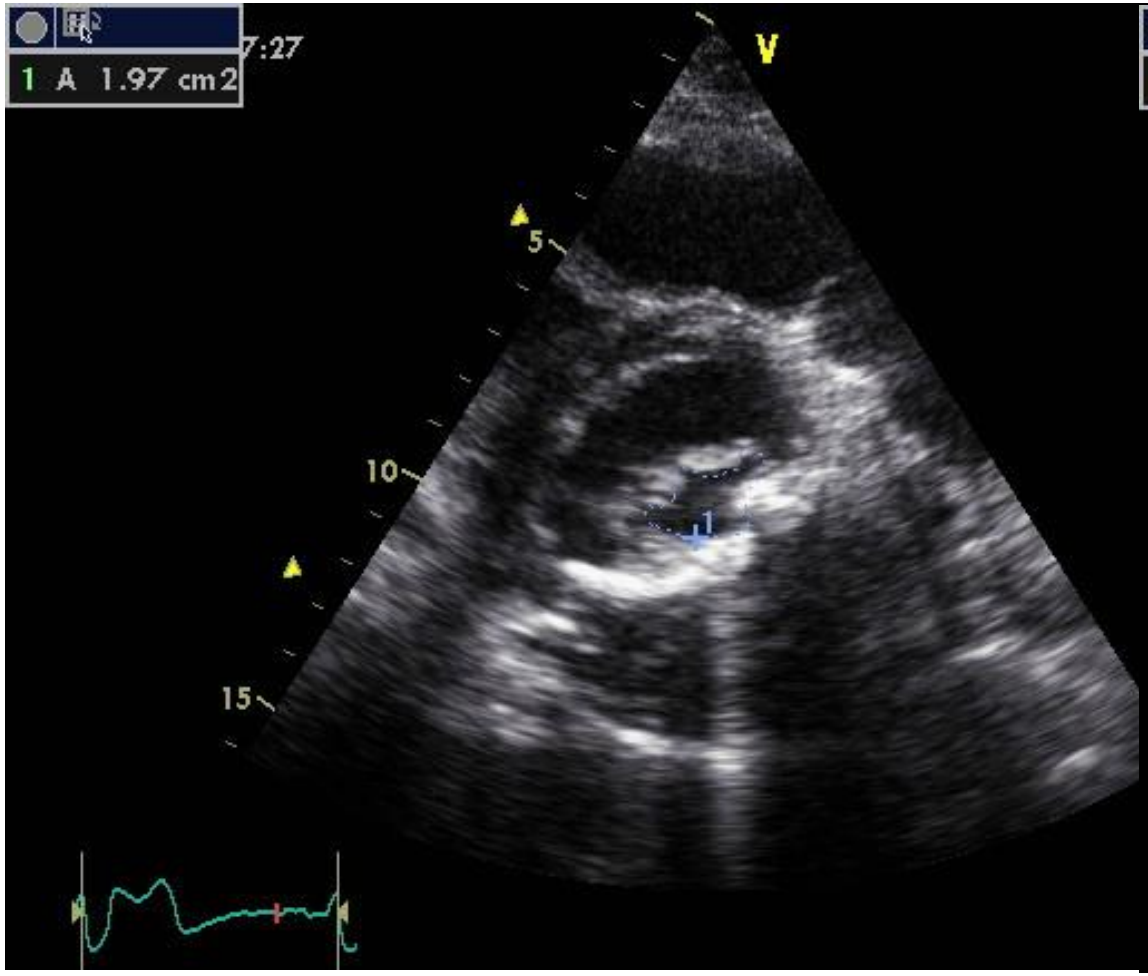
MVA planimetry – parasternal short axis

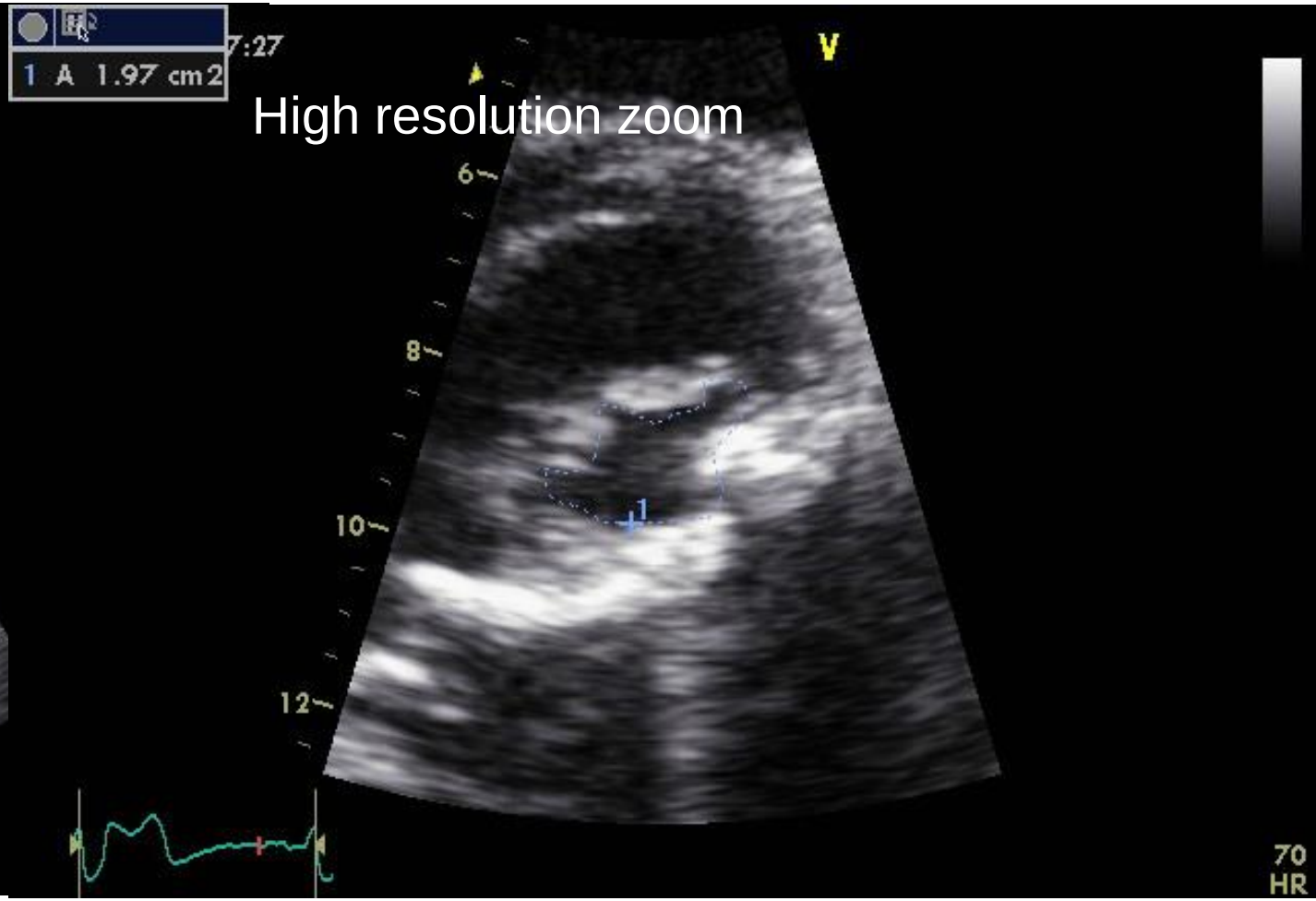




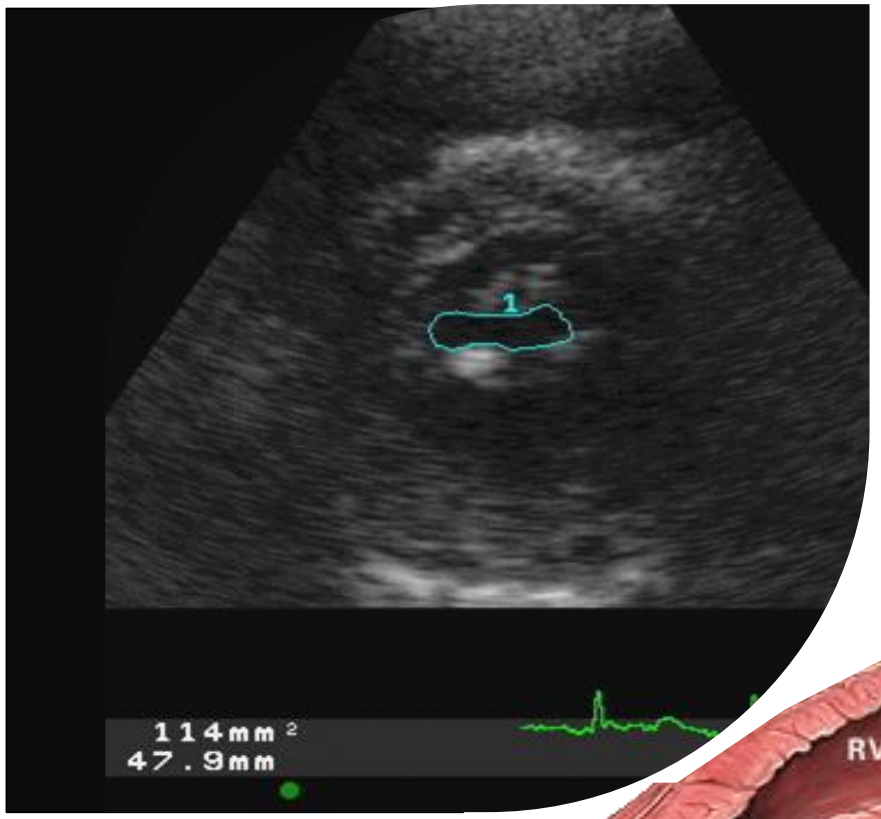
Cases and imaging: General University Hospital, Prague

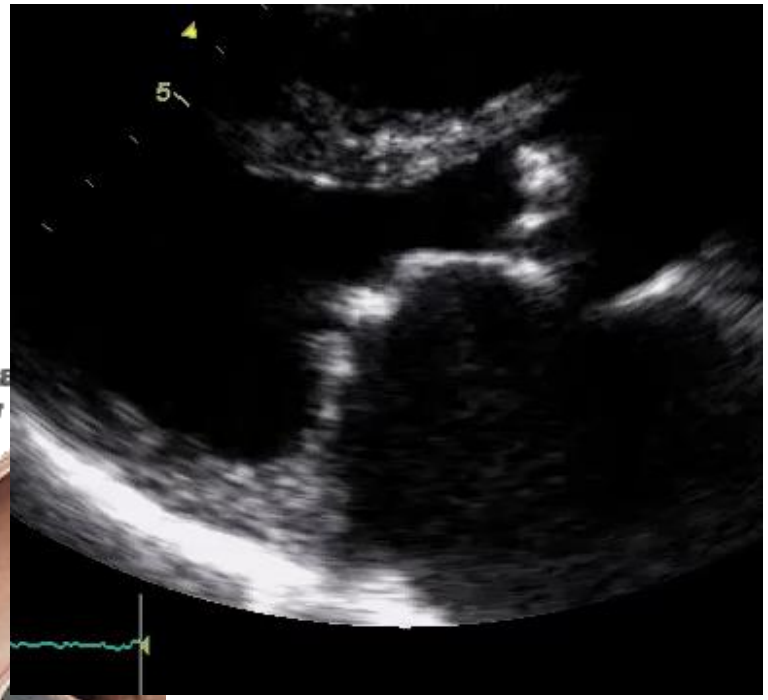
MVA planimetry – the use of zoom

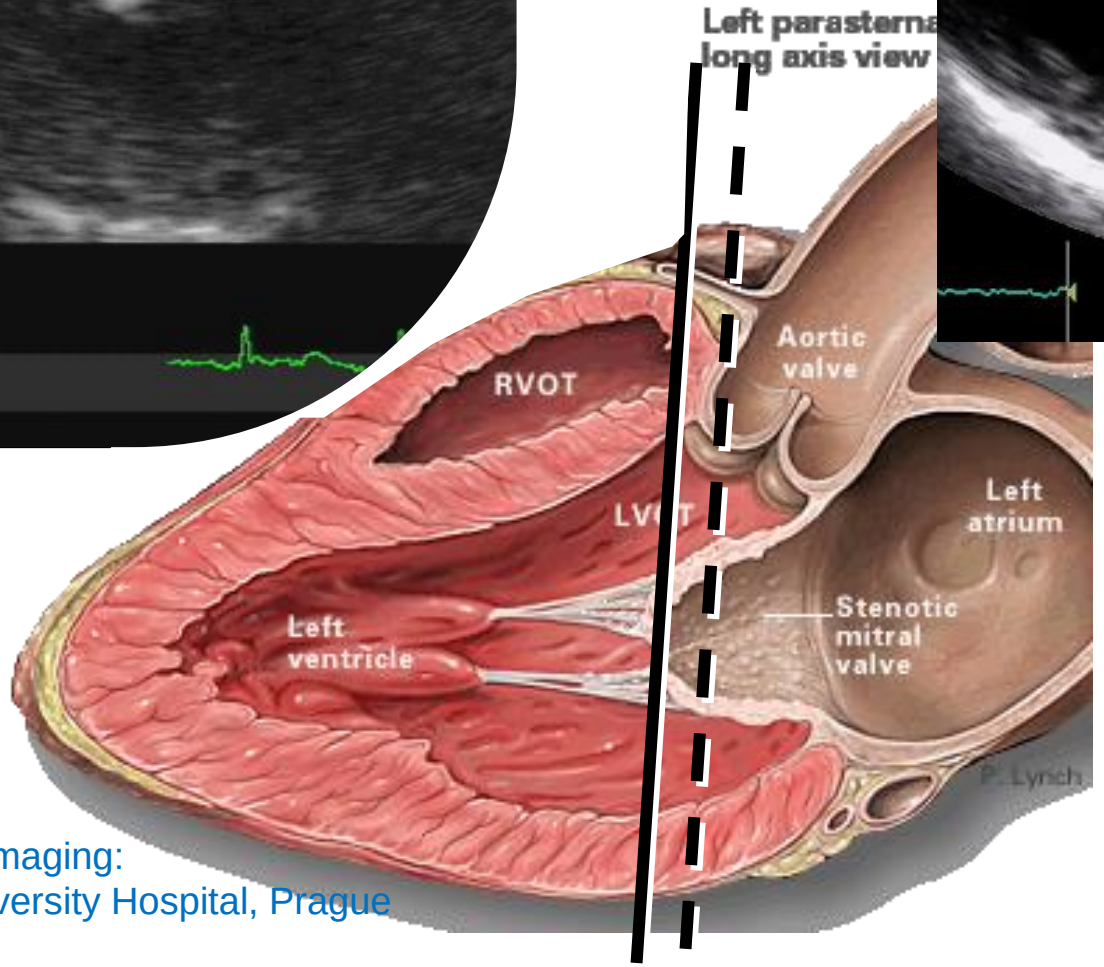




Cases and imaging: General University Hospital, Prague





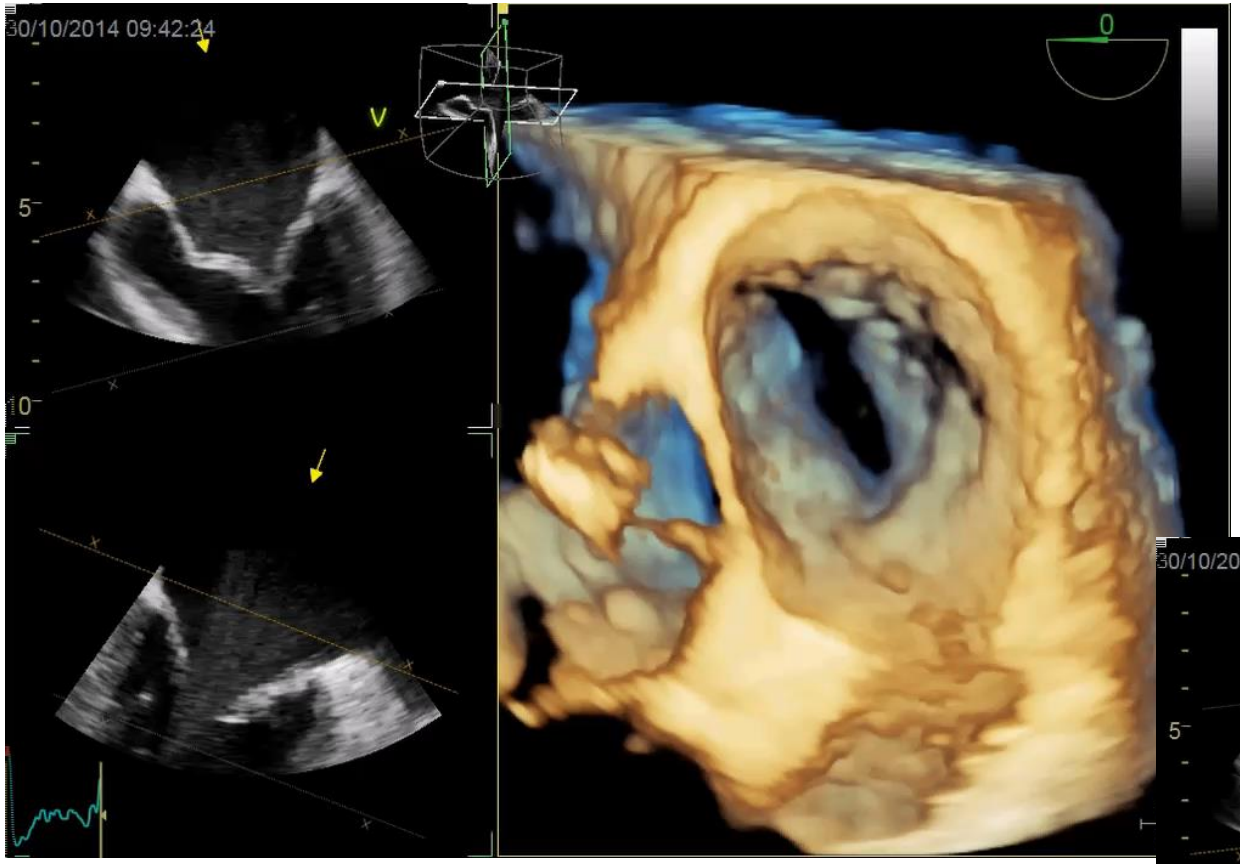


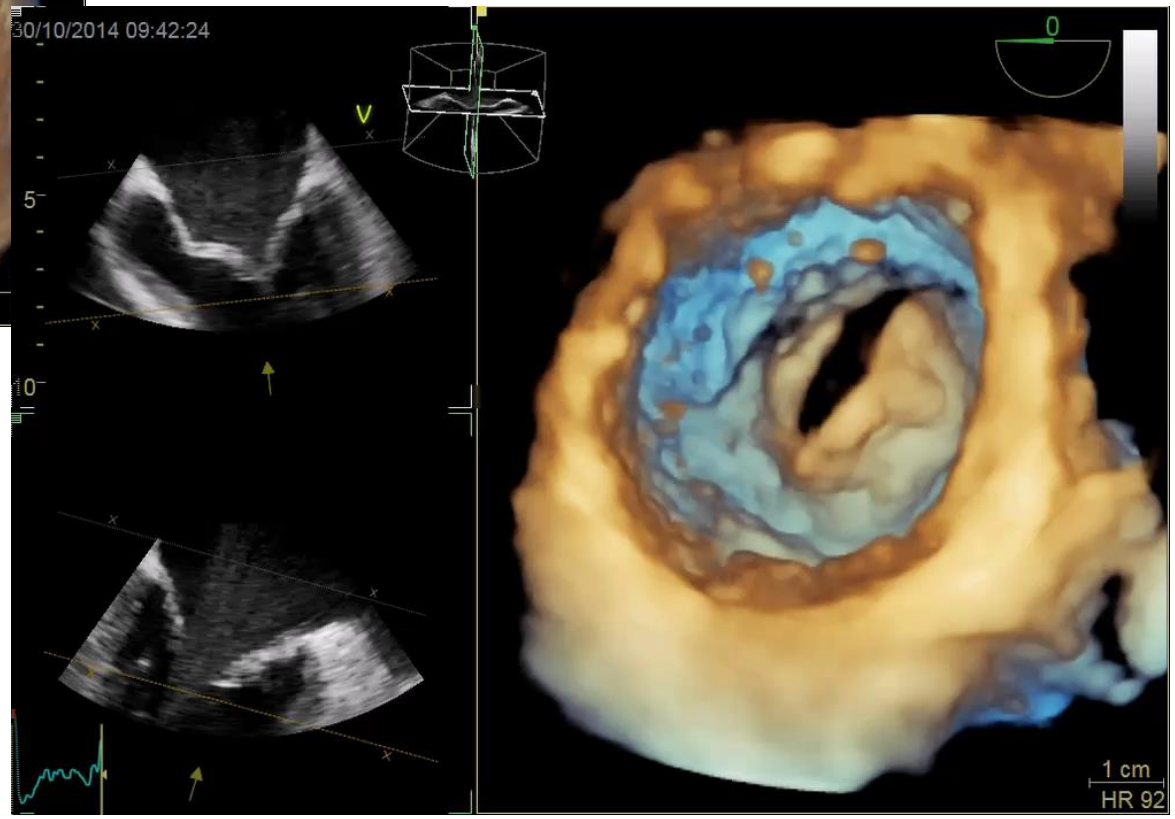
Main pitfalls of MVA planimetry

Cases and imaging:
General University Hospital, Prague

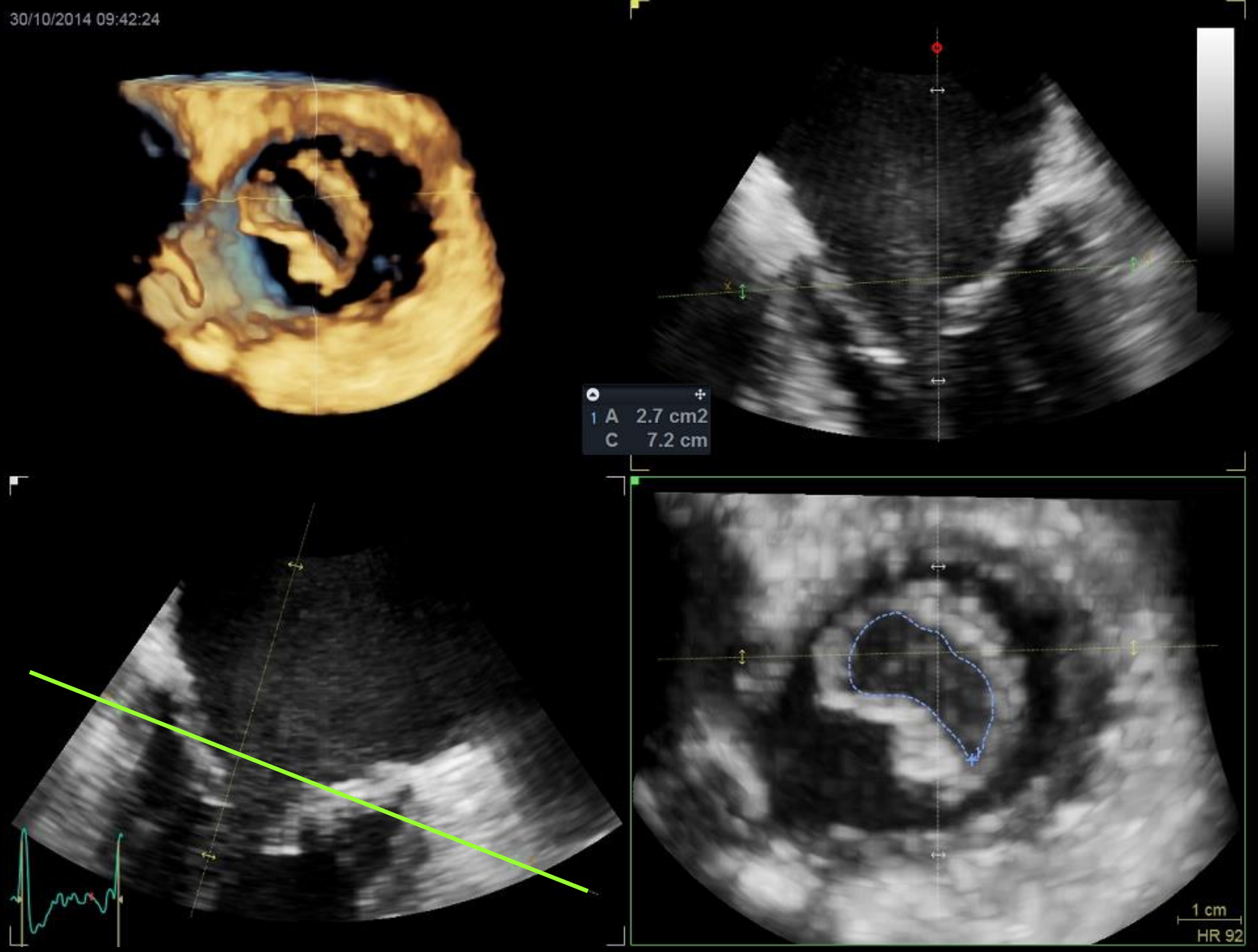
Patrick Lynch
Yale Atlas of Echocardiography

3D echo visualization

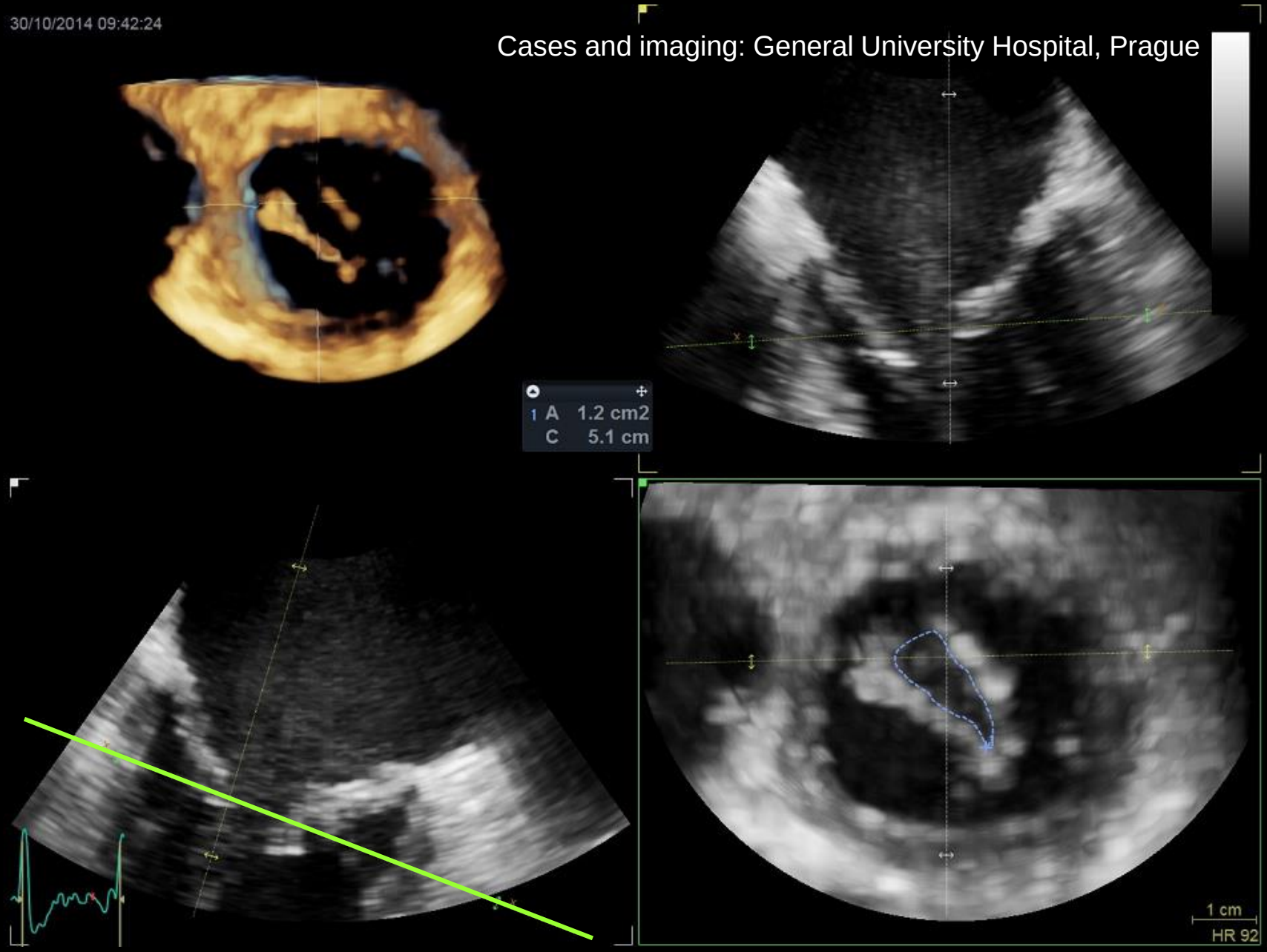




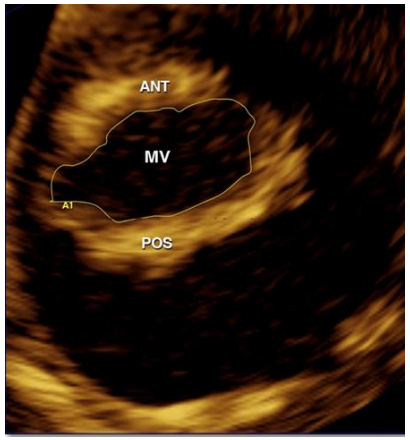
Cases and imaging:
General University Hospital, Prague


30/10/2014 09:42:24
1 A 2.7 cm2
C 7.2 cm
1 cm
HR 92

Cases and imaging: General University Hospital, Prague



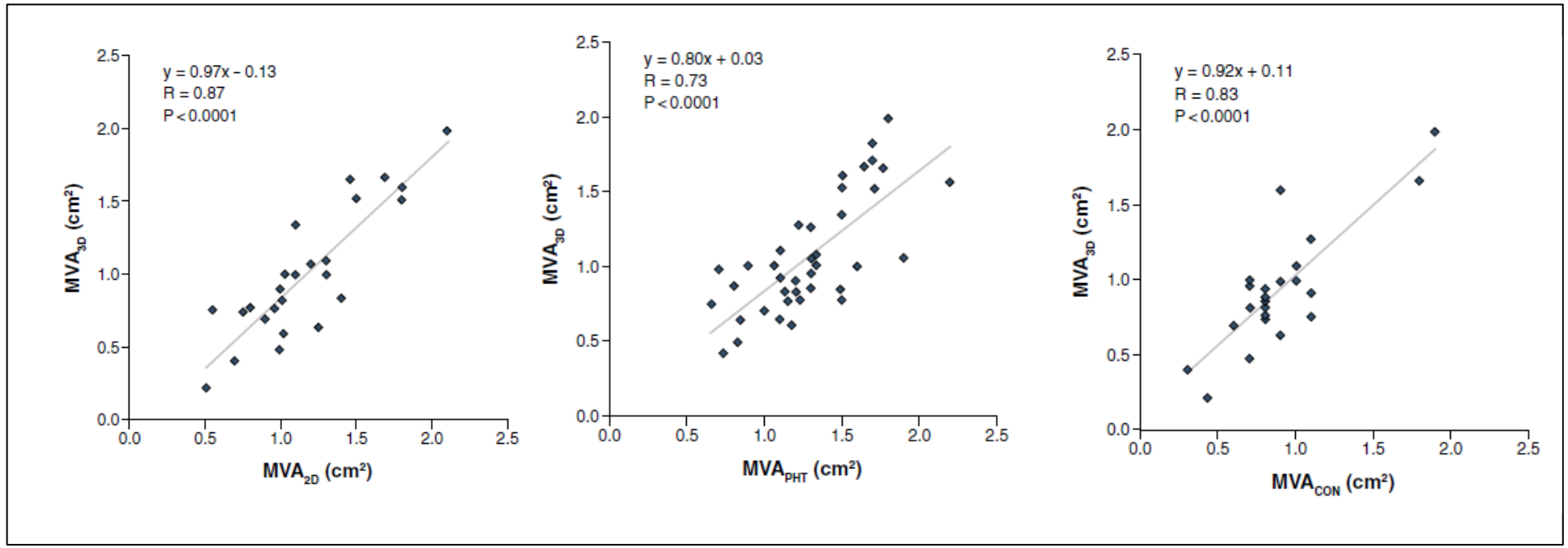
Comparison of 3D echocardiography to other methods



2D planimetry

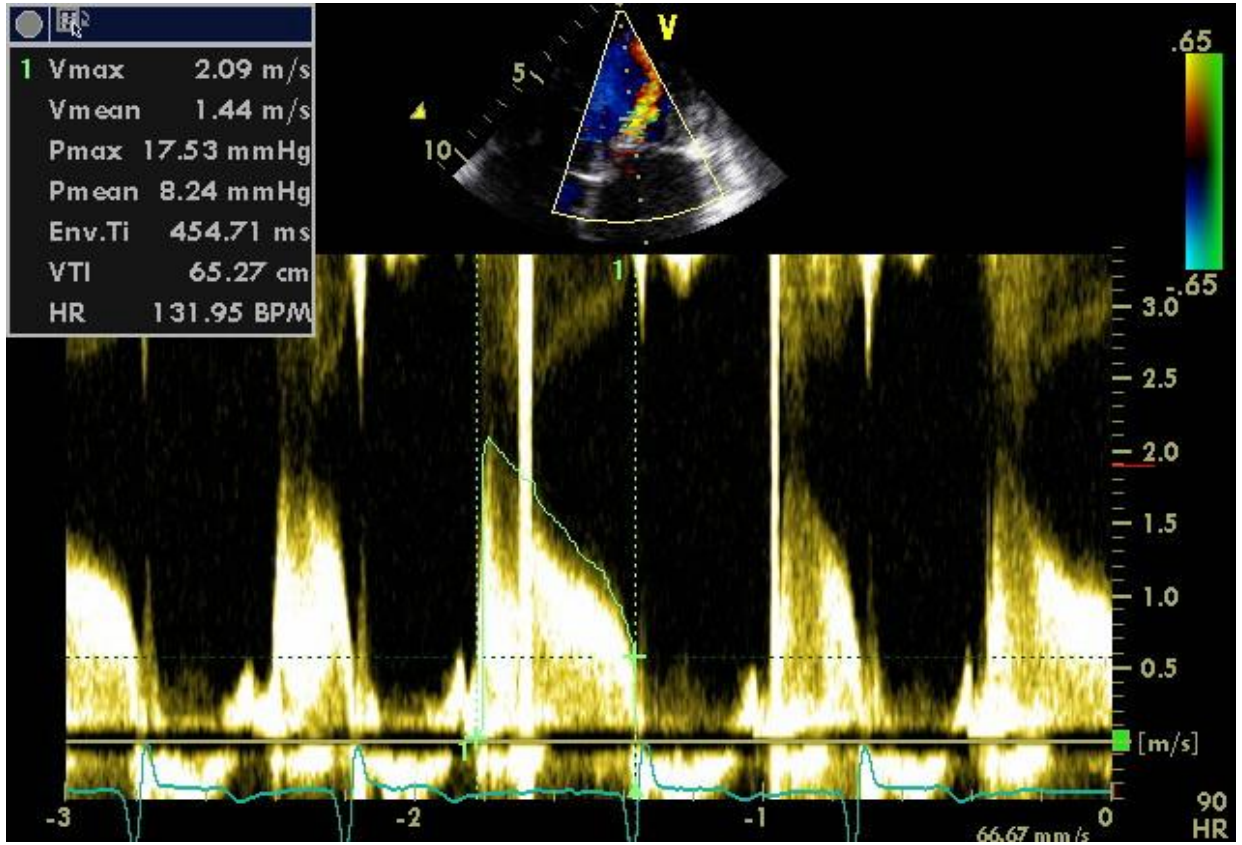
Pressure half-time

Continuity equation



Schloshahn et al. Am Coll Cardiol Img 2011;4:580–8

Doppler – peak and mean pressure gradients



Peak - diastolic PG

Normal : < 2 mmHg
Mild MS : 2 – 7 mmHg
Moderate MS: 7 -15 mmHg
Severe MS : >15 mmHg

Mean PG

Mild MS : < 5 mmHg
Moderate MS : 5 – 10 mm Hg
Severe MS : > 10 mm Hg

Popelová et al. Cor Vasa 2007;49(7.8):Kardio
Cases and imaging: General University Hospital, Prague

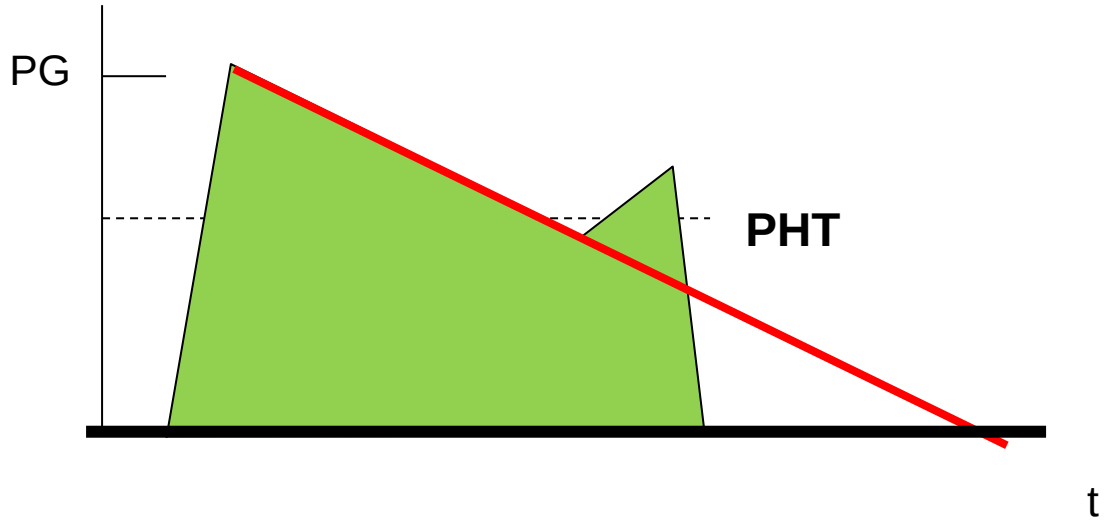
Doppler quantification

Pressure half-time method

- Doppler ⇒ flow velocity
- Velocity ⇒ pressure gradient (Bernoulli) ($PG=4v^2$)
- Half-time of pressure decay (PHT) ⇒ slower in smaller orrifices

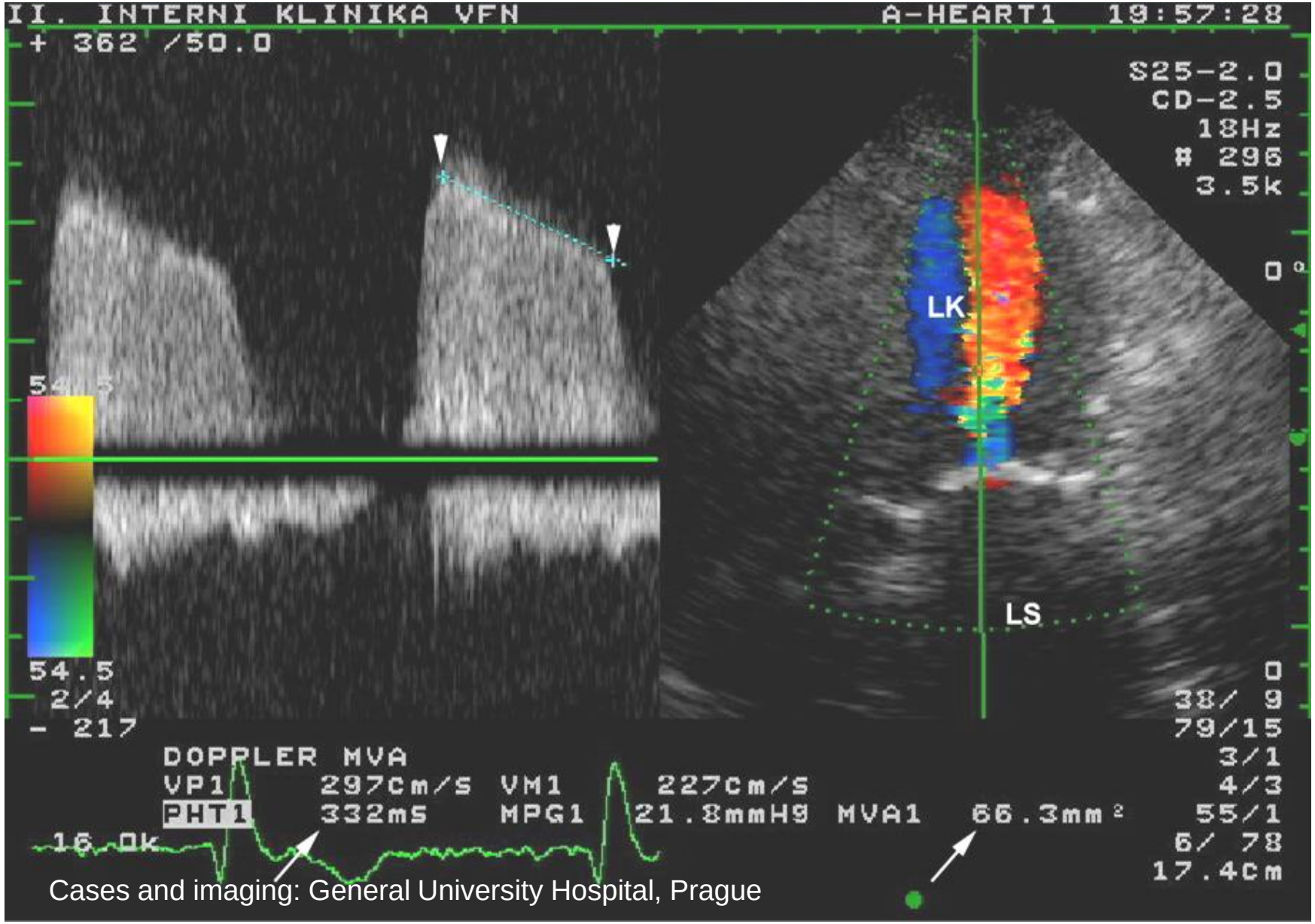
MVA = 220 / PHT

(r = 0.87)



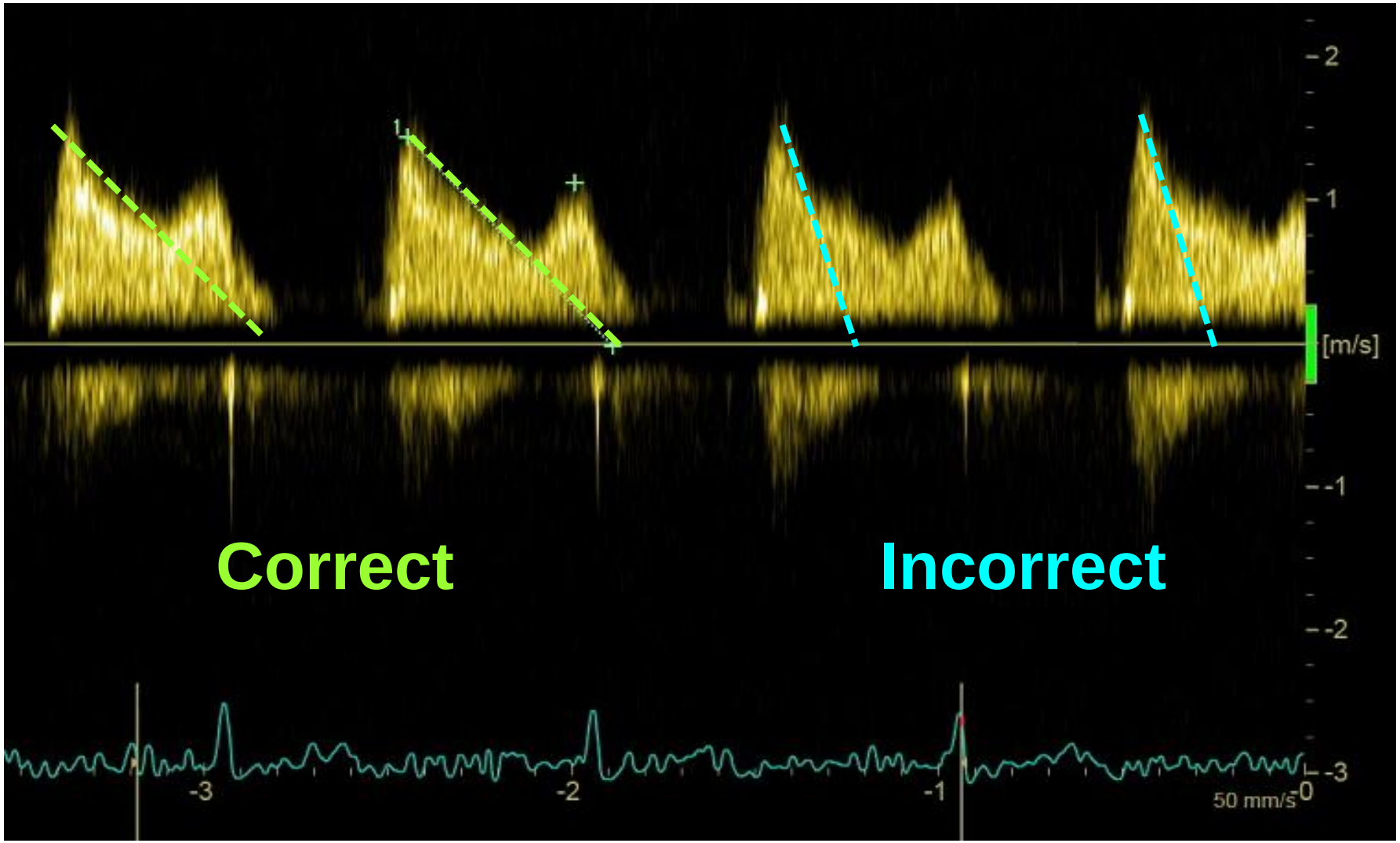
Hatle L et al. Circulation. 1979;60(5):1096-104

Doppler quantification - PHT measurement



Cases and imaging: General University Hospital, Prague

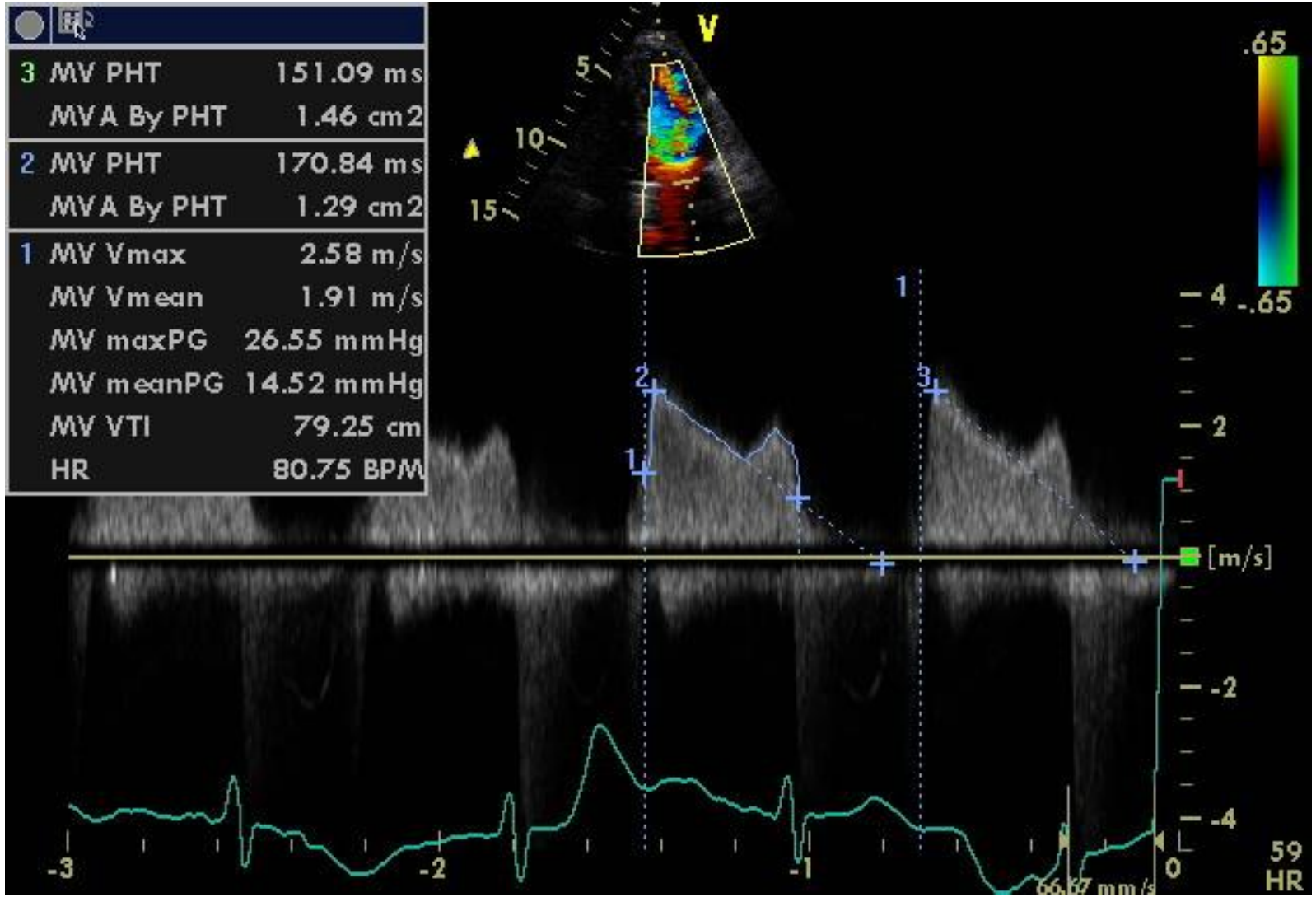
The correct way of PHT measurement



Cases and imaging: General University Hospital, Prague

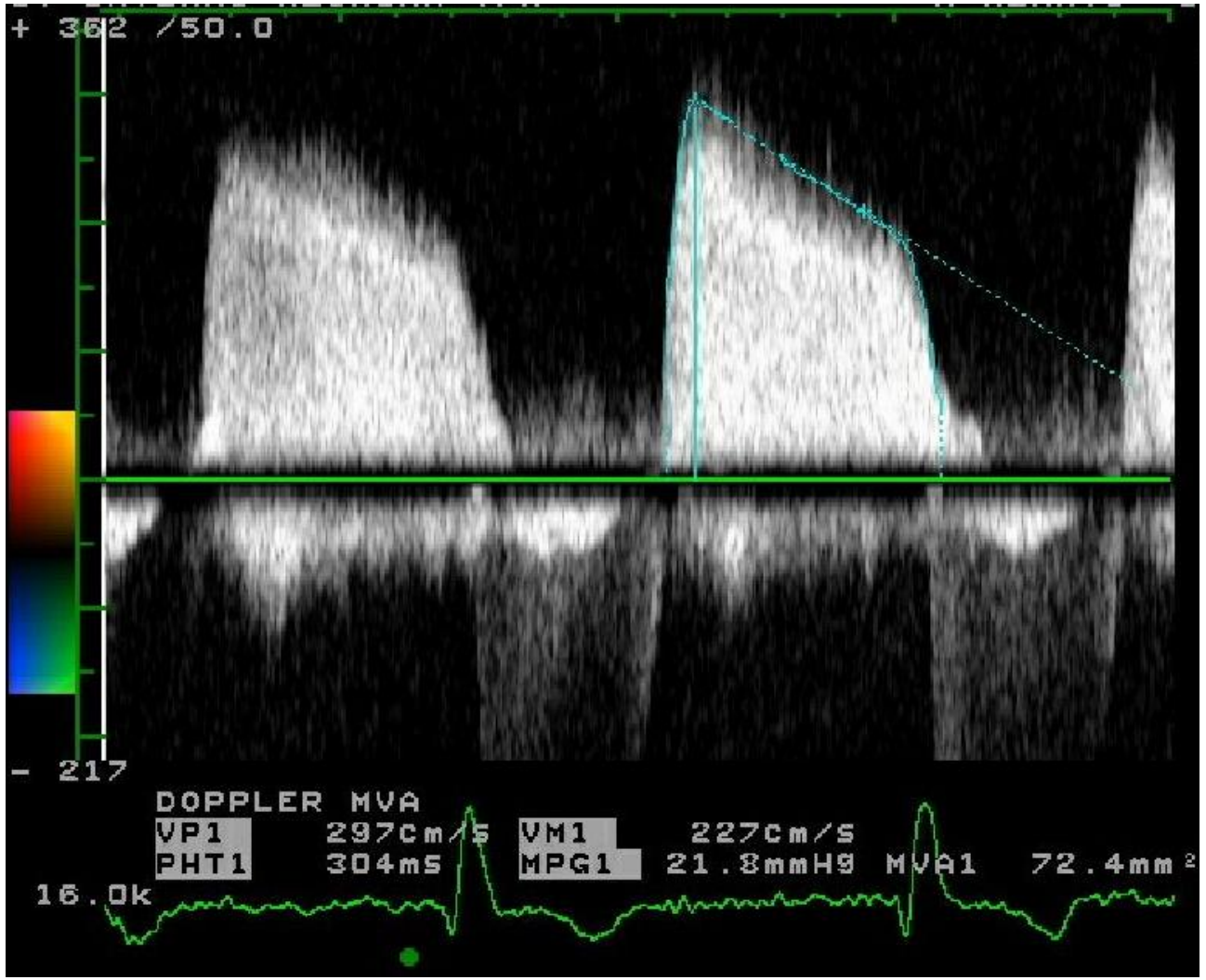
Gonzalez MA et al. Am J Cardiol 1987;60:327–32.

PHT in atrial fibrillation and in sinus rhythm



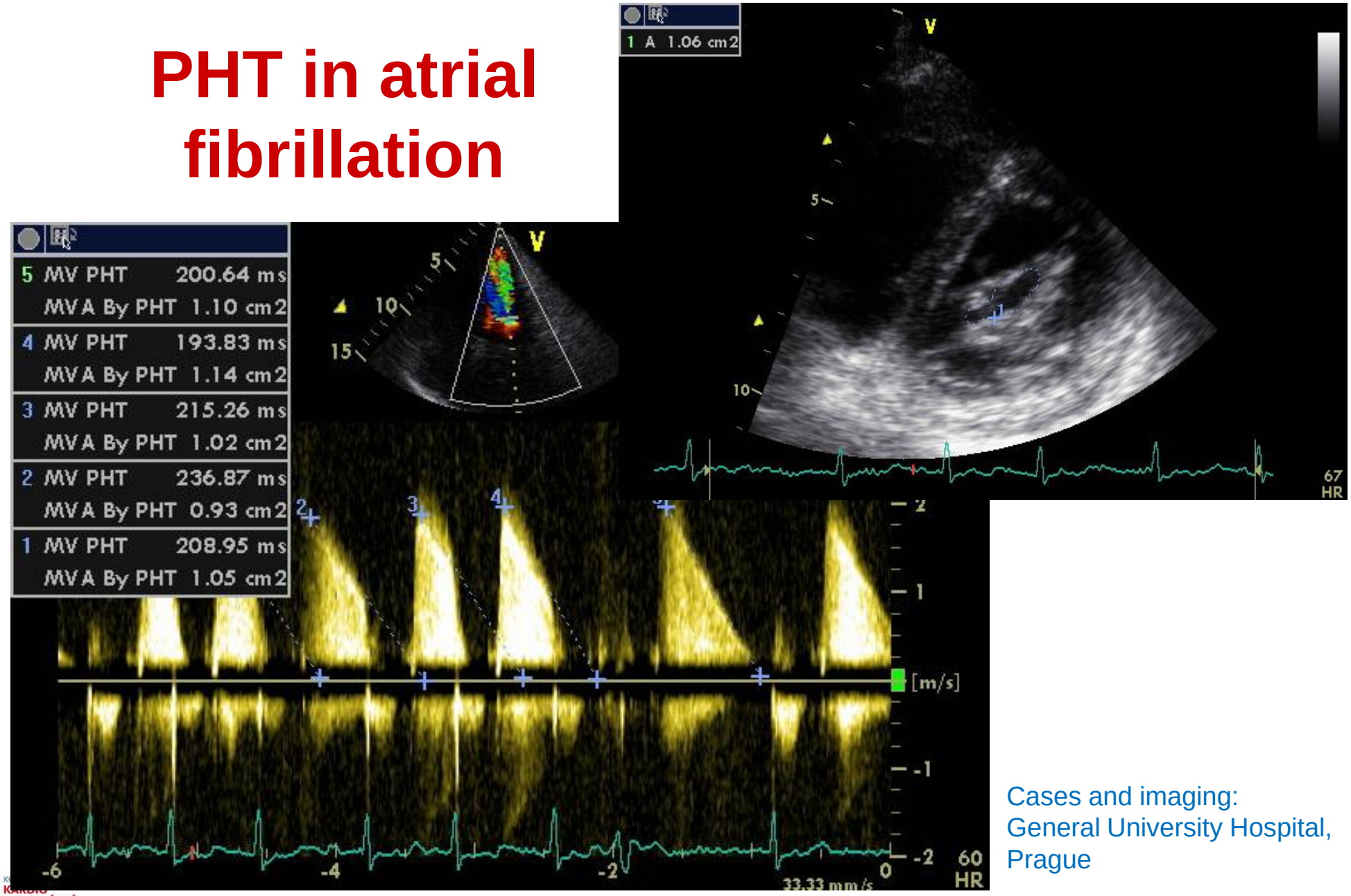
Cases and imaging: General University Hospital, Prague

PHT in atrial fibrillation and in sinus rhythm



Cases and imaging: General University Hospital, Prague

PHT in atrial fibrillation

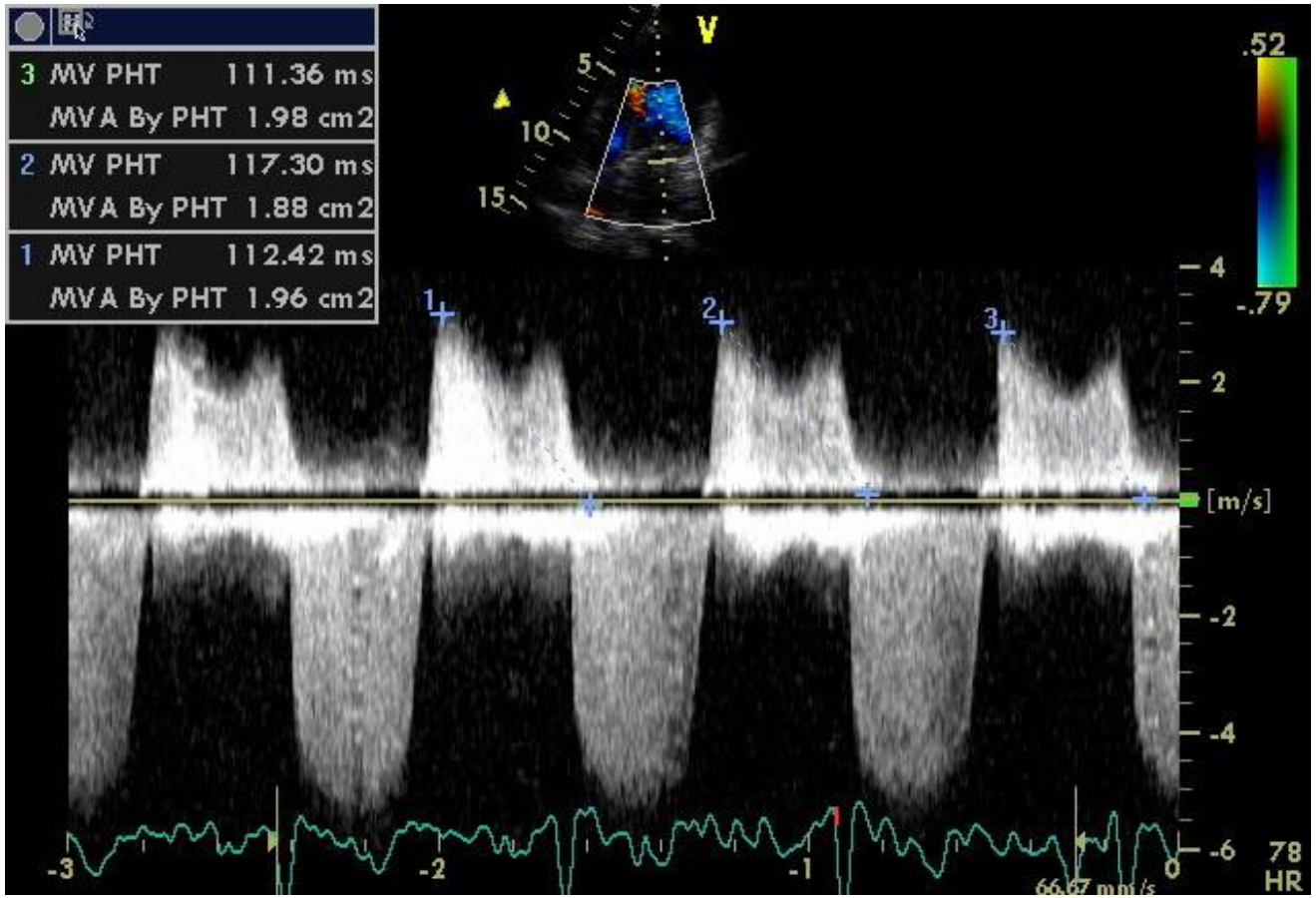


Cases and imaging:
General University Hospital, Prague

PHT in patients with mitral regurgitation

PHT correlates with MVA well even in presence of MR, however…….

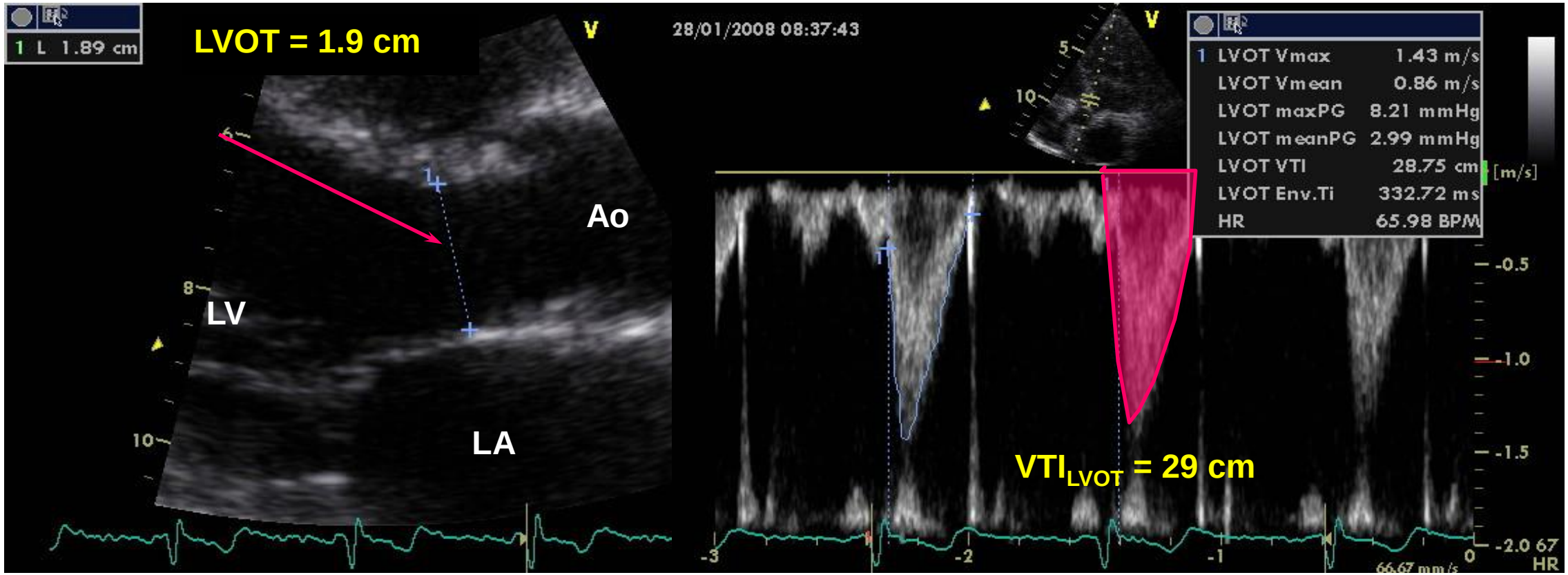
Underestimates the MVA by > 20%
- in small MR in 17% patients
- in mild to moderate MR in 35% pts



Immediately after PBMV
- irrelevant

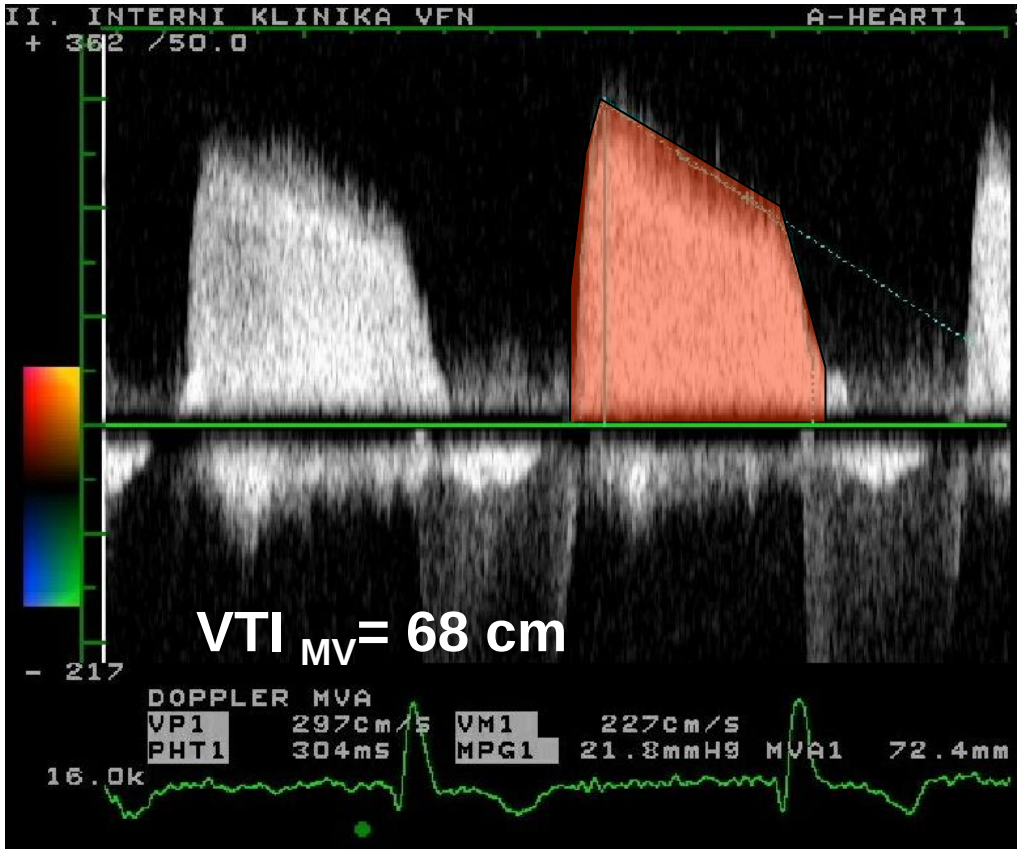
Mohan et al. American Heart Journal 2004; 148: 703-709

MVA – Continuity equation – Step 1.



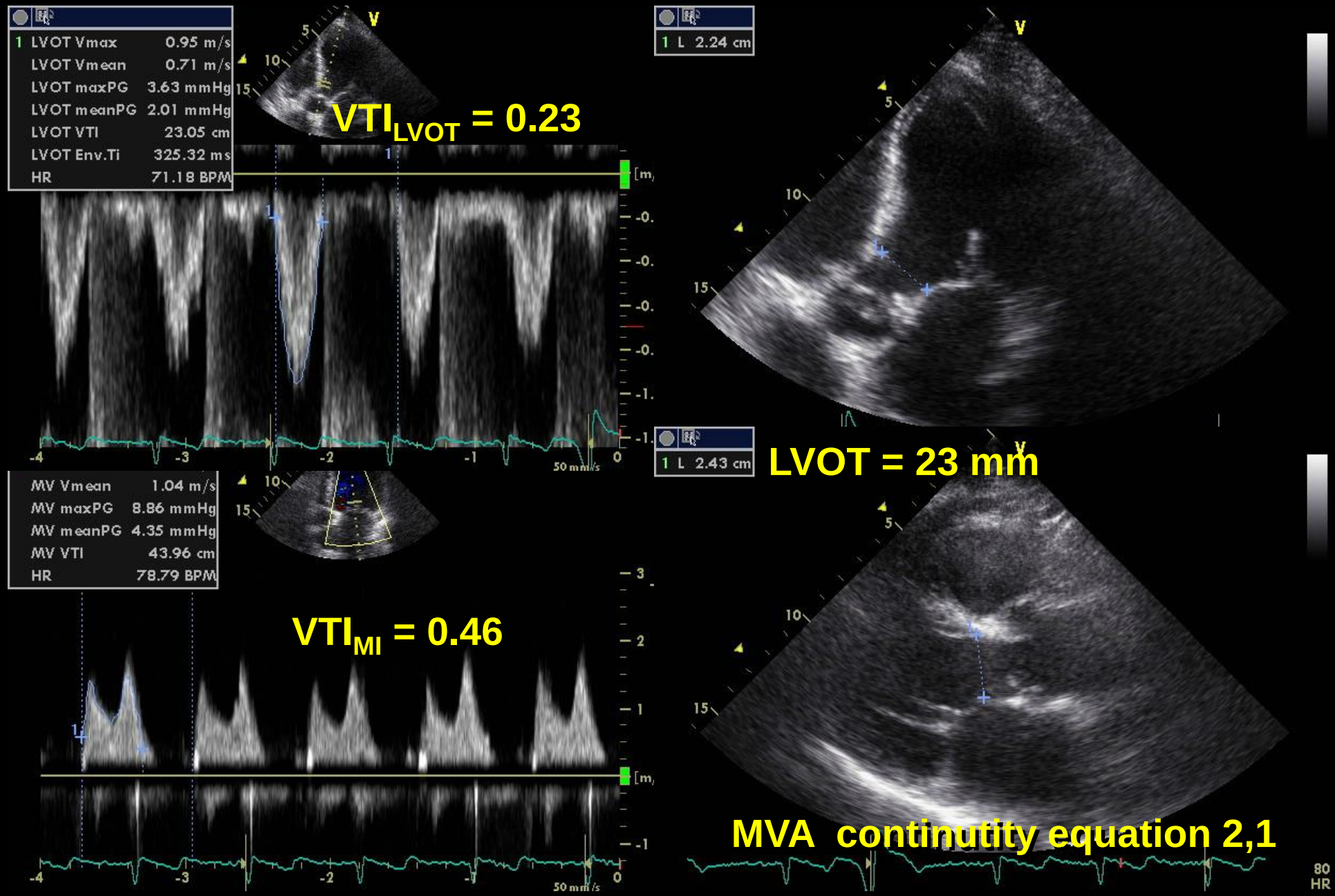
$$\text{Stroke volume} = \pi \cdot \frac{LVOT^2}{4} \cdot VTI_{LVOT}$$

MVA – Continuity equation – Step 2.

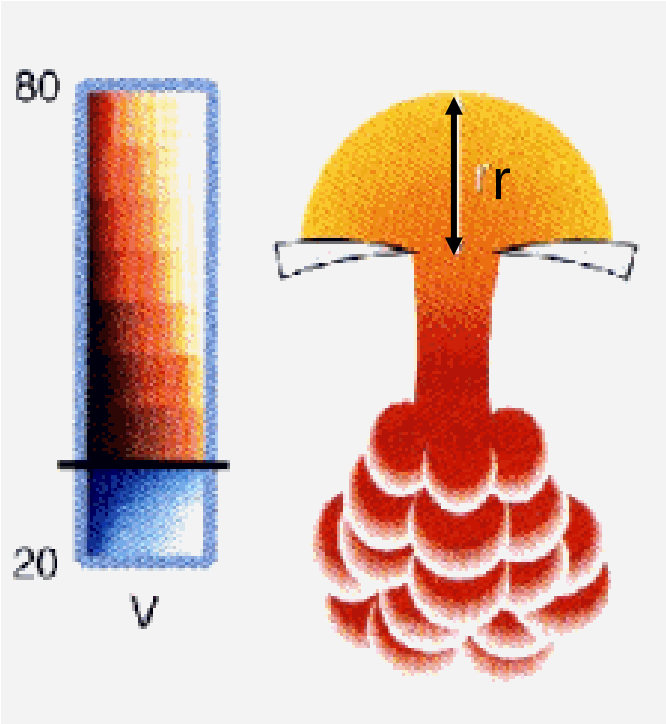


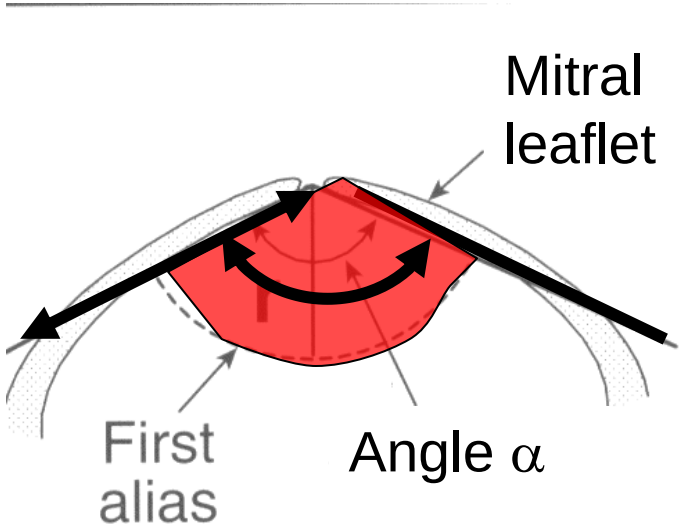
Cases and imaging:
General University Hospital, Prague

$$MVA = \frac{\pi \cdot \frac{LVOT^2}{4} \cdot VTI_{LVOT}}{VTI_{MV}}$$


1 LVOT Vmax 0.95 m/s
LVOT Vmean 0.71 m/s
LVOT maxPG 3.63 mmHg
LVOT meanPG 2.01 mmHg
LVOT VTI 23.05 cm
LVOT Env.Ti 325.32 ms
HR 71.18 BPM
VTILVOT = 0.23
1 L 2.24 cm
LVOT = 23 mm
1 L 2.43 cm
MV Vmean 1.04 m/s
MV maxPG 8.86 mmHg
MV meanPG 4.35 mmHg
MV VTI 43.96 cm
HR 78.79 BPM
VTIMI = 0.46
MVA continutity equation 2,1
50 mm/s
80 HR

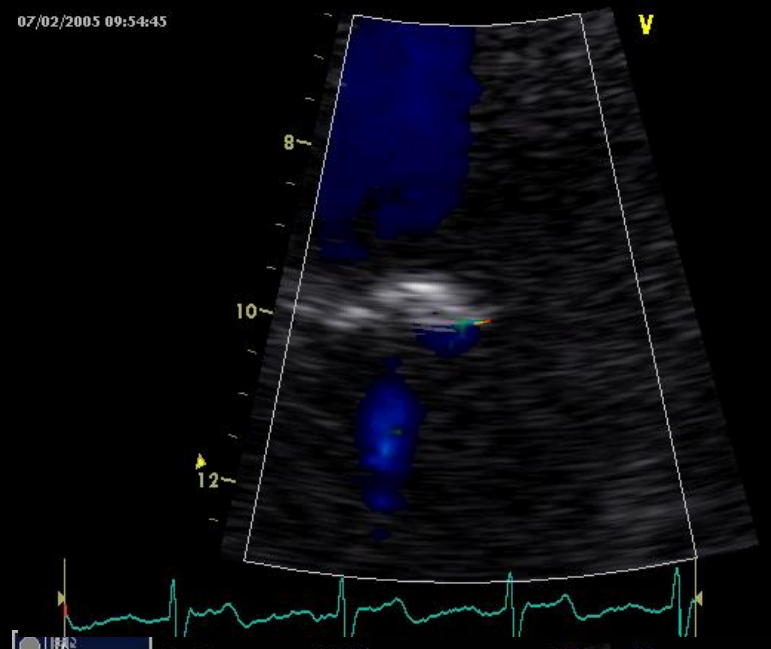
PISA

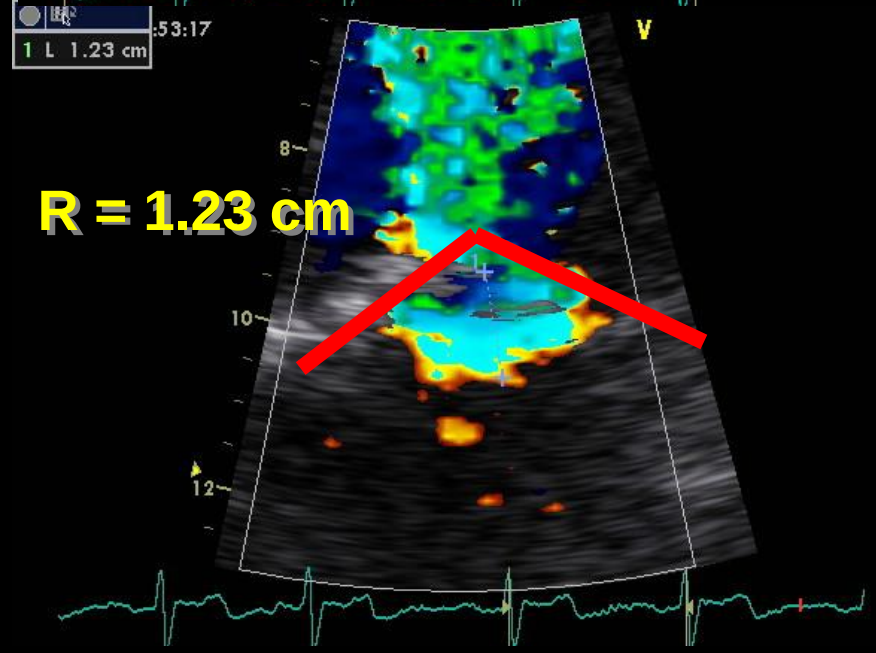




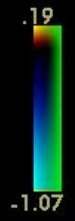
Flow (Q) = $2\pi . R^2 . Va$

$$MVA = \frac{2\,\pi\,.\,r^2\,(cm^2)\ \ x\ Va\ (cm/s)}{Vmax\ MS\ (CW\ -\ cm/s)}\ x\ \frac{\alpha}{180°}$$





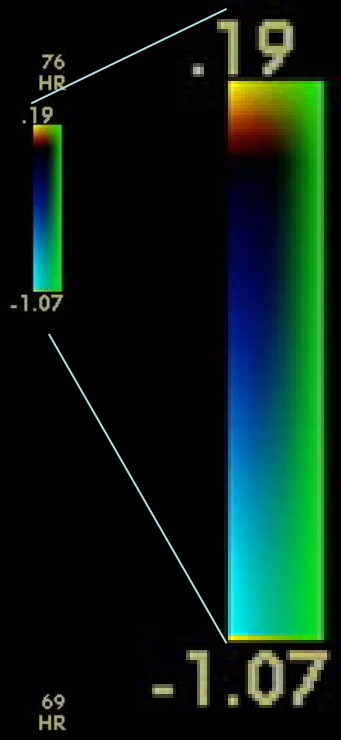
R = 1.23 cm



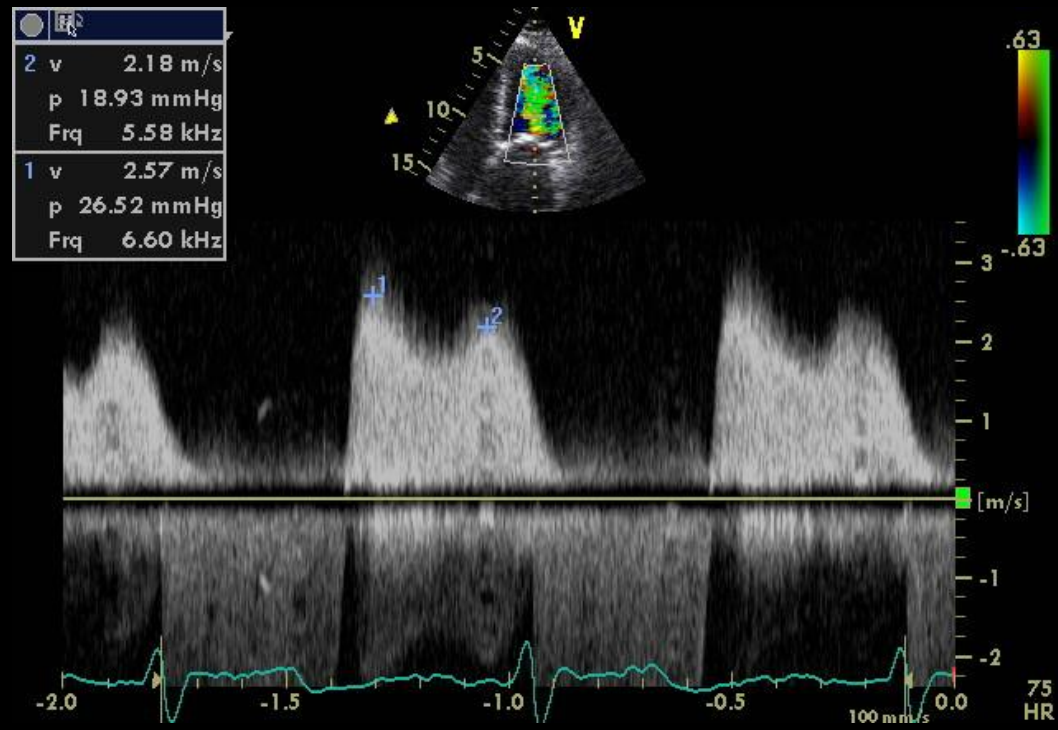
$$\frac{6{,}28 \,.\, 1{,}51 \,.\, 19}{220} \times \frac{150}{180} = 0{,}65$$

Va = 0,19 cm

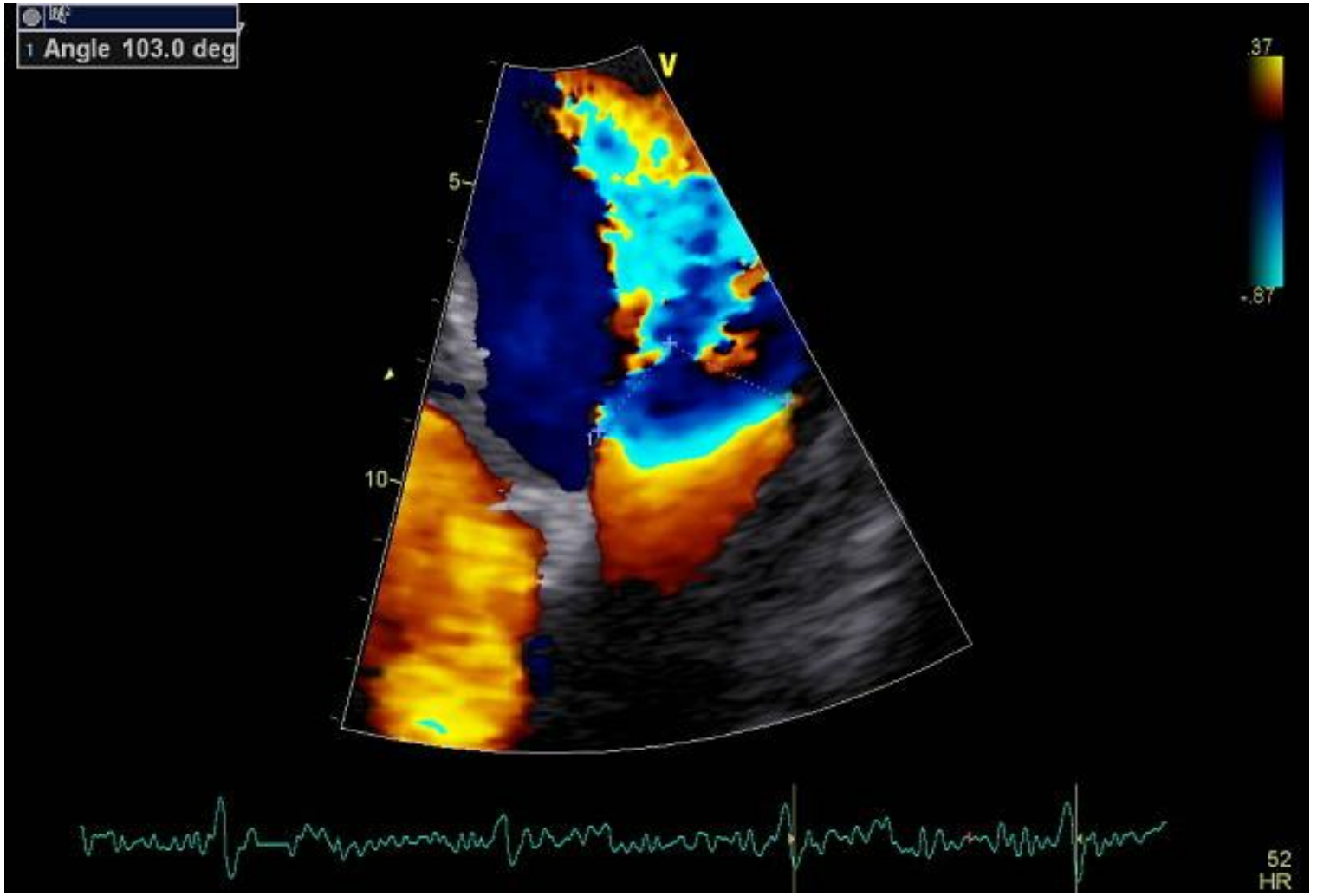
Ideally 10% Vmax



Vmax = 257 cm/s



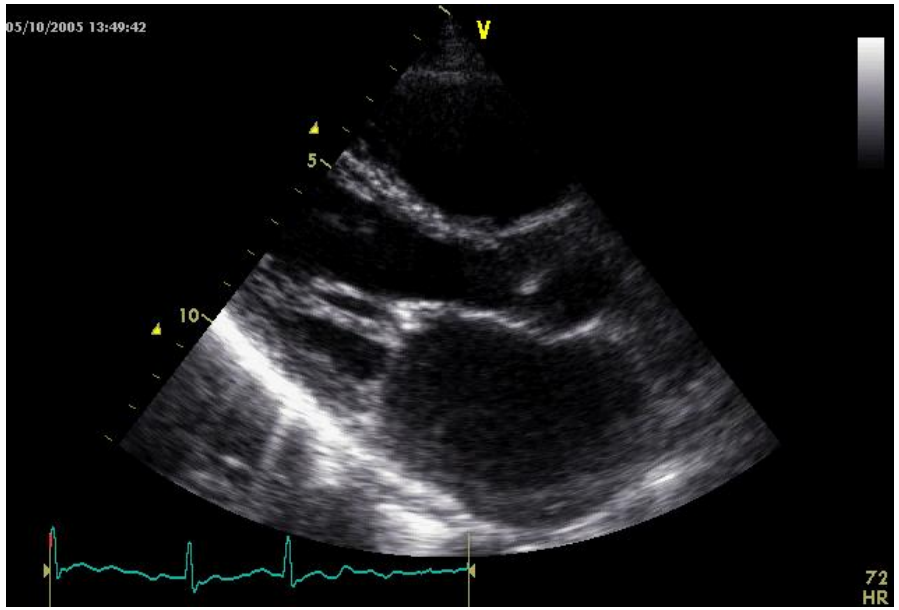
PISA angle correction measurement

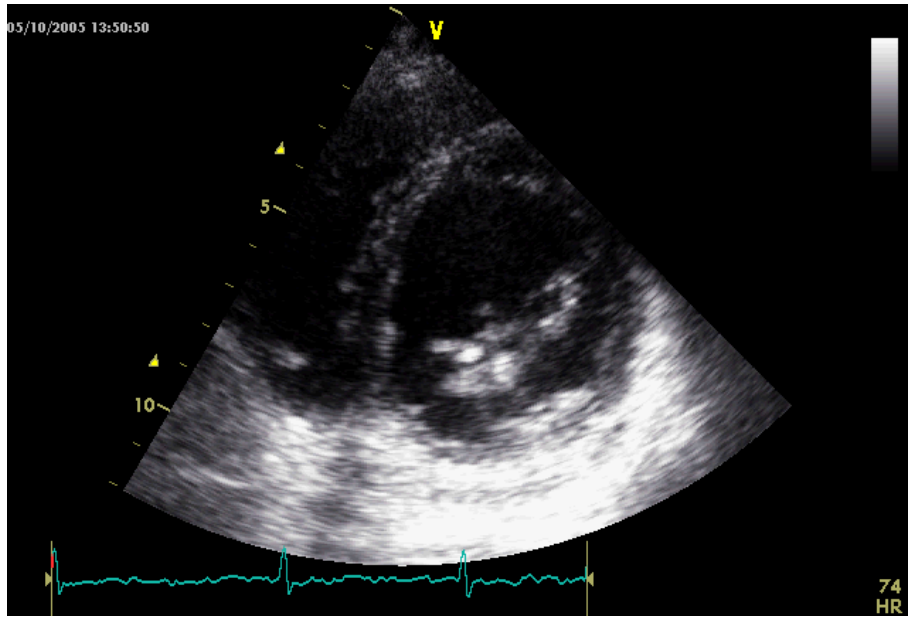


Cases and imaging: General University Hospital, Prague

COMPLICATIONS

LV function

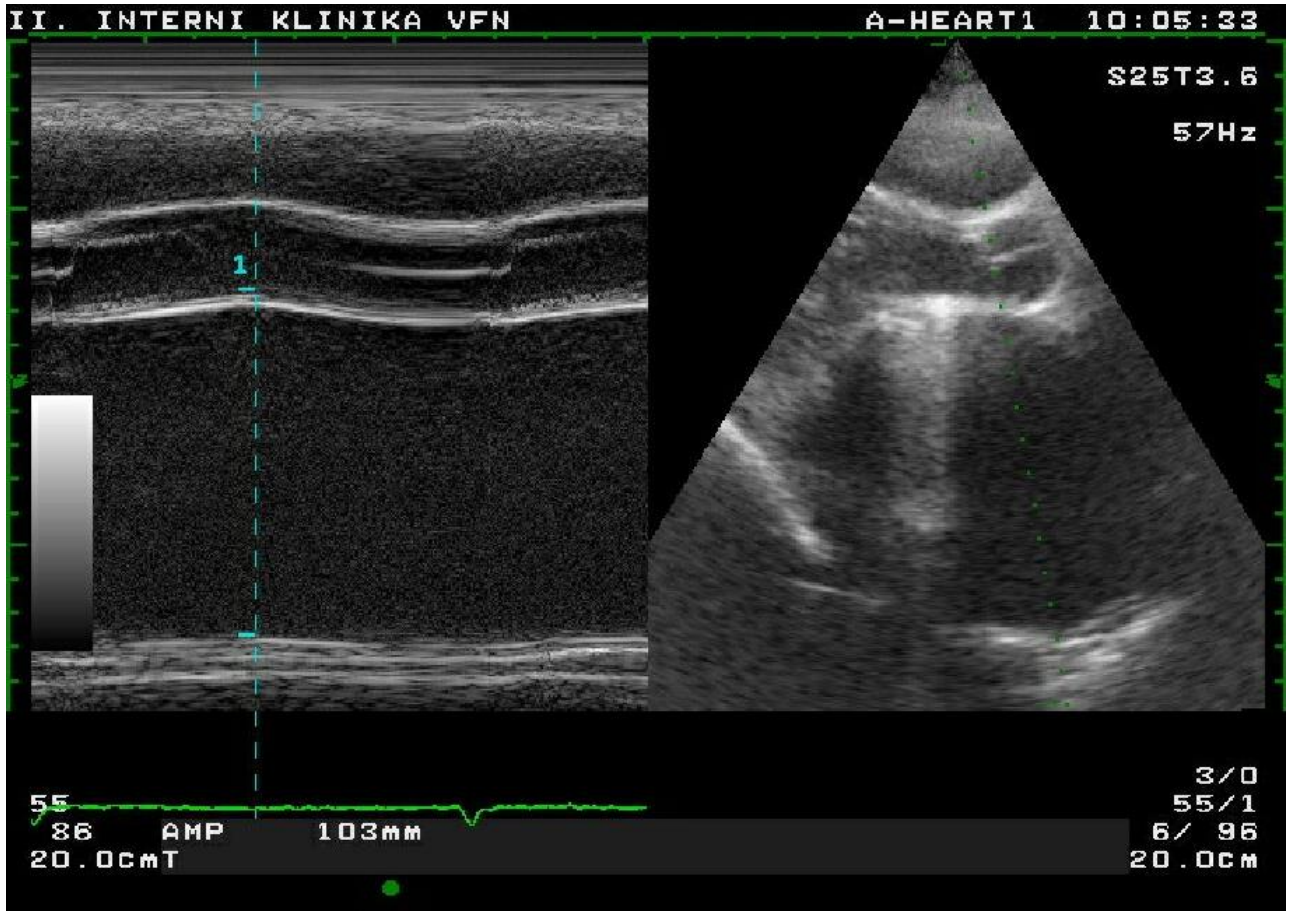


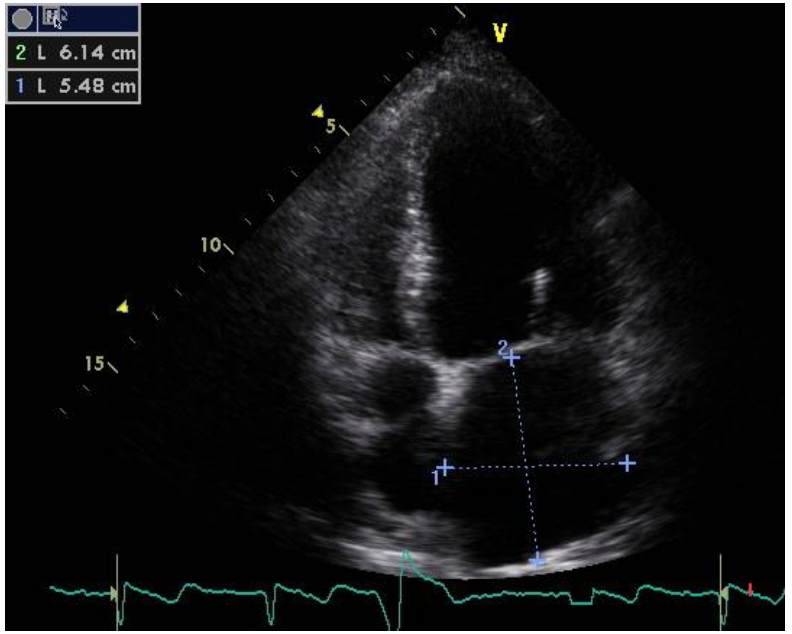


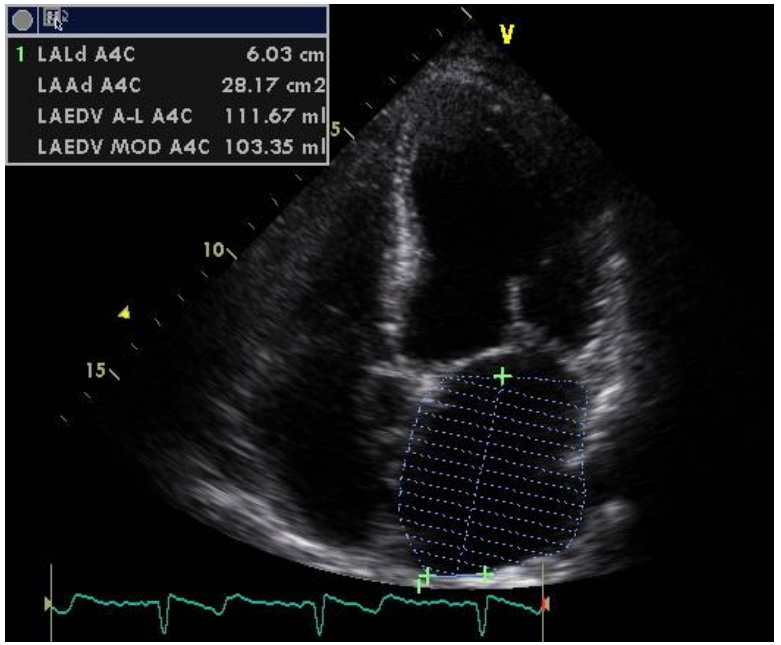
- LV usually non dilated or smaller
- No LV hypertrophy
- IVS compression – paradoxical movement
- LV EF borderline or even slightly depressed
  - underloading
  - abnormal IVS movement (interventricular dependence)
  - tachycardia induced cardiomyopathy

Cases and Imaging: General University Hospital, Prague

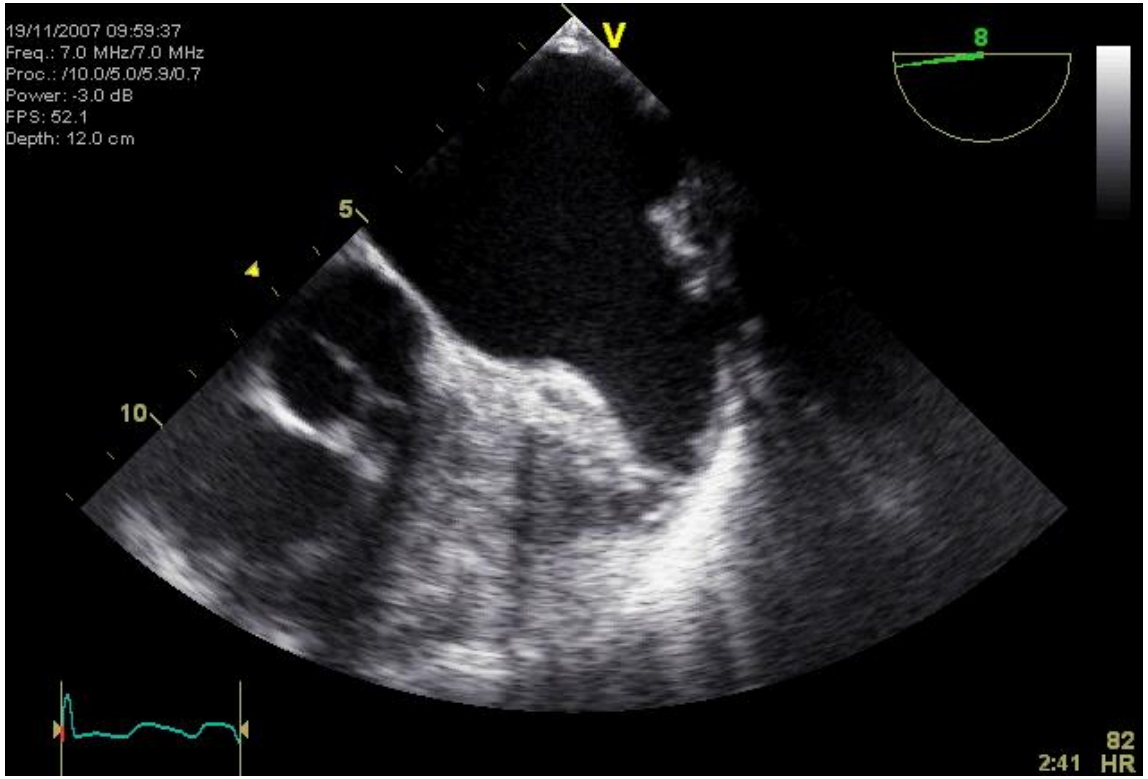
Left atrial dilatation

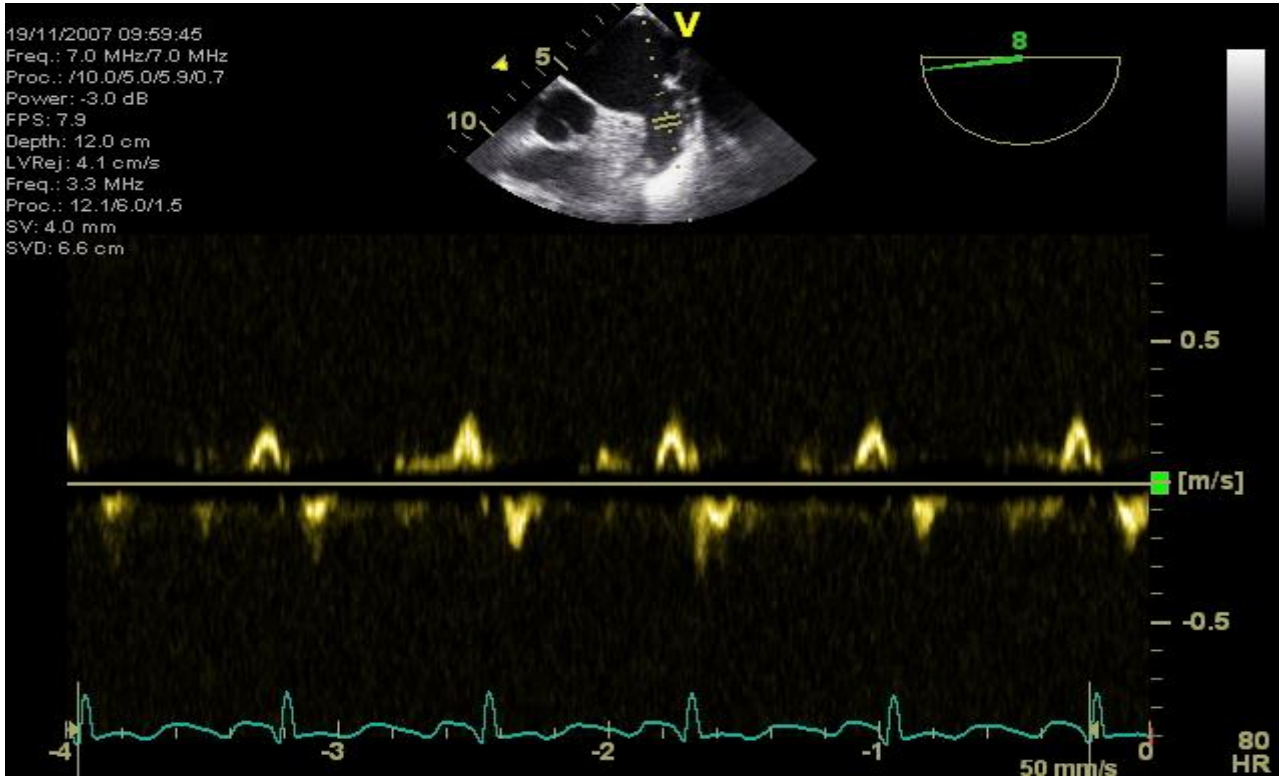






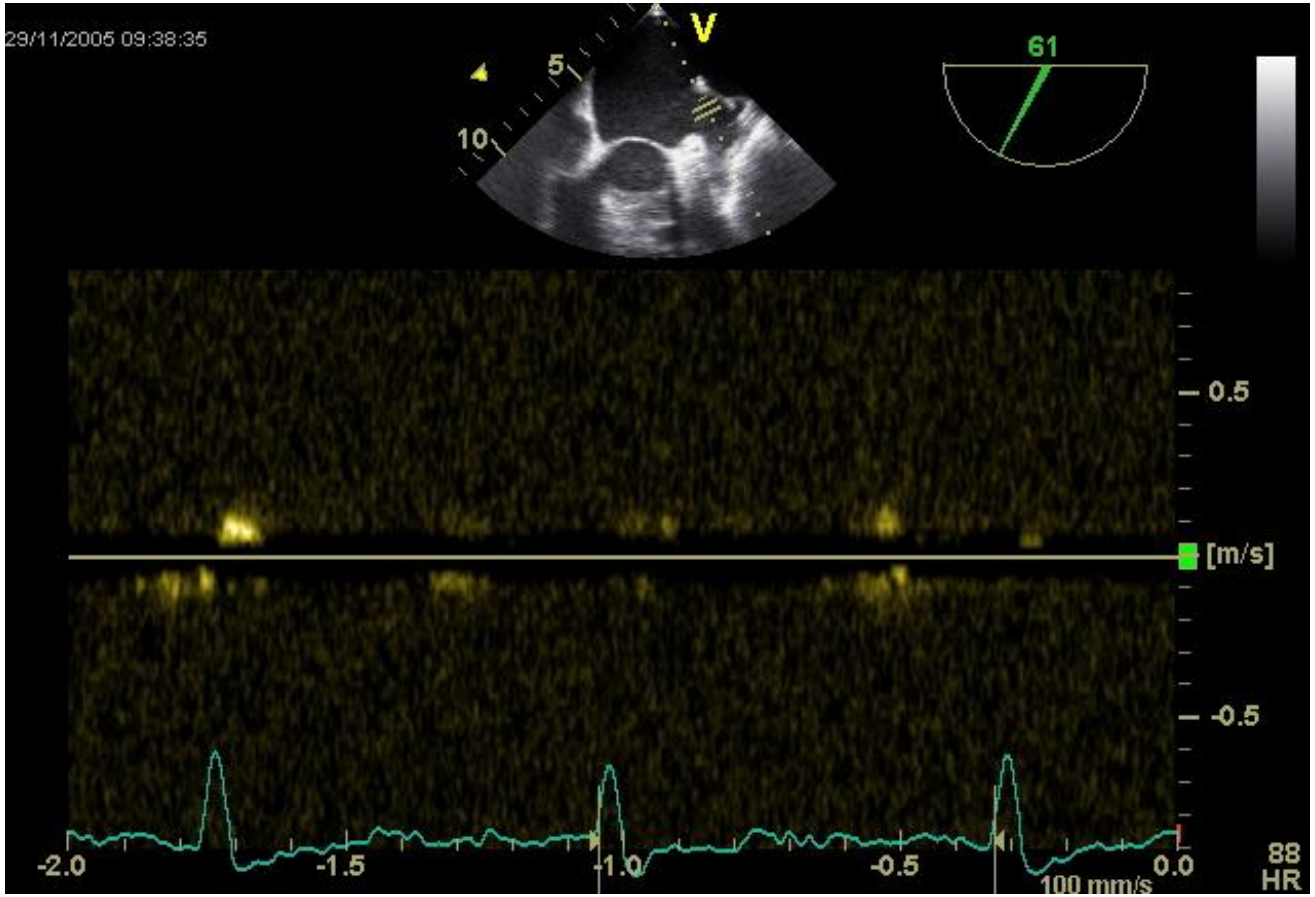
Left atrial dysfunction



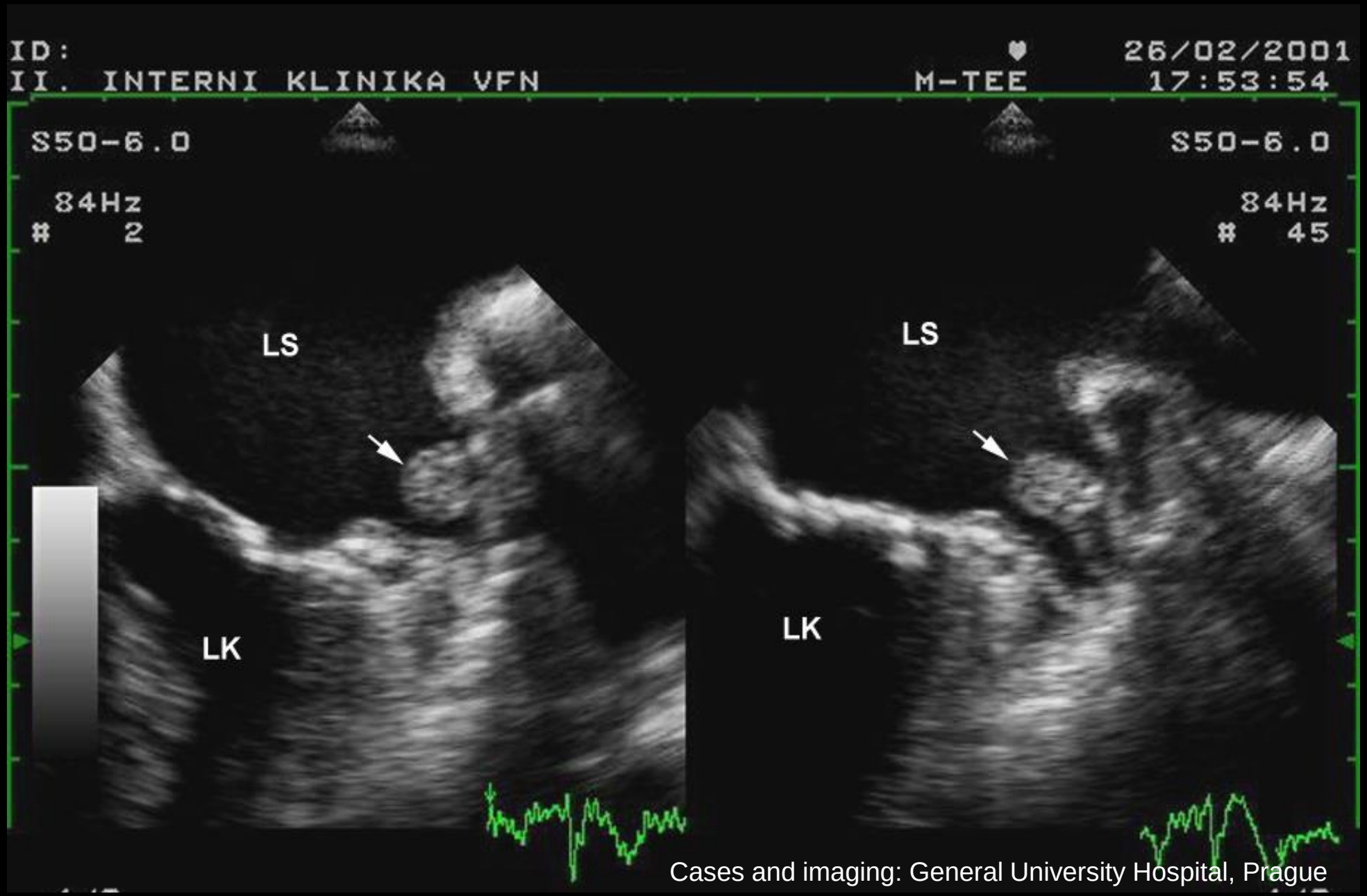


Cases and imaging: General University Hospital, Prague

Severely depressed LAA contractile function in valvular atrial fibrillation

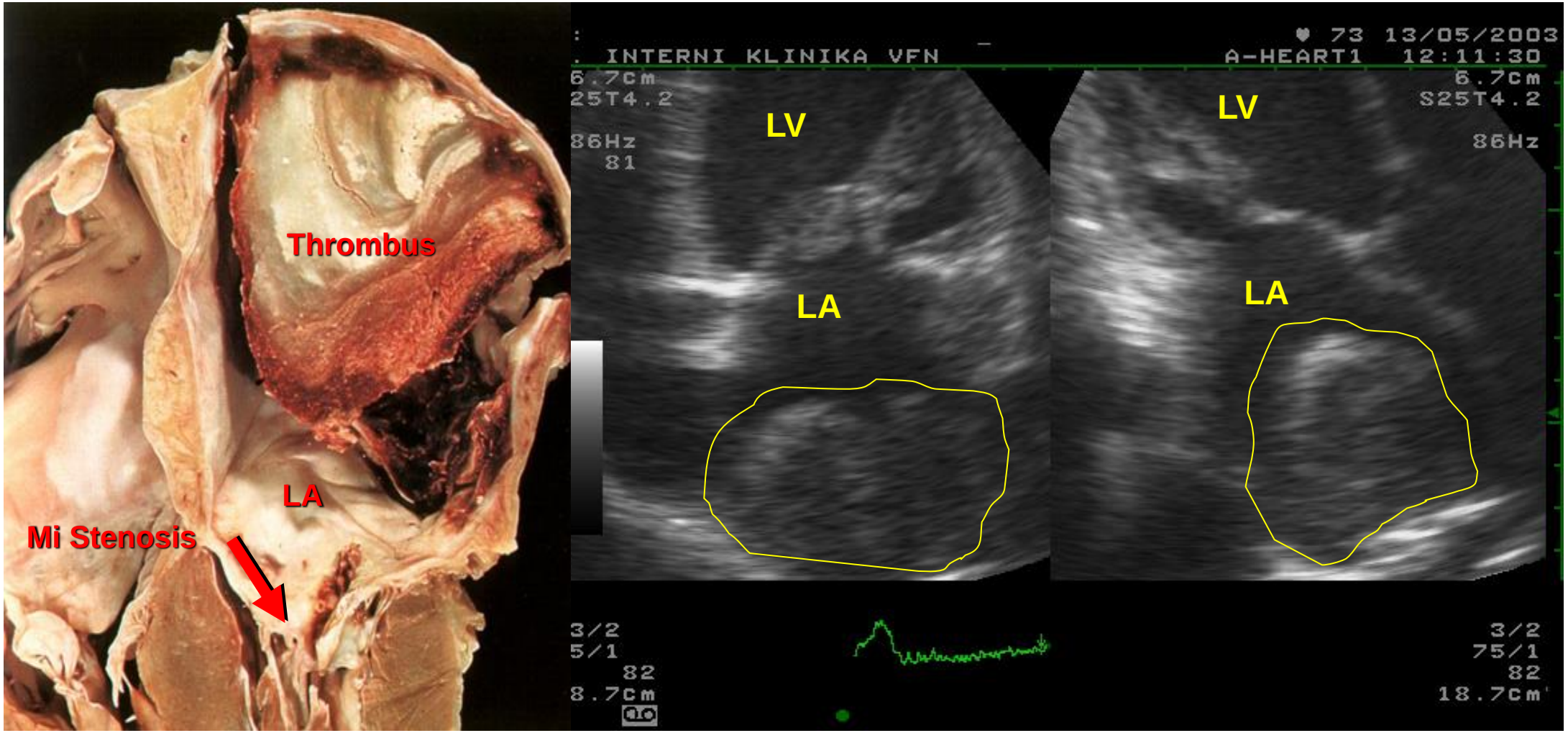


Cases and imaging: General University Hospital, Prague



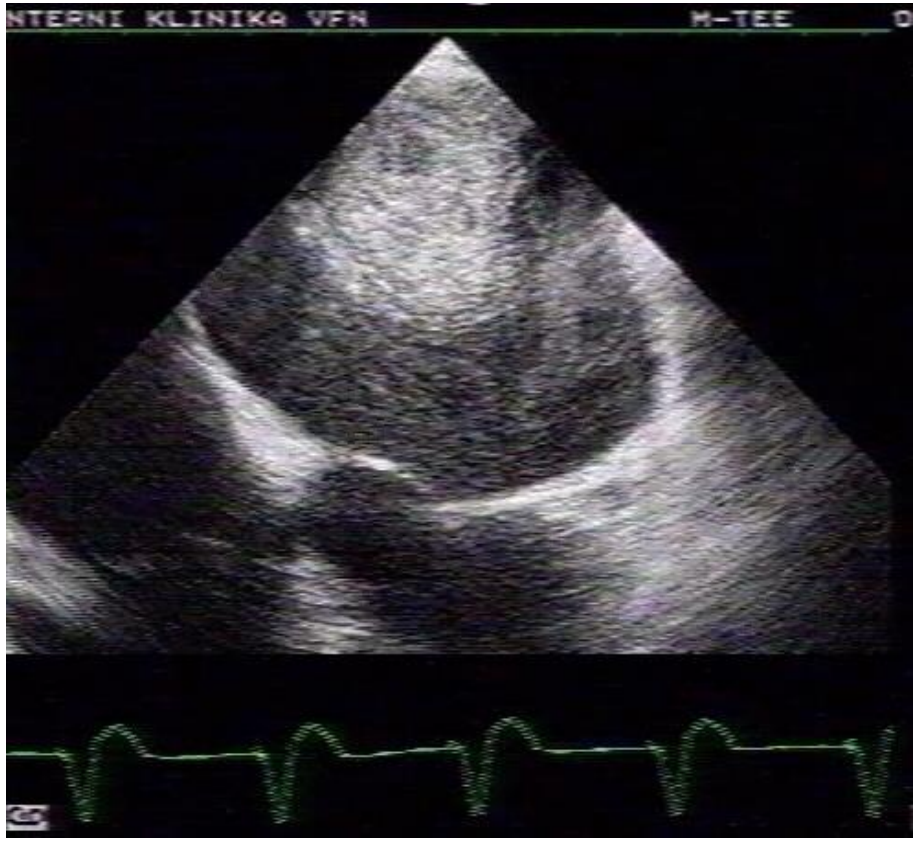
Cases and imaging: General University Hospital, Prague

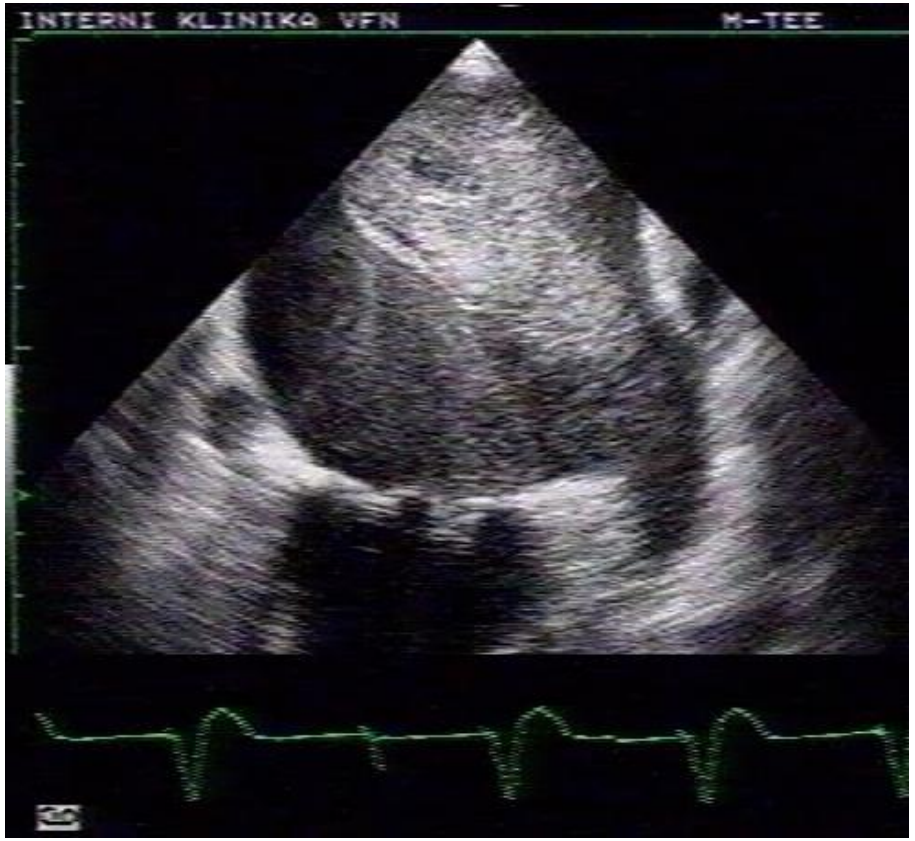
Massive LA thrombosis



Cases and imaging: General University Hospital, Prague

Massive left atrial thrombosis in mitral stenosis

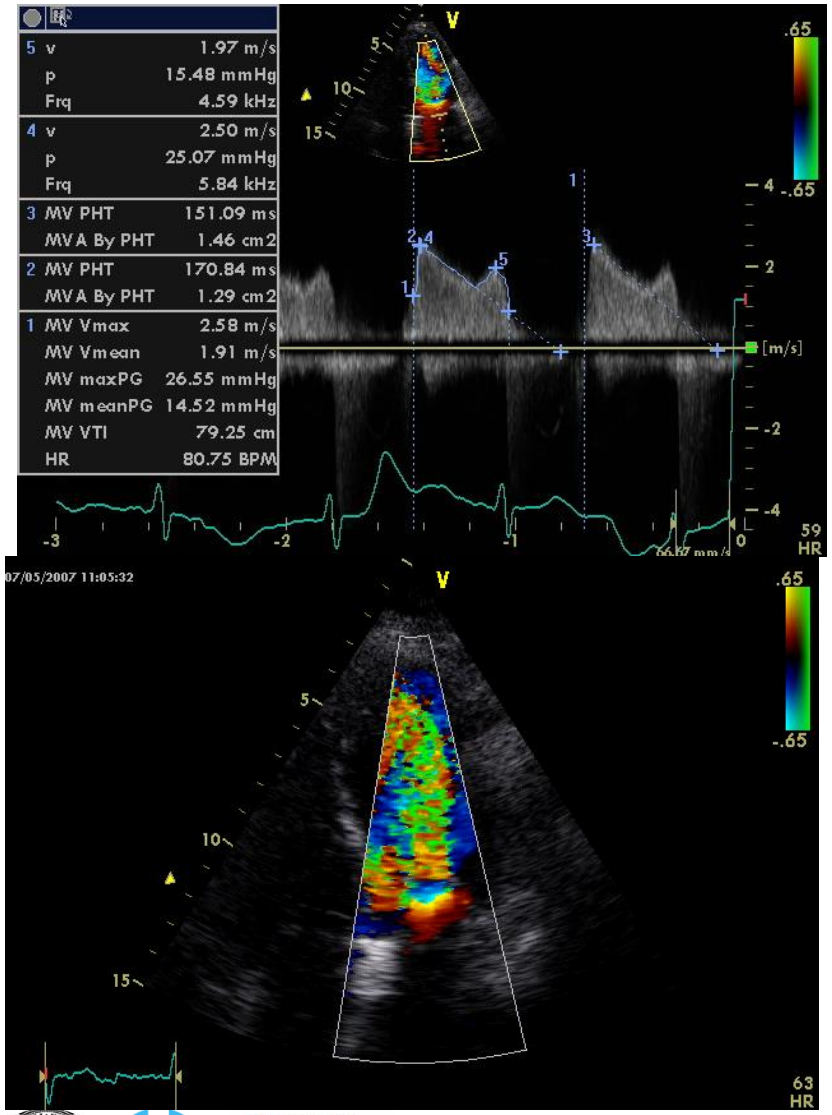


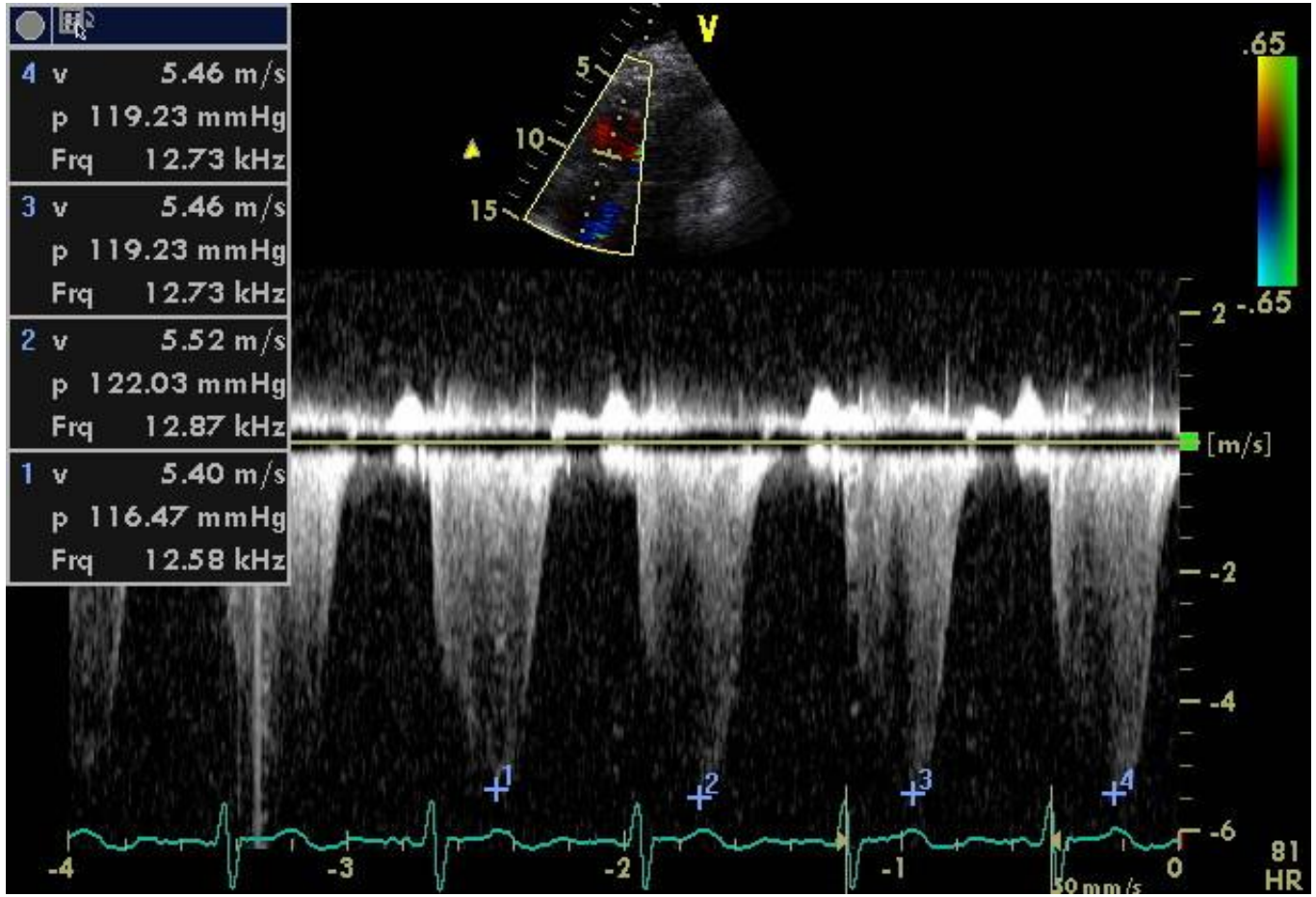


Thrombotic complications in about 10-20% patients
About 0,6-1,5% yearly

Cases and imaging: General University Hospital, Prague

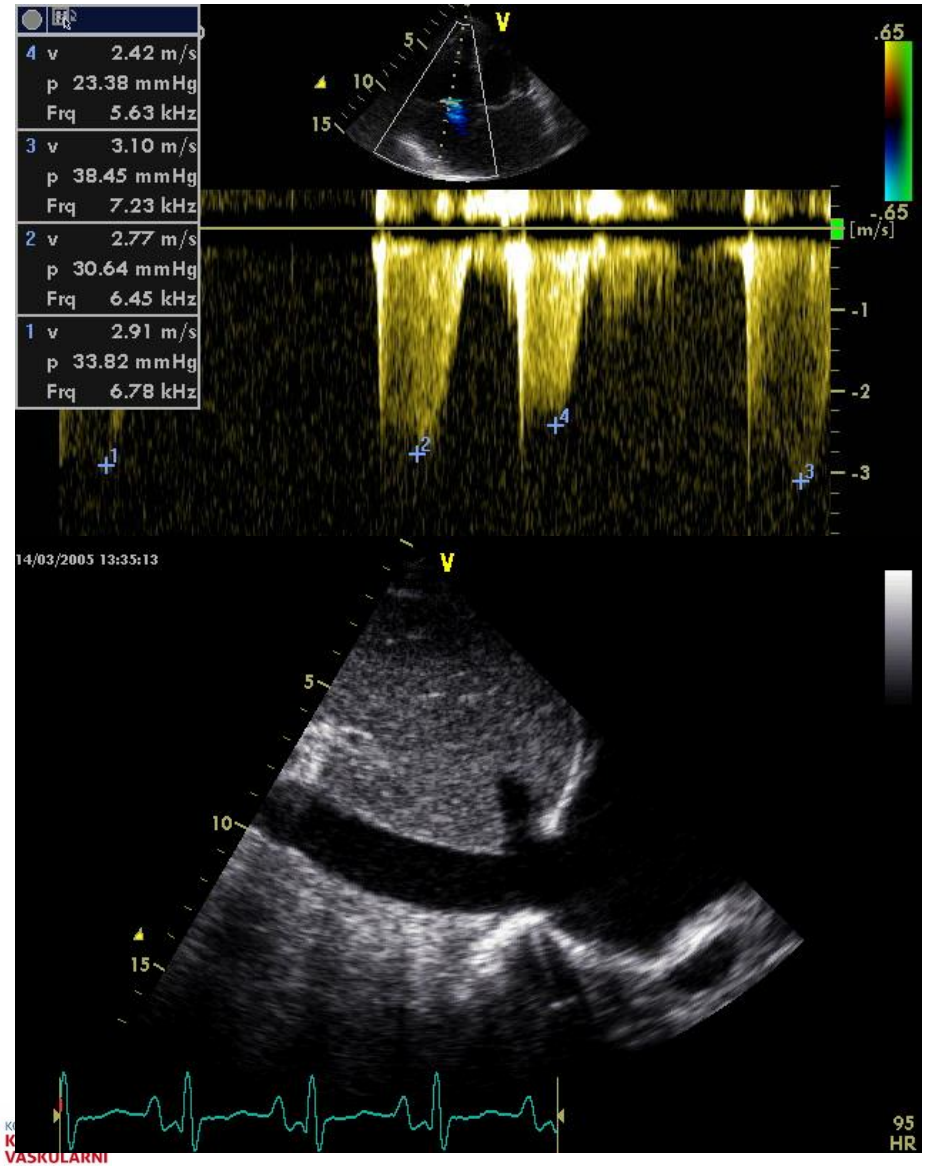
Pulmonary hypertension

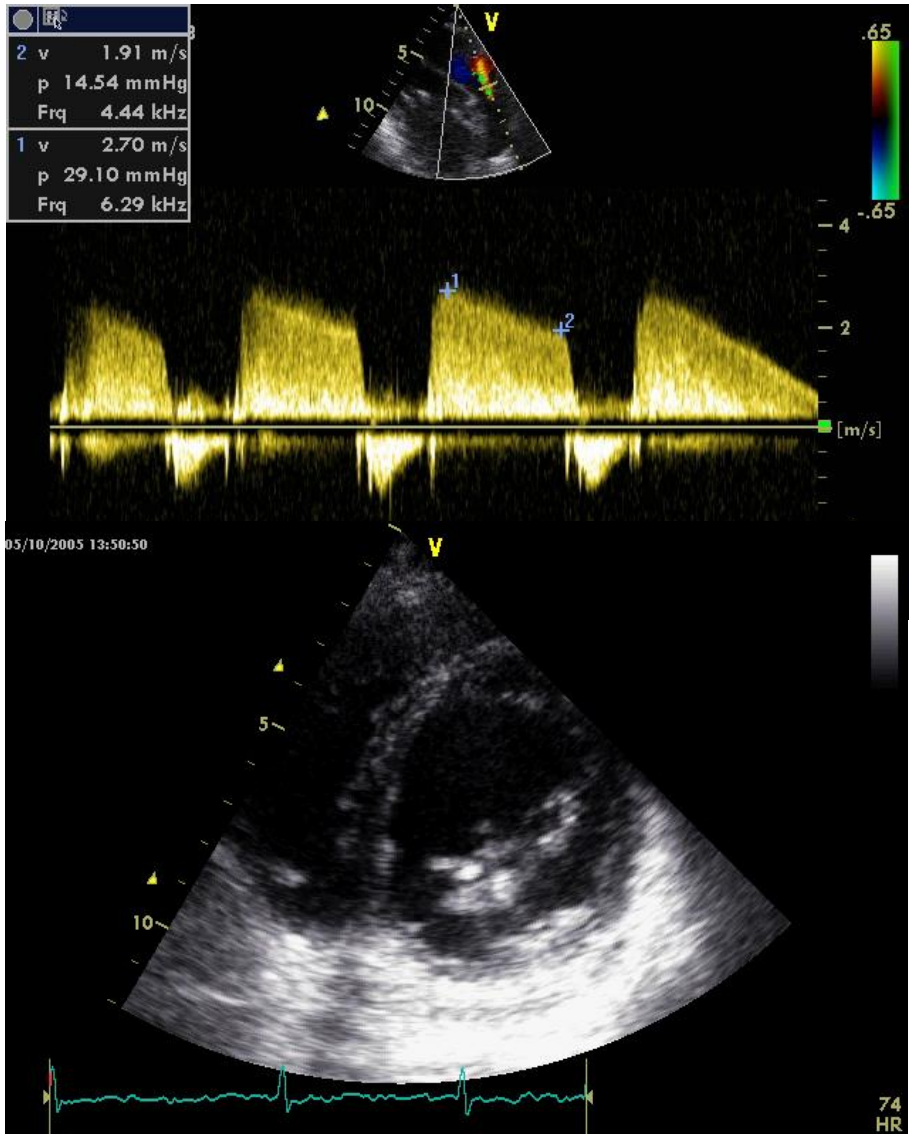




Cases and imaging:
General University Hospital,
Prague

Quantitation of pulmonary pressures





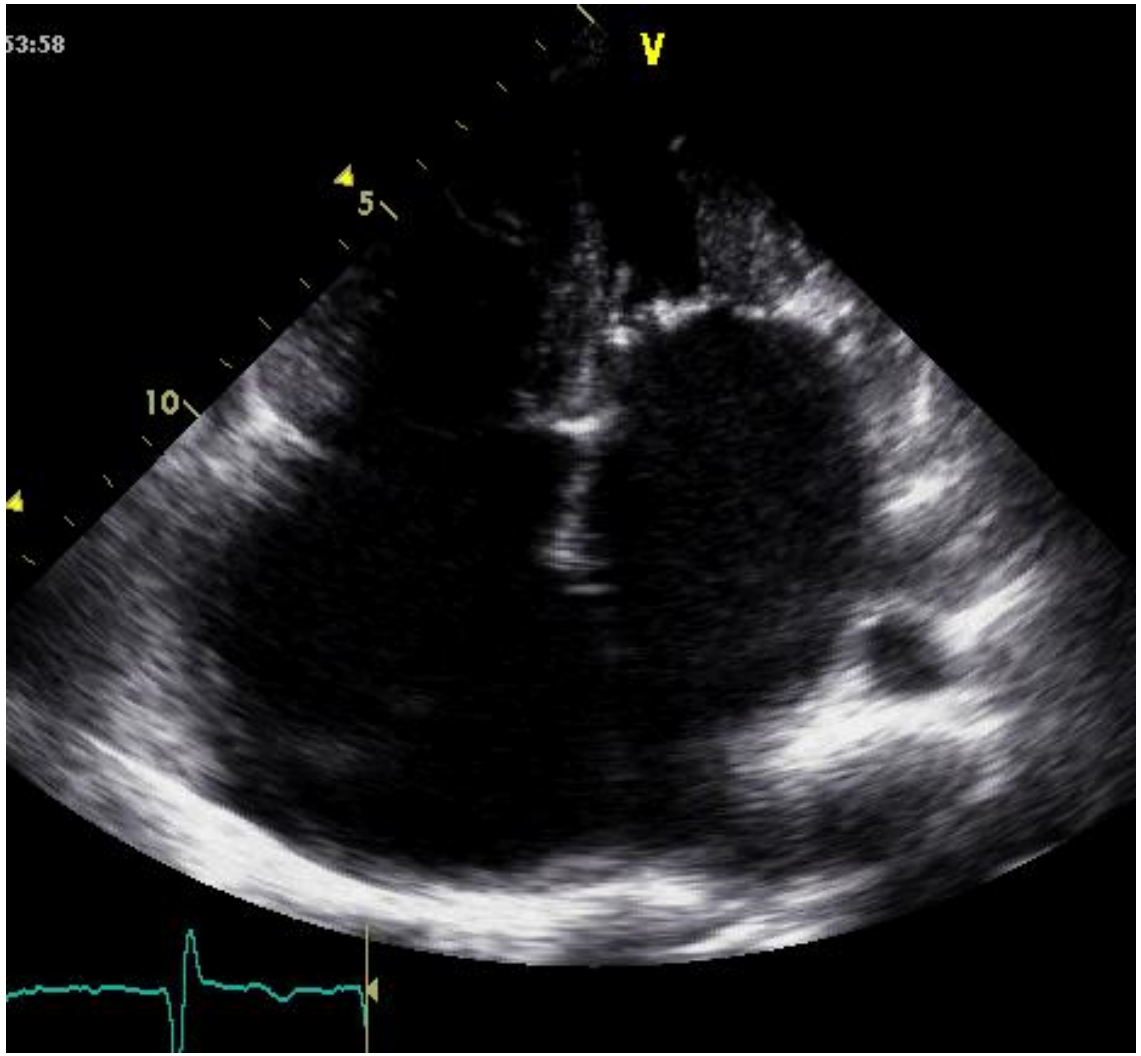
Cases and imaging: General University Hospital, Prague

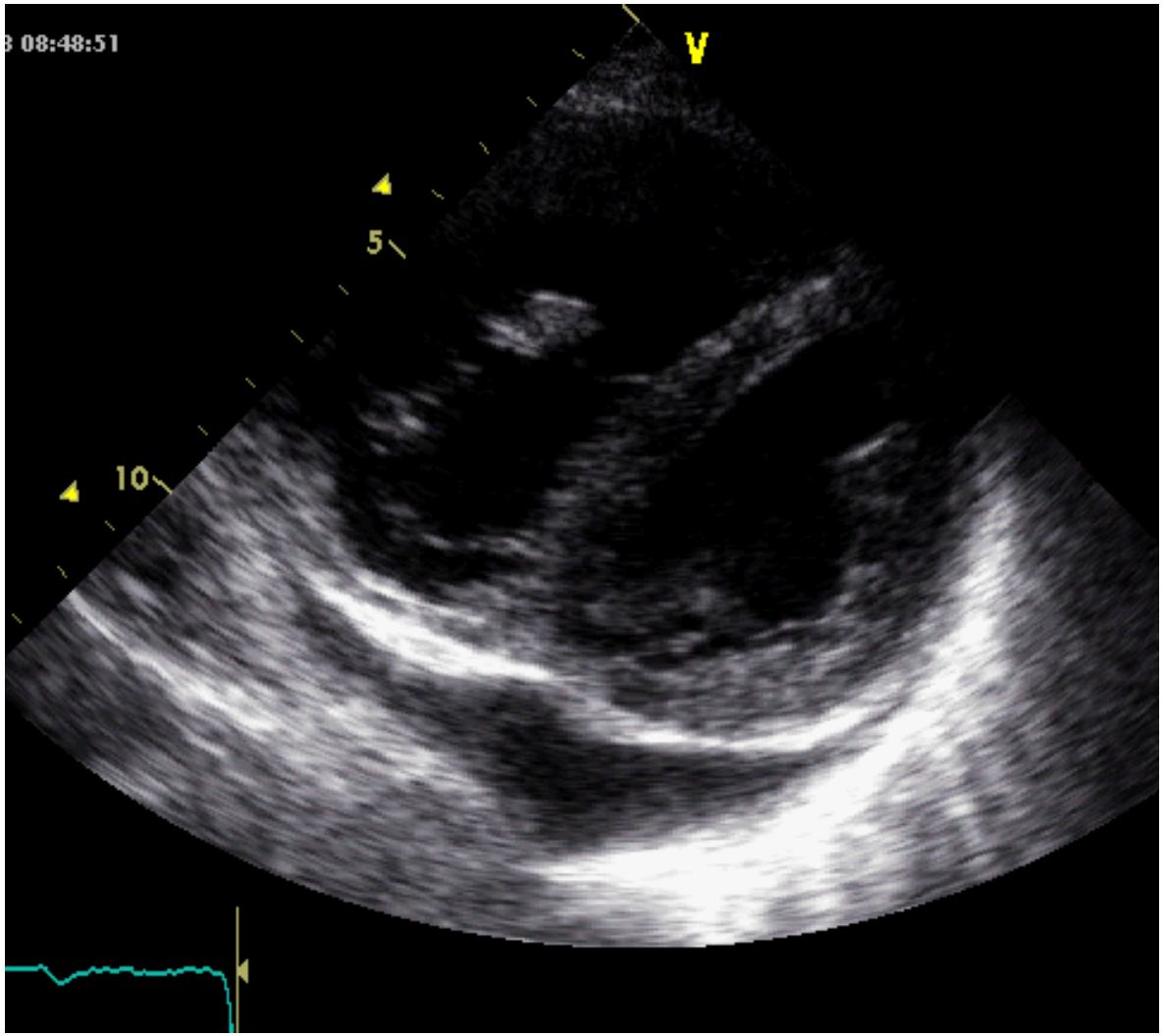
Stress echocardiography to identify subjects benefiting from PBMV

- In asymptomatic severe MS (PGmean >10 mmHg and MVA<1.0 cm^2) or symptomatic moderate MS (PGmean 5–10 mmHg and MVA 1.0–1.5 cm^2)
- Treadmill or supine paddle Ex or dobutamine
- Transmitral gradient
  - >15 mm Hg during Ex,
  - >18 mmHg during dobutamine
- Pulmonary artery systolic pressure - PASP >60 mmHg
- ACC/AHA class I, level of evidence C

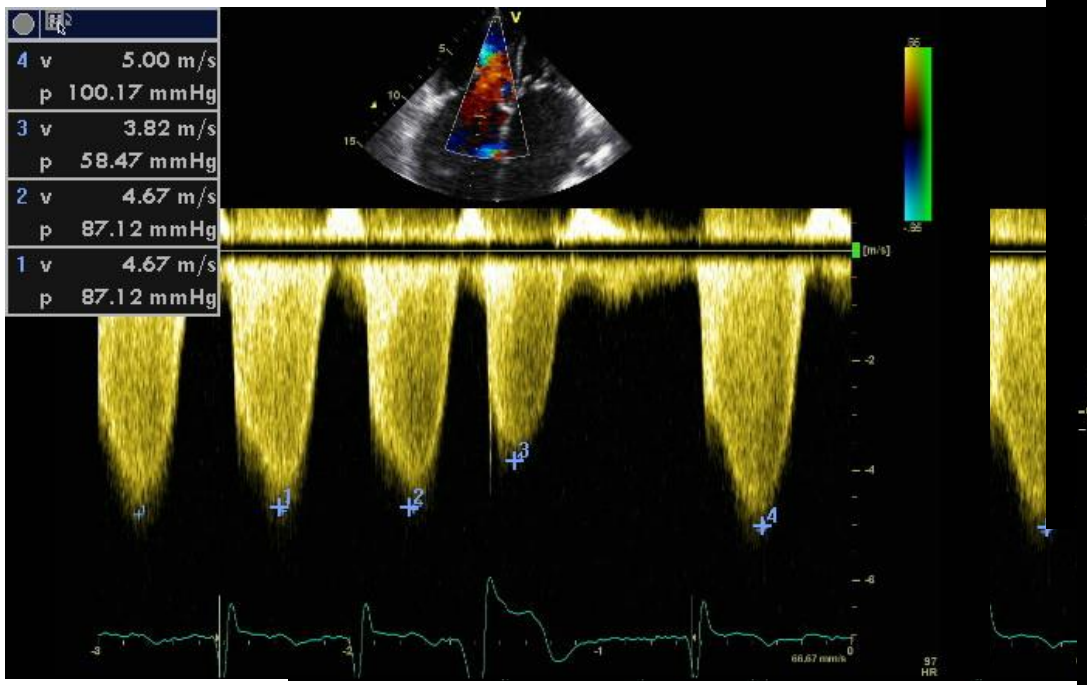
Yavagal et al. Indian Heart J. 2014 Jan-Feb; 66(1): 131–138.

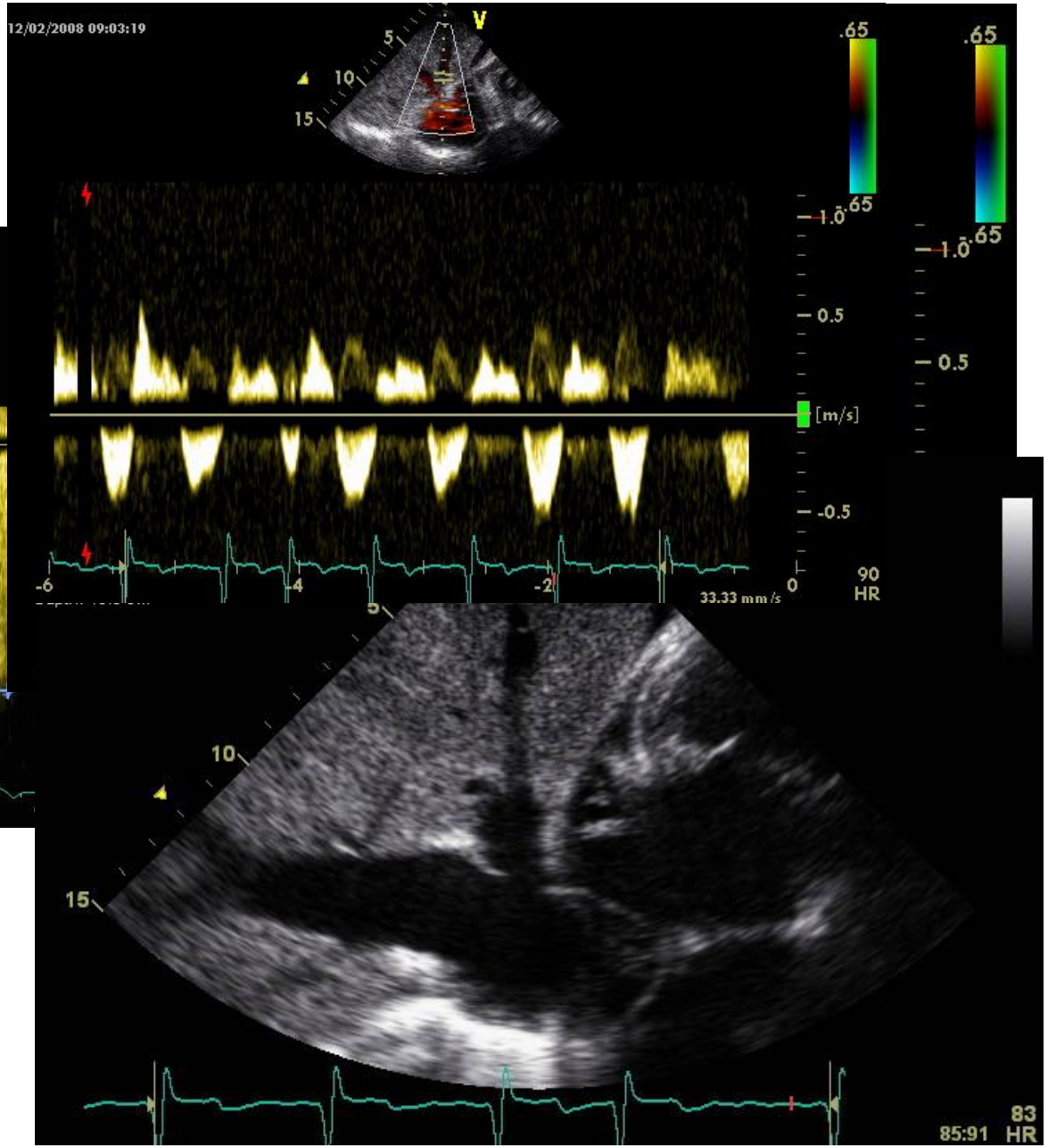
Right ventricular overload and failure





Cases and imaging: General University Hospital, Prague

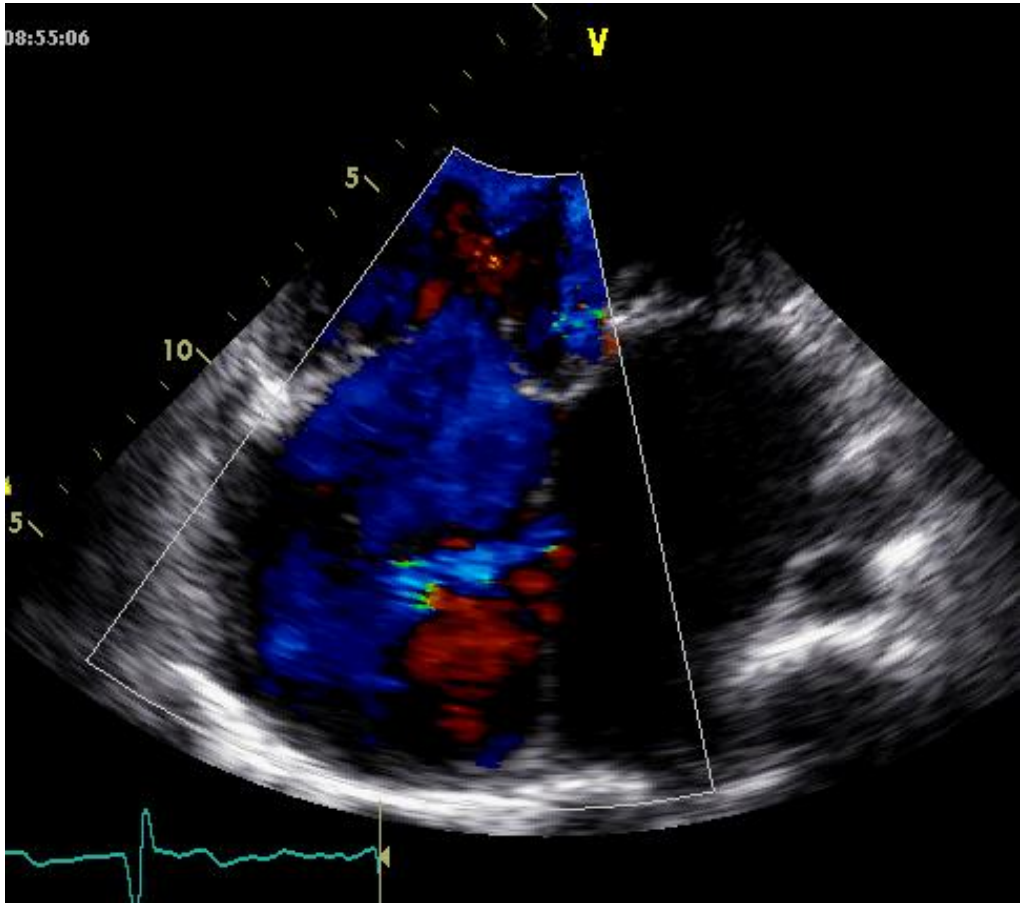


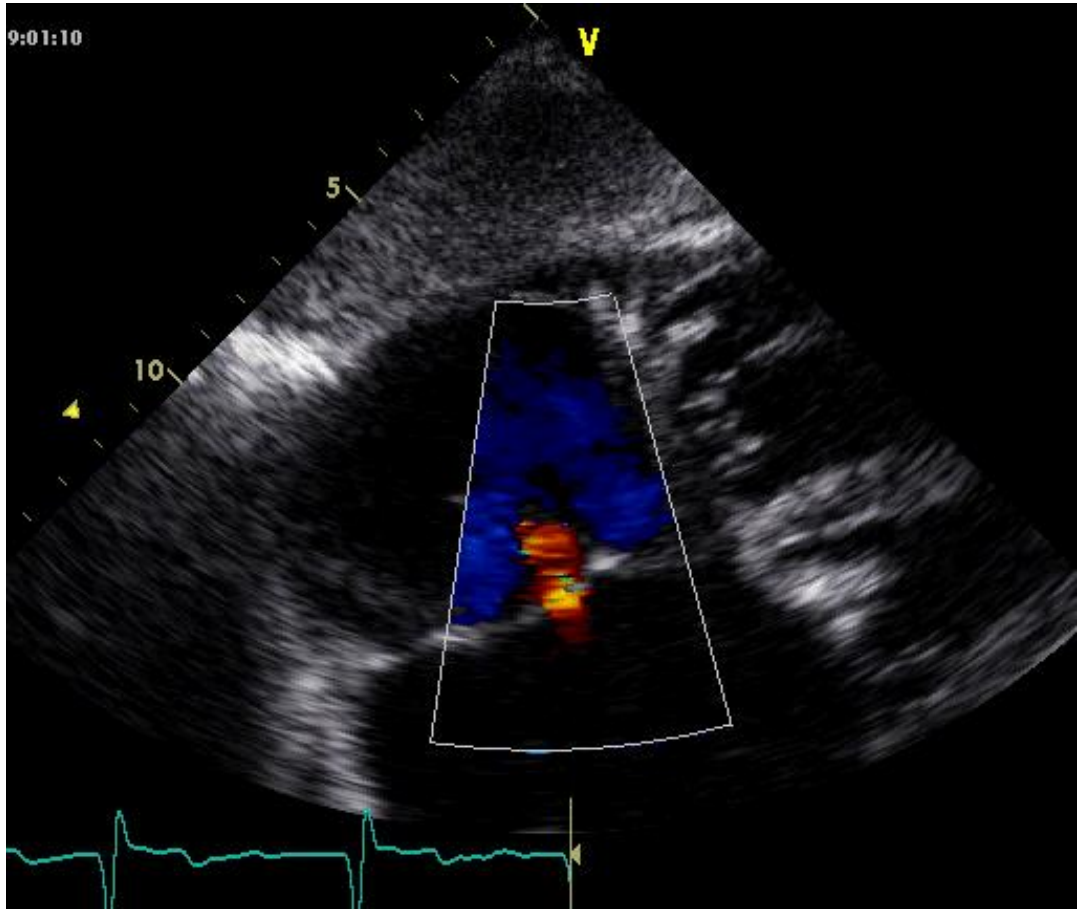


Cases and imaging:
General University Hospital Prague

KOMPLEXNÍ KARDIO VASKULÁRNÍ CENTRUM VFN Praha

Worsening of atrial septal defect
Lutembacher syndrome

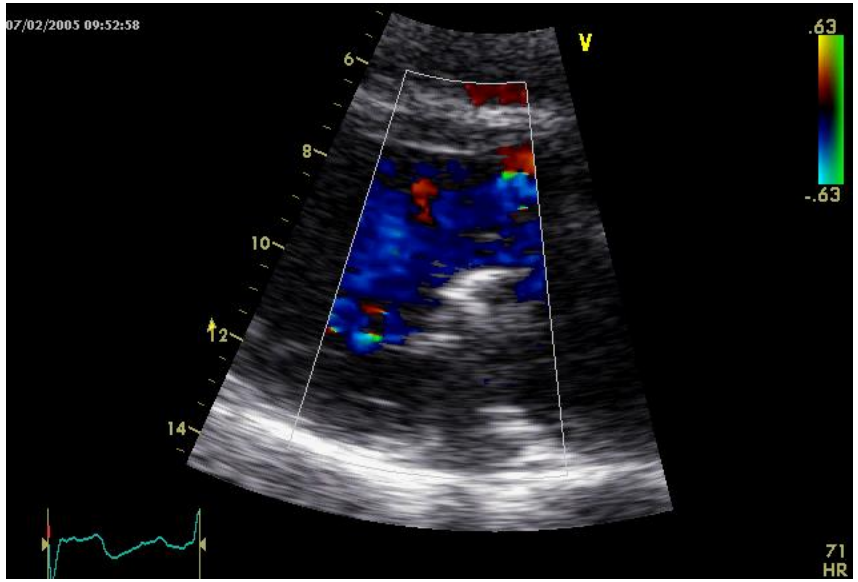


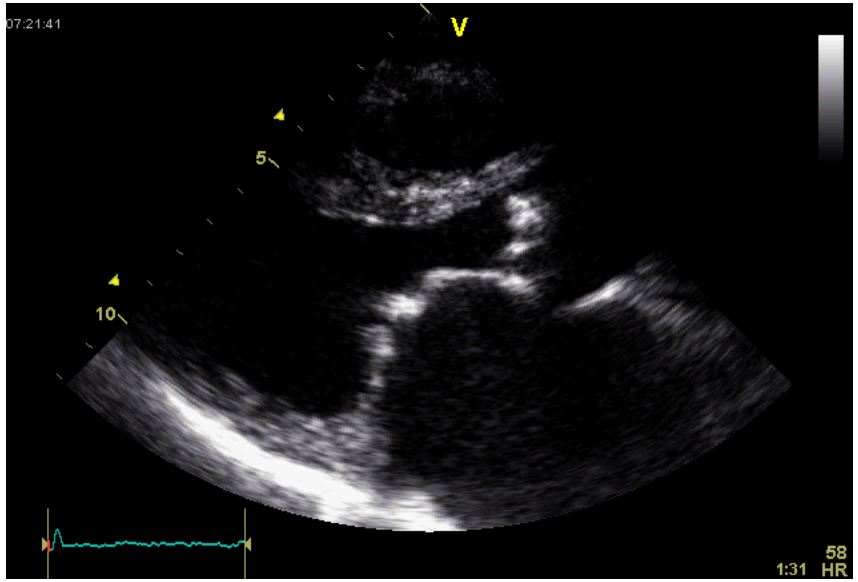


R. Lutembacher. De la sténose mitrale avec communication interauriculaire. Archives des maladies du coeur et des vaisseaux, Paris, 1916, 9: 237-260.

Associated pathological changes

- **Mitral regurgitation**
- **Rheumatic aortic valve disease (stenosis/regurgitation)**
- **Lutembacher**
- **Tricuspid rheumatic valve disease**





Cases and imaging: General University Hospital, Prague

THERAPY

10 years survival

- Asymptomatic 84 %,
- Mildly symptomatic 45 %,
- Limiting symptoms 0-15%.
- Significant pulmonary hypertension < 3 years
- Worse survival in atrial fibrillation

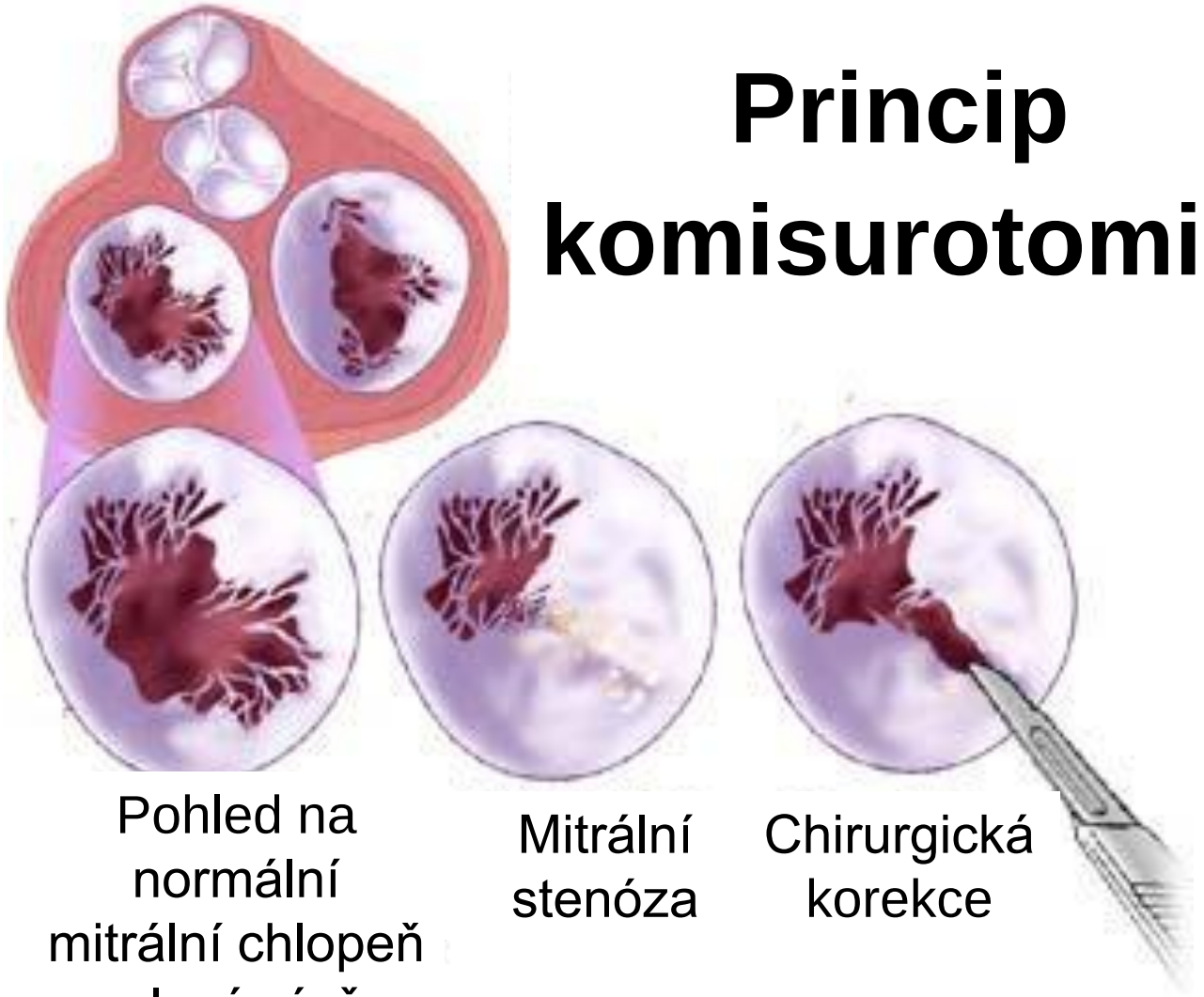
Horenstein et al. http://emedicine.medscape.com/ 2014

Anticoagulation

- **Vitamin K antagonist** (VKA) – INR 2 - 3 in patients with AF.
- Patients with moderate-to-severe mitral stenosis and AF should be kept on VKA and **not receive NOACs**.
- **OAC is recommended**
  - history of systemic embolism
  - thrombus is present in the LA
- **OAC should be considered**
  - dense spontaneous echocardiographic contrast
  - enlarged LA (M-mode >50 mm or LAVi >60 mL/m^2).

Vahanian et al. Eur Heart J. 2021 Aug 28:ehab395. doi: 10.1093/eurheartj/ehab395.

Princip komisurotomie



Pohled na normální mitrální chlopeň z levé síně

Mitrální stenóza

Chirurgická korekce

Close chest valvulotomy

Baker C, Brock RC, Campbell M, Wood P (1952). Valvulotomy for mitral stenosis; a further report on 100 cases. BMJ 1:1043–1055.

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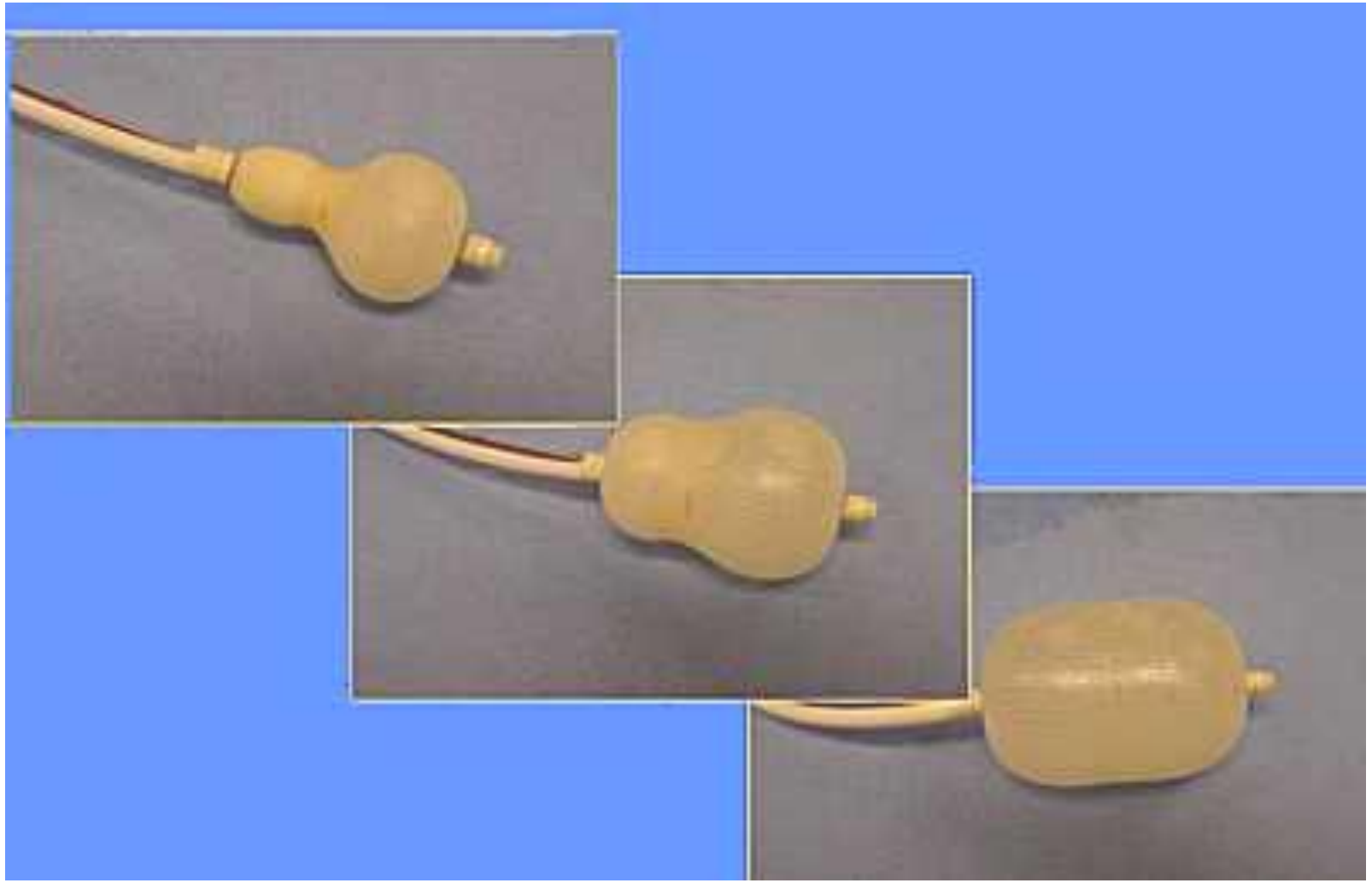
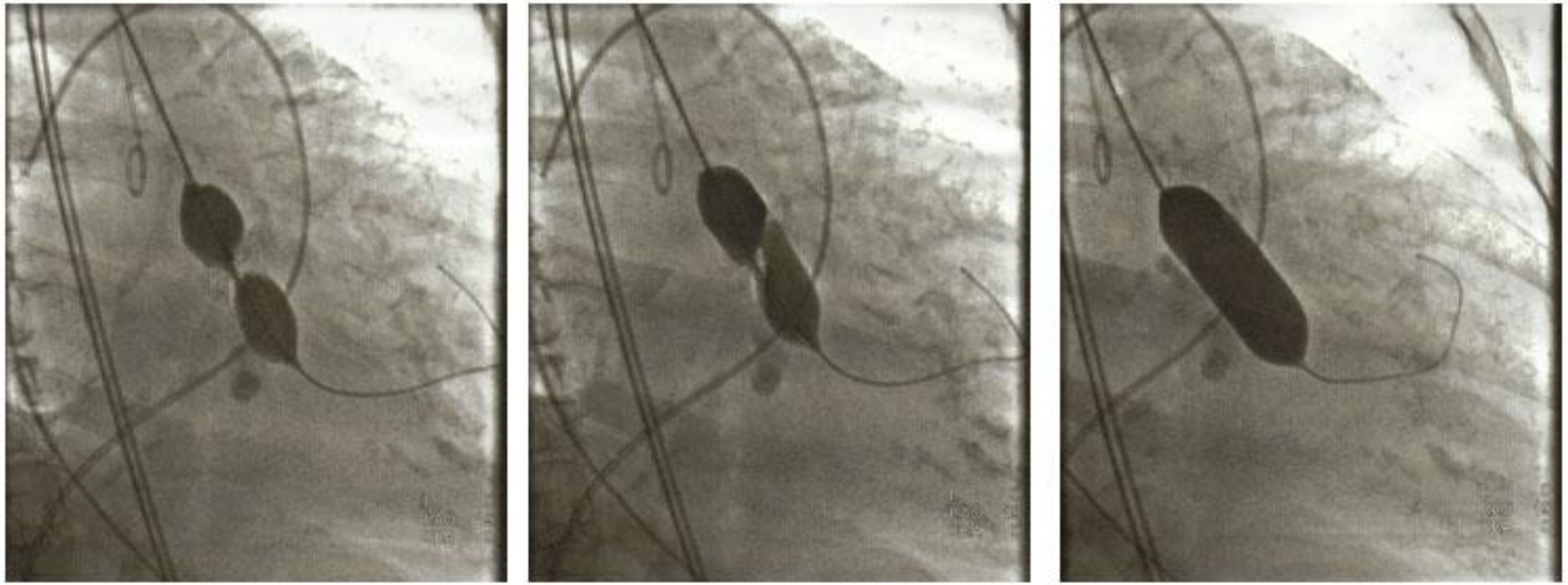
Balónková valvuloplastika

- Balónkový katétr /Inoueho balón/
- Zavedení transseptálním přístupem
- Dilatace na úrovni mitrální chlopně
- Roztržení srostlých komisur

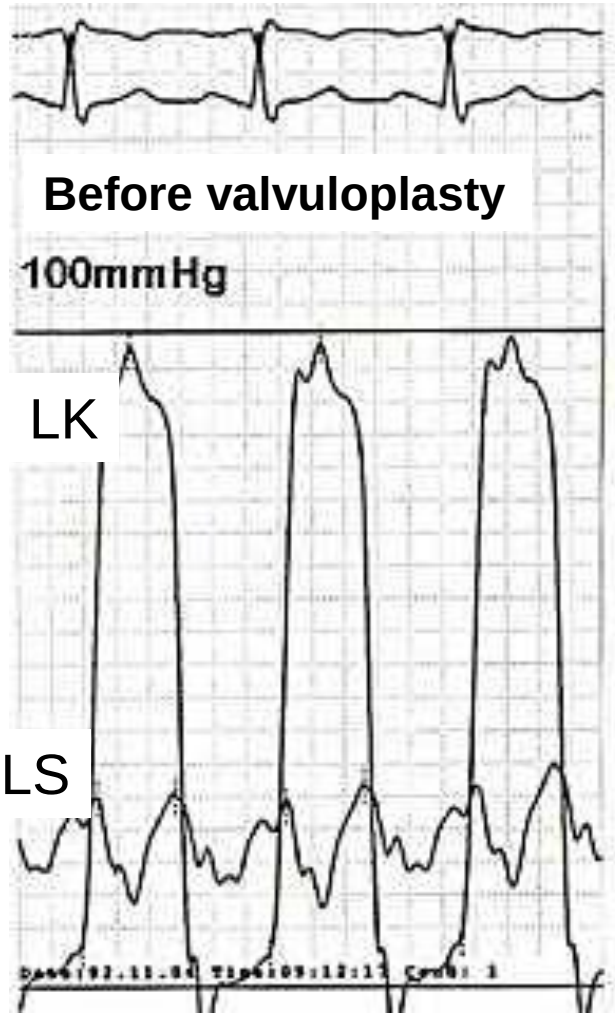
Mitral balloon valvuloplasty

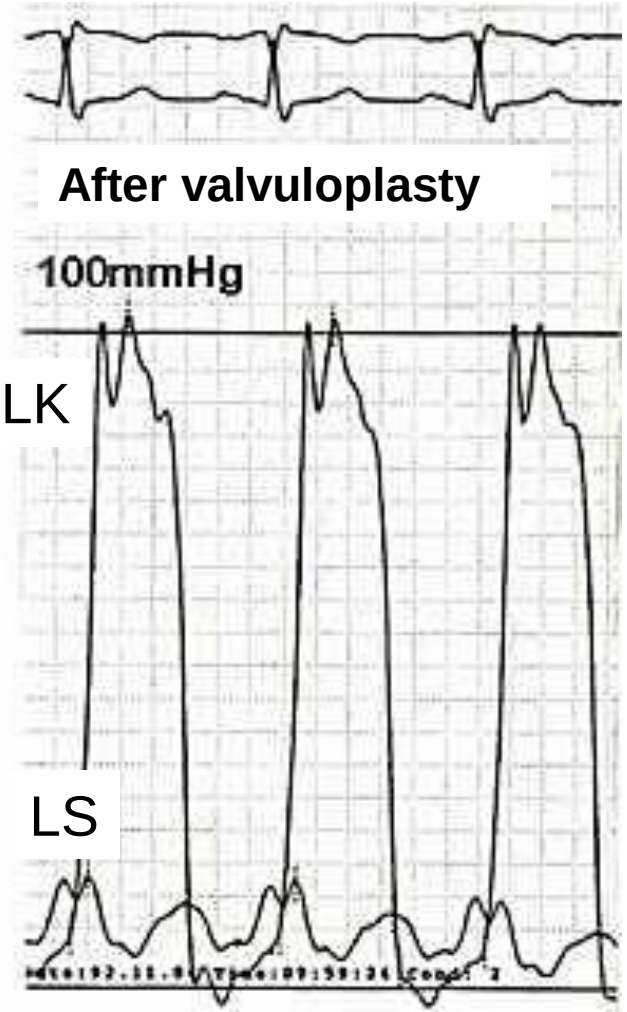


Mitral balloon valvuloplasty (PBMV)



Hemodynamic effects of valvuloplasty





Assessment of mitral valve anatomy according to the Wilkins score.

Assessment of mitral valve anatomy according to the Wilkins score[18]				
Grade	**Mobility**	**Thickening**	**Calcification**	**Subvalvular thickening**
1	Highly mobile valve with only leaflet tips restricted	Leaflets near normal in thickness (4–5 mm)	A single area of increased echo brightness	Minimal thickening just below the mitral leaflets
2	Leaflet mid and base portions have normal mobility	Mid leaflets normal, considerable thickening of margins (5–8 mm)	Scattered areas of brightness confined to leaflet margins	Thickening of chordal structures extending to one third of the chordal length
3	Valve continues to move forward in diastole, mainly from the base	Thickening extending through the entire leaflet (5–8 mm)	Brightness extending into the mid portions of the leaflets	Thickening extended to distal third of the chords
4	No or minimal forward movement of the leaflets in diastole	Considerable thickening of all leaflet tissue (>8–10 mm)	Extensive brightness throughout much of the leaflet tissue	Extensive thickening and shortening of all chordal structures extending down to the papillary muscles
The total score is the sum of the four items and ranges between 4 and 16.				

European Journal of Echocardiography 2009;10:1-25
Eur Heart J 2021, Supplementary file

KOMPLEXNÍ KARDIO VASKULÁRNÍ CENTRUM VFN Praha

Assessment of mitral valve anatomy according to the Wilkins score.

- Grades 1-4 (1= best, 4=worst)

- Mobility (mobile….rigid)
- Subvalvular thickening (minimal….extensive)
- Leaflets thickening (<5 mm …>8-10 mm)
- Calcifications (single area… extensive)

European Journal of Echocardiography 2009;10:1-25

Cormier and Echo score revisited

Assessment of mitral valve anatomy according to the Cormier score[19]	
Echocardiographic group	Mitral valve anatomy
Group 1	Pliable non-calcified anterior mitral leaflet and mild subvalvular disease (i.e. thin chordae ≥10 mm long)
Group 2	Pliable non-calcified anterior mitral leaflet and severe subvalvular disease (i.e. thickened chordae <10 mm long)
Group 3	Calcification of mitral valve of any extent, as assessed by fluoroscopy, whatever the state of subvalvular apparatus

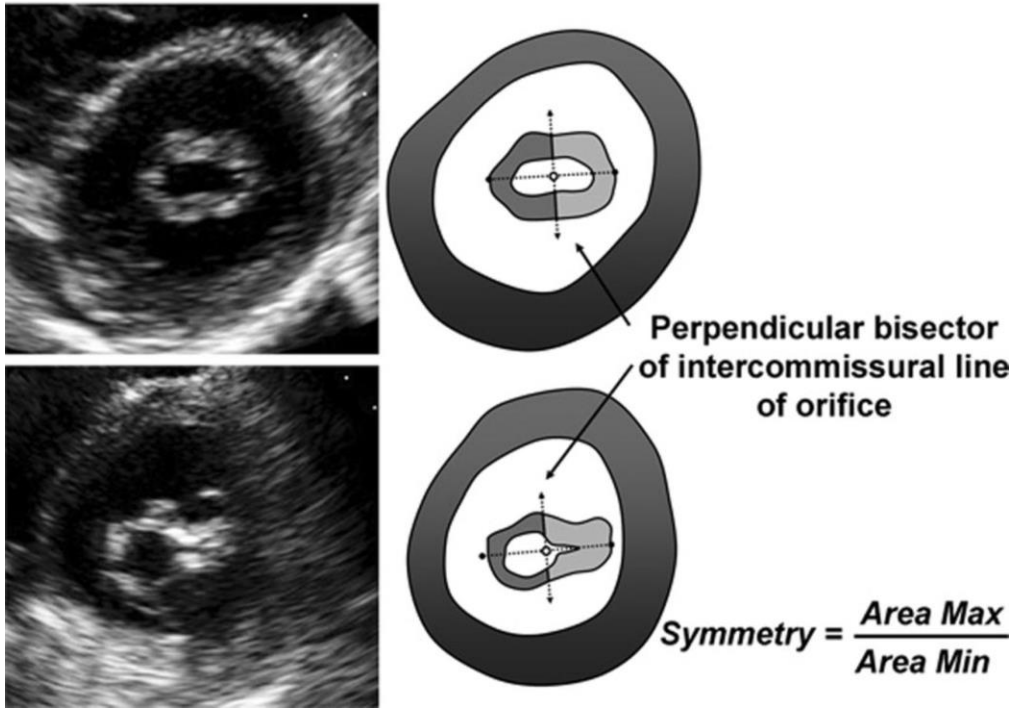
Echo score 'Revisited' for immediate outcome prediction[20]	
Echocardiographic variables	**Points for score (0 to 11)**
Mitral valve area ≤1 cm^2	2
Maximum leaflet displacement ≤12 mm	3
Commissural area ratio ≥1.25	3
Subvalvular involvement	3

Risk groups for Echo score 'Revisited': low (score 0-3); intermediate (score 4-5); high (score 6-11)

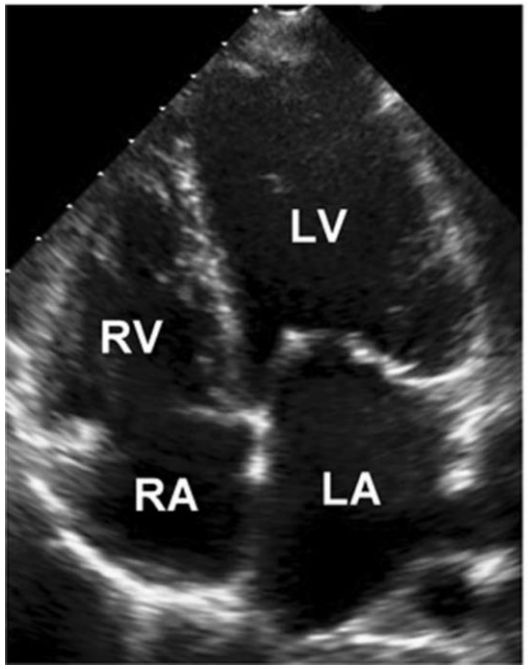
Baumgartner H et al. 2017 ESC/EACTS Guidelines for the management of valvular heart disease. Eur Heart J 2017;38:2739-2791,

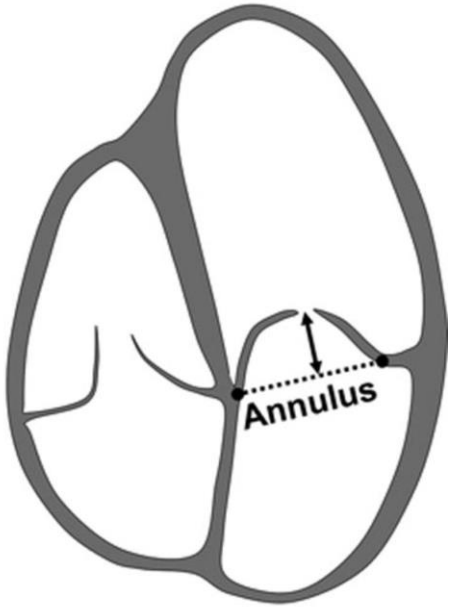
Echo score 'Revisited' for immediate outcome prediction[20]	
Echocardiographic variables	**Points for score (0 to 11)**
Mitral valve area ≤1 cm^2	2
Maximum leaflet displacement ≤12 mm	3
Commissural area ratio ≥1.25	3
Subvalvular involvement	3

Commissural Area Ratio



Leaflet Displacement





The symmetry of commissural thickening - the ratio between the leaflet areas on either side of the minor dimension.

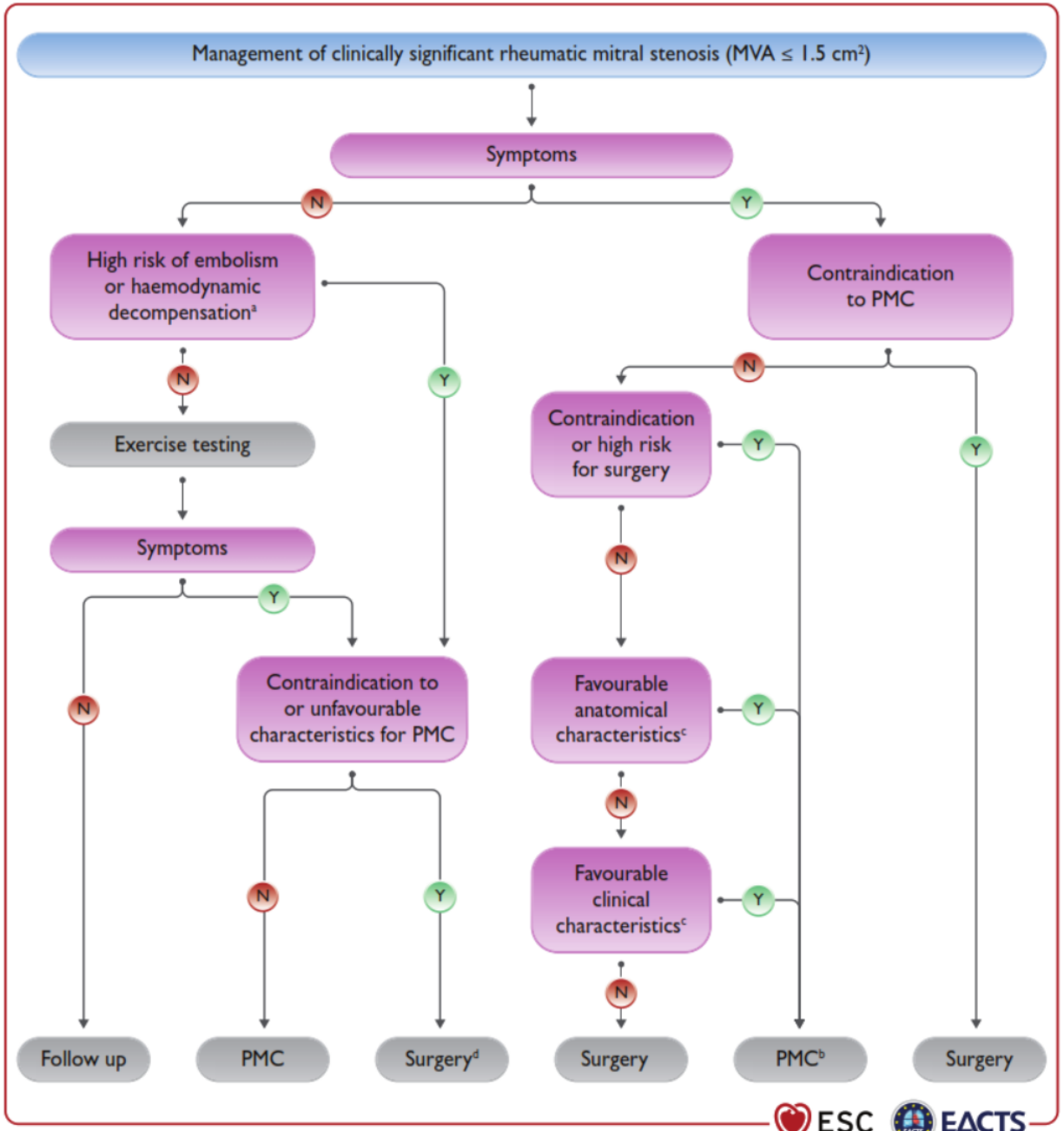
The Echo score revisited: impact of incorporating commissural morphology and leaflet displacement to the prediction of outcome for patients undergoing percutaneous mitral valvuloplasty. Circulation 2014;129:886-895.
Baumgartner H et al. 2017 ESC/EACTS Guidelines for the management of valvular heart disease. Eur Heart J 2017;38:2739-2791,

Contraindications for PMC

Contraindications
MVA >1.5 cm^{2a}
LA thrombus
More than mild mitral regurgitation
Severe or bi-commissural calcification
Absence of commissural fusion
Severe concomitant aortic valve disease, or severe combined tricuspid stenosis and regurgitation requiring surgery
Concomitant CAD requiring bypass surgery

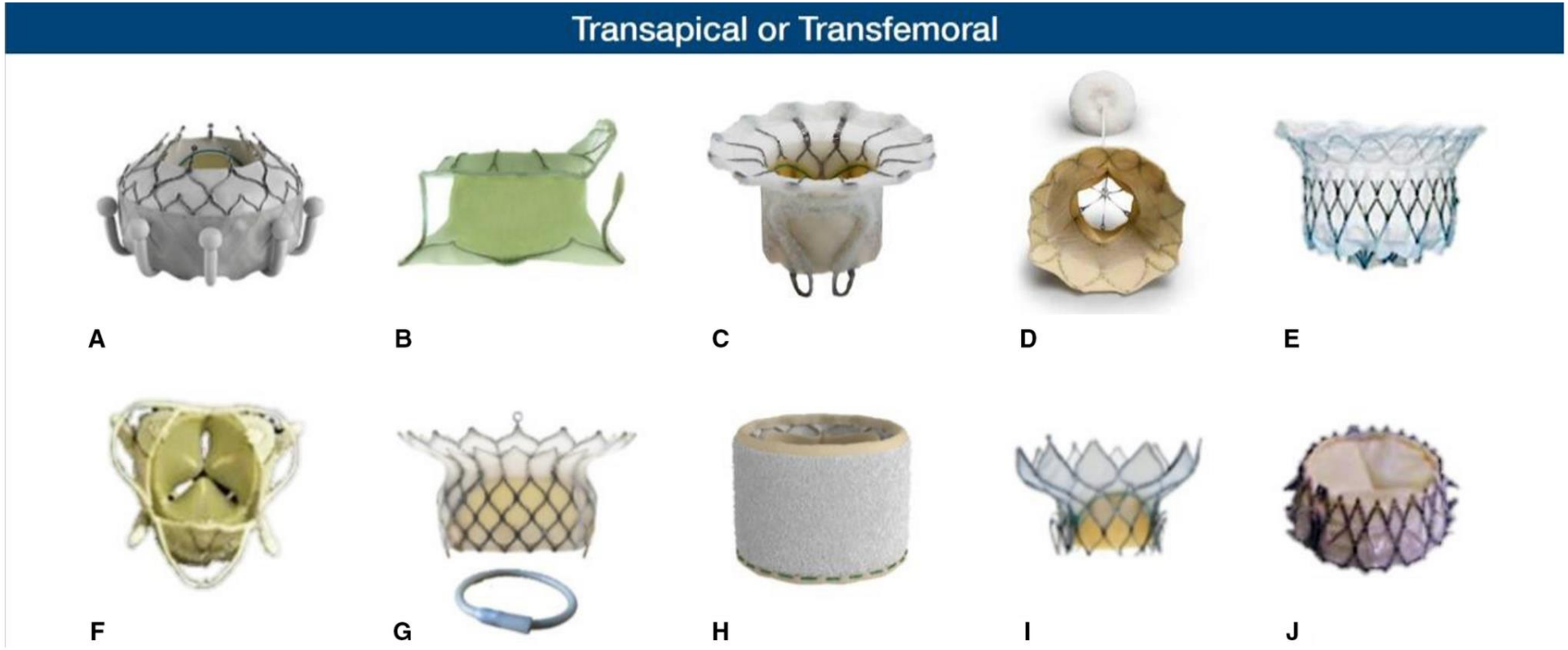
CAD = coronary artery disease; LA = left atrium/left atrial; MVA = mitral valve area; PMC = percutaneous mitral commissurotomy.

Vahanian et al. Eur Heart J 2021



Vahanian et al. Eur Heart J. 2021 Aug 28:ehab395. doi: 10.1093/eurheartj/ehab395.

Trascatherer mitral valve replacement
- not tested in stenotic valves – used off-label



Current transcatheter mitral valve replacement devices. **A**, CardiAQ/EVOQUE (Edwards Lifesciences Inc). **B**, Tiara (Neovasc Inc, Canada). **C**, FORTIS (Edwards Lifesciences Inc). **D**, Tendyne (Abbott Inc). **E**, Intrepid (Medtronic Inc). **F**, Caisson (LivaNova, UK). **G**, HighLife Bioprosthesis and Subannular Implant (HighLife SAS, France). **H**, SAPIEN M3 (Edwards Lifesciences Inc). **I**, Cardiovalve (Cardiovalve, Israel). **J**, NaviGate (NaviGate Cardiac Structures, Inc, CA).

Luca Testa. Journal of the American Heart Association. Transcatheter Mitral Valve Replacement in the Transcatheter Aortic Valve Replacement Era, Volume: 8, Issue: 22, DOI: (10.1161/JAHA.119.013352)

Conclusions

- MVA 1.5 cm^2 is the decisive limit for MS treatment
- Multiplicate echo methods, TOE mandatory before intervention
- 3D
- Stress testing (asymptomatic, moderate)
- PMC still a valid option
- Anticoagulate