

MRI

multimodalitní zobrazování u plicní hypertenze

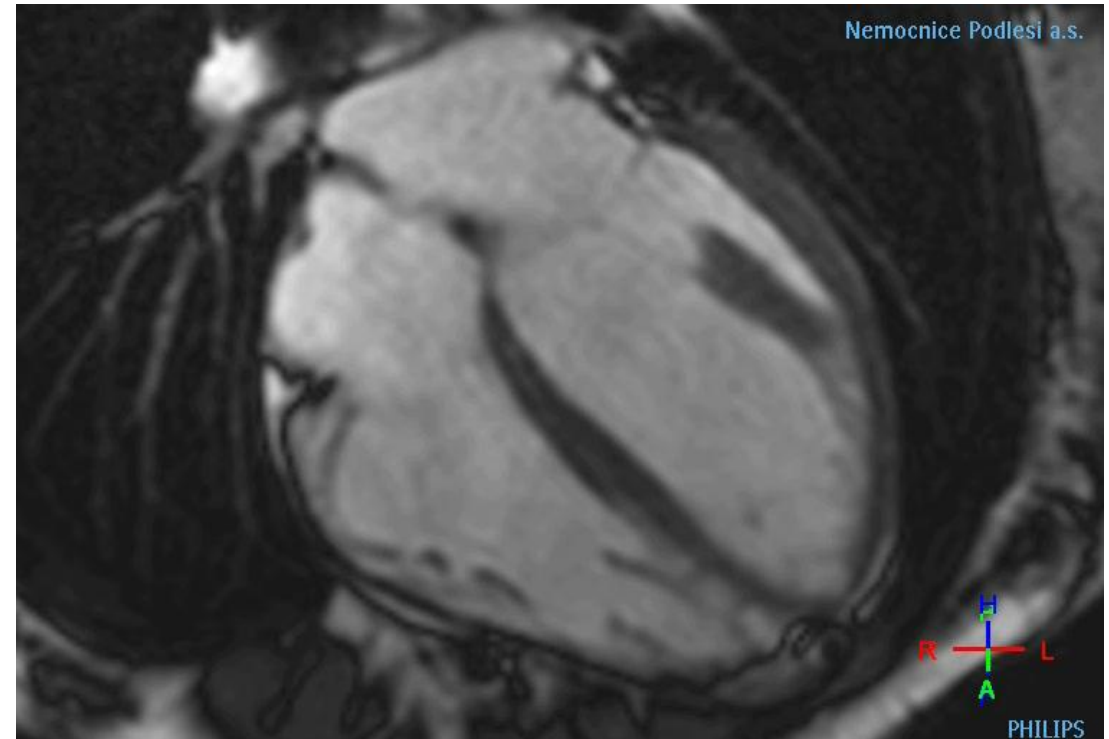
Pleva Martin

Nemocnice Podlesí, a.s., Třinec

Vítkovická nemocnice, a.s., Ostrava

MRI – přednosti

- nejlepší kombinace časově-prostorového rozlišení
- nejlepší tkáňové rozlišení
- zdraví neškodné vyšetření
- možnost volit libovolnou rovinu vyšetření
- výborně tolerovaná kontrastní látka



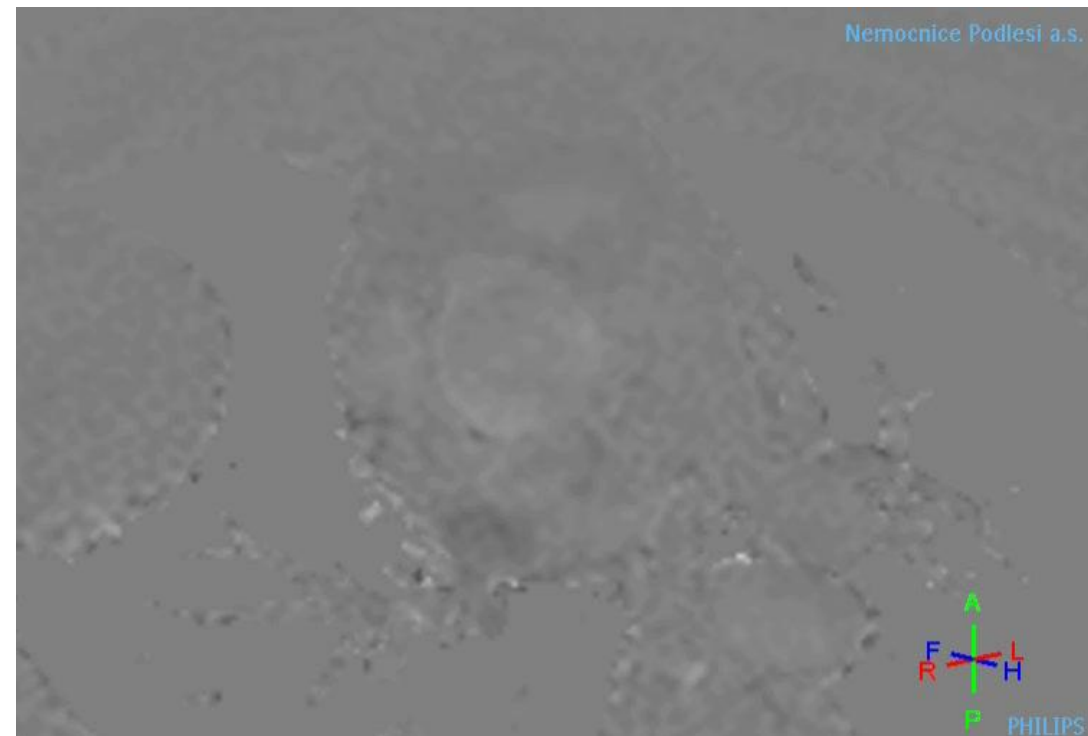
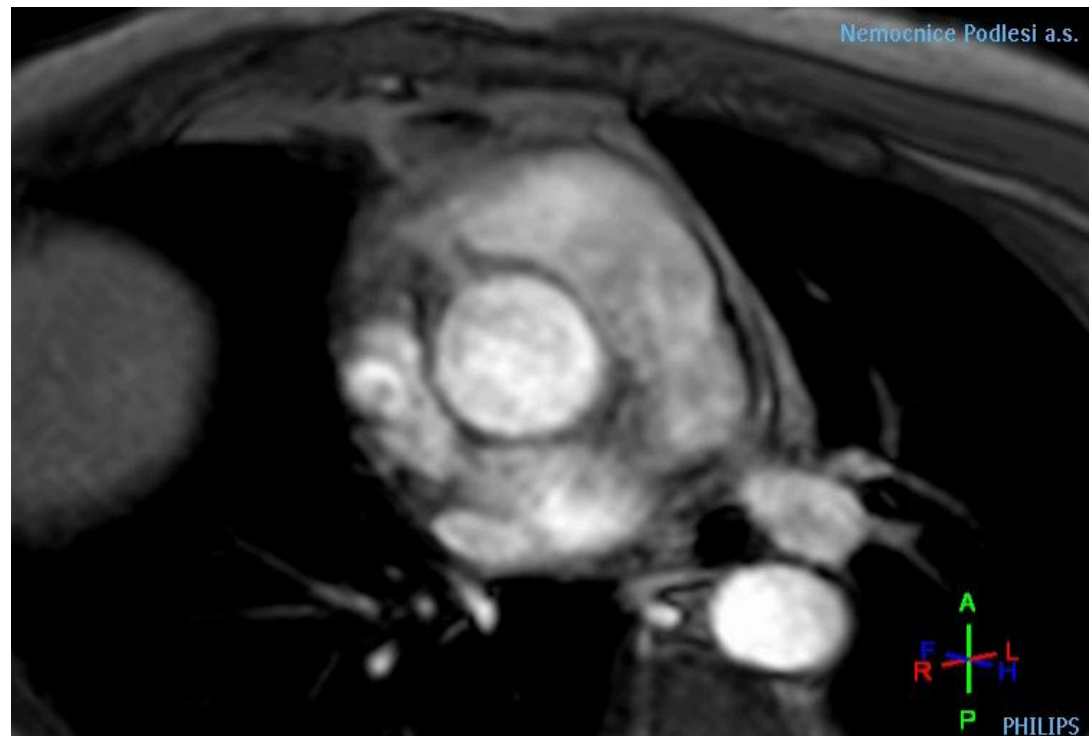
MRI – nevhodné indikace

- detekce a kvantifikace regurgitačních vad na A-V chlopních
- detekce PFO či drobných DSS
- detekce trombu v oušku LS
- schopnost vyloučit IE
- detekce kalcifikací
- **detekce a kvantifikace plicní hypertenze**

MRI a PHT – možnosti

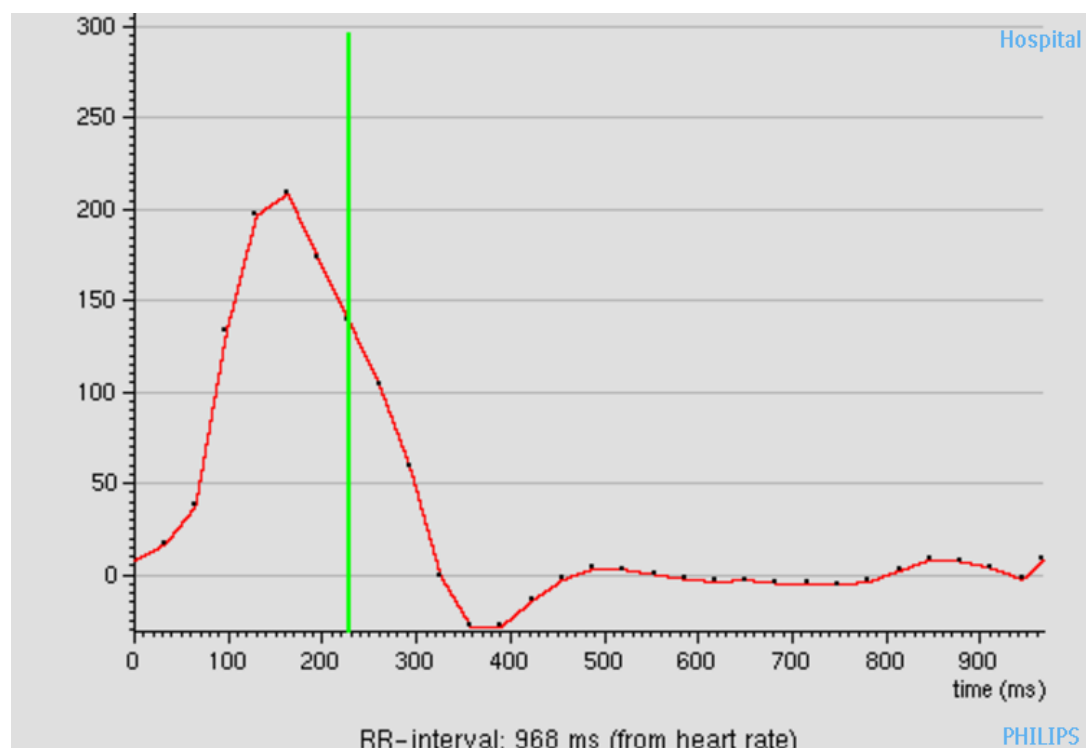
- kvantifikace plicní hypertenze – **NE** (katetrizace)
- odhad její závažnosti (semikvantifikace) – **NE** (ECHO)
- detekce nepřímých známek PHT – **ANO**
(hypertrofie PK a její systolická funkce – „zlatý standard“)

Směr a kvantifikace toku



Metoda fázového kontrastu

Směr a kvantifikace toku



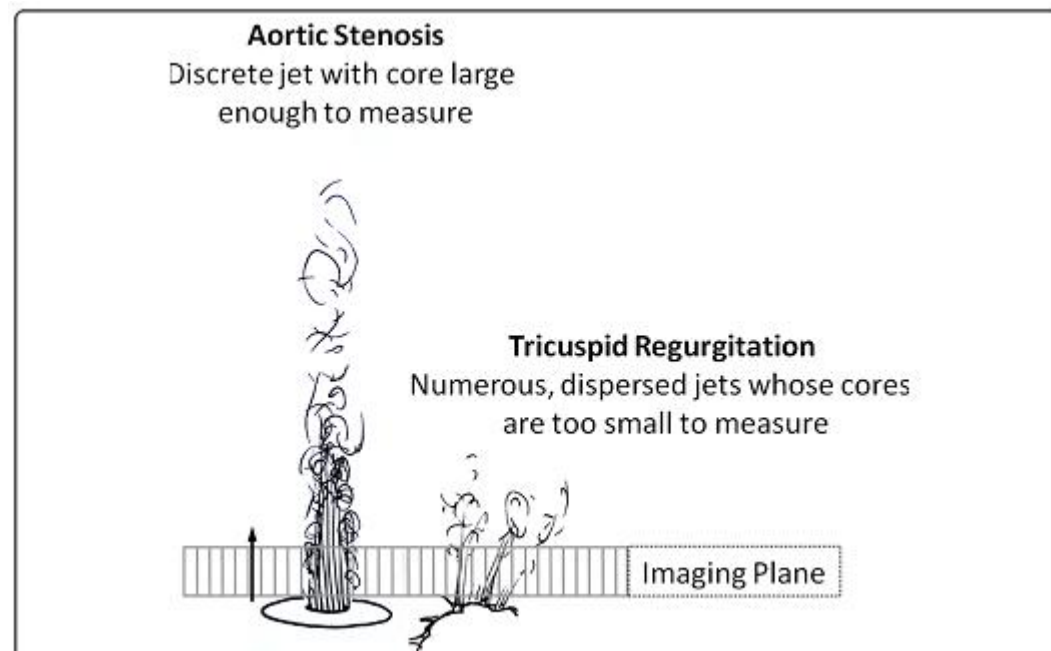
Stroke volume (ml) | 32.4
 Forward flow vol. (ml) | 35.7
 Backward flow vol. (ml) | 3.4
 Regurgitant fract. (%) | 9.4
 Abs. stroke volume (ml) | 39.1
 Mean flux (ml/s) | 33.4
 Stroke distance (cm) | 4.3
 Mean velocity (cm/s) | 4.5

Vessel 1, slice 1

Nr	Td ms	Flux ml/s	Area cm ²	Area pixels	Mean vel. cm/s	Max. vel. cm/s	Min. vel. cm/s	Peak vel. cm/s	Vel stddev cm/s
1	0	7.8	7.3	475	1.1	10.7	-9.8	10.7	4.9
2	33	16.5	7.2	470	2.3	13.5	-12.1	13.5	5.5
3	65	37.3	7.4	483	5.0	15.2	-12.0	15.2	6.3
4	98	132.8	7.7	498	17.3	34.7	-3.5	34.7	8.3
5	130	196.5	7.6	494	25.8	84.1	-23.3	84.1	24.5
6	163	208.5	7.3	475	28.5	113.1	-38.5	113.1	43.4
7	196	172.8	7.3	472	23.8	119.2	-59.5	119.2	50.0
8	228	139.1	7.6	495	18.2	100.5	-57.8	100.5	45.4
9	261	103.5	7.6	495	13.6	83.0	-57.5	83.0	39.2
10	293	59.1	7.5	489	7.8	69.8	-48.1	69.8	33.5
11	326	-0.8	7.8	506	-0.1	49.1	-47.7	49.1	26.0
12	358	-28.3	7.9	514	-3.6	31.8	-40.5	-40.5	19.2
13	391	-28.4	8.2	530	-3.5	23.0	-29.0	-29.0	13.2
14	424	-14.1	8.3	538	-1.7	20.7	-19.5	20.7	9.6
15	456	-2.8	8.3	538	-0.3	16.5	-17.5	-17.5	7.3
16	489	3.0	8.2	531	0.4	12.3	-12.6	-12.6	4.9
17	521	2.5	8.2	532	0.3	10.8	-10.3	10.8	4.0
18	554	0.0	8.1	524	0.0	12.2	-8.8	12.2	4.3
19	587	-2.7	8.0	521	-0.3	11.8	-11.1	11.8	4.2
20	619	-4.0	8.0	520	-0.5	10.7	-12.0	-12.0	4.3
21	652	-3.1	8.0	517	-0.4	10.1	-13.0	-13.0	4.9

Metoda fázového kontrastu

Odhad závažnosti plicní hypertenze



Detekce nepřímých známek PHT

Morfologické změny PK:

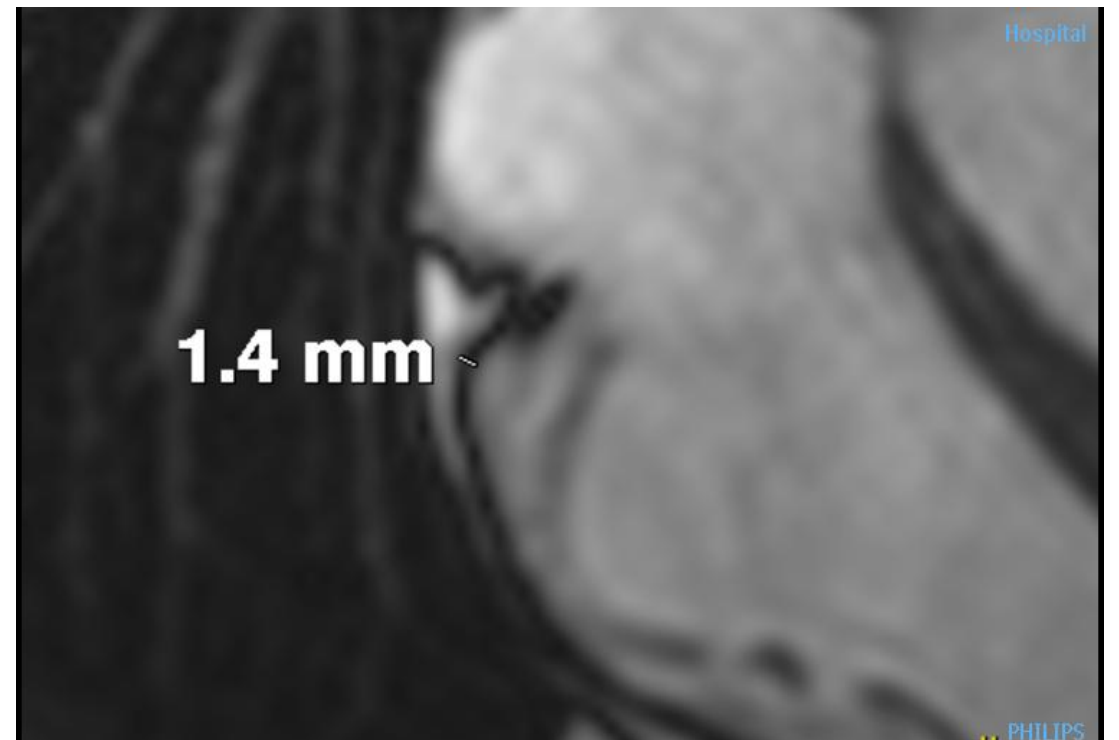
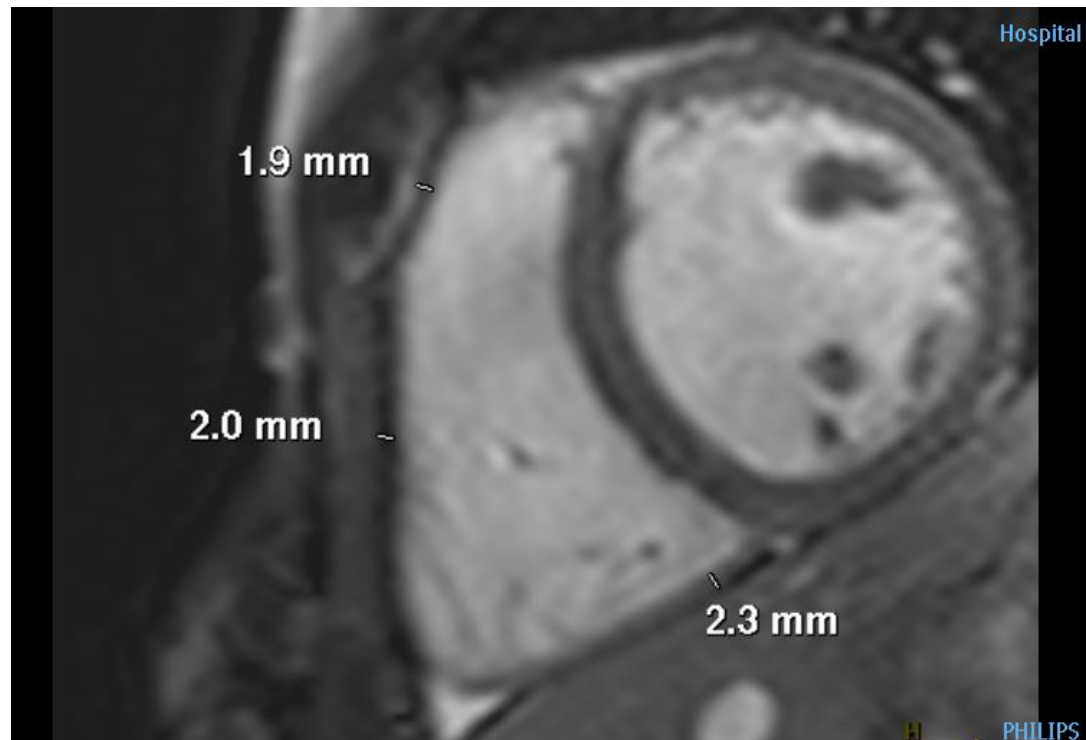
- hypertrofie/hmotnost myokardu PK
- velikost a systolická funkce PK
- tvar a pohyb mezikomorového septa

Morfologické a funkční změny plicnice:

- dilatace
- snížená pulsilita
- zpomalený průtok

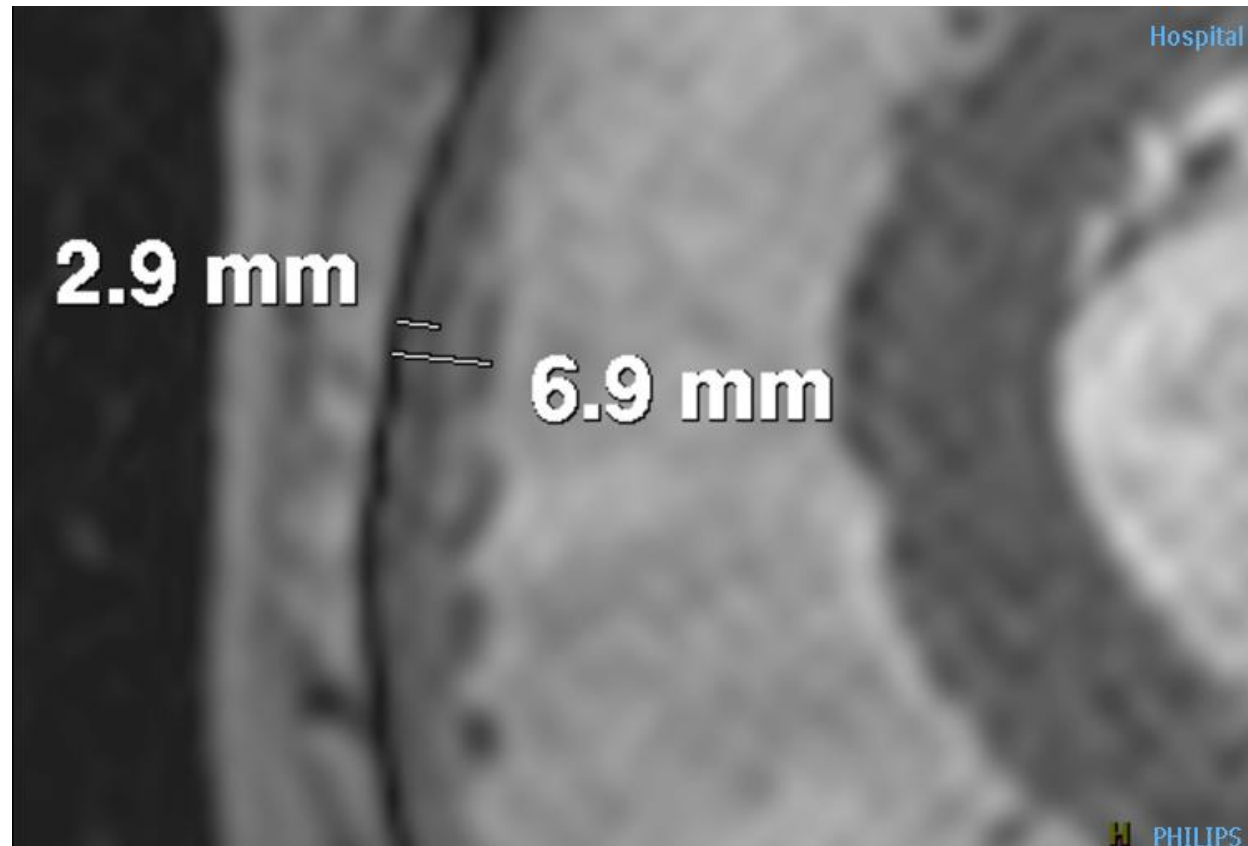
Hypertrofie PK

- MRI norma: 2-4 mm!!

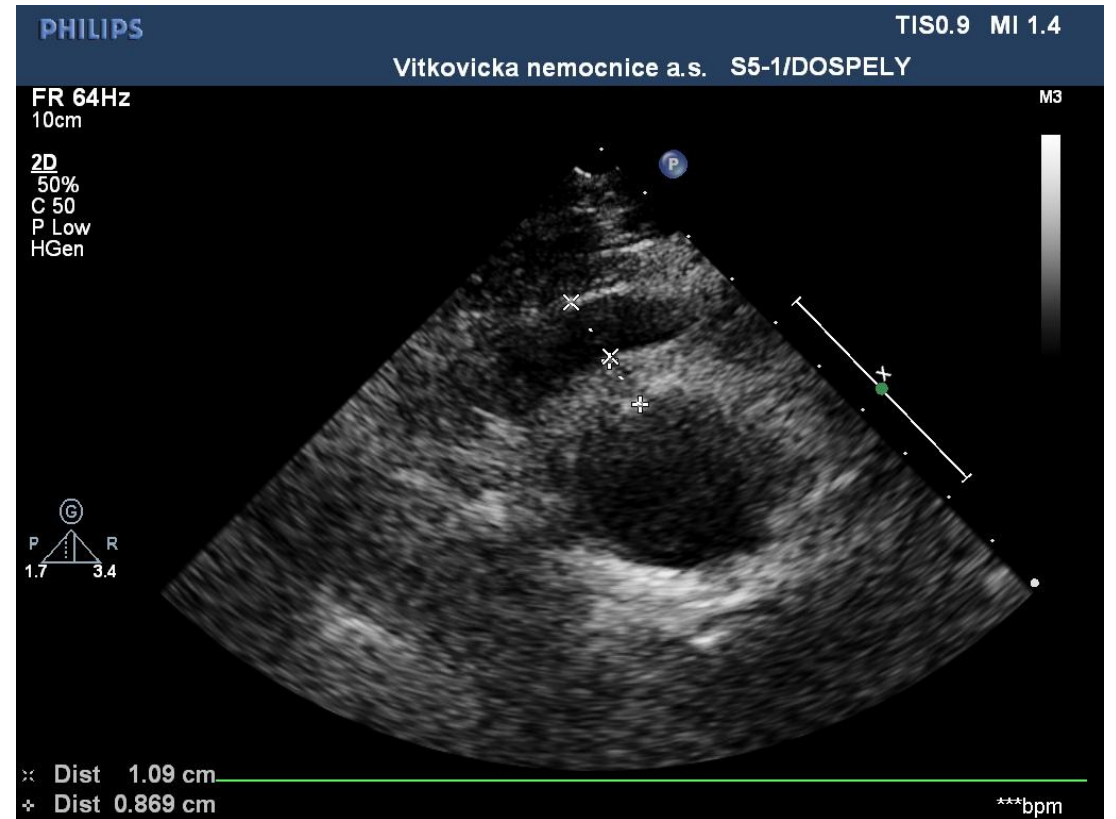
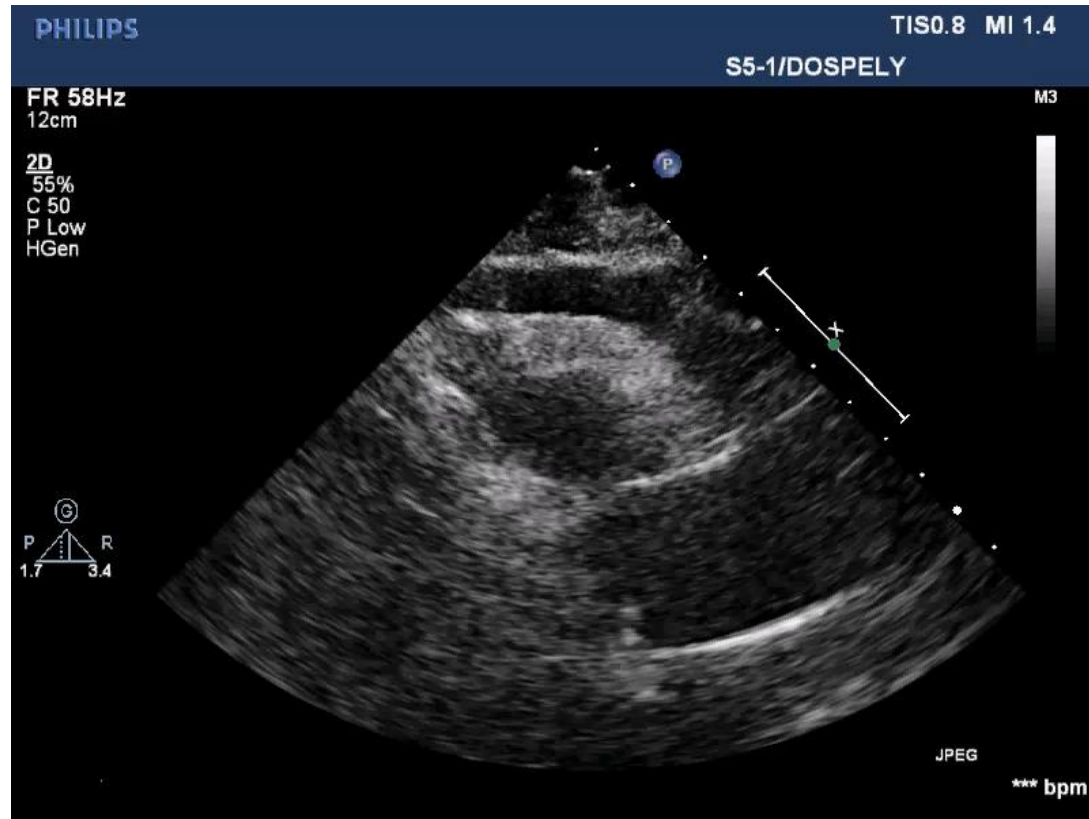


Hypertrofie PK

- výrazná diskrepance mezi ECHO a MRI

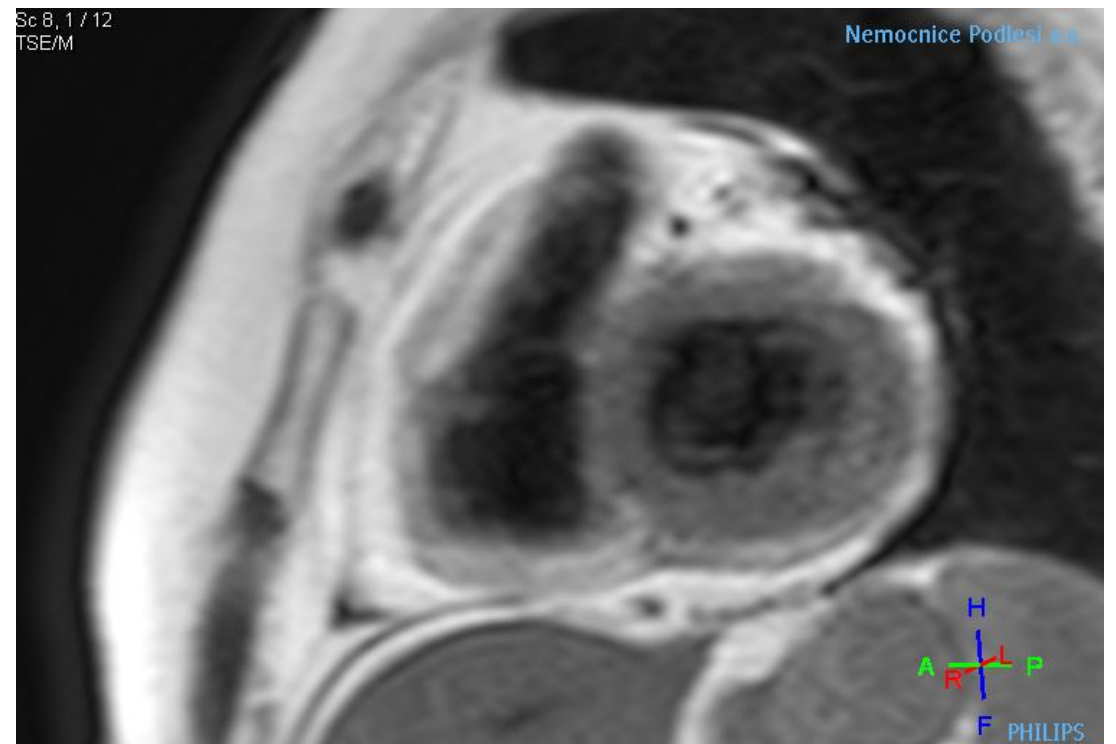
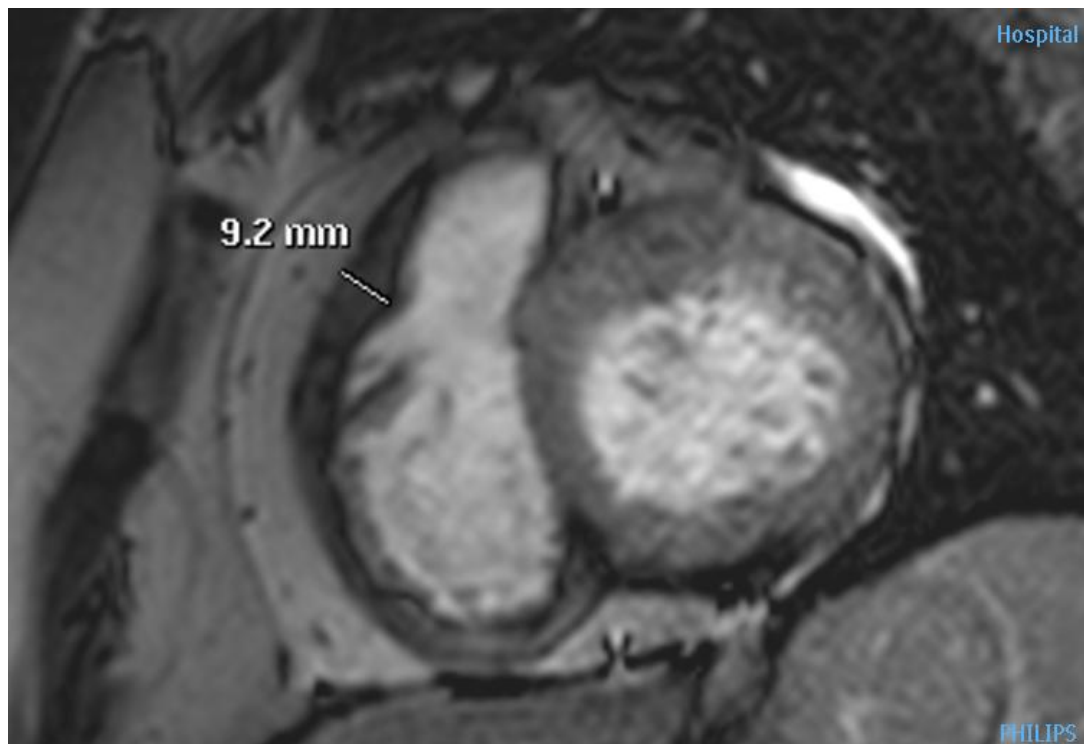


Hypertrofie PK

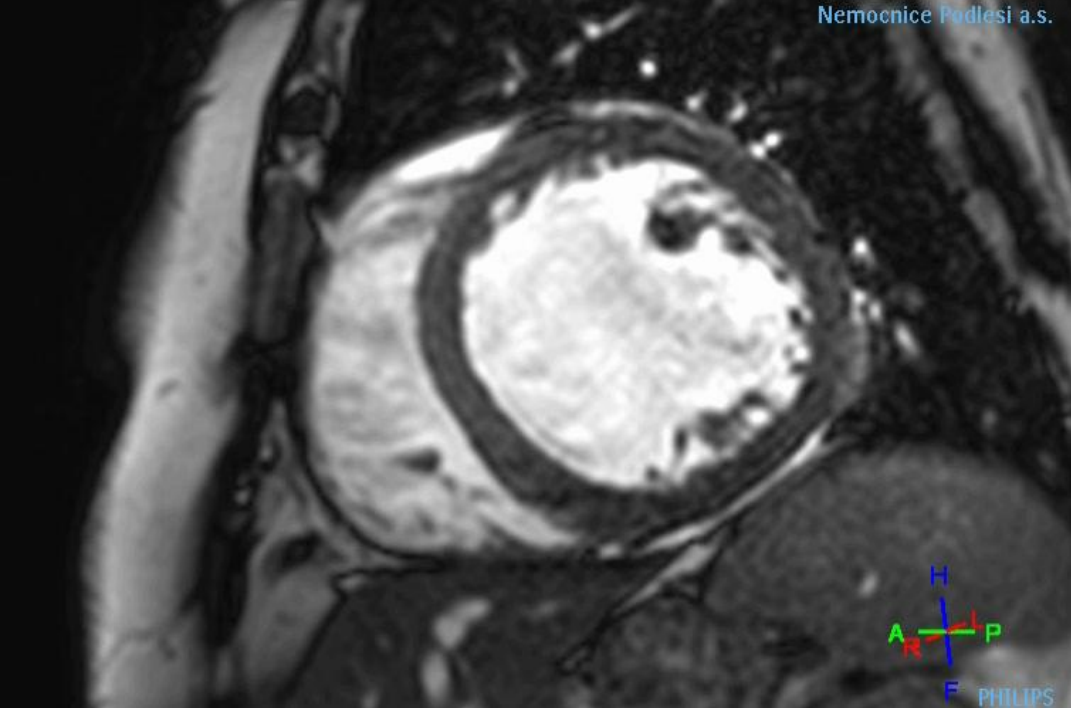


Hypertrofie PK

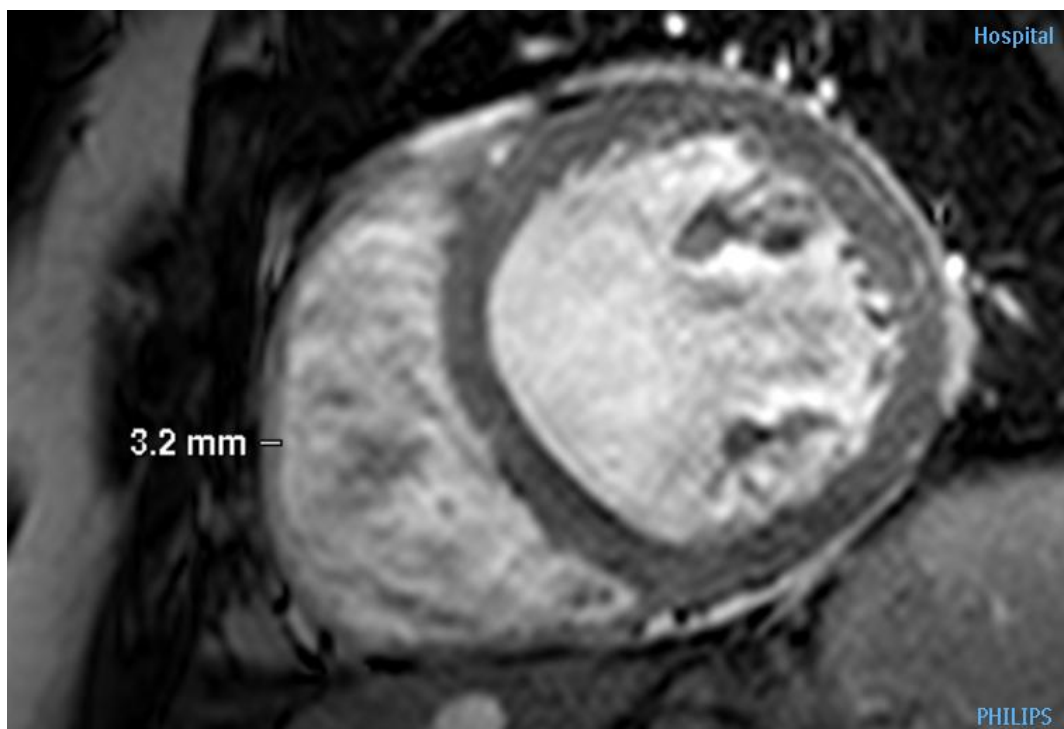
- je hypertrofie stěny PK způsobená skutečně hypertrofií myokardu?

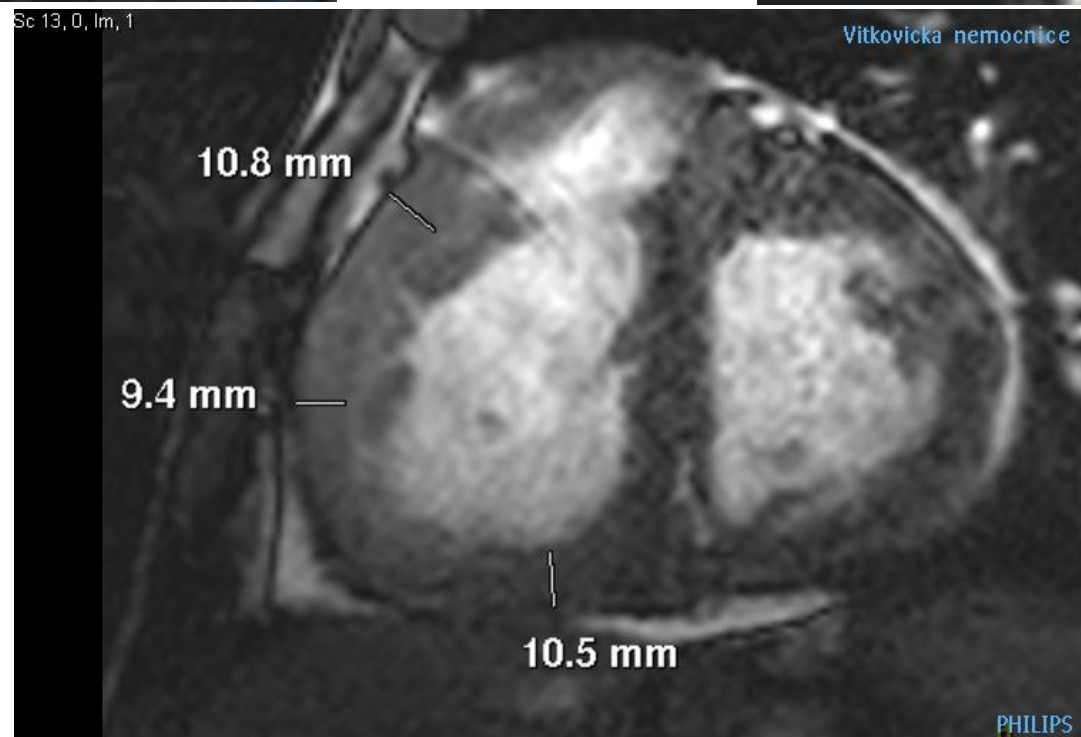
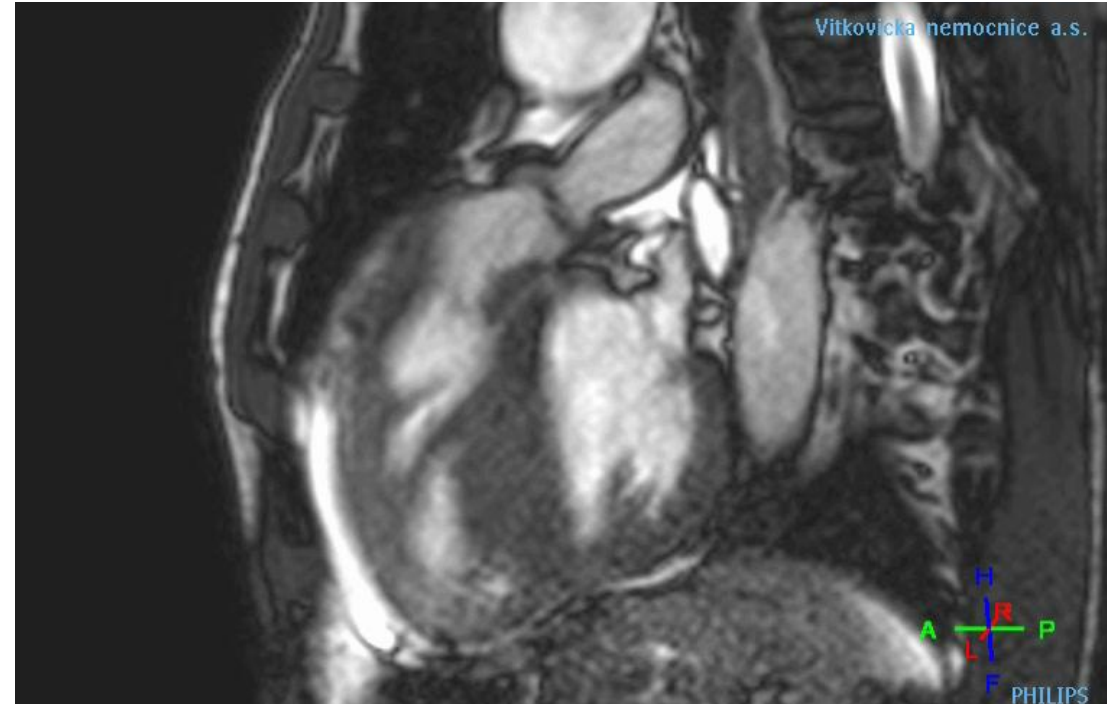
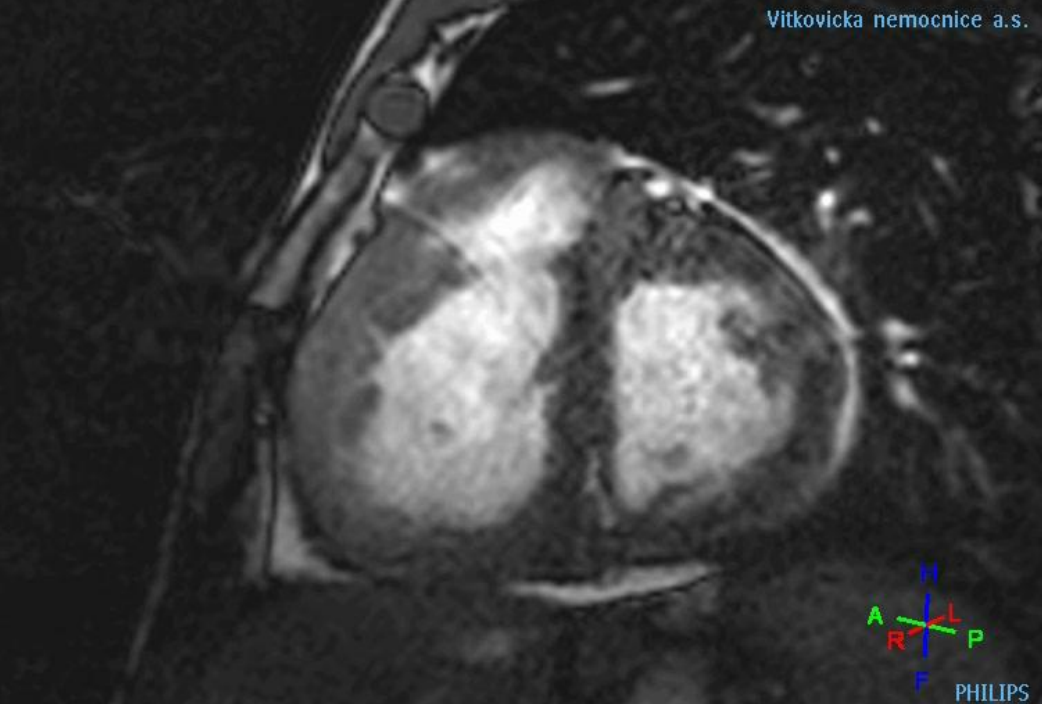


Tuková infiltrace myokardu PK



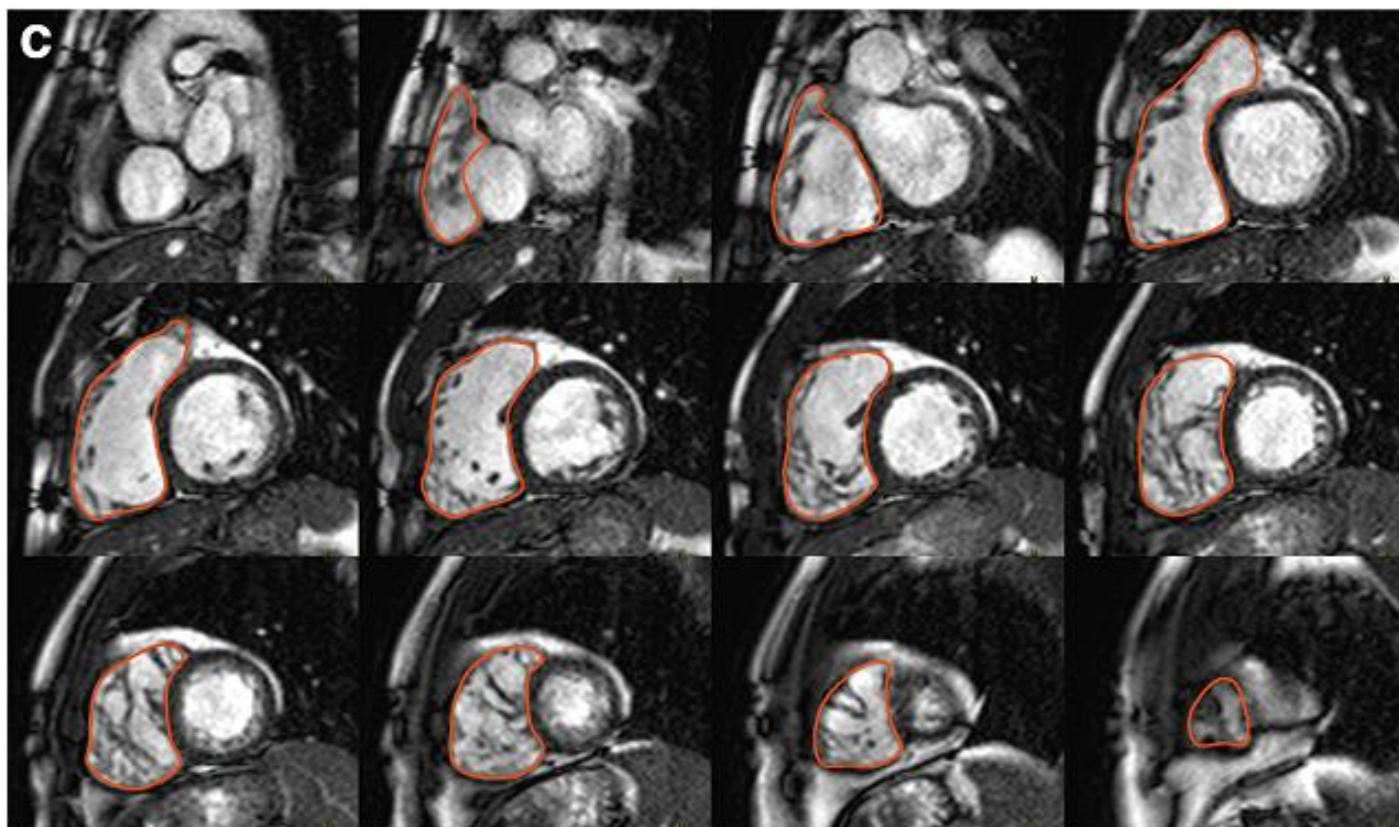
Dle ECHO těžká klidová
PHT s odhadovaným
sPAP 70 mm HG



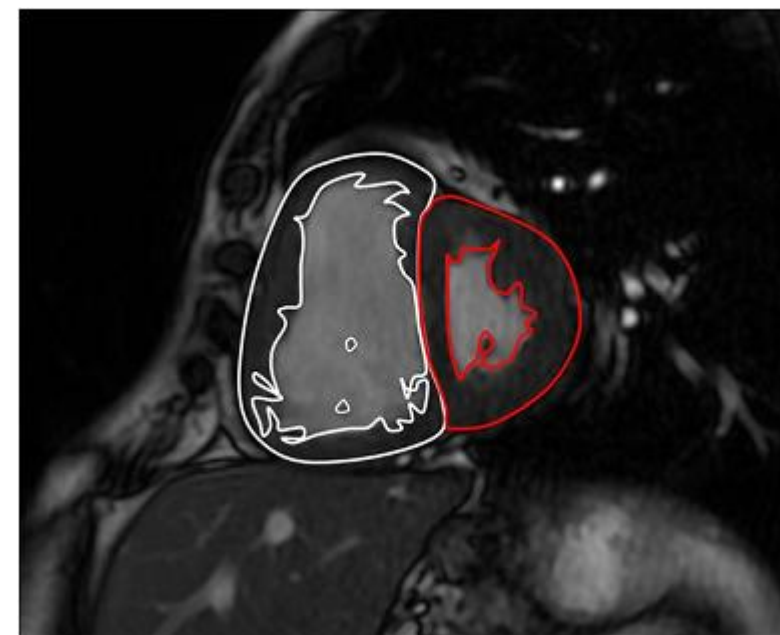


60-letý pacient s
Fallotovou tetralogií s
těžkou stenózou
pulmonální chlopně

Funkce a hmotnost pravé komory



Schulz-Menger J et al. Standardized image interpretation and post processing in cardiovascular magnetic resonance: Society for Cardiovascular Magnetic Resonance (SCMR). Board of Trustees Task Force on Standardized Post Processing. *Journal of Cardiovascular Magnetic Resonance*. 2013;15:35.



Swift AJ et al. Diagnostic accuracy of cardiovascular magnetic resonance imaging of right ventricular morphology and function in the assessment of suspected pulmonary hypertension results from the ASPIRE registry. *Journal of Cardiovascular Magnetic Resonance*. 2012;14:40.

Funkce pravé komory

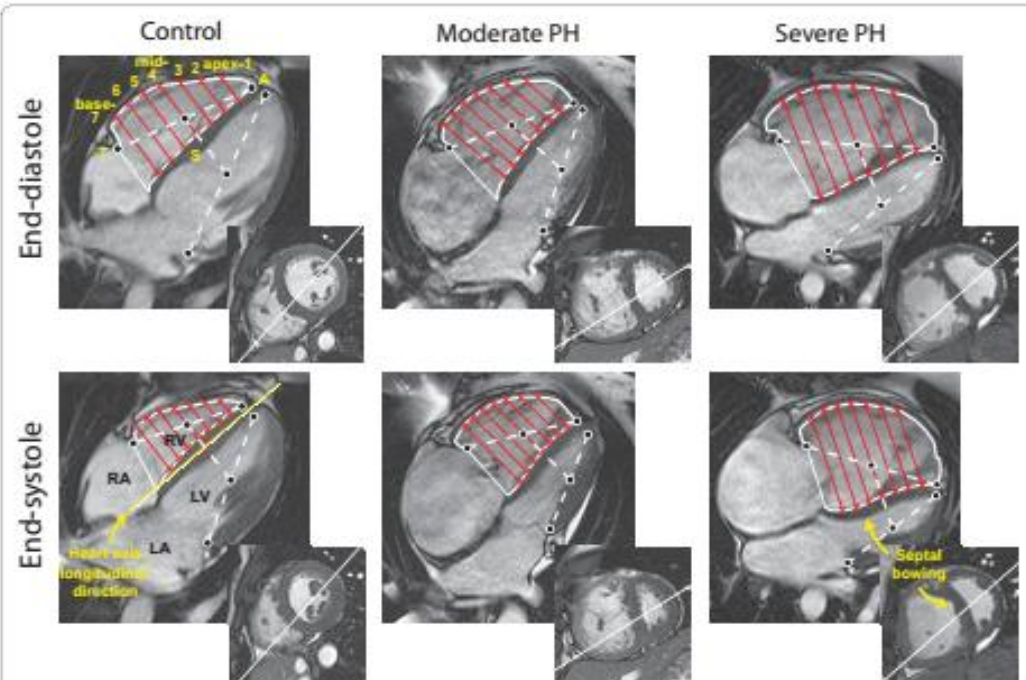


Figure 1 Four-chamber and short axis views of a healthy subject, a patient with moderate PH and a patient with severe PH. The figure illustrates how the longitudinal dimension (from tricuspid annulus to apex (TA)) and transverse dimensions (from septum to free-wall (SF)) are determined. Firstly, both in end-diastole and end-systole, the left and right lateral annulus-apex lines were drawn. Secondly, the intersection through the centres of these lines was drawn. SF dimensions were considered parallel to this intersecting line. Thirdly, RV endocardial contours were drawn to determine the SF dimension at seven different levels covering the whole RV (indicated as apex-1 through base-7, with level mid-4 exactly halfway through the RV). The white lines in the short axis views indicate the intersections of the four-chamber views. RV = right ventricle, RA = right atrium, LV = left ventricle, LA = left atrium, A = Apex, T = lateral tricuspid annulus, S = RV endocardial septum, F = RV endocardial free wall.

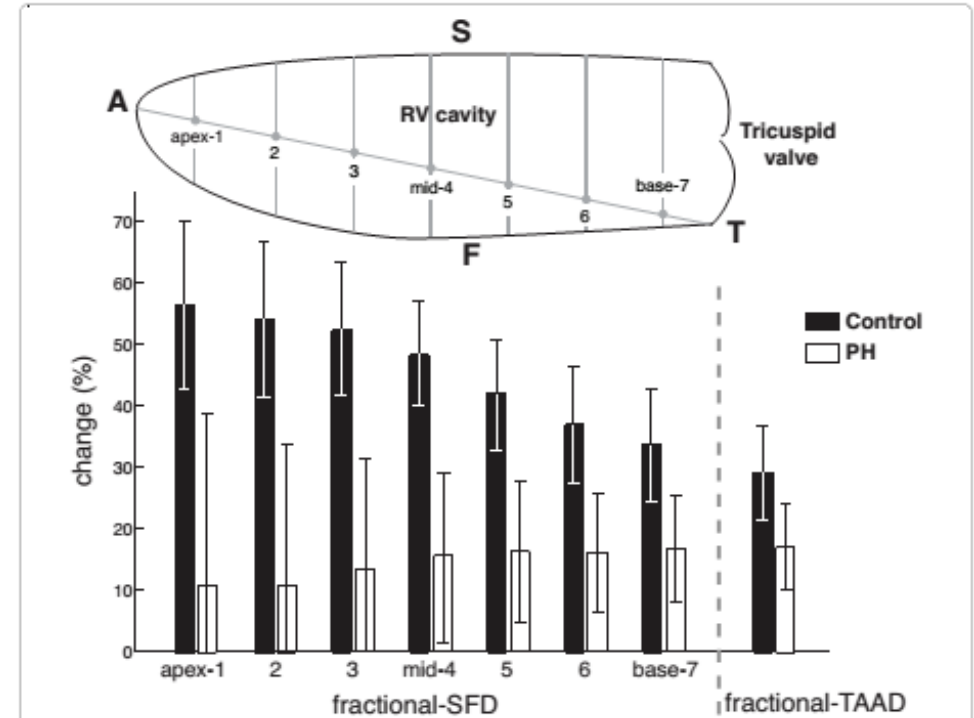
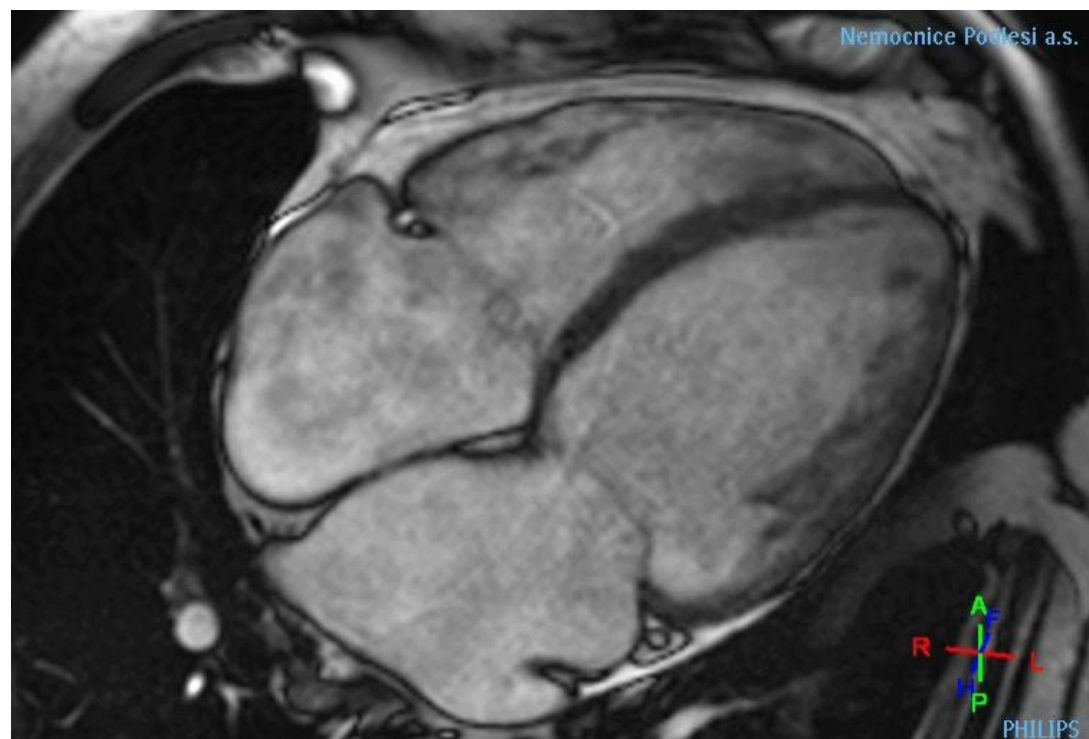


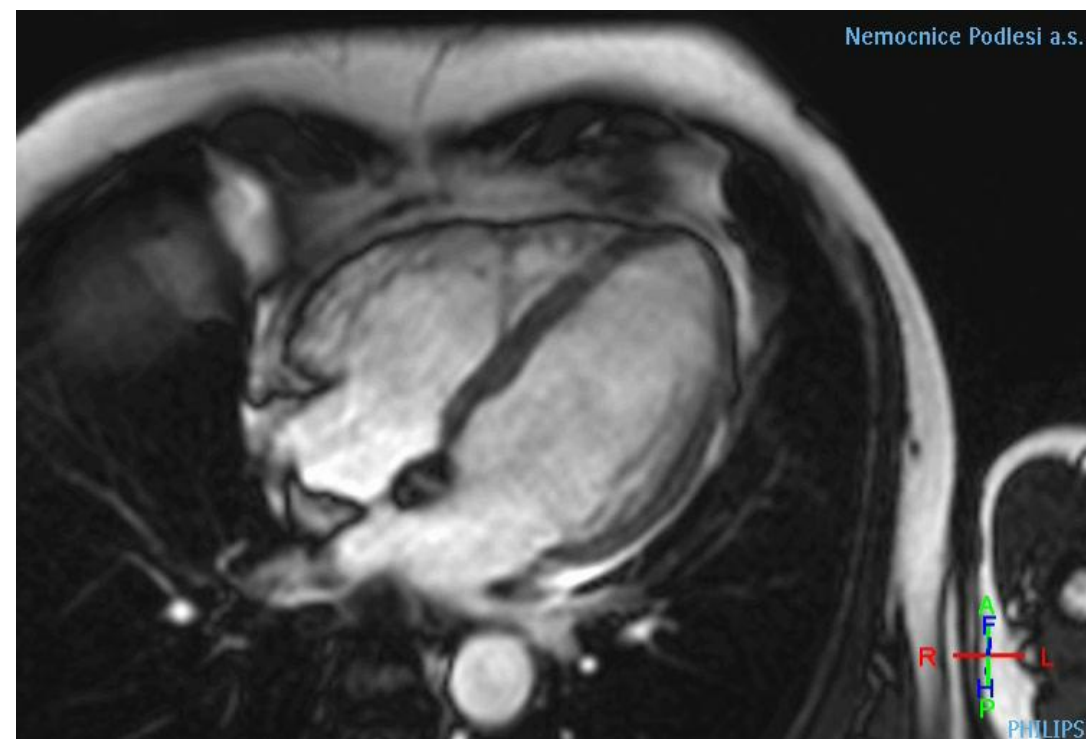
Figure 2 Fractional-SFD in control subjects and PH patients, for seven longitudinal levels in the RV, from apex (level 1) to base (level 7). Fractional-TAAD is shown on the right. In patients, the RV exhibits for each ventricular level approximately the same fractional-SFD. In contrast, control subjects show the highest fractional-SFD around the apex, with less fractional-SFD around the base. For every longitudinal level, differences in fractional change between controls and patients were significant with $p < 0.0001$. A = Apex, T = lateral annulus of tricuspid valve, S = RV endocardial septum, F = RV endocardial free wall.

Kind T et al. Right ventricular ejection fraction is better reflected by transverse rather than longitudinal wall motion in pulmonary hypertension. *Journal of Cardiovascular Magnetic Resonance*. 2010;12:35.

Lokalizace poruch kinetiky

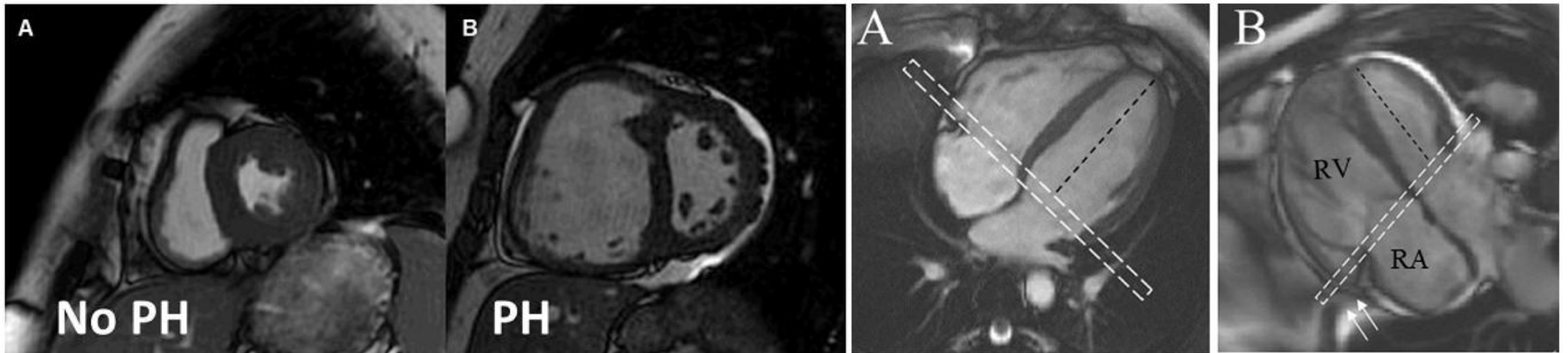


PHT



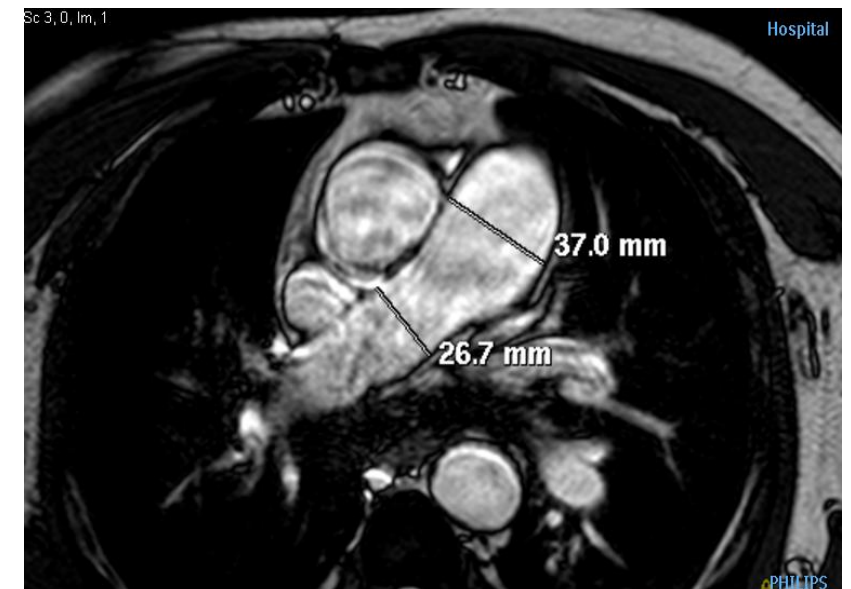
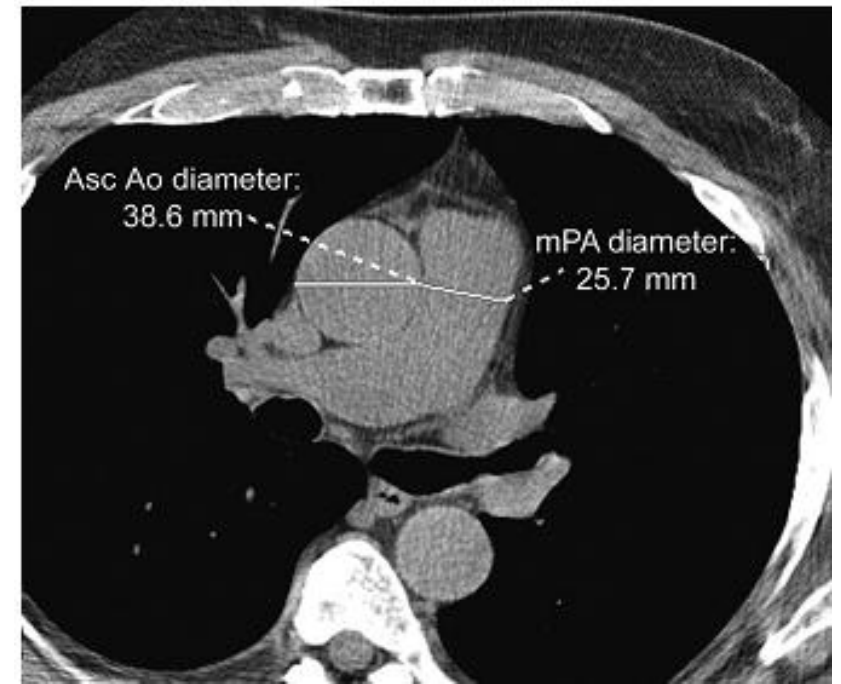
ARVD

Nepřímé známky PHT



Dilatace plicnice

- kmen plicnice ≤ 29 mm muži, ≤ 27 mm ženy
- poměr kmen plicnice / asc. aorta $\leq 0,9$



Dilatate plicnice

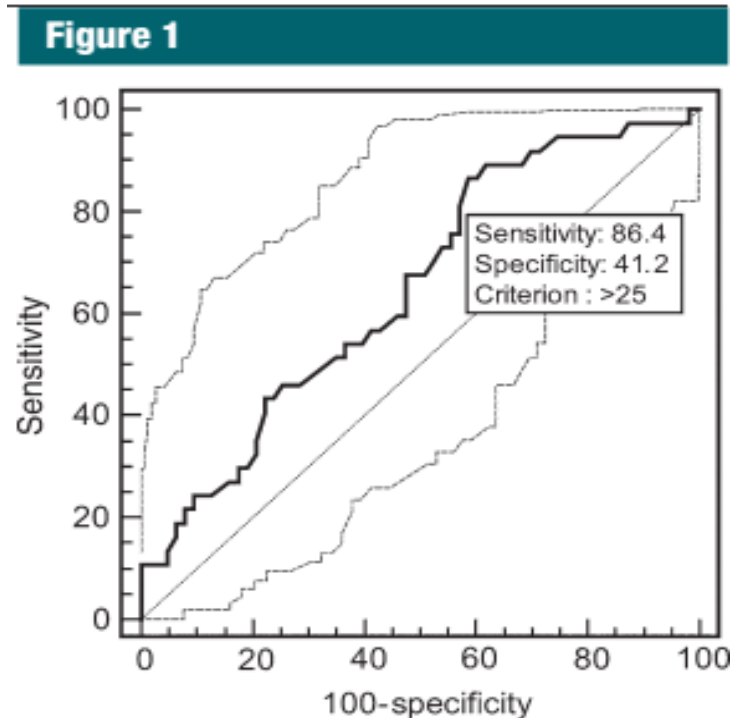


Figure 1: Graph shows ROC curves for main PAD used as a predictor of PH in group A patients. A PAD cutoff of greater than 25 mm yielded sensitivity and specificity of 86.4% and 41.2%, respectively.

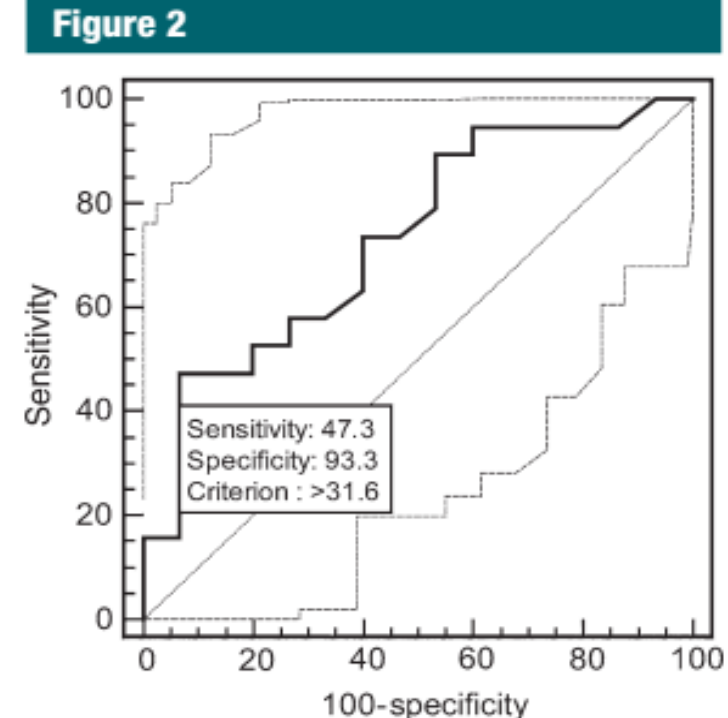
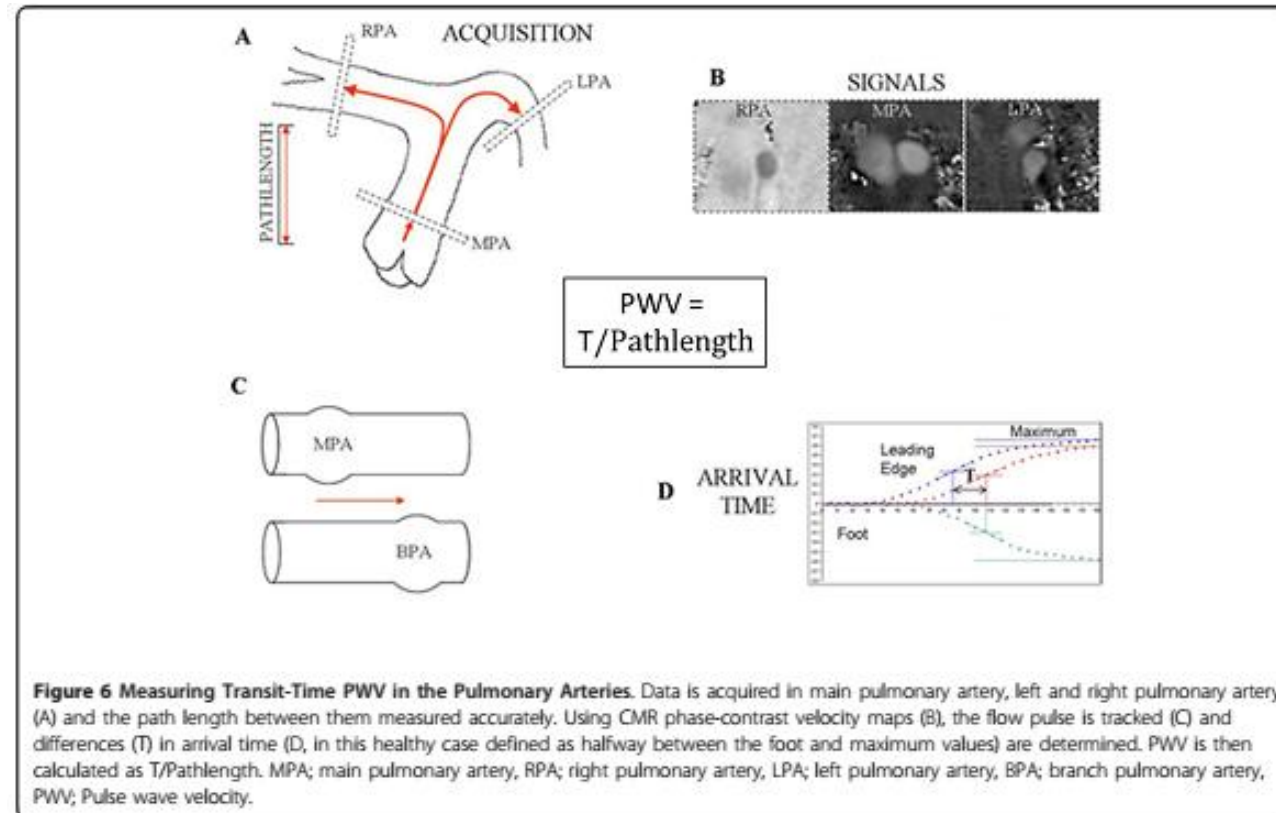


Figure 2: Graph shows ROC curves for main PAD used as a predictor of PH in group B patients. A PAD cutoff of greater than 31.6 mm yielded sensitivity and specificity of 47.3% and 93.3%, respectively.

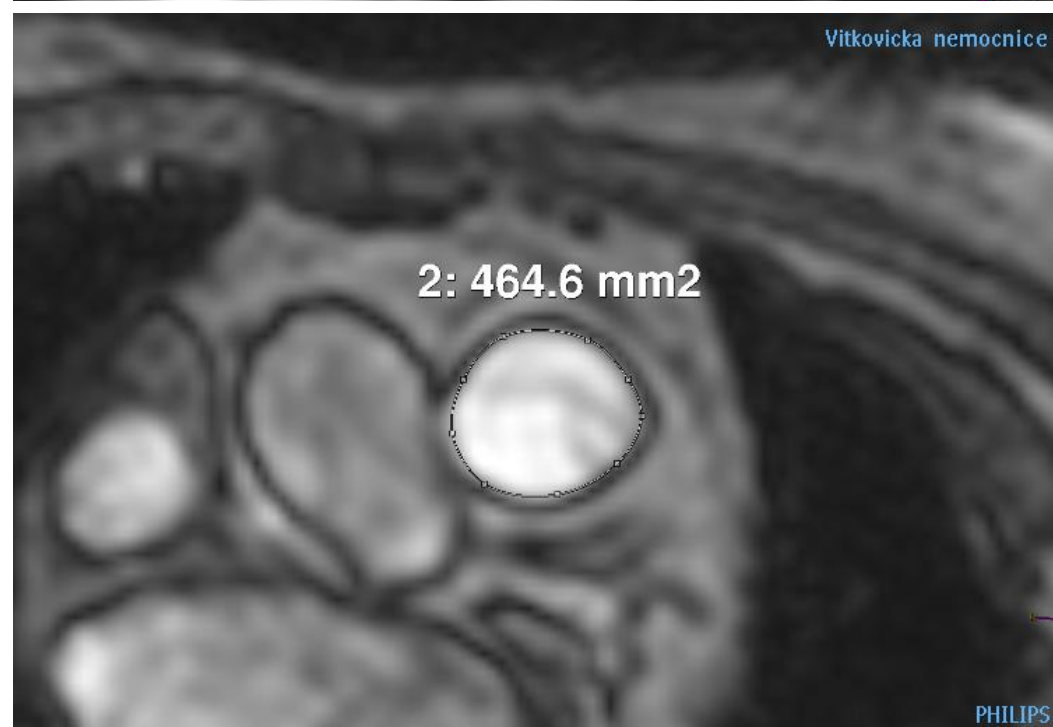
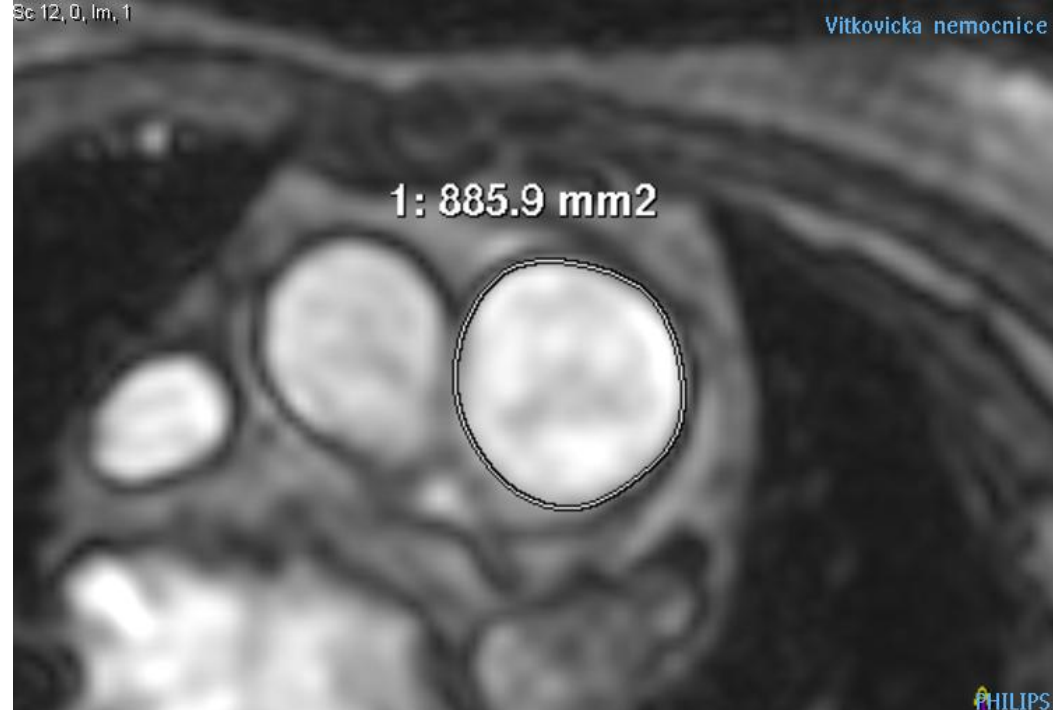
PHT a plicnice



Pulsatilita plicnice

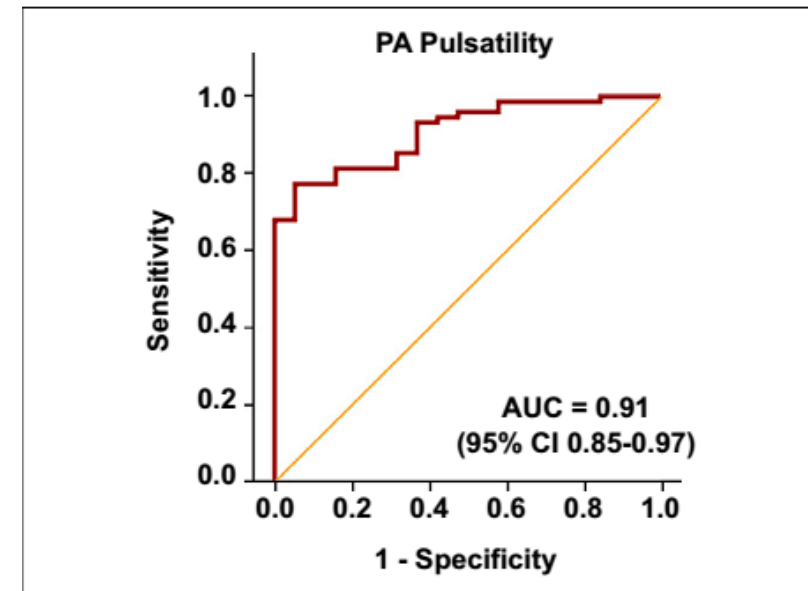
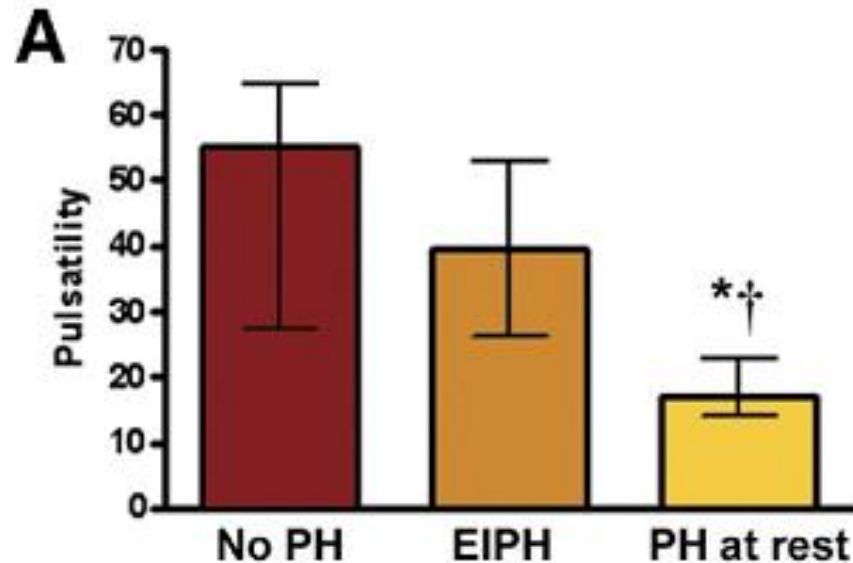


$$\text{RAC} = (\text{max. PA area} - \text{min. PA area}) / \text{min. PA area} (\%)$$

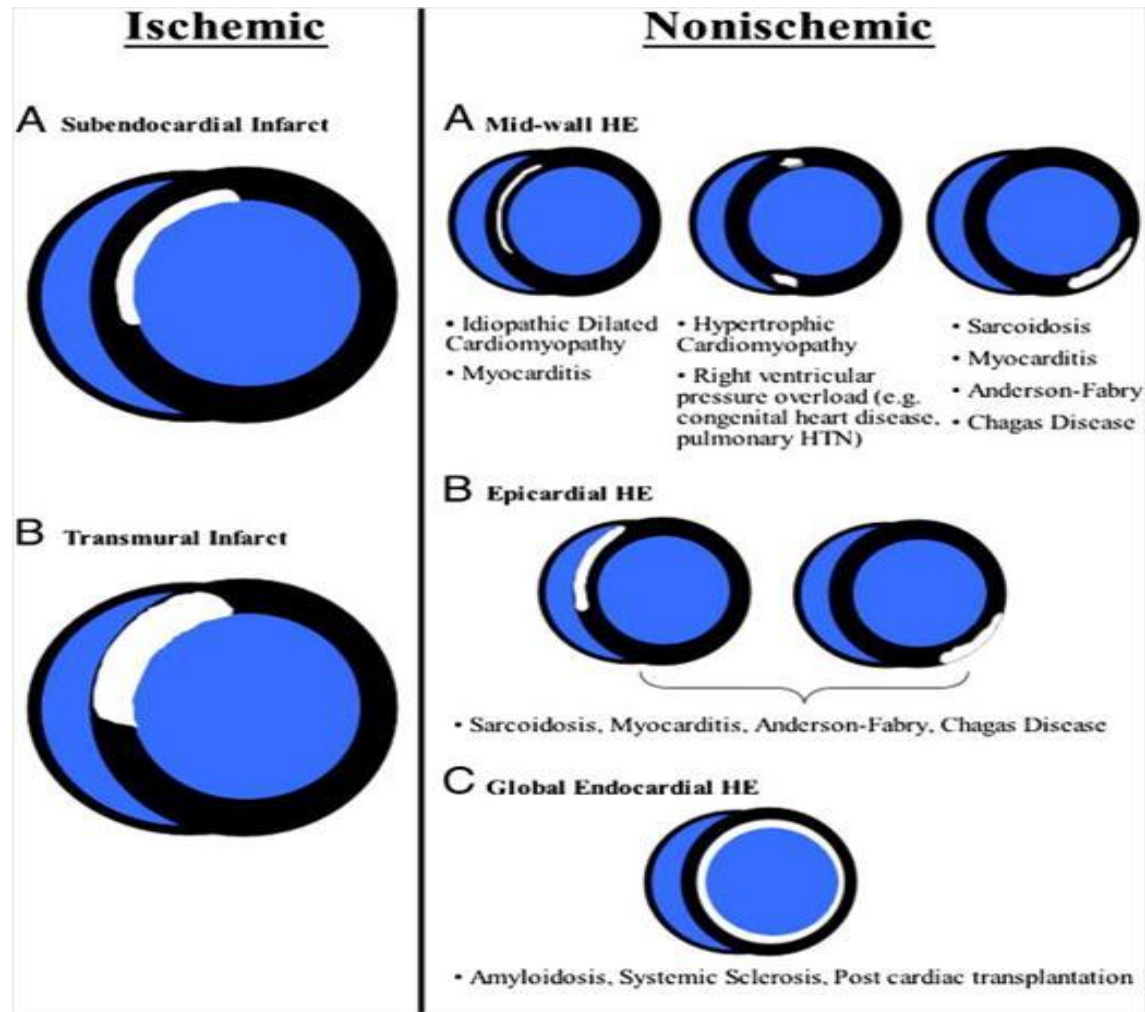


Pulsatilita plicnice

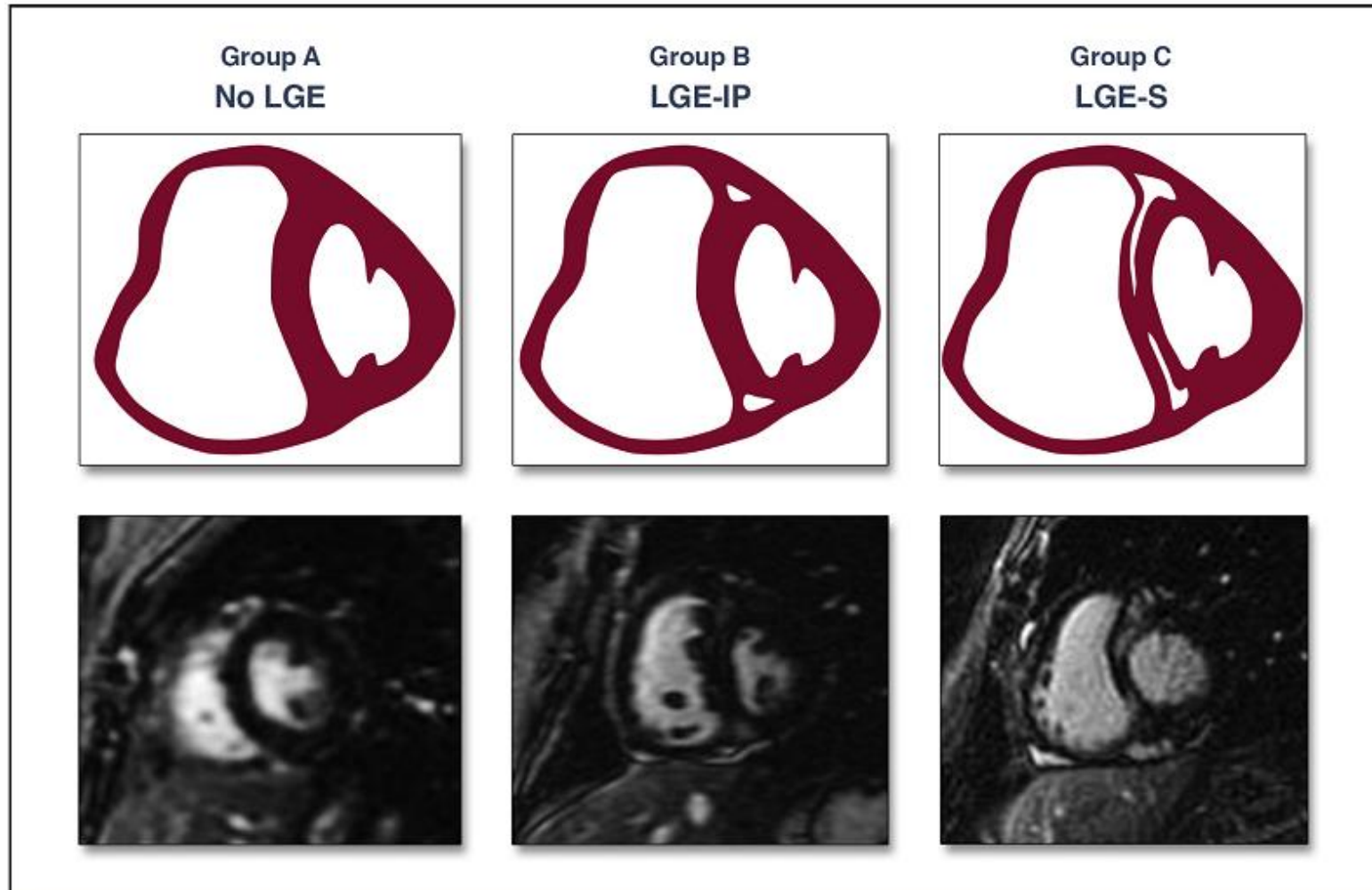
- pulsatilita (RAC) < 40 % – senzitivita 93 % a specificita 63 % pro diagnostiku mPAP > 25 mm HG
- **pulsatilita < 24 %** – senzitivita 77 % a specificita 95 %



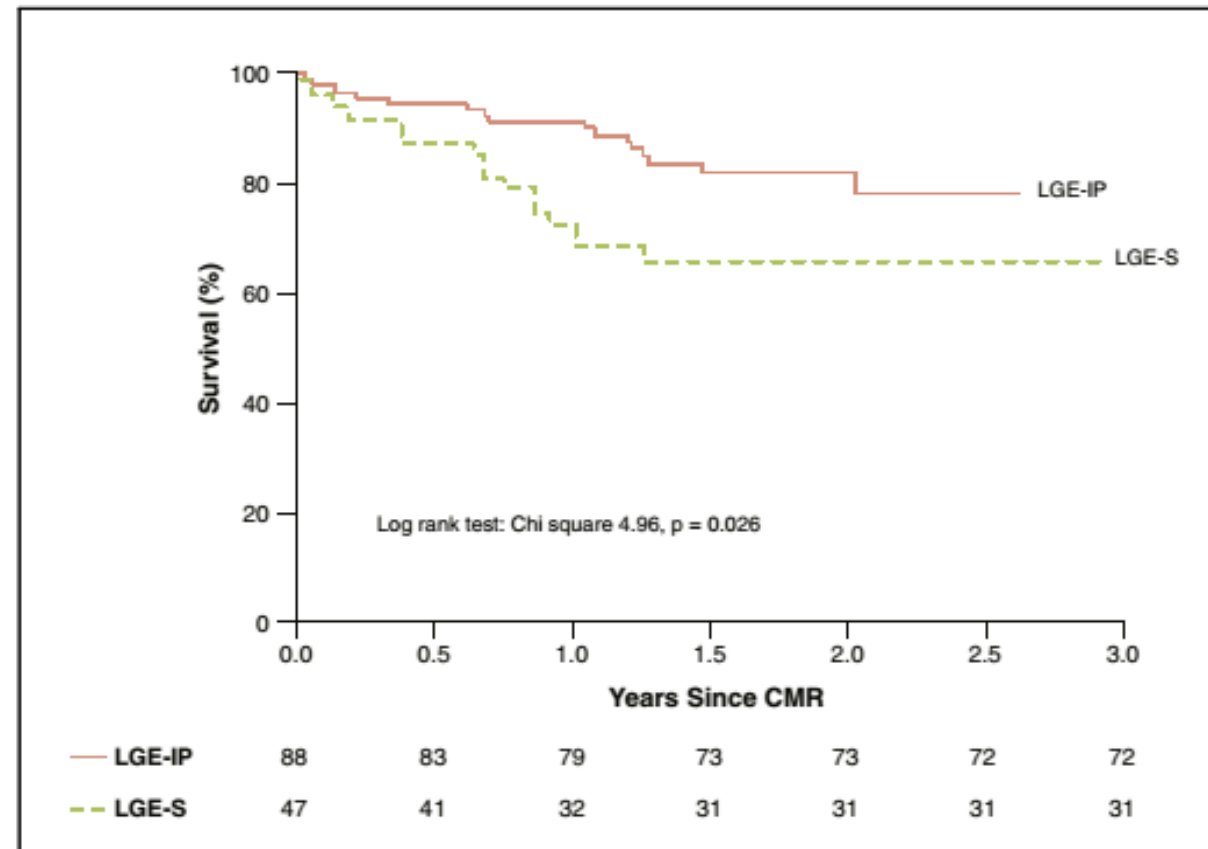
LGE



LGE



LGE



ASPIRE registry

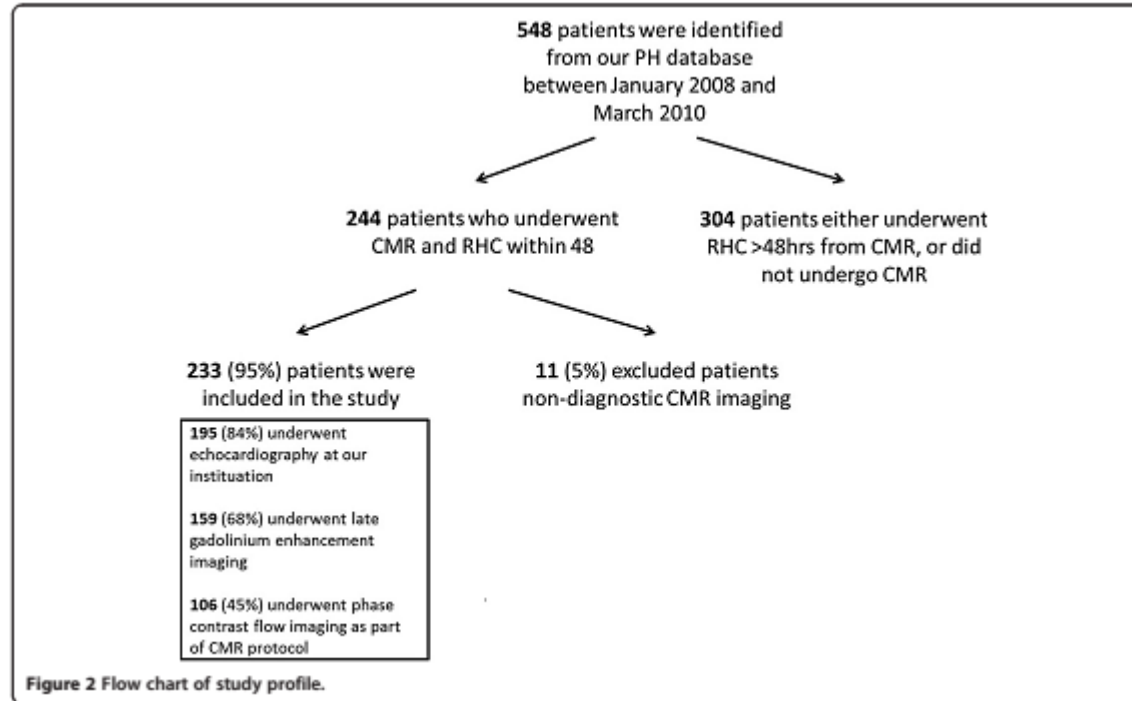


Table 5 Sensitivity, Specificity, Positive and Negative Predictive Values and area under the receiver operating characteristic curve (AUC) of CMR Indices for the Detection of PH

	Sensitivity	Specificity	PPV	NPV	AUC
Cardiac morphology					
RVEDV index ≥ 75 ml/m ²	67	50	89	20	0.72*
RV mass index ≥ 20 g/m ²	83	84	96	50	0.91*
VMI ≥ 0.4	81	88	97	50	0.91*
Late gadolinium enhancement	83	94	98	58	0.89*
Right heart functional indices					
RVEF $\leq 35\%$	67	71	93	28	0.72*
RVSWI ≤ 30 ml/m ²	70	47	89	21	0.68*
TAPSE ≤ 2 cm	76	64	92	32	0.75*
f-TAAD $\leq 25\%$	88	56	92	44	0.78*
SFD ≤ 1 cm	77	67	93	34	0.73*
f-SFD $\leq 25\%$	79	64	92	35	0.78*
RVRAC $\leq 30\%$	61	81	95	28	0.79*
sEI ≥ 1.2	65	61	90	24	0.72*
dEI ≥ 1.17	62	54	88	20	0.57
Phase contrast CMR					
Average velocity ≤ 10 (cm/s)	82	62	94	32	0.80*
Retrograde flow ≥ 0.3 (L/min/m ²)	83	71	95	38	0.84*
Retrograde flow (%)	73	56	87	34	0.75*
PA relative area change $\geq 15\%$	86	70	94	48	0.87*
Systolic PA area ≥ 8 cm ²	74	67	92	32	0.77*
Diastolic PA area ≥ 6 cm ²	88	66	94	52	0.82*

AUC (area under the curve) *p < 0.05.

MRI a prognóza

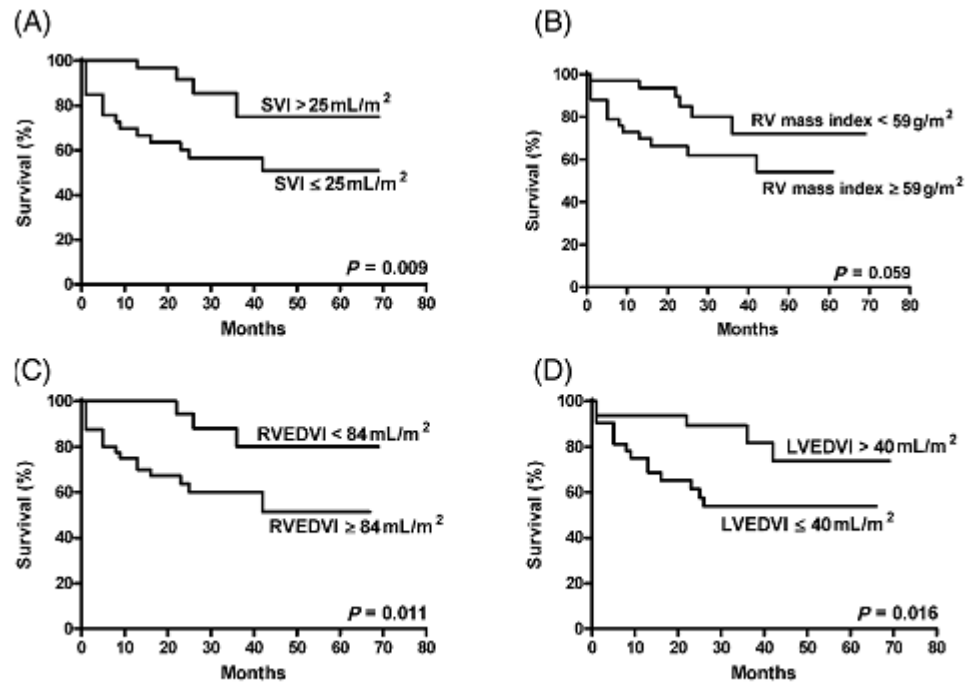


Figure 4 Kaplan-Meier survival curves for baseline cardiac MRI variables according to the median value in patients with pulmonary hypertension. SVI ≤ 25.0 mL/m² (A), RV mass index ≥ 59 g/m² (B), an RVEDVI ≥ 84 mL/m² (C), and an LVEDVI ≤ 40 mL/m² (D) were predictors of mortality.

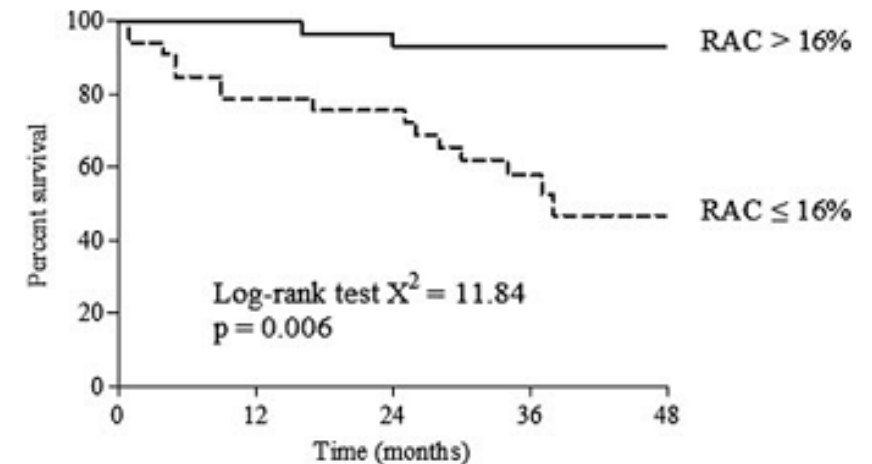


FIGURE 4. Kaplan-Meier survival curve for PAH patients with $\Delta A/A$ above and below the median value.

van Wolferen SA et al. Prognostic value of right ventricular mass, volume, and function in idiopathic pulmonary arterial hypertension. *European Heart Journal*. 2007;28:1250-1257.

Gan CT et al. Noninvasively Assessed Pulmonary Artery Stiffness Predicts Mortality in Pulmonary Arterial Hypertension. *CHEST*. 2007;132:1906-1912.

MRI a prognóza

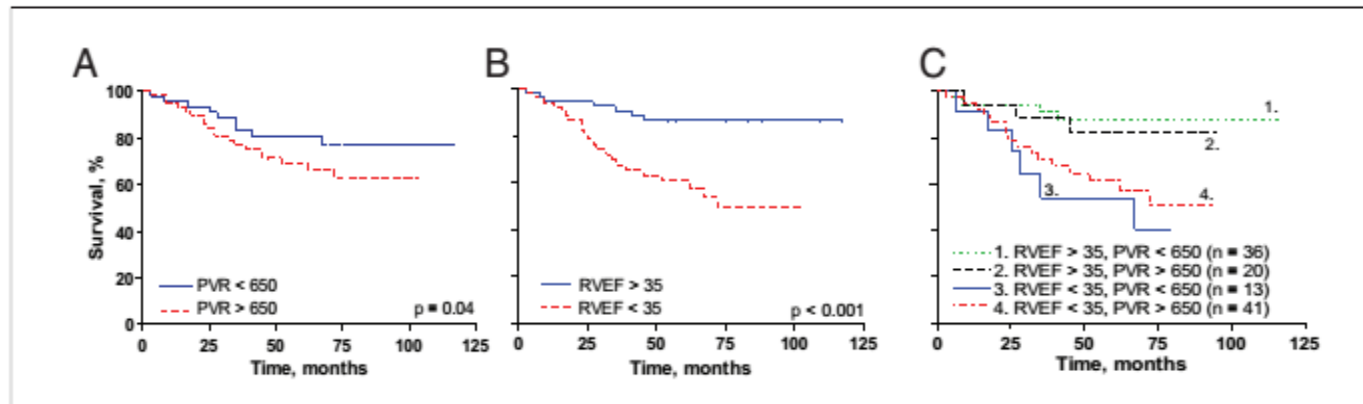


Figure 2 Survival Rates of Patients With PAH Stratified According to PVR and RVEF at Baseline

(A) Patients with pulmonary vascular resistance (PVR) $< 650 \text{ dyne}\cdot\text{s}\cdot\text{cm}^{-5}$ showed better survival rates than patients with PVR $> 650 \text{ dyne}\cdot\text{s}\cdot\text{cm}^{-5}$ ($p = 0.04$).
(B) Patients with right ventricular ejection fraction (RVEF) $> 35\%$ showed better survival rates compared with patients with RVEF $< 35\%$ ($p < 0.001$).
(C) Survival rates based on the coupling of PVR and RVEF. PAH = pulmonary arterial hypertension.

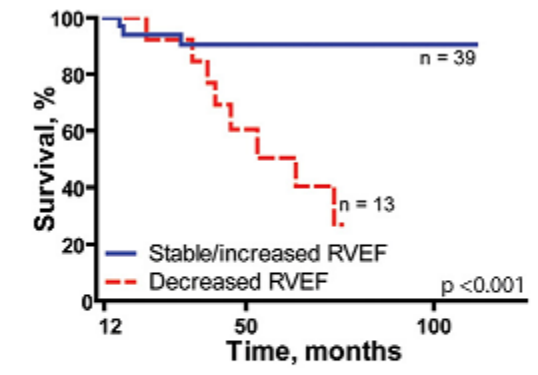


Figure 5 Landmark Analysis

Landmark analysis at month 12 of 52 patients with decreased PVR after therapy. Patients with stable/increased RVEF ($n = 39$) had better survival rates than patients with decreased RVEF ($n = 13$) ($p < 0.001$). Abbreviations as in Figure 2.

MRI a trombembolická nemoc

- angiografie plicnice – **ANO**
- perfuze plic – **ANO**
- zobrazení plic – **ANO**
- ventilační sken – **NE** (*jen experimentálně*)

MR angiografie plicnice

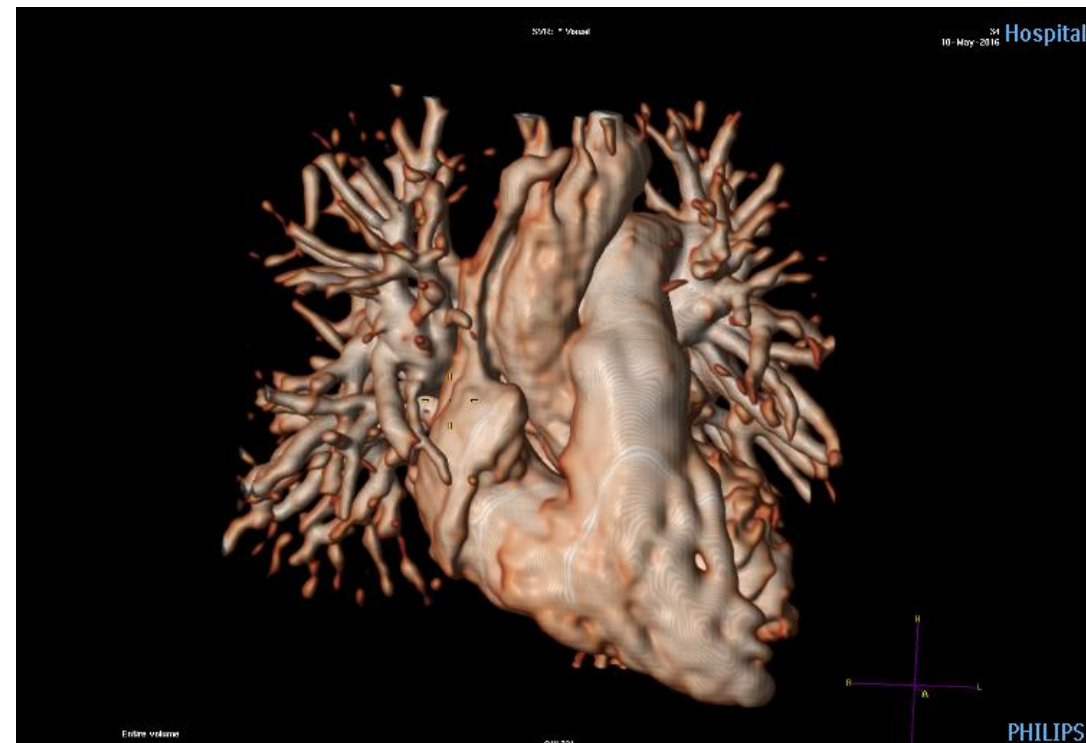
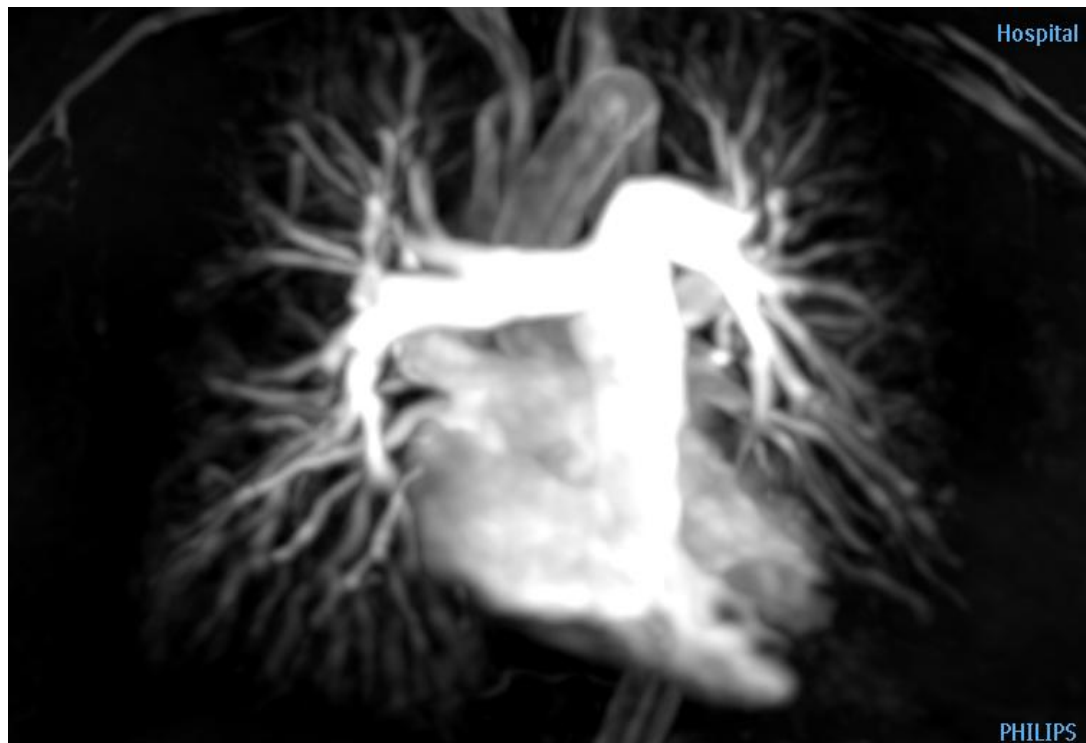
s použitím kontrastu:

- trojrozměrná angiografie (3D CE – MRA)
- dynamická angiografie (4D CE – MRA)

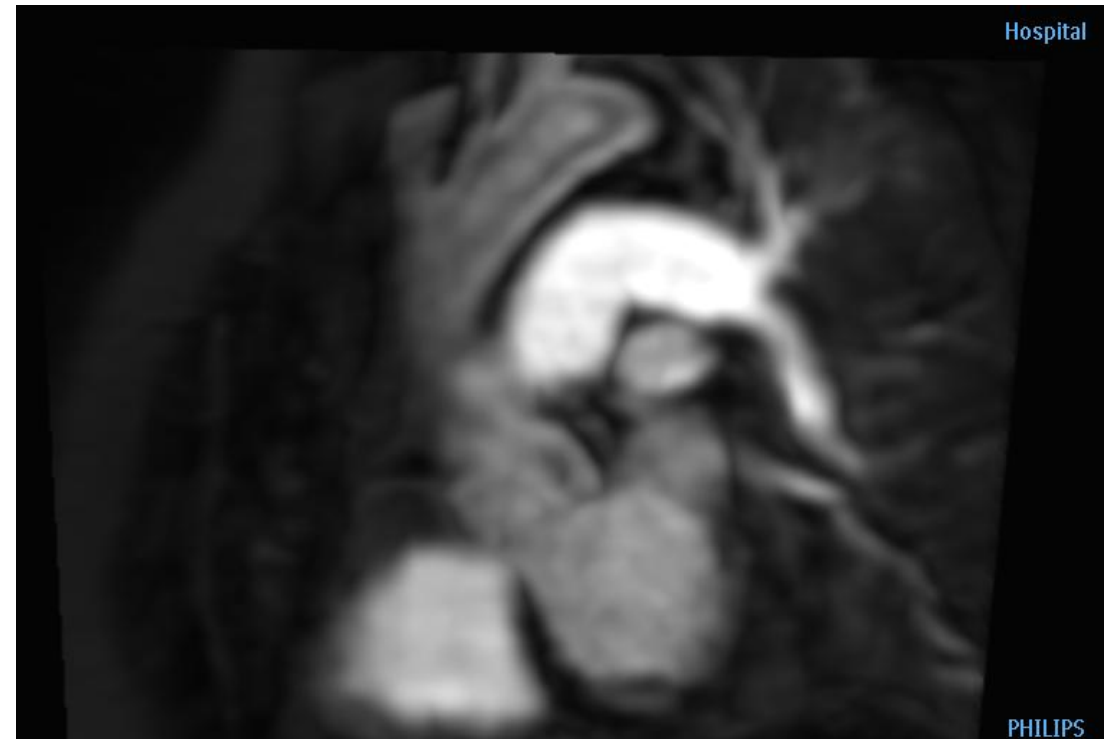
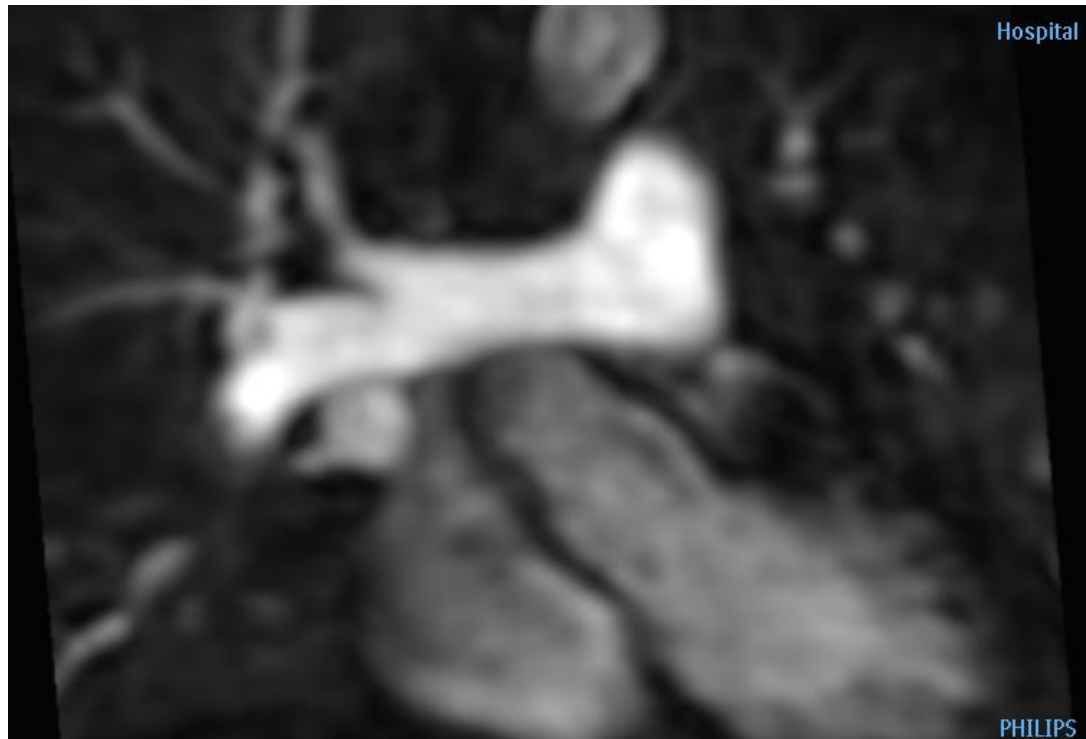
bez použití kontrastu:

- trojrozměrný náběh dat za použití dechového navigátoru (3D BTFE WH)
- metoda fázového kontrastu (3D PC – MRA)

CE – MRA plicnice (3D)



CE – MRA plicnice (MIP)



Senzitivita CE – MRA x plicní angiografie

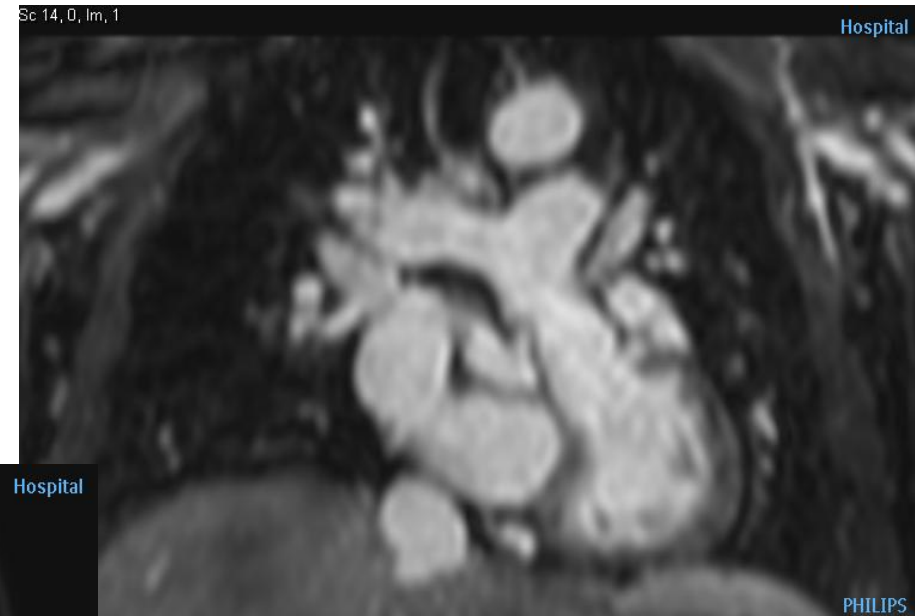
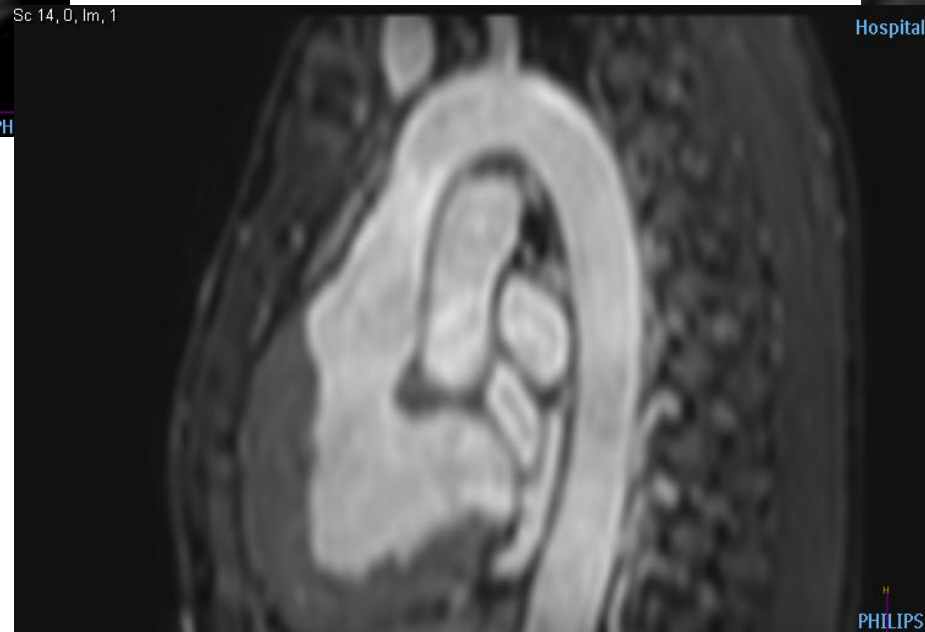
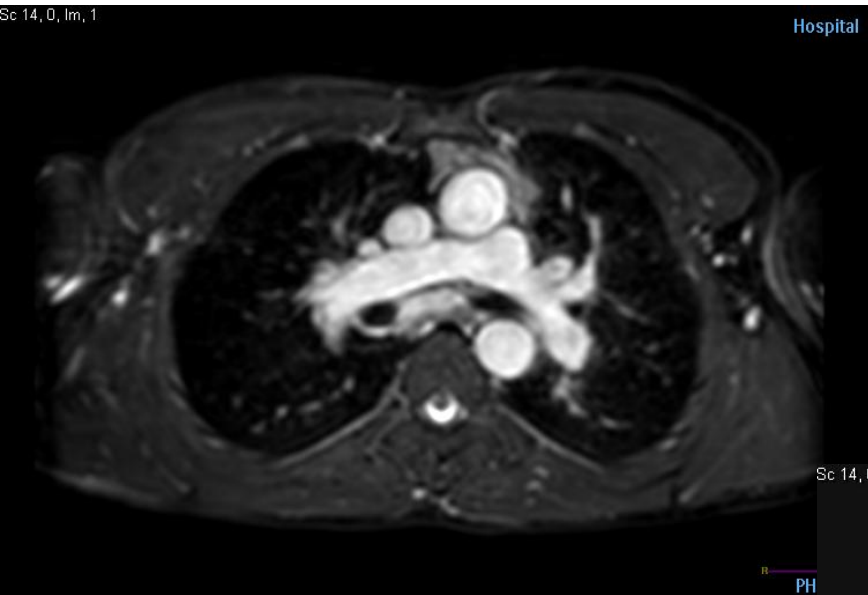
141 pacientů se suspekci na plicní embolii a abnormálním perfuzním skenem

- subsegmentární plicní embolie – 40 %
- segmentární – 80 %
- centrální nebo lobární – 100 %

4D CE MRA



3D BTFE WH

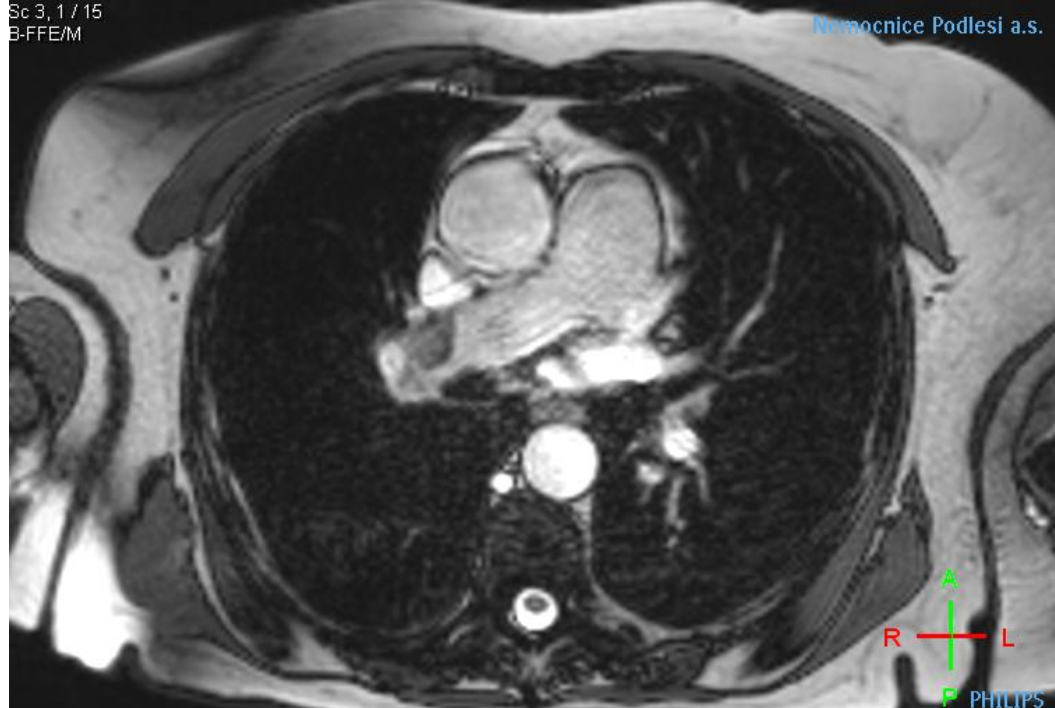


3D BTFE WH



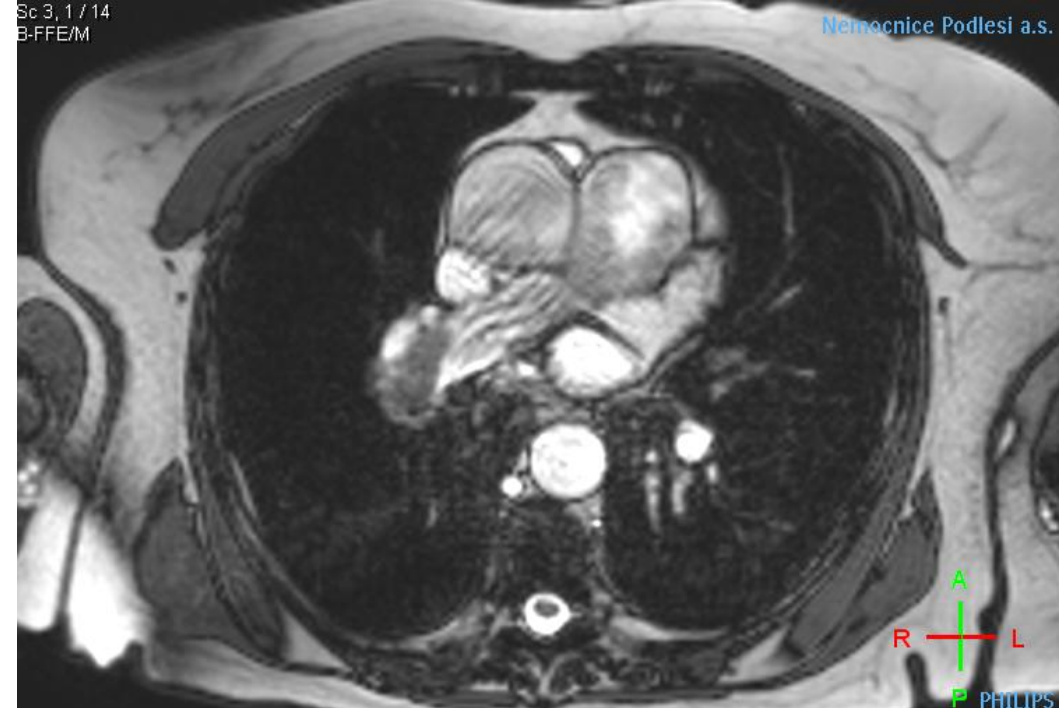
Sc 3, 1 / 15
B-FFE/M

Nemocnice Podlesi a.s.



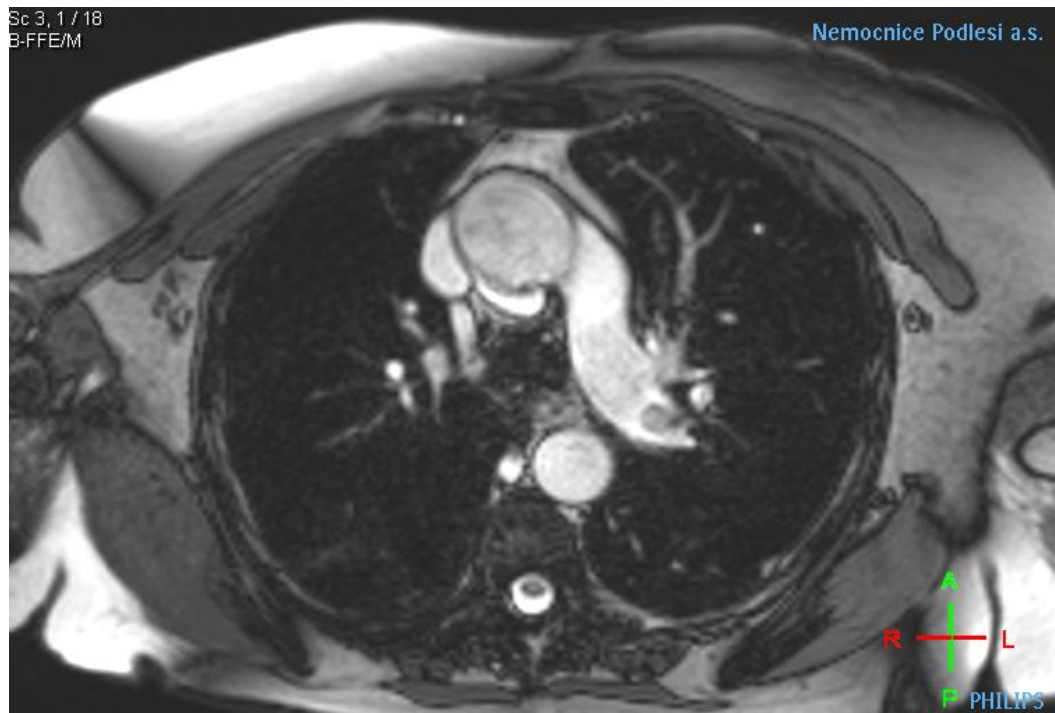
Sc 3, 1 / 14
B-FFE/M

Nemocnice Podlesi a.s.



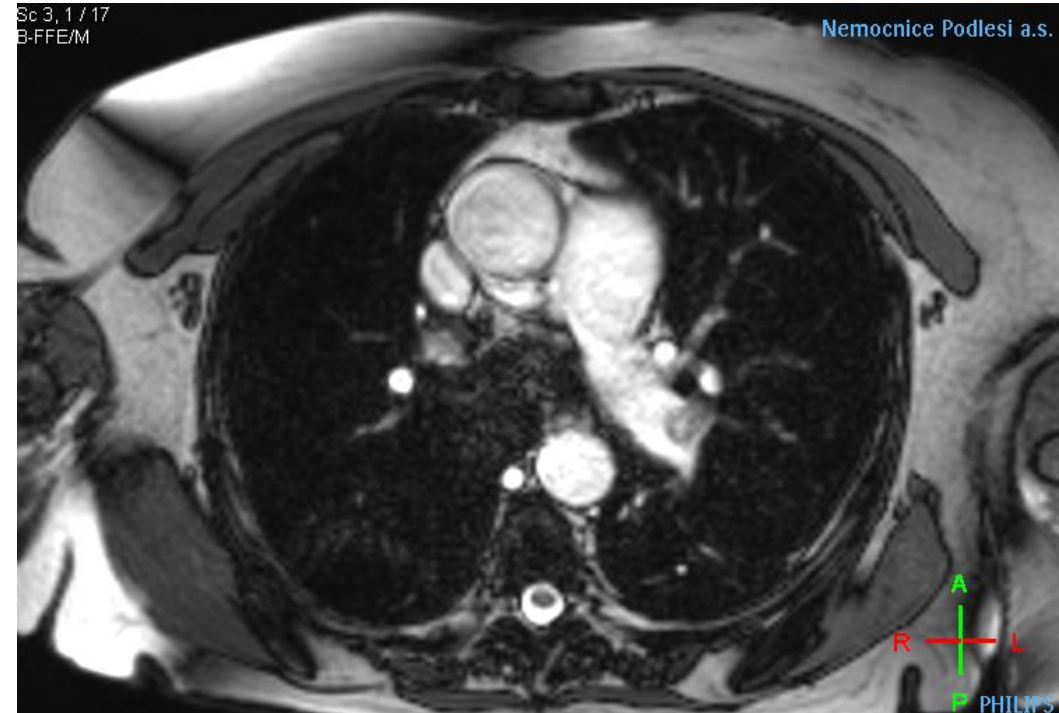
Sc 3, 1 / 18
B-FFE/M

Nemocnice Podlesi a.s.

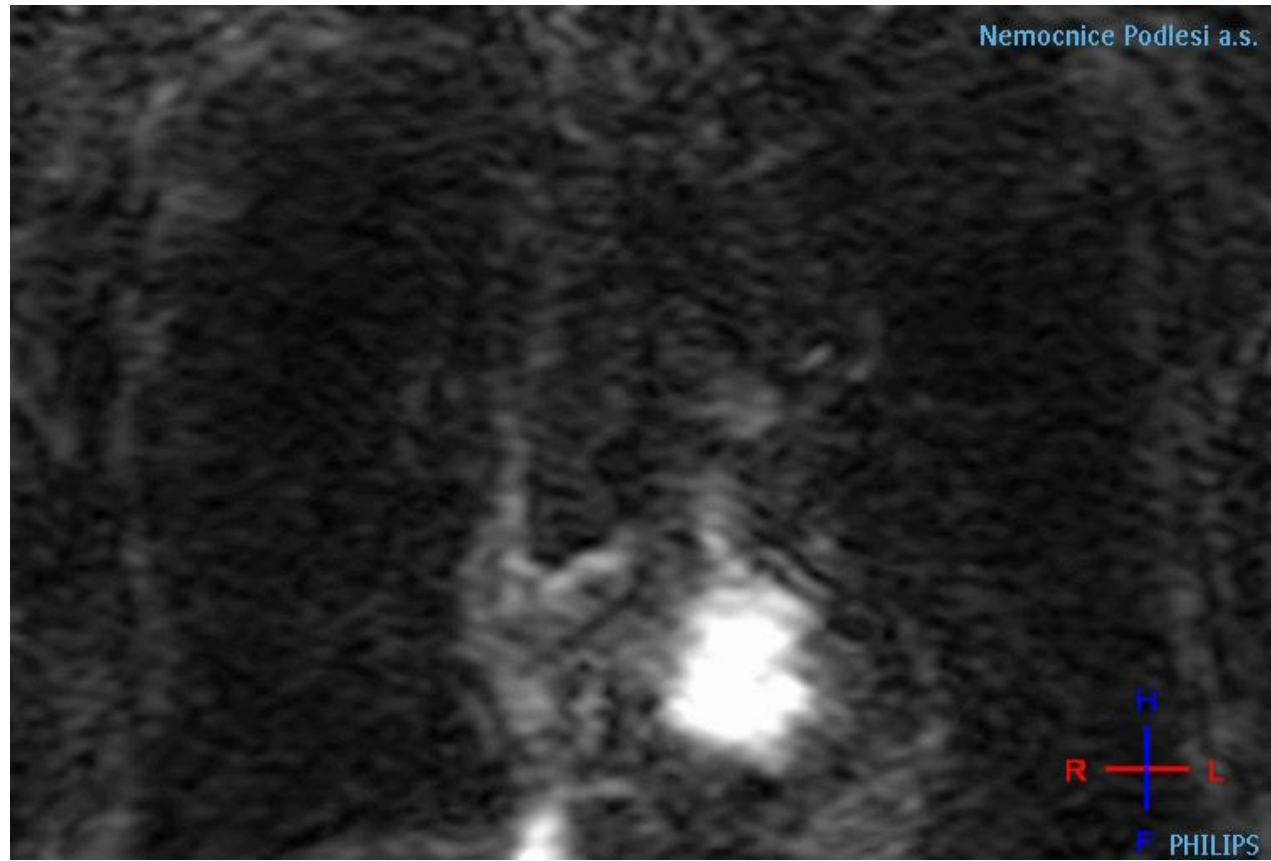


Sc 3, 1 / 17
B-FFE/M

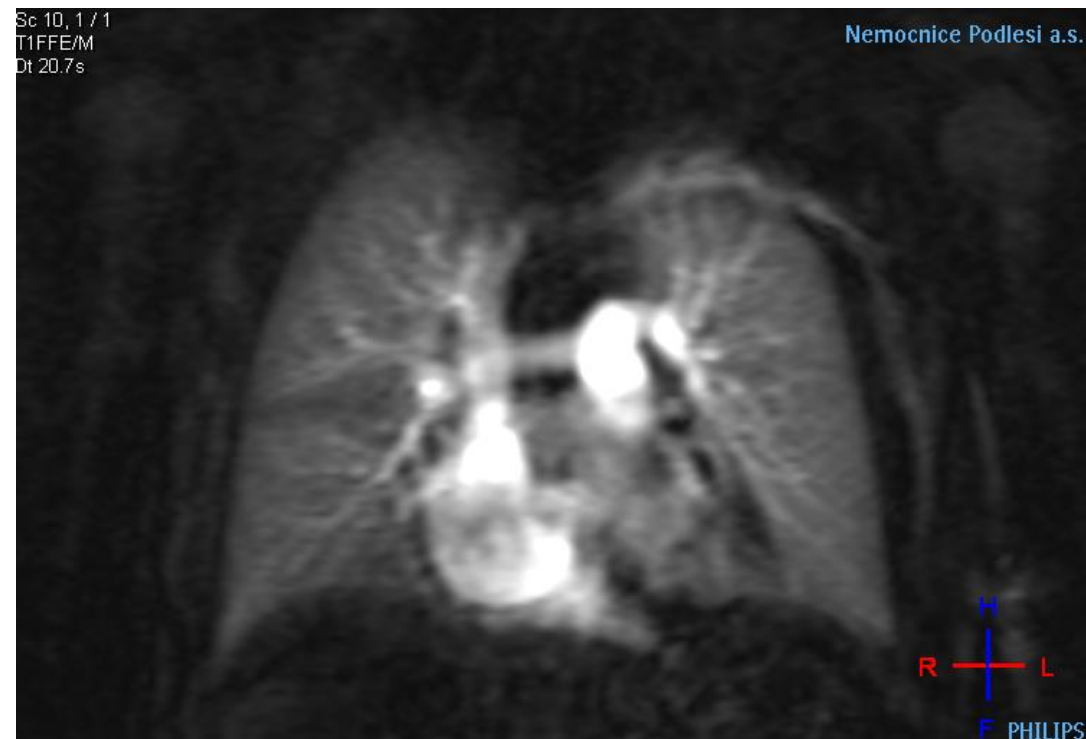
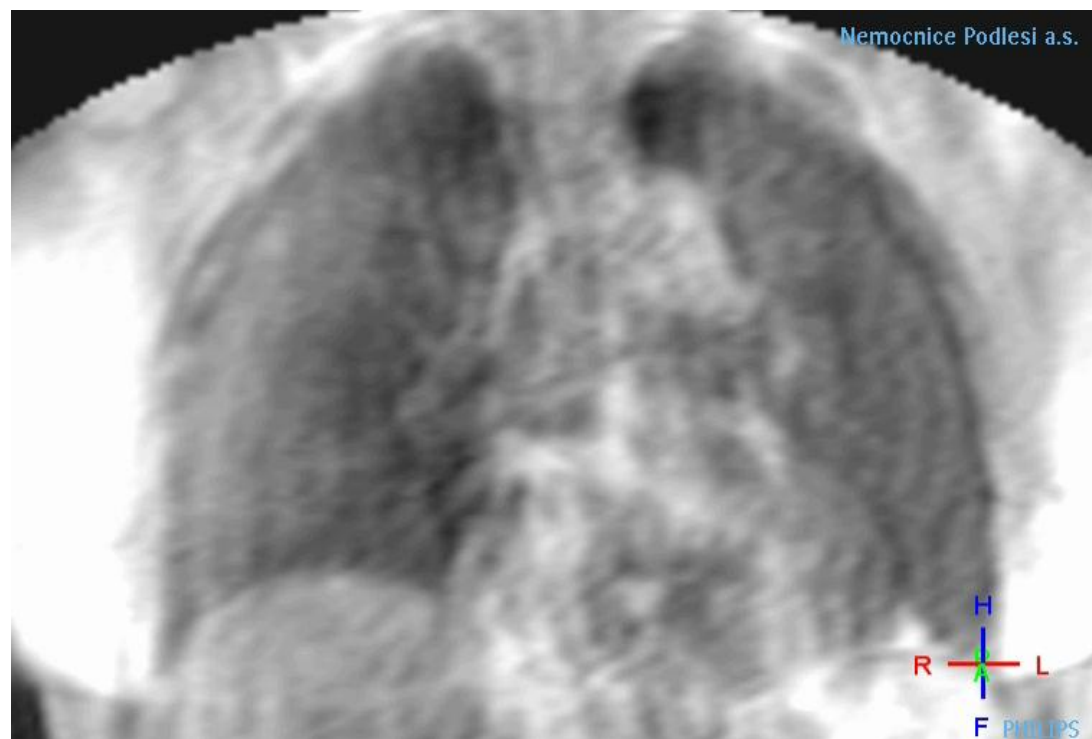
Nemocnice Podlesi a.s.

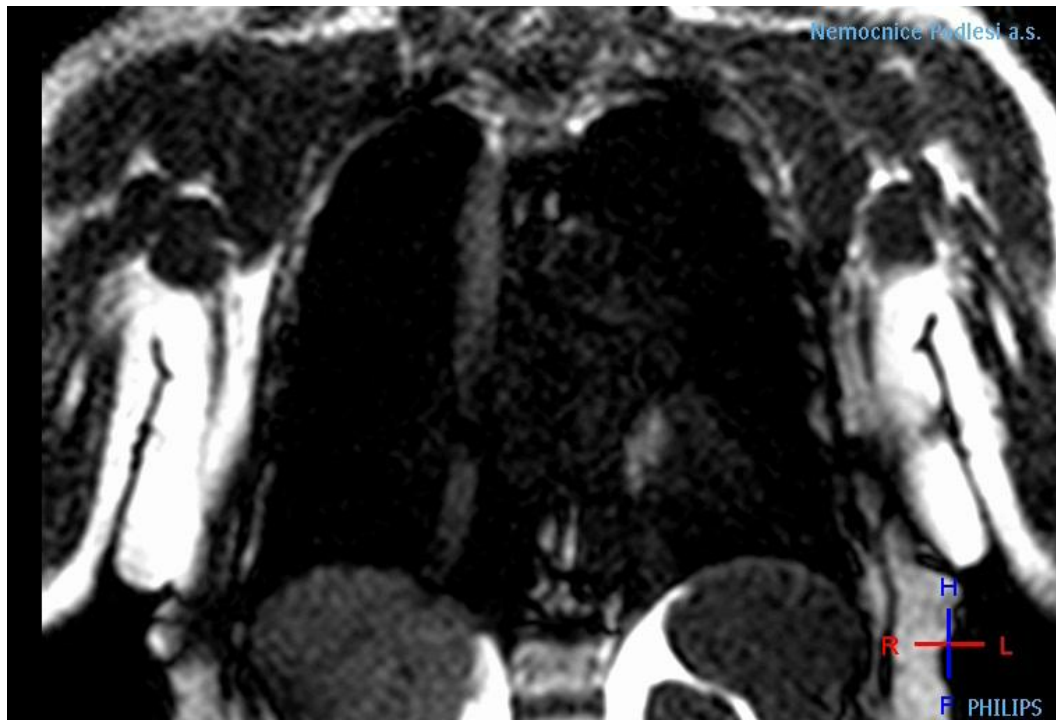


PC – MRA

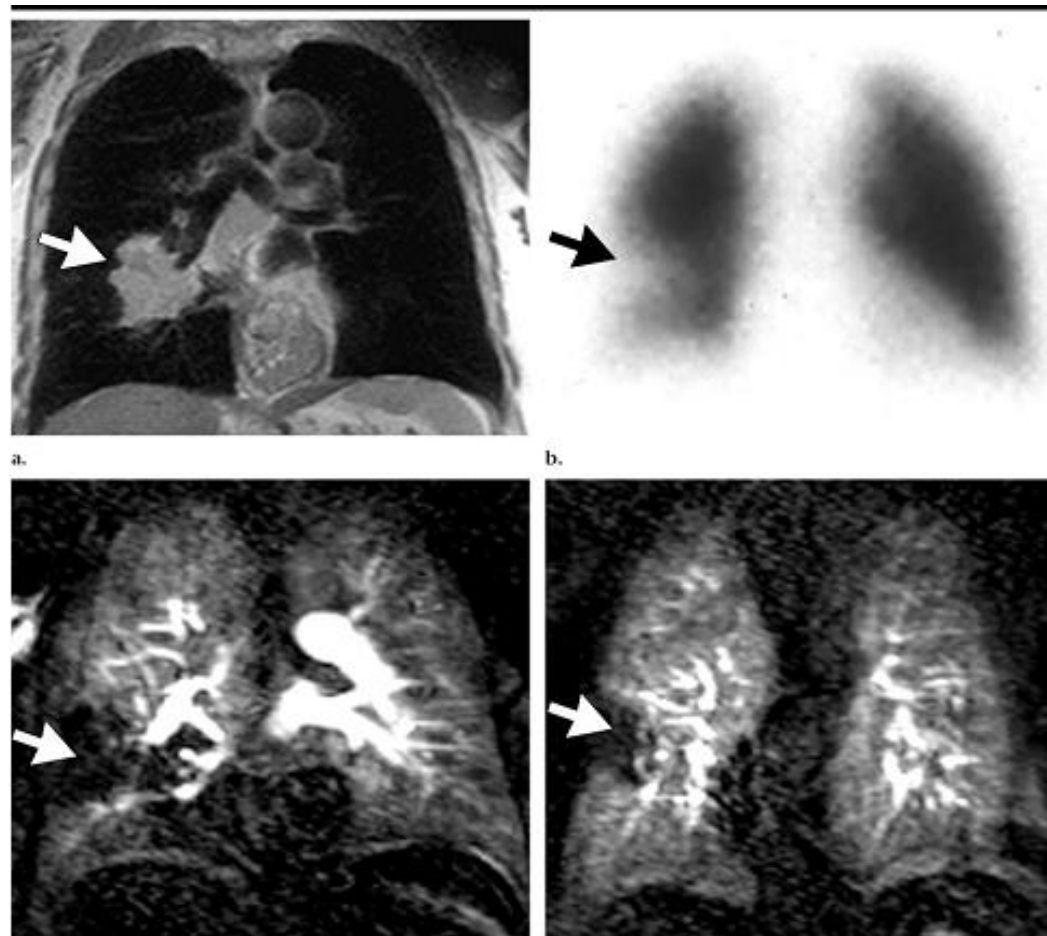


MR perfuze plic

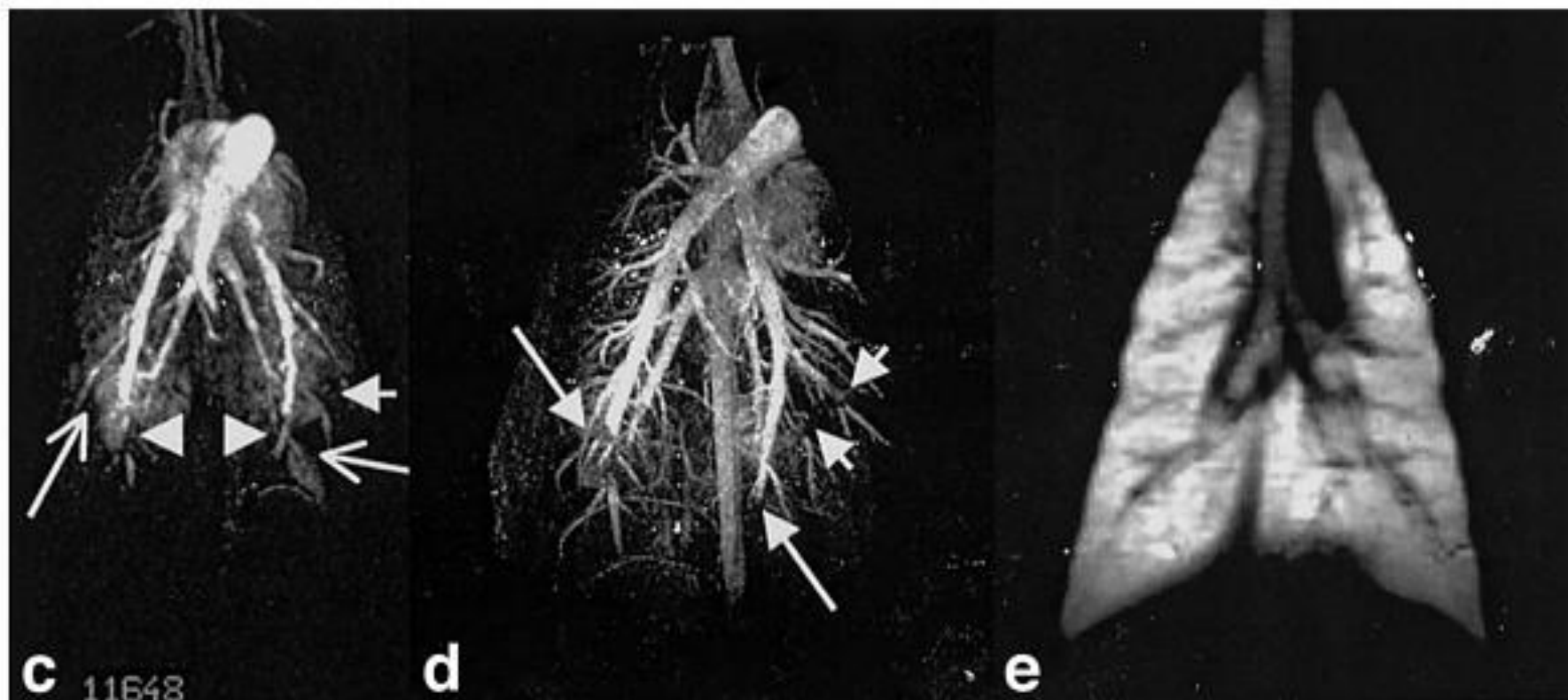




MR perfuze plic



MR ventilační sken (experimentální)



Závěr – plicní hypertenze

1. MRI není schopno semikvantifikovat plicní hypertenzi, pouze detekuje její nepřímé známky



není indikací pro MRI diagnostika plicní hypertenze

2. Uvádět suspekci na PHT u MR vyšetření
 - morfologické změny PK
 - dilatace plicnice a její pulsatilita

Závěr – plicní hypertenze

- „zlatý standard“ pro stanovení objemů, hmotnosti a systolické funkce pravé komory
- nízká interpersonální variabilita měření
- napomáhá určit prognózu onemocnění



- možnou indikací je dlouhodobé sledování pacientů s chronickou plicní hypertenzí v terciálních centrech

MRI – možnosti

Table 35-1 Comparison of Cardiovascular Magnetic Resonance, Echocardiography and Right Heart Catheterization for Characterizing the Right Heart and Pulmonary Artery

Parameter	Cardiovascular Magnetic Resonance	Echocardiography	Right Heart Catheterization
RV volumes	++++	++	+
RV ejection fraction	++++	++	+
RV stroke volume	++++	++	+
RV mass	+++	+	
RV strain	+++	++	
RV pressure	+	+++	++++
RV remodeling (septal curvature)	+++	++	
Tricuspid regurgitation	++	+++	+
Miscellaneous (pericardial effusion, pulmonary embolism)	+++	++	+
RA volume	+++	++	
RA pressure	++	++	+++
PA size	+++	++	+
PA distensibility	+++	+	
Quantitative lung flow	+++	+	+

PA, pulmonary artery; RA, right atrium; RV, right ventricle.

Source: Adapted from Benza R, Biederman R, Murali S, Gupta H. Role of cardiac magnetic resonance imaging in the management of patient with pulmonary arterial hypertension. *J Am Coll Cardiol.* 2008;52:1683–1692.

Závěr – trombembolická nemoc

MRI je obecně metodou 3. volby

- MRA plicnice metodou druhé volby (po CTA)
pozn.: při jednoznačně závažné alergické reakci na jódovou k.l. !!
- MR perfuze plic metodou druhé volby (po V/P skenu)
pozn.: není v praxi možnost provést MR ventilační sken
- kombinovat obě metody během jednoho vyšetření!

Doporučení pro... | Guidelines

Doporučené postupy Evropské kardiologické společnosti pro diagnostiku a léčbu akutní plicní embolie, verze 2014.

Stručný přehled vypracovaný Českou kardiologickou společností

(2014 ESC Guidelines on the diagnosis and management of acute pulmonary embolism. Summary document prepared by the Czech Society of Cardiology)



ČESKÁ KARDIOLOGICKÁ SPOLEČNOST
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3.7 Magnetická rezonanční angiografie

Tato metoda, i když je slibná, zatím není pro klinickou praxi doporučena.

2015 ESC/ERS Guidelines for the diagnosis and treatment of pulmonary hypertension

The Joint Task Force for the Diagnosis and Treatment of Pulmonary Hypertension of the European Society of Cardiology (ESC) and the European Respiratory Society (ERS)

Endorsed by: Association for European Paediatric and Congenital Cardiology (AEPC), International Society for Heart and Lung Transplantation (ISHLT)

5.1.8 Cardiac magnetic resonance imaging

CMR imaging is accurate and reproducible in the assessment of RV size, morphology and function and allows non-invasive assessment of blood flow, including stroke volume, CO, pulmonary arterial distensibility and RV mass.

In patients with suspected PH, the presence of late gadolinium enhancement, reduced pulmonary arterial distensibility and retrograde flow have high predictive value for the identification of PH; however, no single CMR measurement can exclude PH.^{60–62} In patients with PH, CMR may also be useful in cases of suspected CHD if echocardiography is not conclusive.

Contrast-enhanced and unenhanced MR angiography have a potential in the study of the pulmonary vasculature in patients with suspected CTEPH, particularly in clinical scenarios such as suspected chronic embolism in pregnant women, young patients or when iodine-based contrast media injection is contraindicated.⁶³

CMR provides useful prognostic information in patients with PAH both at baseline and at follow-up.^{64–66}

Děkuji Vám za pozornost