JAK OPTIMÁLNĚ IMPLANTOVAT A OPTIMALIZOVAT NASTAVENÍ BIVENTRIKULÁNÍCH CRT PŘÍSTROJŮ

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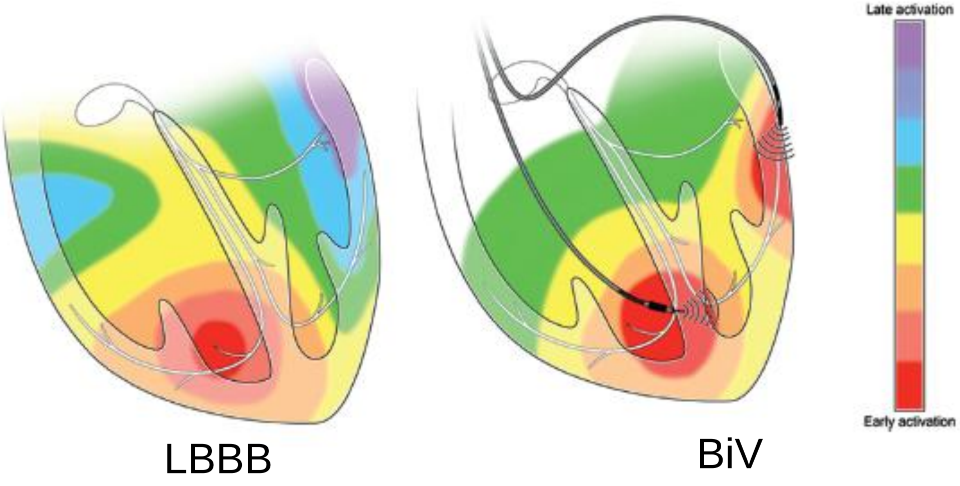
Kardiologická klinika UK 2.LF a FN Motol

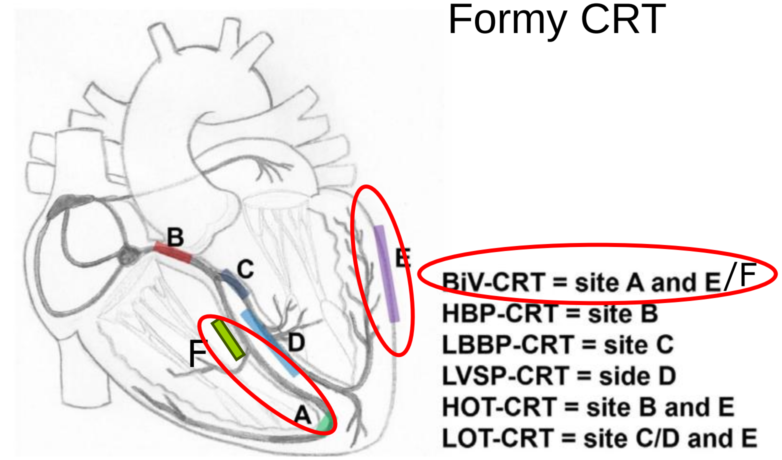
XXII. české a slovenské sympozium o arytmiích a kardiostimulaci,
Clarion hotel Olomouc 9.11.2025

Aktivace komor

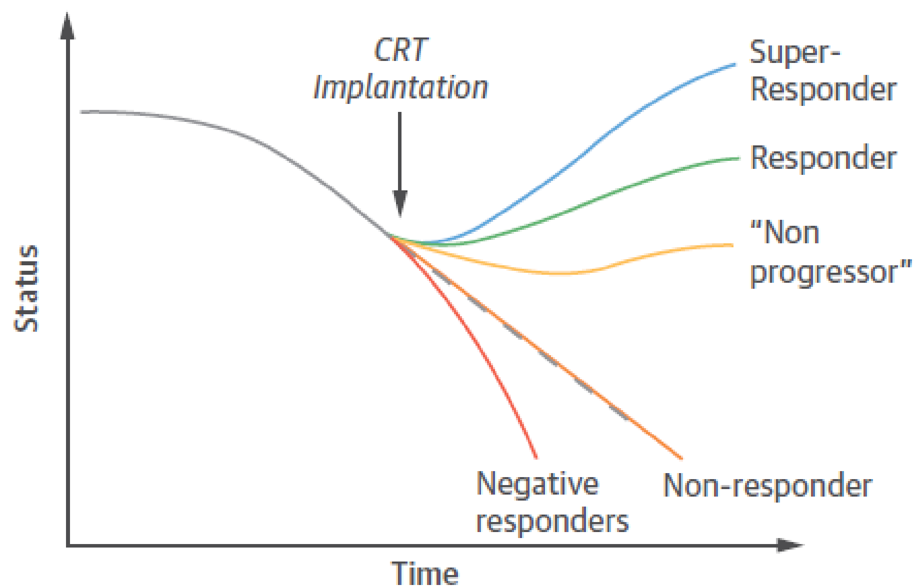


Madhavan, JACC 2017;69:211–35

Formy CRT



J. Cardiovasc. Dev. Dis. 2024, 11, 76



Steffel, Circulation 2014;130:87–90

Jak dosáhnout maximálního efektu CRT?

Před implantací → Selekce kandidátů CRT

- Symptomatické srdeční selhání
- LVEF ≤ 35%
- LBBB x nonLBBB
- Šíře QRS (≥ 150ms)
- Vysoké % komorové stimulace trvalého PM

Implantace

- Správné umístění LV elektrody- místo pozdní aktivace
- Správné umístění RV elektrody

Po implantaci → Dosažení maximální resynchronizace a % BiV stimulace

- Optimalizace morfologie stimulovaného QRS komplexu
- Zajištění „true“ BiV stimulace ve >95% času
- Léčba frekventních KES
- Dobrá „rate control“ fibrilace síní (včetně případné RFA AVN)
- ECHO optimalizace AV a VV zpoždění

Selekce kandidátů BiV

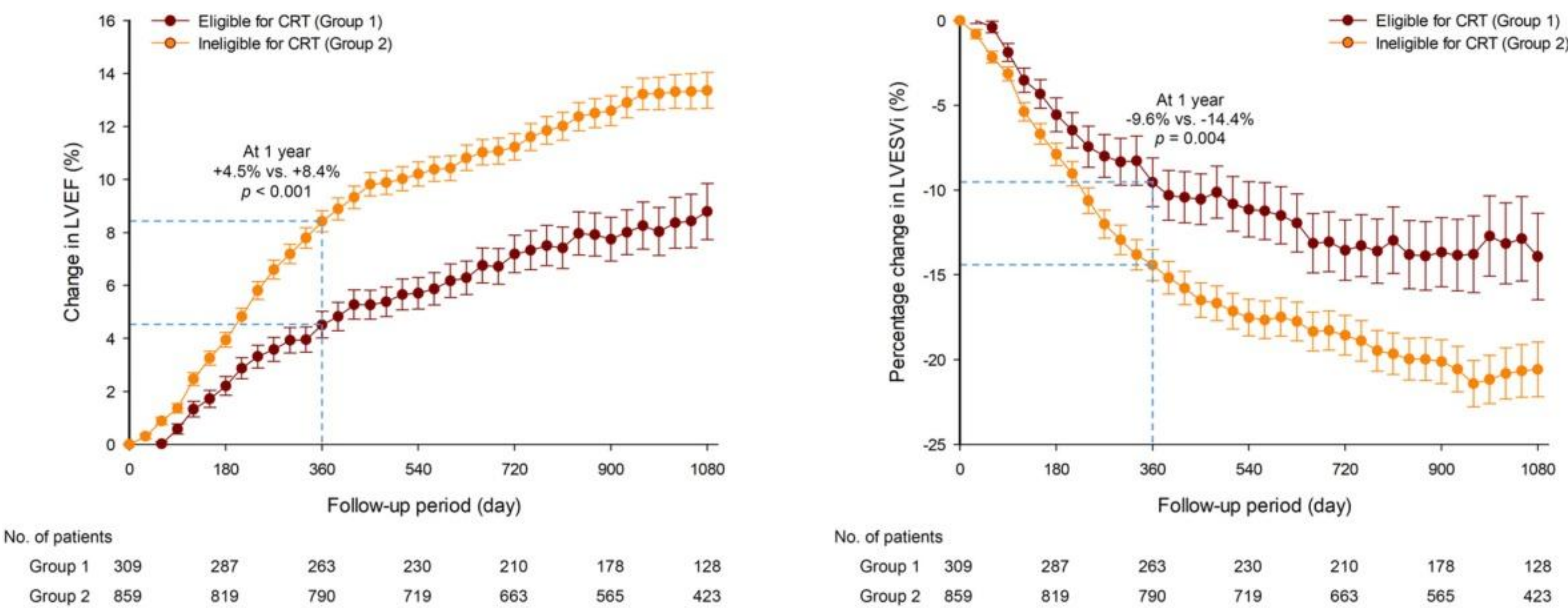
ESC
European Society of Cardiology
European Heart Journal (2021) **00**, 1–94
doi:10.1093/eurheartj/ehab364
ESC GUIDELINES

2021 ESC Guidelines on cardiac pacing and cardiac resynchronization therapy

HFrEF s LVEF ≤ 35%
NYHA II-IV
Optimalizovaná medikace

??? NYHA I – MADIT CRT:
265 pac (7,8%)- FU 7let
- nesignifikantní ↓ mortality
  u ischemiků s LBBB

Clinical impacts of sacubitril/valsartan on patients eligible for CRT



(A) *ESC Heart Failure 2022, Volume: 9, Issue: 6, 3825-3835* (B)

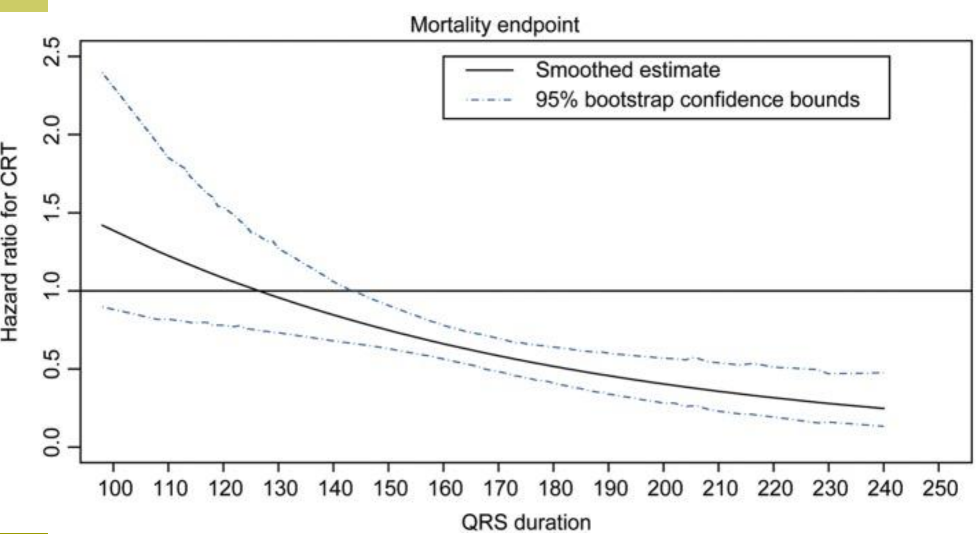
Selekce kandidátů BiV Dyssynchronie

Šíře QRS komplexu
→ celkové trvání aktivace komor

Morfologie QRS komplexu
→ aktivační sekvence komor

QRS≥130ms = 2x ↑ mortalita

For every 10 ms increase in QRS duration, mortality rate increases 10%
Kalahasti V, AJC 2003 Oct 1;92(7):798-803



Cleland JG, European Heart Journal (2013) 34, 3547–3556

Recommendations	Class[a]	Level[b]
LBBB QRS morphology		
CRT is recommended for symptomatic patients with HF in SR with LVEF ≤35%, QRS duration ≥150 ms, and LBBB QRS morphology despite OMT, in order to improve symptoms and reduce morbidity and mortality.[37,39,40,254–266,283,284]	I	A
CRT should be considered for symptomatic patients with HF in SR with LVEF ≤35%, QRS duration 130–149 ms, and LBBB QRS morphology despite OMT, in order to improve symptoms and reduce morbidity and mortality.[37,39,40,254–266,283,284]	IIa	B
Non-LBBB QRS morphology		
CRT should be considered for symptomatic patients with HF in SR with LVEF ≤35%, QRS duration ≥150 ms, and non-LBBB QRS morphology despite OMT, in order to improve symptoms and reduce morbidity.[37,39,40,254–266,283,284]	IIa	B
CRT may be considered for symptomatic patients with HF in SR with LVEF ≤35%, QRS duration 130–149 ms, and non-LBBB QRS morphology despite OMT, in order to improve symptoms and reduce morbidity.[273–278,281]	IIb	B
QRS duration		
CRT is not indicated in patients with HF and QRS duration <130 ms without an indication for RV pacing.[264,282]	III	A

ESC guidelines 2021 (cardiac pacing)

Selekce kandidátů BiV Dyssynchronie

Šíře QRS komplexu
→ celkové trvání aktivace komor

Morfologie QRS komplexu
→ aktivační sekvence komor

LBBB
Non-LBBB

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Non-LBBB QRS morphology		
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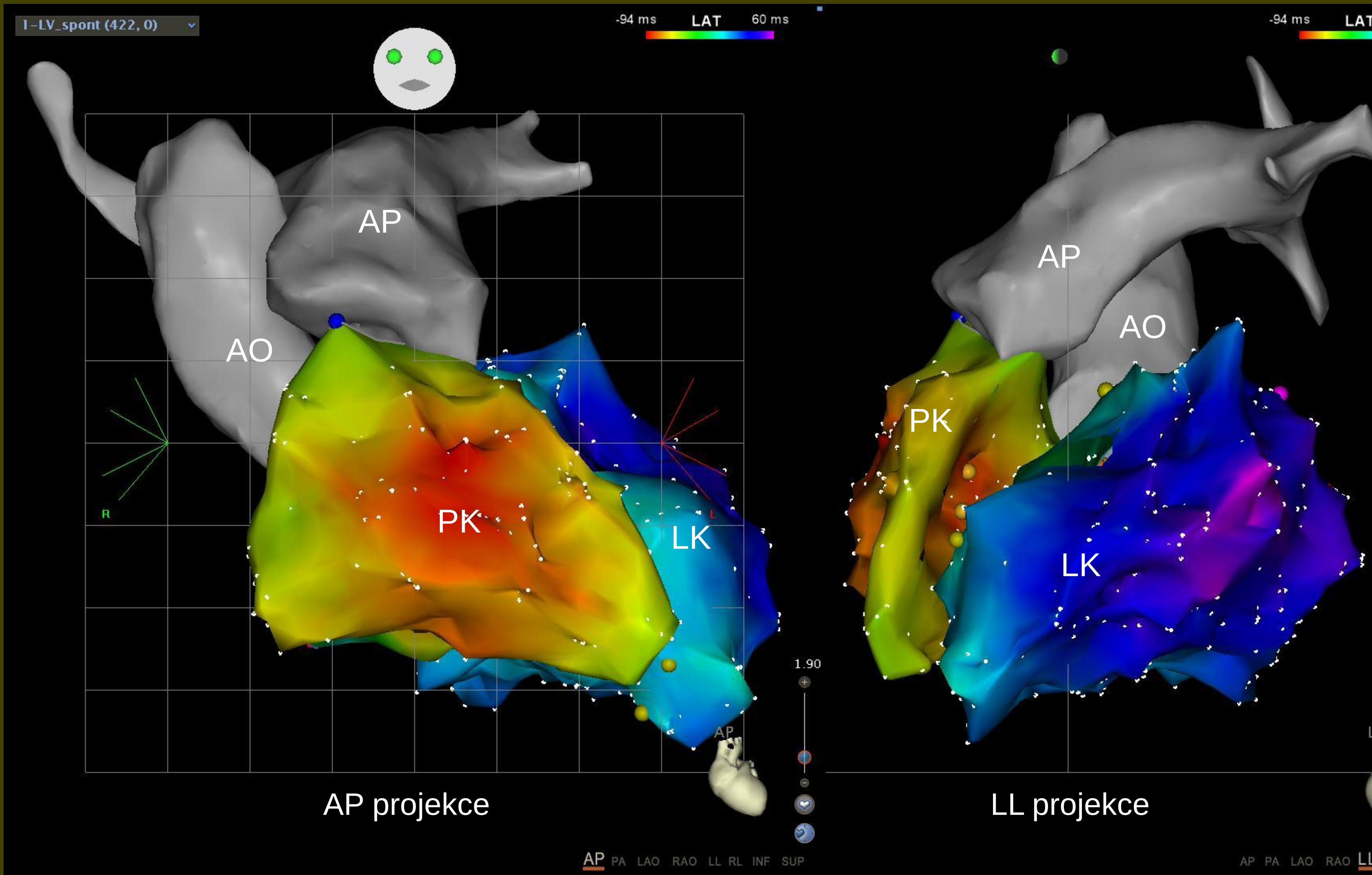
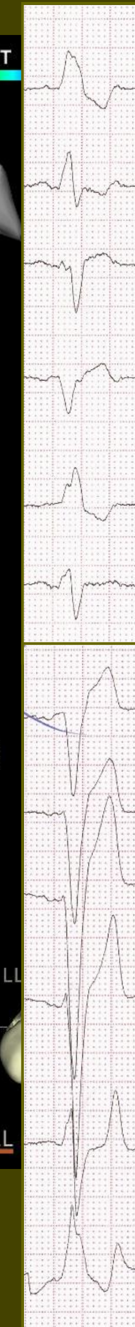
CRT is not indicated in patients with HF and QRS duration <130 ms without an indication for RV pacing.[264,282]	III	A

ESC guidelines 2021 (cardiac pacing)

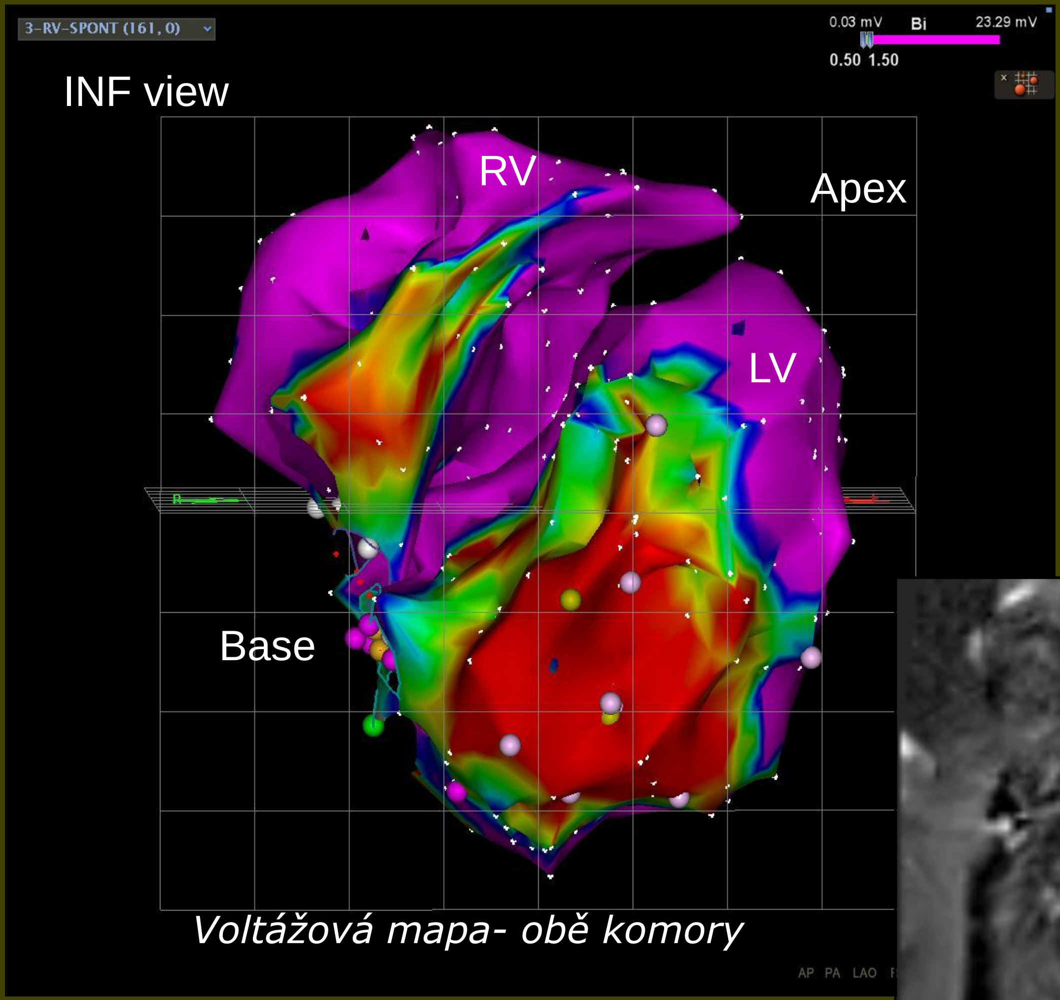
Riedlbauchová L, PACE 2020;43(5):486-494





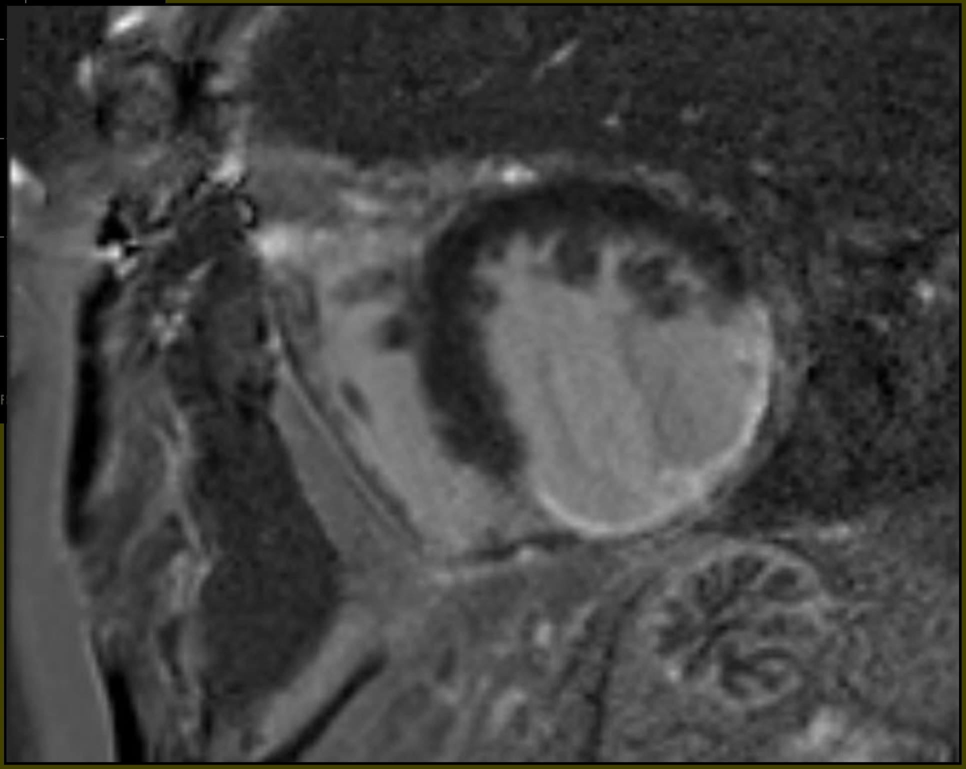
Aktivační sekvence obou komor v přítomnosti typické LBBB

- časná aktivace volné stěny PK, následuje aktivace septa, mezikomorové zpoždění 38±18ms.
- místo pozdní aktivace lokalizováno vždy v bazální nebo střední třetině LK laterálně.



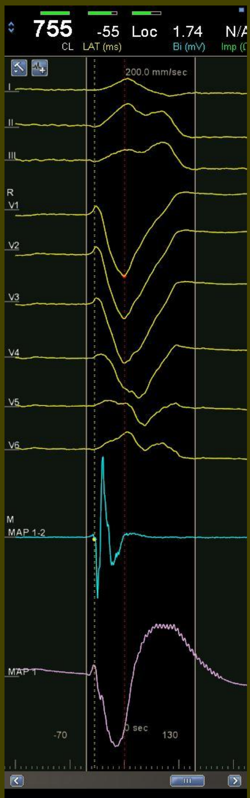
P2- ICHS
st.p.IM spodní stěny

LGE transmurálně,
24% masy myokardu LK

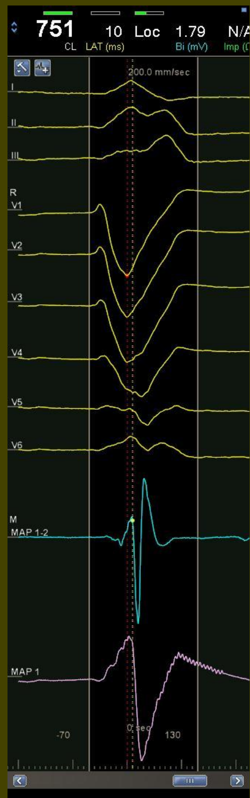


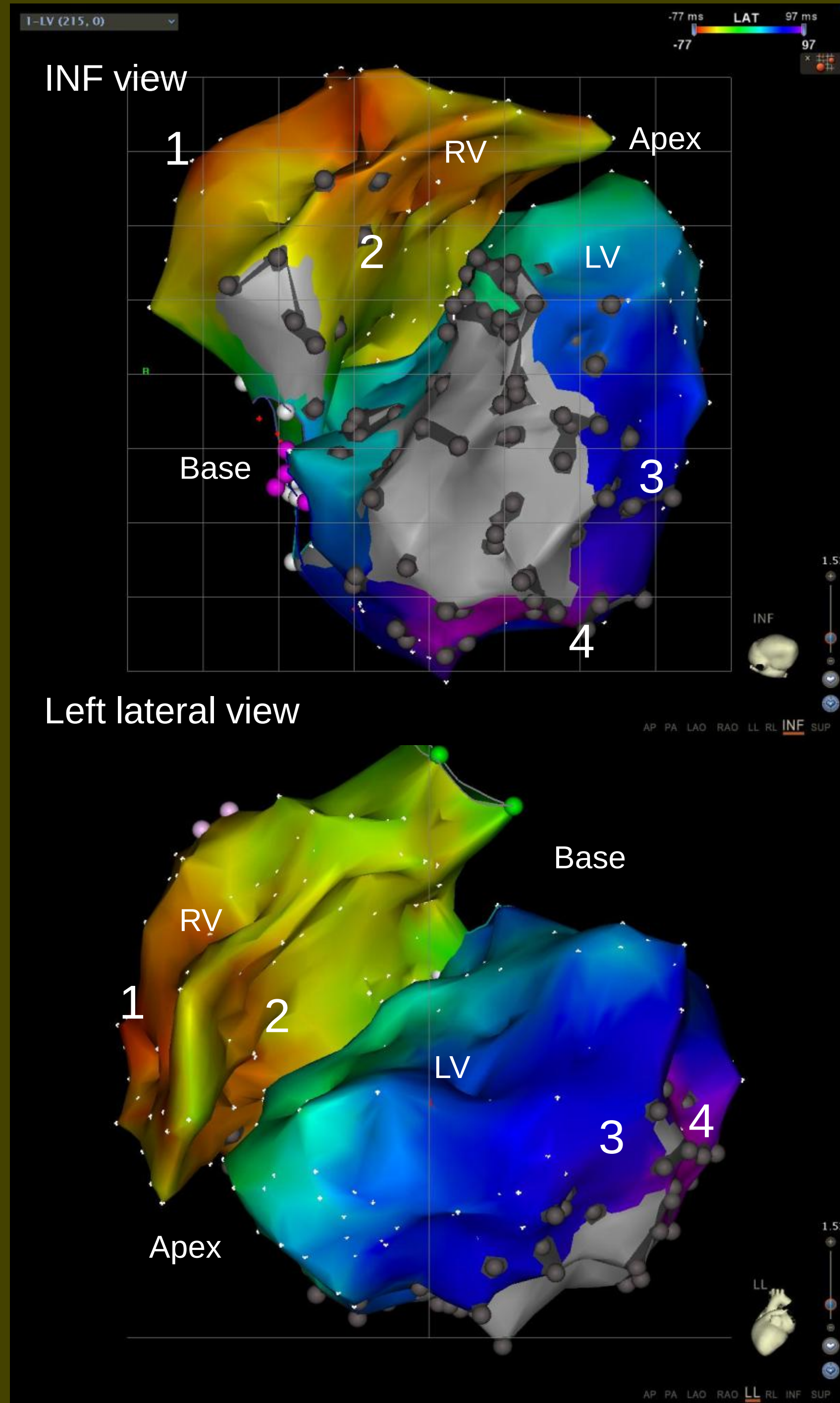
Riedlbauchová L, PACE 2020;43(5):486-494

Point 1
RV free wall

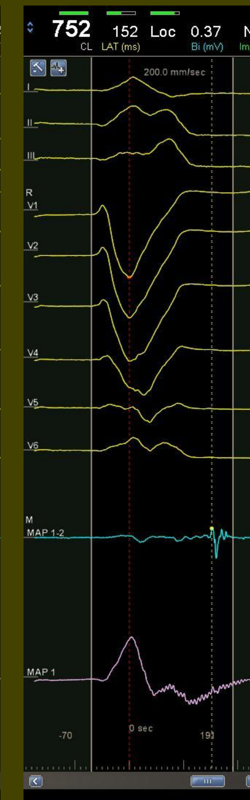


Point 2
IVS





Point 4
LV Inferolat-base



P2- ICHS
st.p.IM spodní stěny

„True“ LBBB

* QRS ≥120ms
* Svody V1 a V2:
    * dominantní S (QS nebo rS)
    * mírné STE a pozitivní asymetrická T vlna
* Svody I, aVL, V5, V6:
    * široký, monofázický R kmit
    * absence Q kmitu
    * většinou mírné STD a neg.asymetrická T vlna
* Svod aVR: * většinou QS komplex s pozitivní T vlnou

* mid-QRS notching/ slurring alespoň ve 2 svodech (V1, V2, V5, V6, I, aVL)
* R-wave peak time >60ms ve V5 nebo V6

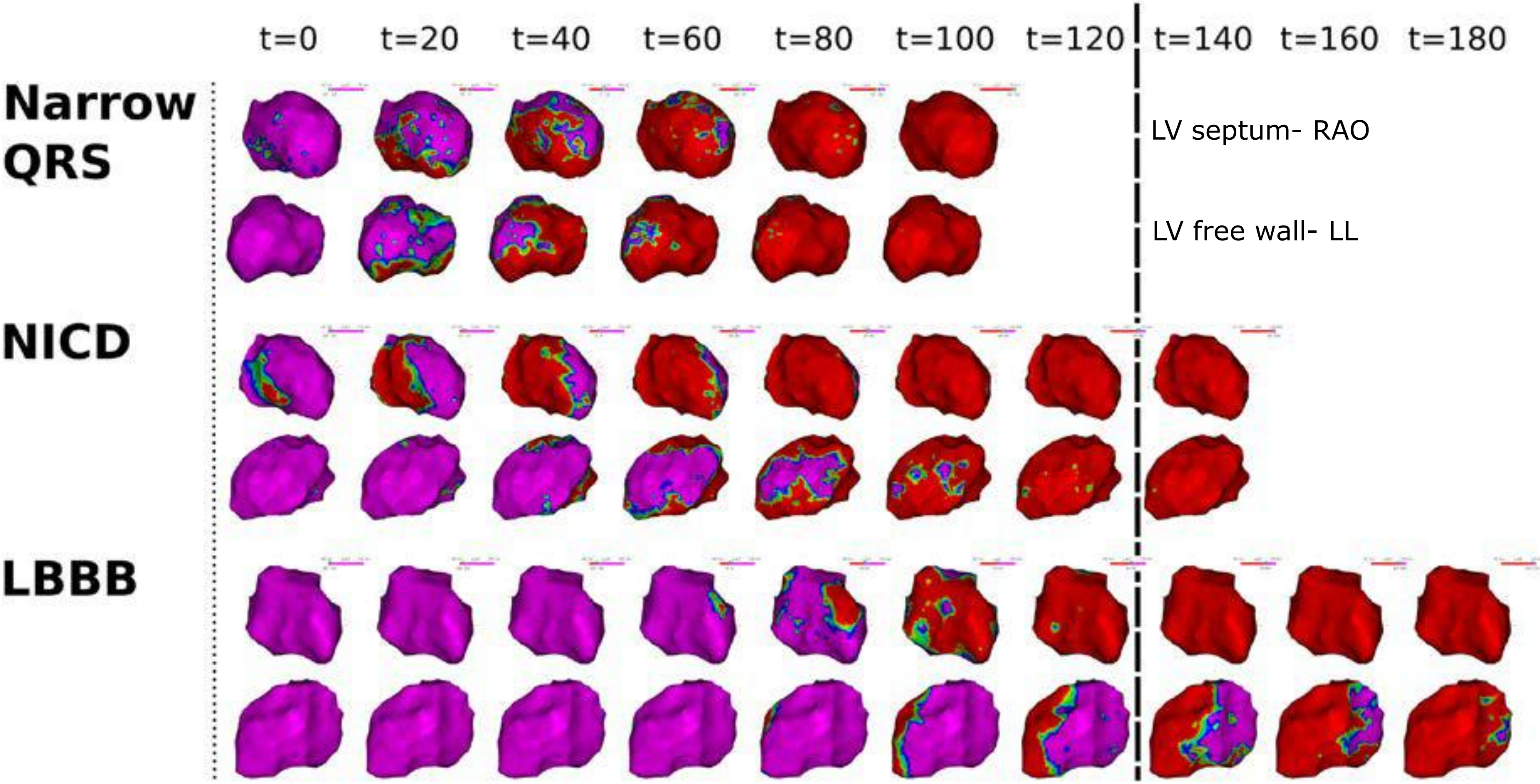
* Patients with LBBB with mid-QRS notching or slurring in front-to-back (V1, V2) or left-to-right leads (I, aVL, V5, V6), have better response to CRT than do patients with LBBB without notches or with intraventricular conduction delays.

* Presence of LBBB with mid-QRS notching or slurring is a strong predictor of super-response to CRT and may help to identify patients suitable for this treatment.

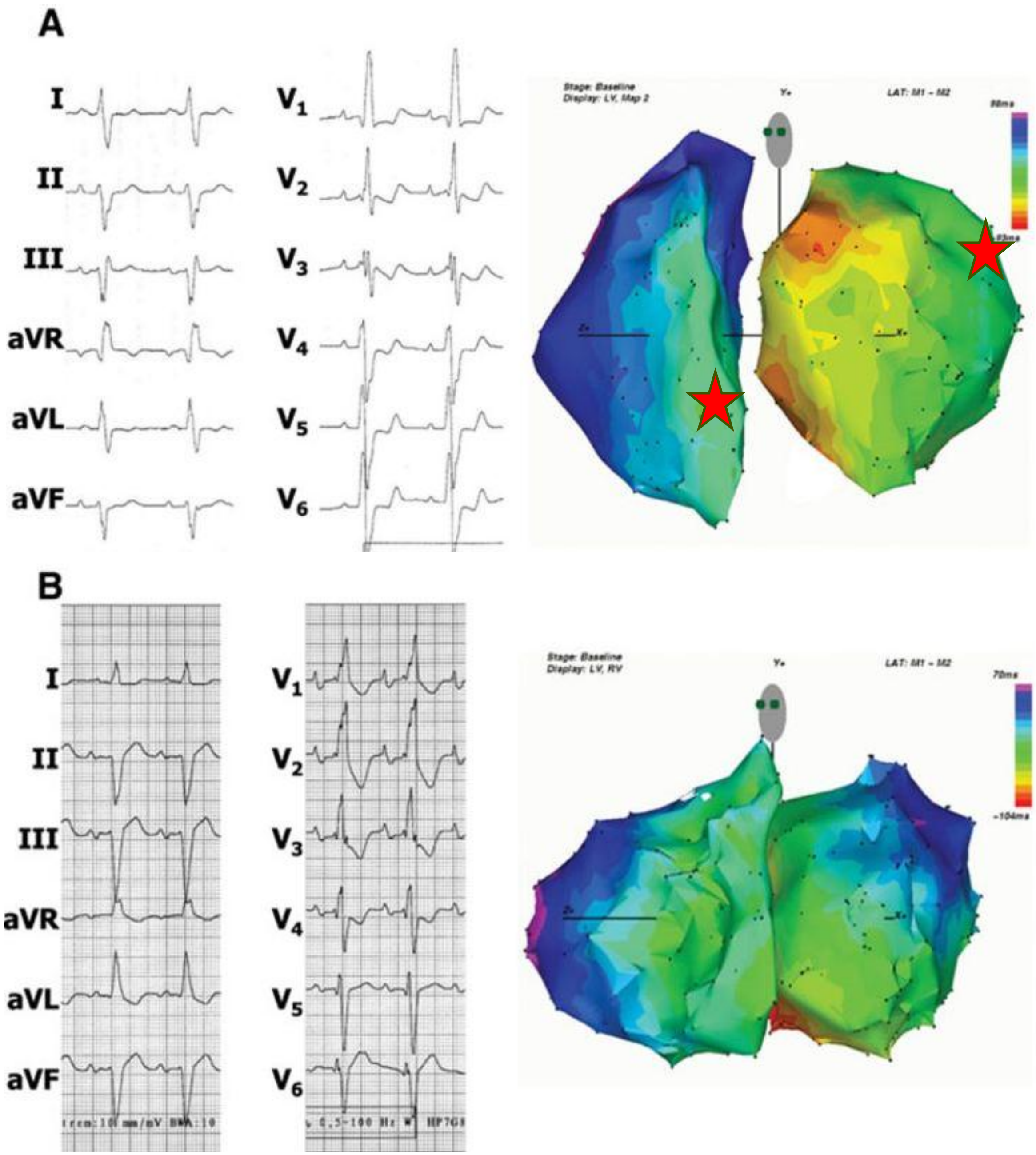
Tian Y, Europace 2013;15:1499–1506

Study	Mean QRS Duration	Total number of patients	Proportion of patients with conduction abnormality		
			LBBB	RBBB	IVCD
Prospective randomized studies*					
PATH-CHF I[1]	174±30	42	93%	7%	0%
PATH-CHF II[2]	155±20	86	88%	5%	6%
CONTAK CD[3]	155±27	490	54%	14%	33%
MIRACLE[4]	166±21	453	80%	11%	9%
MIRACLE ICD II[5]	166±24	186	NA	17%	NA
COMPANION[6]	158	1520	71%	11%	18%
CARE-HF[7]	160†	813	94%	5%	1%
REVERSE[8]	151±23	680	54%	8%	19%
MADIT-CRT[9]	152±18	1817	70%	13%	17%
RAFT[10]	158±24	1866	69%	9%	11%

Auricchio A, Circ Arrhythm Electrophysiol. 2014;7:532-542.



Derwal N, Circ Arrhythm Electrophysiol. 2017



RBBB

* QRS ≥120ms
* Svody V1 a V2:
  * rsR´ komplex+ slurring R´
  * STD a neg. asymetrická T vlna
* Svody V4-V6, I, aVL:
  * hluboký a široký S kmit
  * slurring S kmitu
* Svod aVR:
  * QR komplex+ slurring R+ neg.T

„RBBB masking LBBB“

* Svody I, aVL:
  * široký R kmit + slurring/ notching
* sklon osy doleva
  * I,aVL- dominantně pozitivní QRS
  * II, III, aVF- dominantně neg.QRS

RBBB+LAH x RBBB:
- menší reverzní remodelace
- srovnatelná mortalita

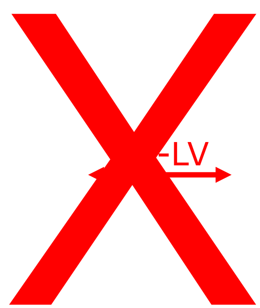
(MADIT-CRT)

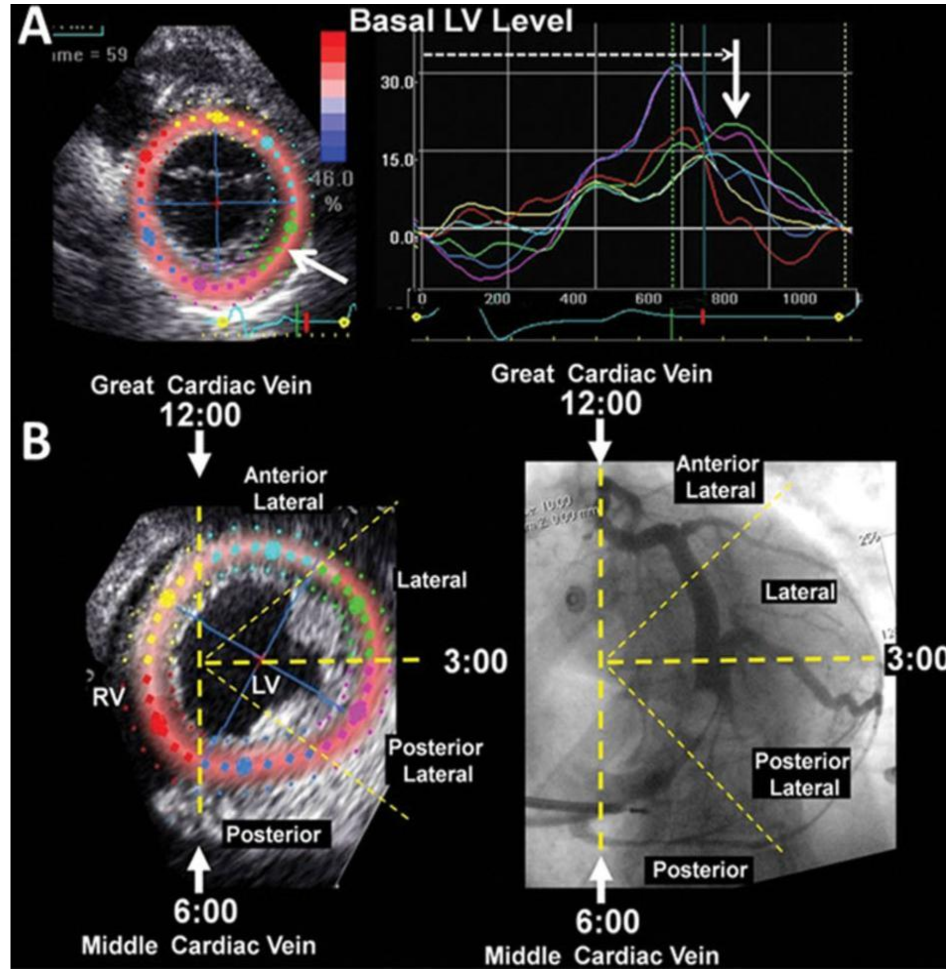
Auricchio A, Circ Arrhythm Electrophysiol. 2014;7:532-542.

Umístění LK elektrody

NE: LV anterior/ LV apex

Speckle tracking- latest peak radial strain
- dyssynchrony





Yagishita
JACC EP 2021;7:796–805

ENHANCE-CRT

žádný rozdíl v kompozitním endpointu
(↓NYHA, HF hospitalizace , úmrtí)

TARGET study *(Am Coll Cardiol 2012;59:1509–18)*

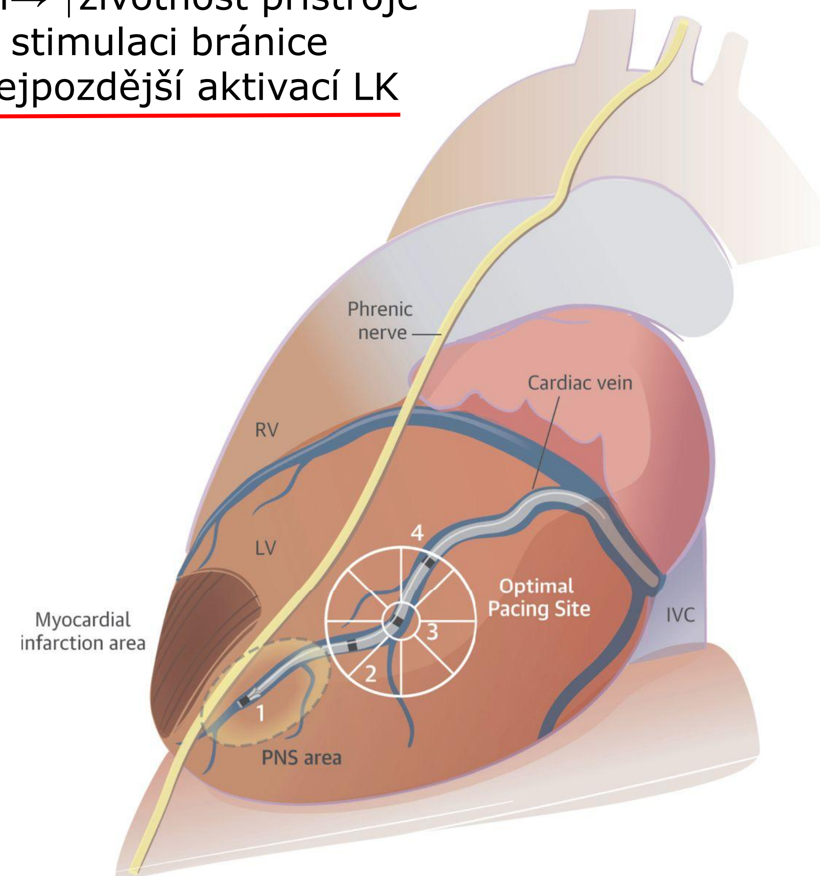
STARTER study *(Circ Heart Fail 2013;6:427–34)*

Variabilita větvení CS
Stabilita el. v cílové větvi
Dobré stimulační parametry

Kvadripolární elektrody

- stabilizace elektrody v cílové větvi
- stimulace s nejnižší energií→ ↑životnost přístroje
- možnost reprogramace při stimulaci bránice
- výběr místa se skutečně nejpozdější aktivací LK

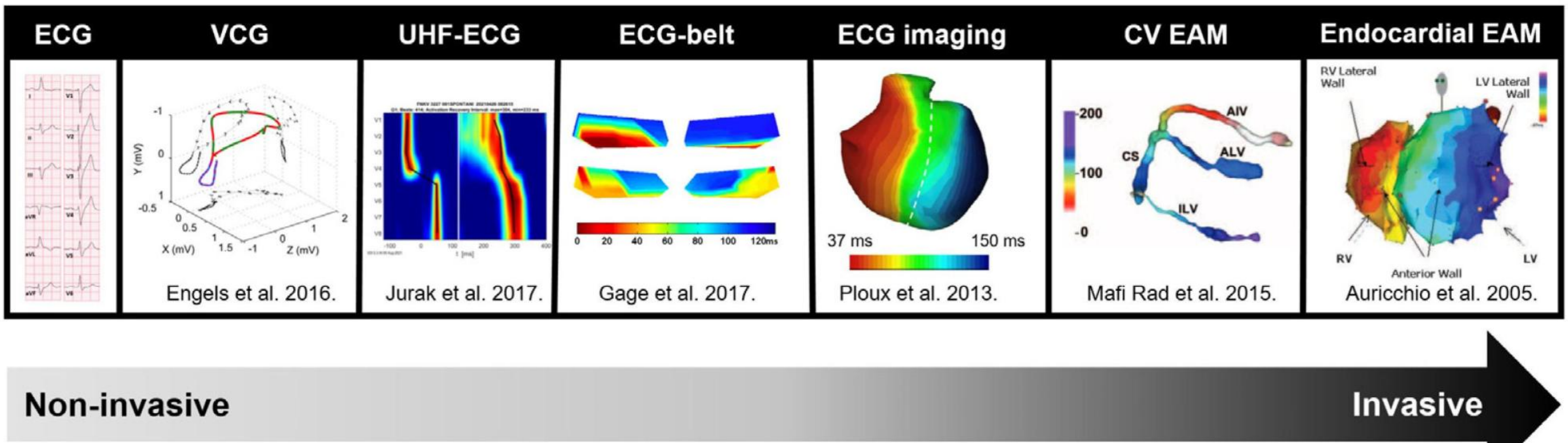
Bipolární Kvadripolární



van Everdingen, W.M. et al. J Am Coll Cardiol EP. 2015; 1(4):225-37.

Detailnější vyšetření aktivační sekvence komor

Elektrická dyssynchronie



Nguyen. J. Cardiovasc. Dev. Dis. 2024, 11, 76.

Mechanická dyssynchronie

ECHO, MRI

Jak dosáhnout maximálního efektu CRT?

Před implantací → Selekce kandidátů CRT

Symptomatické srdeční selhání
LVEF ≤ 35%
LBBB x nonLBBB
Šíře QRS (≥ 150ms)
Vysoké % komorové stimulace trvalého PM

Implantace

Správné umístění LV elektrody- místo pozdní aktivace
Správné umístění RV elektrody

Po implantaci → Dosažení maximální resynchronizace a % BiV stimulace

„True“ BiV stimulace ve >95% času
Léčba frekventních KES
Dobrá „rate control“ fibrilace síní (včetně případné RFA AVN)
ECHO optimalizace AV a VV zpoždění

Efekt CRT = BiV stimulace ≥92-95% času

Příčiny sníženého % BiV stimulace:

- Neadekvátní nastavení AV delay u SR
  - při vyšších SF se uplatní spont. převod na komory

→ *úprava nastavení AV zpoždění reprogramací*

- Vznik fibrilace síní nebo jiné SVT se spont. převodem na komory

→ *léčba SVT (kontrola rytmu- antiarytmika, ablace)*
→ *dobrá „rate control"(včetně případné RFA AVN)*

- Výskyt zvýšené extrasystolie (SVES, KES)

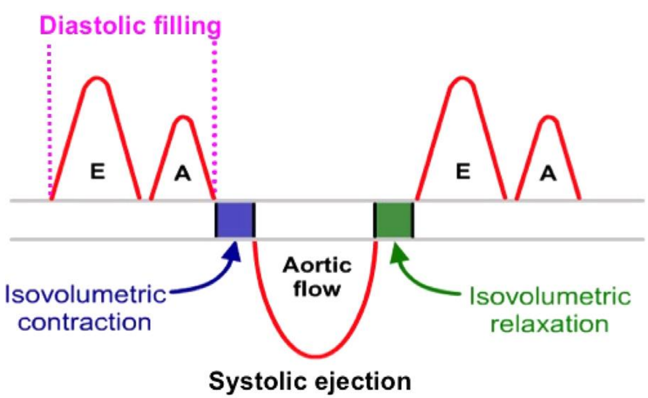
→ *antiarytmika, ablace*

- Poruchy sensingu/ pacingu

Optimalizace
AV a VV delay

ECHO

PW Doppler of mitral inflow
Mi VTI
MR jet
Aortic/ LVOT VTI
Tissue doppler imaging
Speckle tracking strain imaging



Brabham, Journal of Arrhythmia 29 (2013) 153–161

Table 1: Options for Optimisation of Atrioventricular Delays and Ventriculoventricular Timing in CRT Pacing

Echocardiographic Methods	
Ritter: pulsed wave Doppler of mitral inflow AV optimisation only	Doppler echocardiographic measurement of the time of MVC. AV delay [QRS_{onset}–MVC_{SAVD}–QRS_{onse}–MVC_{LAVD}]+ SAVD, where SAVD and LAVD are short (50–60 msec) and long AV delays (160–200 msec), respectively, and –MVC is the time interval between QRS onset (QRS_{onset}) and MVC at short and long AV delay
Iterative: pulsed wave Doppler of mitral inflow AV optimisation only	AV delay is programmed by assessing mitral inflow pattern to allow for biventricular capture and separation of E and A waves without A wave truncation
Simplified (Meluzin): pulsed wave mitral inflow AV optimisation only	Longest AV delay with full biventricular capture – (5–10 msec) – (the time from the end of the A wave to onset of systolic MR)
Diastolic MR method (Ishikawa) AV optimisation only	Long AV delay is set to observe diastolic MR, and the LAVD – duration of diastolic MR is the optimal AV delay
Aortic or LVOT VTI: continuous wave Doppler of aortic flow AV and VV optimisation	AV delay and VV timing are serially programmed to achieve maximum aortic or LVOT VTI
Mitral VTI AV and VV optimisation	AV delay and VV timing are serially programmed to maximise diastolic mitral inflow of both E and A wave
MR jet AV and VV optimisation	The slope of continuous wave Doppler of the MR jet is measured as a marker of LV contractility. The AV and VV delays are serially programmed to maximise dP/dt
Tissue Doppler imaging AV and VV optimisation	VV timings are optimised to the maximum tissue Doppler velocity sum of all 16 segments of the LV
Speckle tracking strain imaging VV optimisation only	VV timings are optimised to peak global longitudinal strain of the LV
Device-based Methods	
SmartDelay™ (Boston Scientific) AV optimisation only	IEGM-based method that uses sensed atrial and paced atrial AV intervals and intrinsic RV to LV conduction time to calculate AV delay to allow for fusion between native septal activation and biventricular pacing
QuickOpt™ (Abbott) AV and VV optimisation	IEGM-based method that calculates AV interval based on length of RA lead IEGM duration to allow for ventricular pacing to occur after atrial depolarisation is complete. VV interval is calculated by comparing instrinic conduction between the RV and LV IEGMs and conduction time between RV and LV during RV and LV pacing
AdaptiveCRT™ (Medtronic) AV and VV optimisation	IEGM-based method that dynamically calculates AV delay every minute. LV-only pacing is delivered for native AV interval <220 msec and AV delay is time from RA sense or RA pace to RV sense – 40 msec. If instrinic AV interval >220 msec, then biventricular pacing is delivered after the end of the atrial IEGM and >50 msec before RV sense. VV interval is based on AV interval and time between RV sense and end of the ventricular IEGM on the far field signal
SyncAV™ (Abbott) AV optimisation only	IEGM-based method that calculates and dynamically sets AV delay by assessing instrinic AV delay every 256 beats and subtracting a programmed offset (50 msec nominally, but can be set to 10–60 msec)
SonR™ (LivaNova) AV and VV optimisation	Using a lead-based micro-accelerometer to detect mechanical vibrations (endocardial acceleration signal), AV and VV delays are dynamically optimised weekly during rest and exercise to maximise the peak endocardial acceleration signal, which is a surrogate for LV contractility
CRT AutoAdapt™ (Biotronic) AV and VV optimisation	IEGM-based method similar to AdaptiveCRT. AV interval to RV and LV is measured based on sensed and paced atrial beats. LV-only pacing is delivered if A-paced AV interval is <250 msec and A to LV interval is longer than A to RV interval, otherwise biventricular pacing is delivered. AV delay is dynamically set at 70% of AV interval or AV interval – 40 msec, depending on which is shorter
Other Methods	
Invasive haemodynamic AV and VV optimisation	An open-lumen micromanometer catheter or pressure wire directly placed in the LV is used to target maximum rate of increase of LV pressure (dP/dt_{max}) to optimise AV and VV timing
Impedance cardiography (Task Force® Monitor Systems, CNSystems) AV and VV optimisation	Multiple electrodes placed on the chest, neck, and abdomen measure transthoracic impedance. Increased aortic blood flow and cardiac output are associated with lower transthoracic impedance. AV and VV timings are optimised to target the lowest impedance value, which corresponds to maximum cardiac output
Acoustic cardiography (Audicor™, Inovise Medical) AV and VV optimisation	Using an ECG electrodes in V3 and V4 positions to detect the first, second and third heart sounds and the QRS, time from onset of the Q wave to the mitral component of S1 is measured (electromechanical activation time) and the strength of S3 is assessed. AV and VV timings are optimised for the shortest electromechanical activation time and strongest S3
Finger plethysmography AV and VV optimisation	AV and VV delays are optimised using finger oximetry to target the maximum pulse amplitude of the finger plethysmogram wave form
Noninvasive blood pressure measurement AV and VV optimisation	AV and VV delays optimised with serial blood pressure measurements targeting the peak mean systolic blood pressure over multiple measurements

Atrioventricular = AV; IEGM = intracardiac electrogram; LAVD = long atrioventricular delay; LVOT = left ventricular outflow tract; MR = mitral regurgitation; MVC = mitral valve closure;

Thomas G. Arrhythmia & Electrophysiology Review 2019;8(3):220–7.

Závěrem

Selekce kandidátů CRT
Správné umístění stimulační(ch) elektrod(y)
Dosažení maximální resynchronizace a % BiV stimulace

CRT non-respondér
(cca 30%)

- **RTG na polohu elektrod** (AP, bočná)
- **12svod EKG** (nativ, RVP, LVP, BiV)
  - → Dislokace/ nevhodná poloha
    - → Selekce místa stimulace dle reziduální dyssynchronie
    - → Reprogramace (kvadripolární el.)
      - změna konfigurace LV stimulace
      - multipoint LV pacing
    - → Revize/ repozice/ zavedení přídatné LV elektrody/ CSP
    - → CRT OFF
- **Kontrola CIED**
  - → % BiV stimulace
  - Arytmie v paměti CIED → Léčba arytmií, dobrá „rate control“ AF
  - Profil SF (chron.kompetence) → Aktivace „R“
  - Algoritmy AV/ VV optimalizace → AVD/ VVD optimalizace
- **Farmakoterapie HFrEF** → Titrace terapie HFrEF
- **Laboratoř vč. NTproBNP** → Vyloučení jiné příčiny selhání, vyloučení anemie

Děkuji za pozornost

„Statická elektřina je strašný svinstvo. Přijďte znova až nebude takový sucho."

Selekce kandidátů BiV non-LBBB

QRS ≥ 150ms → prodloužené vedení v obou raméncích → CRT efektivní
(MADIT CRT)

RBBB + významná mechanická dyssynchronie (radiální strain) → CRT efektivní
(Hara H, Eur Heart J. 2012;33:2680–2691)

Recommendations	Class[a]	Level[b]
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QRS duration		
CRT is not indicated in patients with HF and QRS duration <130 ms without an indication for RV pacing.[264,282]	III	A

ESC guidelines 2021 (cardiac pacing)

„True“ BiV stimulace v >95% času

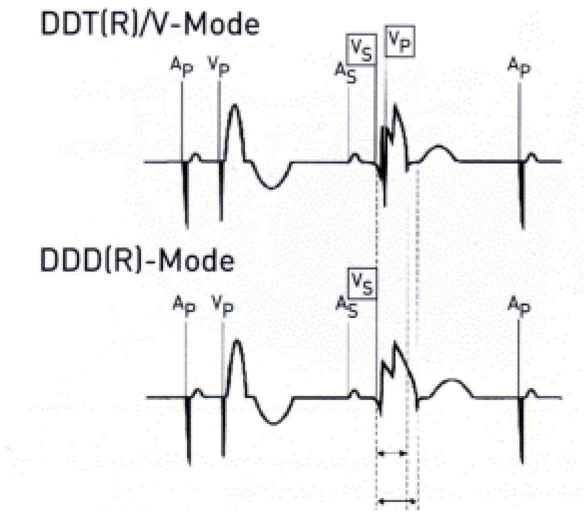
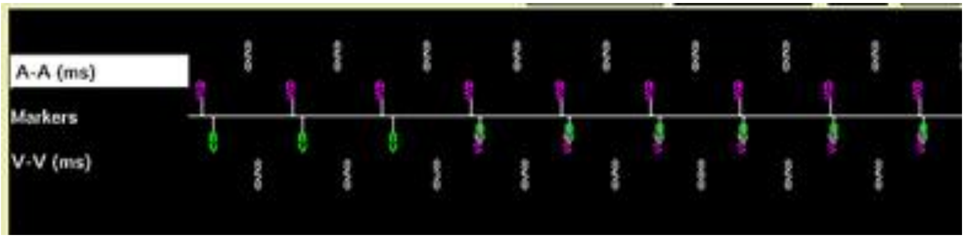
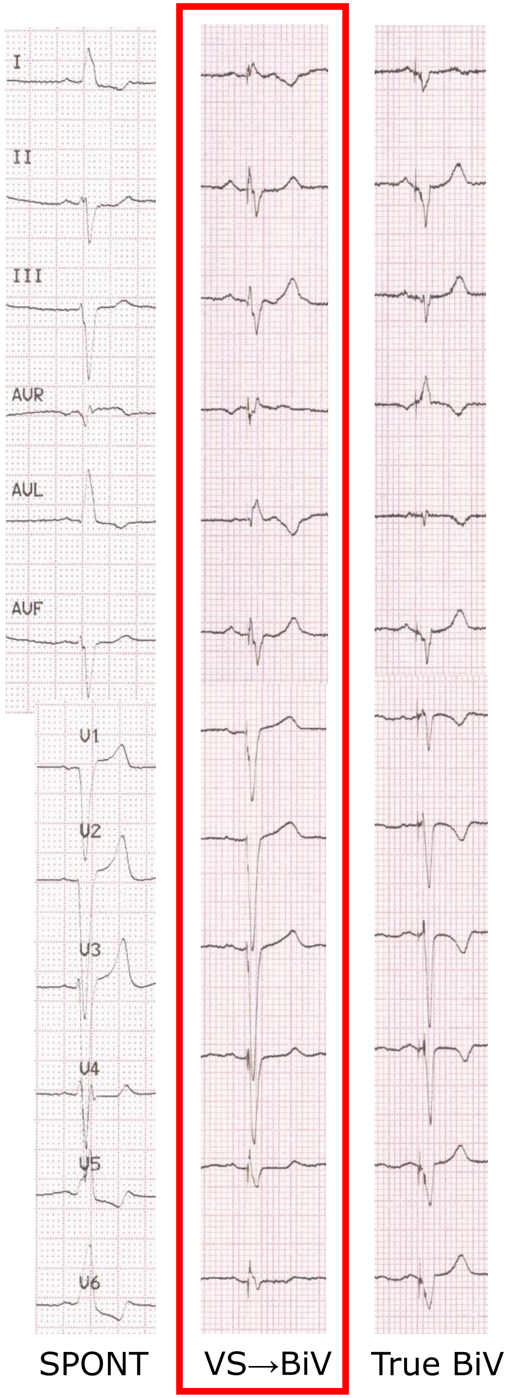
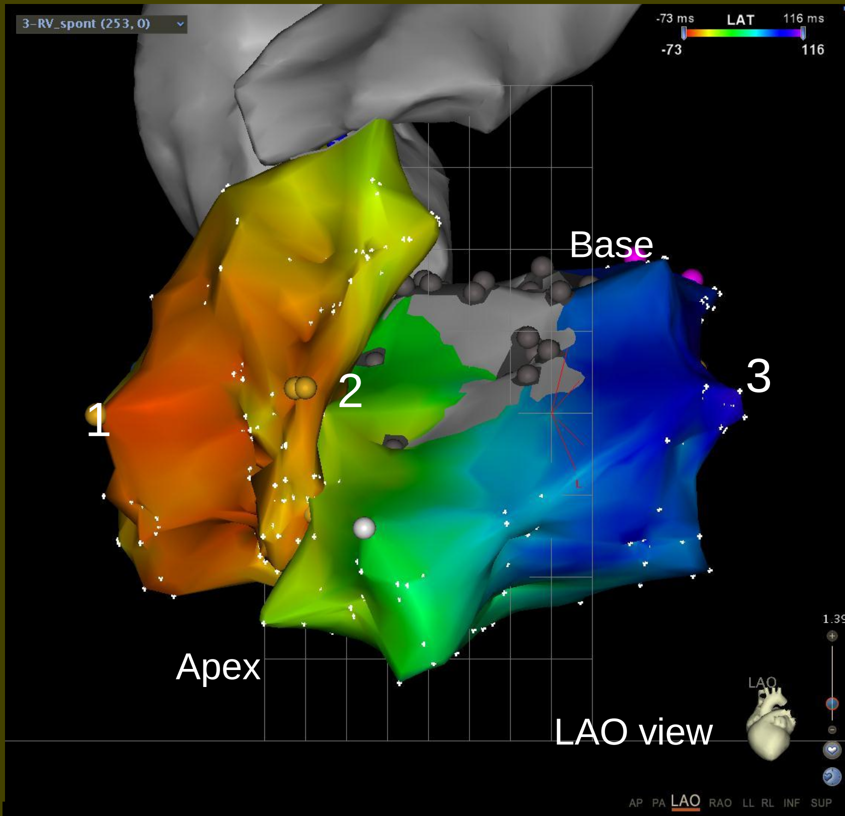
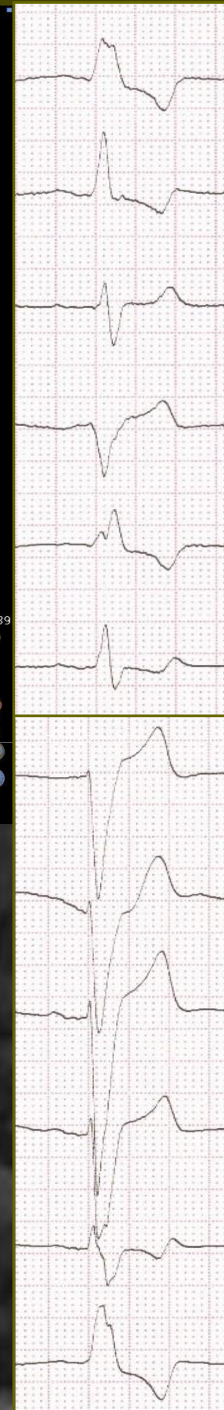


Figure 2: the first beat shows an atrial and ventricular pacing without sensing an intrinsic ventricular beat; the second shows a P sensed followed by an intrinsic ventricular beat that trigger a biventricular pace within 10 msec.









Point 1
RV free wall

Point 2
IVS

Point 3
LV lateral-base

P11- ICHS
-st.p.IM přední stěny

Riedlbauchová L, PACE 2020;43(5):486-494