

Základy léčby implantabilními přístroji

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Klinika kardiologie

IKEM

Praha

6.4.2013

Ohmův zákon

- Vztah mezi napětím, proudem a odporem

$$V = I \times R$$

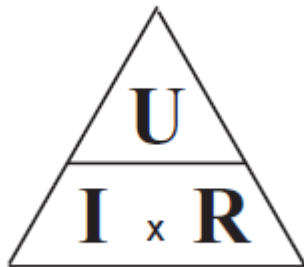
$$I = V/R$$

$$R = V/I$$

Napětí = 5 V, Impedance = 500 Ω

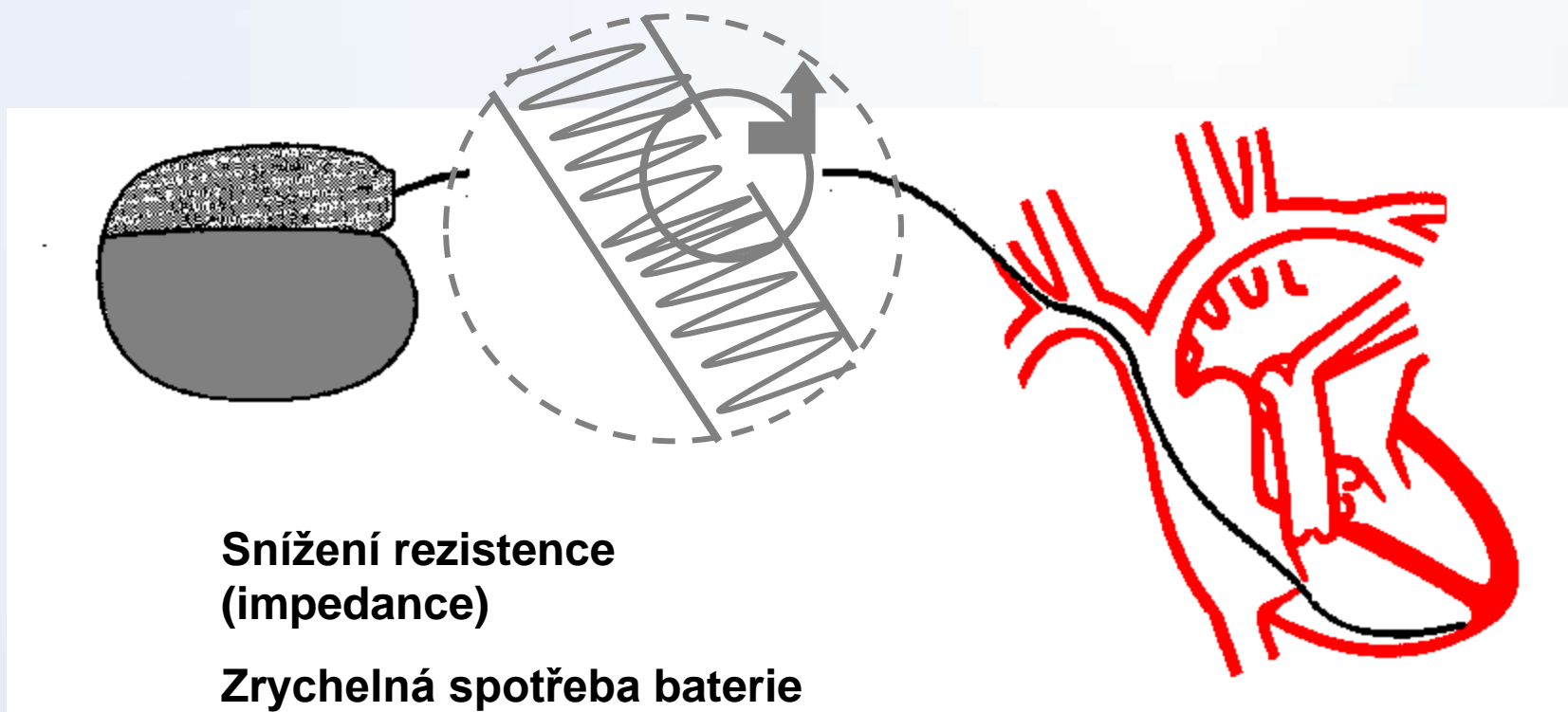
$$I = V/R$$

$$I = 5 \text{ V} \div 500 \text{ } \Omega = 0.010 \text{ A} \\ = 10 \text{ mA}$$



Porucha izolace

Únik proudu



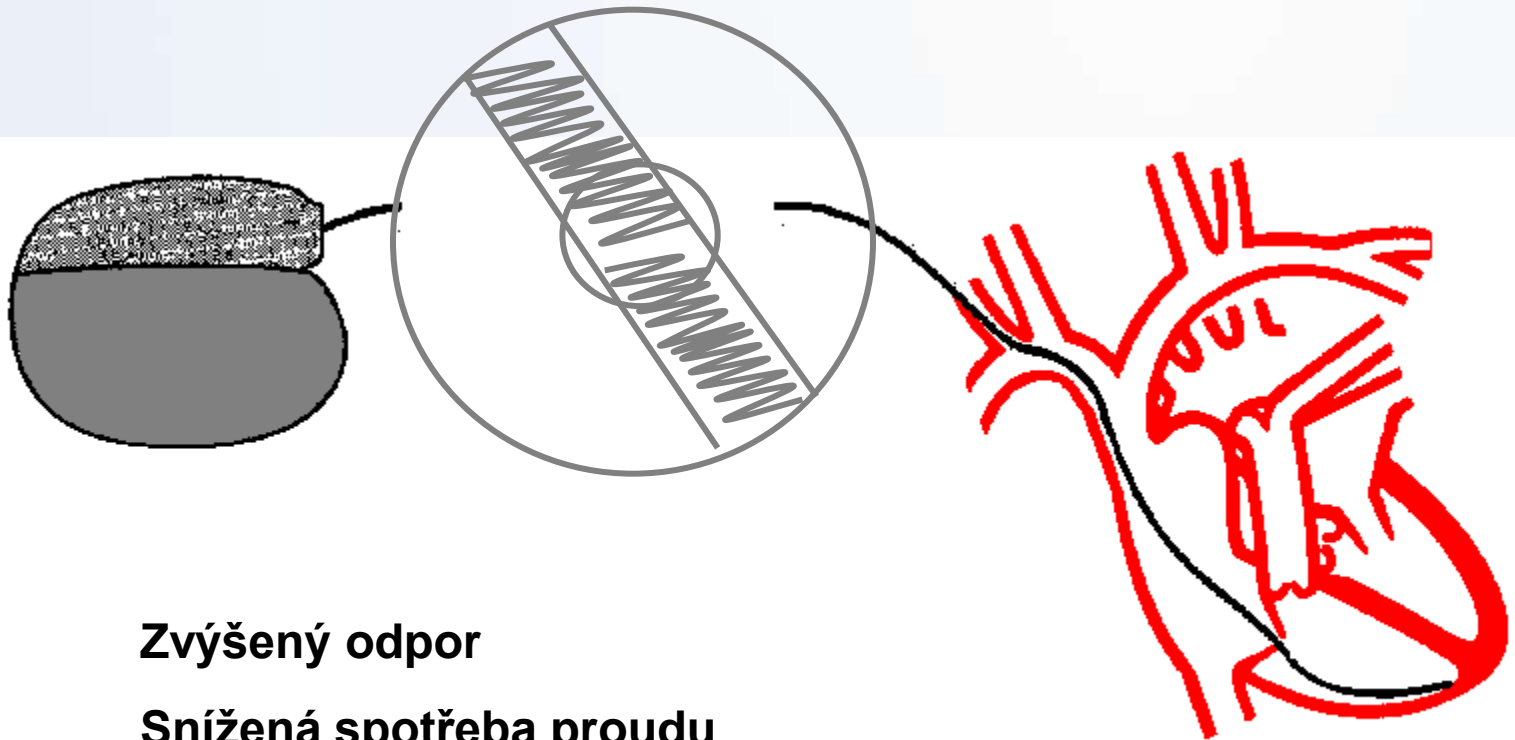
**Snížení rezistence
(impedance)**

Zrychelná spotřeba baterie

Zvýšená spotřeba energie

Zlomená elektroda

Přerušení proudu k srdci



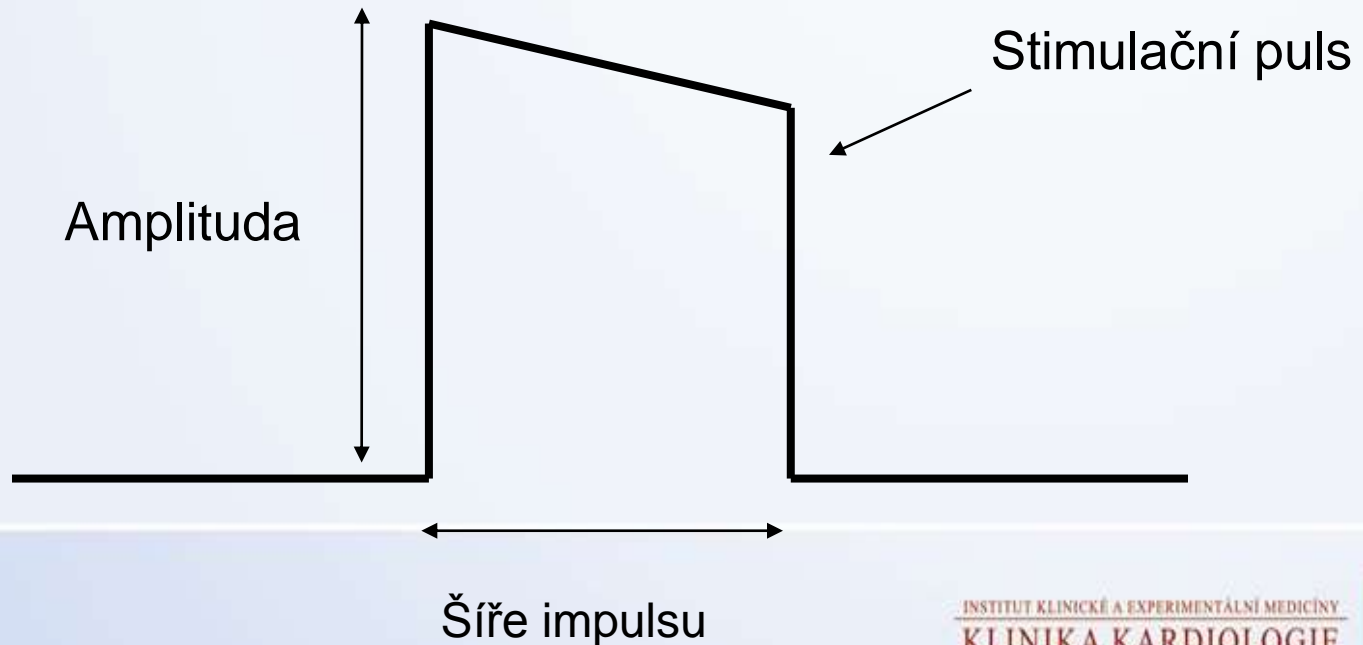
Zvýšený odpor

Snížená spotřeba proudu

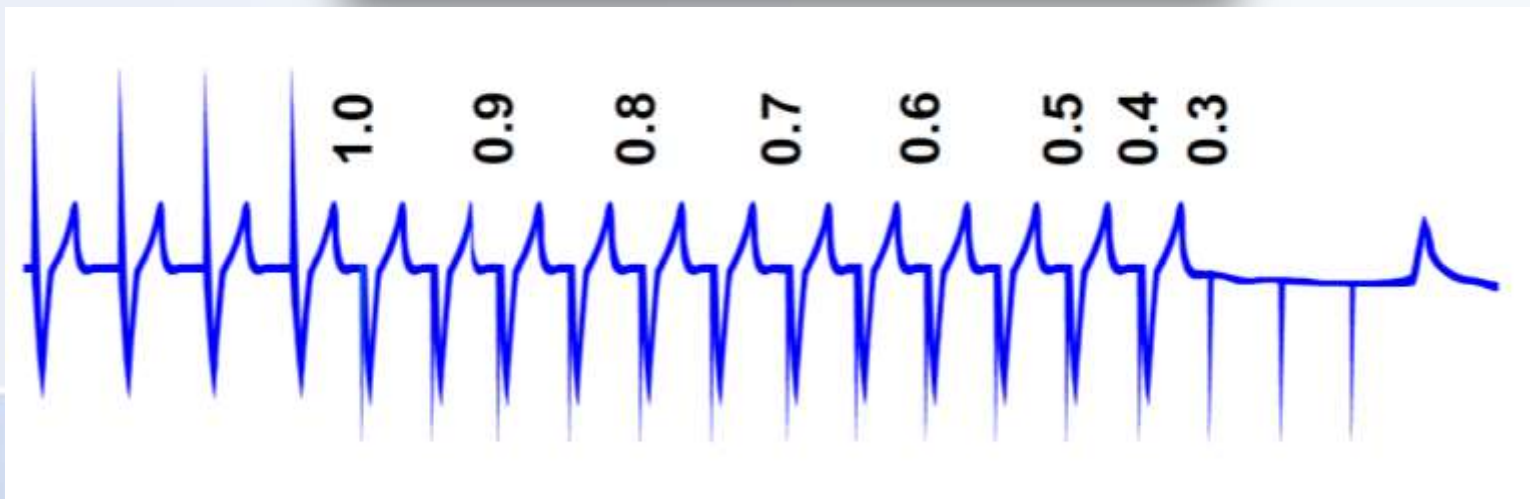
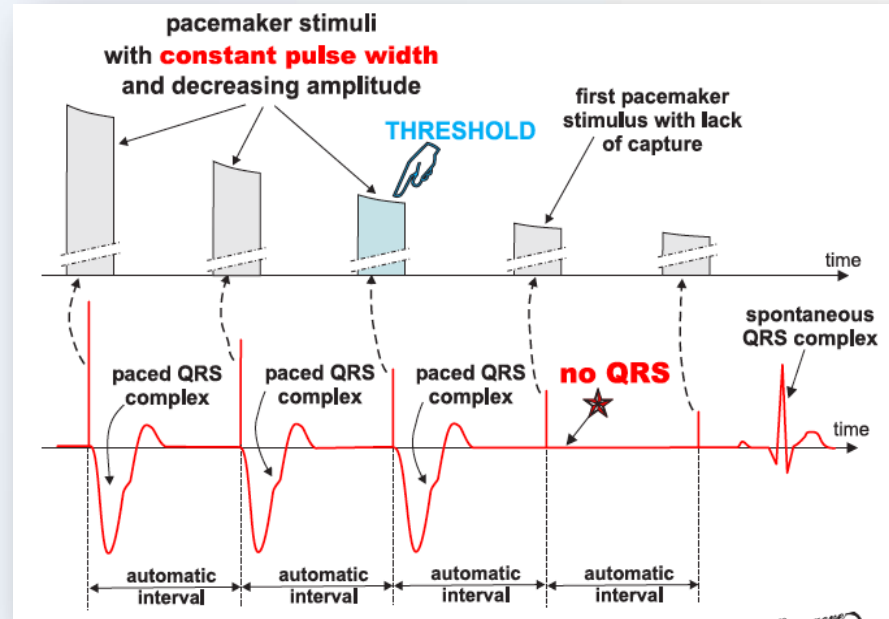
Snížená energie

Stimulační práh

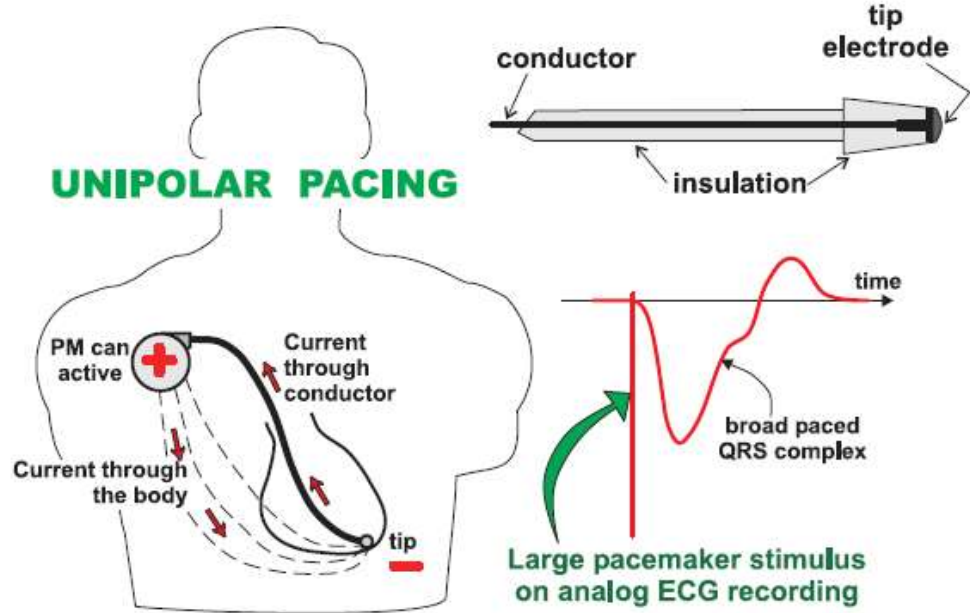
- Minimální energie, která je schopná konzistentně stimulovat myokard mimo refrakterní periodu
- Amplituda (V) + Šíře impulsu (ms) = Výdej



3. Stimulační práh

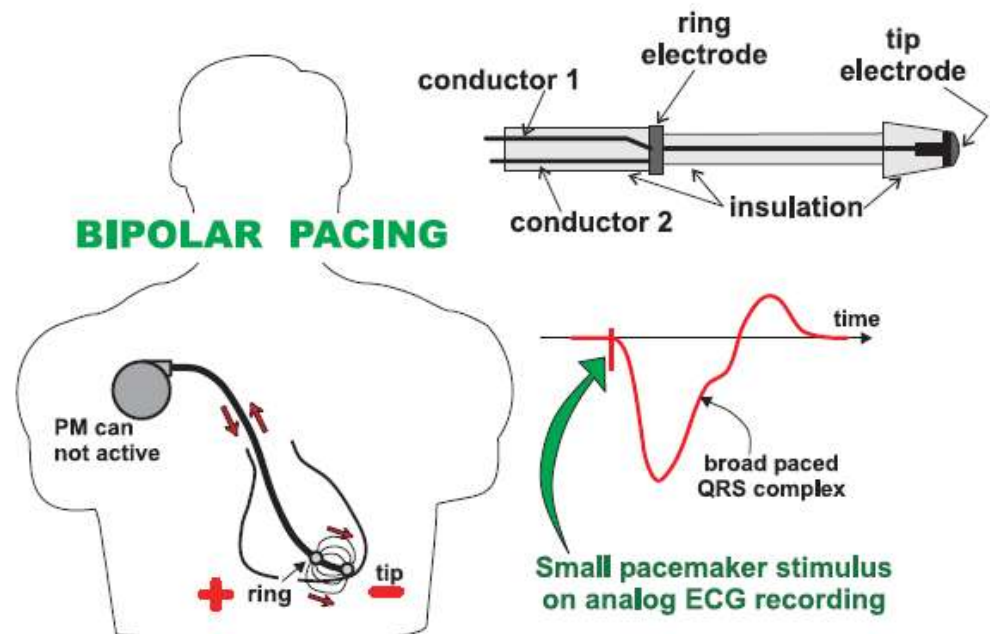


UNIPOLAR PACING



A. F. Sinnaeve

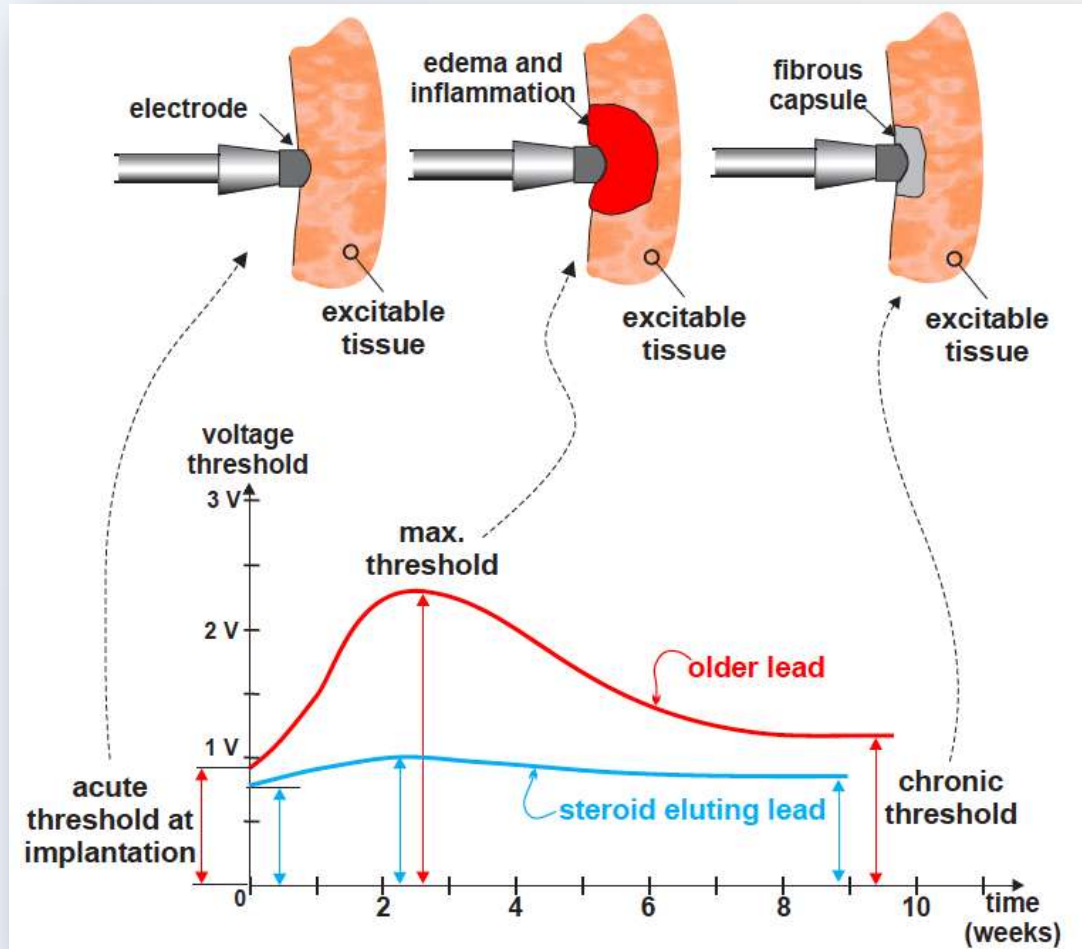
BIPOLAR PACING



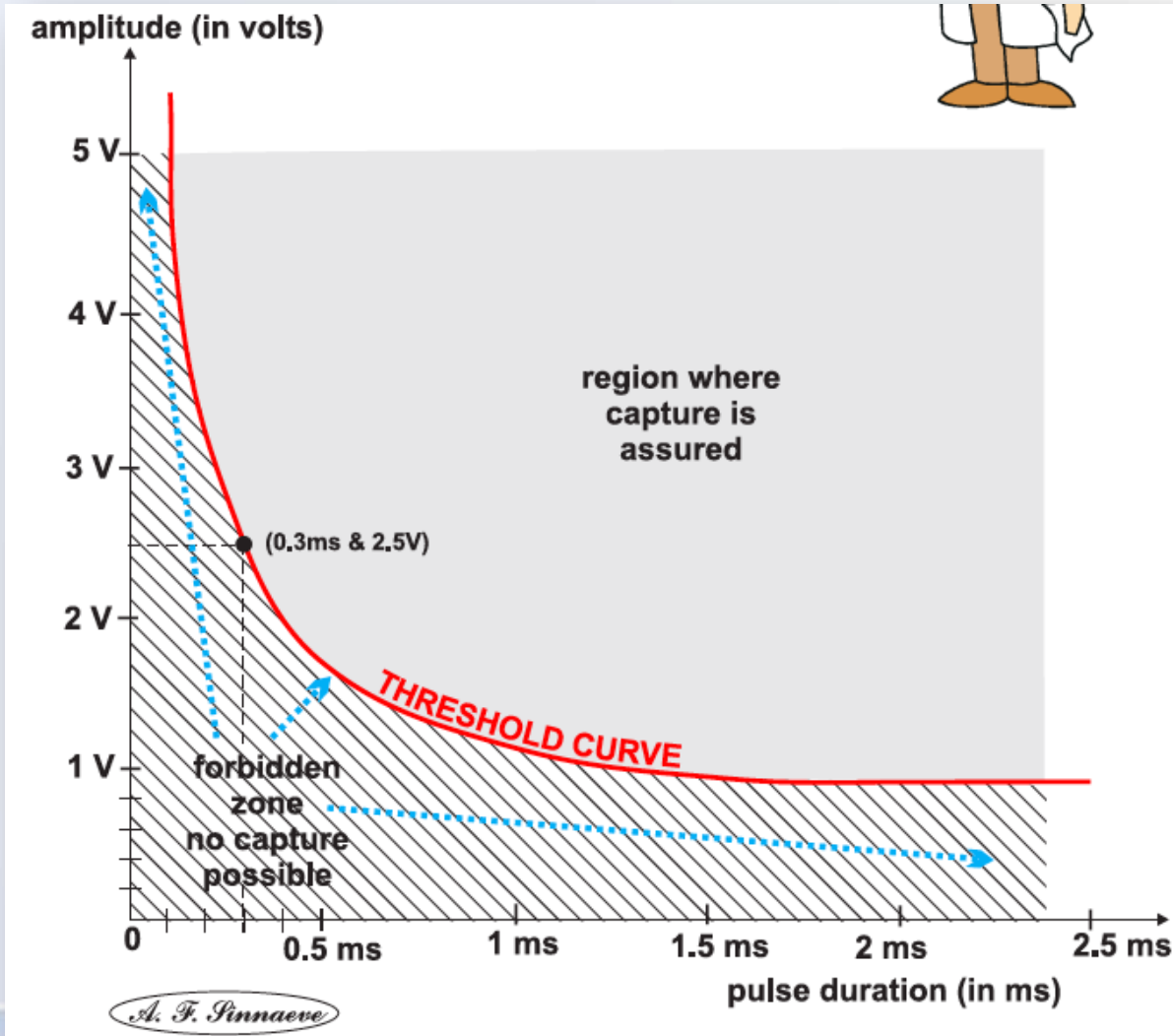
A. F. Sinnaeve



Elektrody se steroidním povlakem

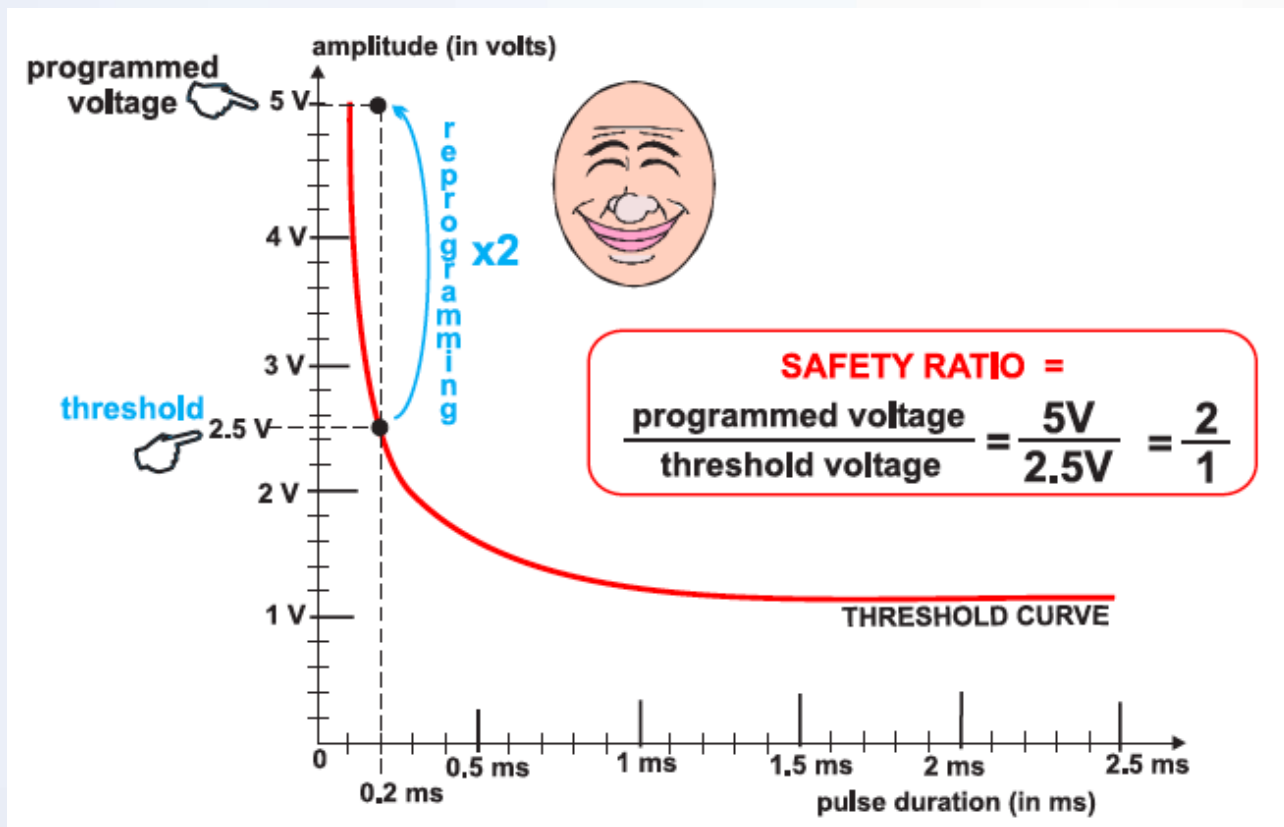


Křivka síla – šíře (strength-duration)



$$E = \frac{V^2 T}{R}$$

Bezpečná stimulační rezerva

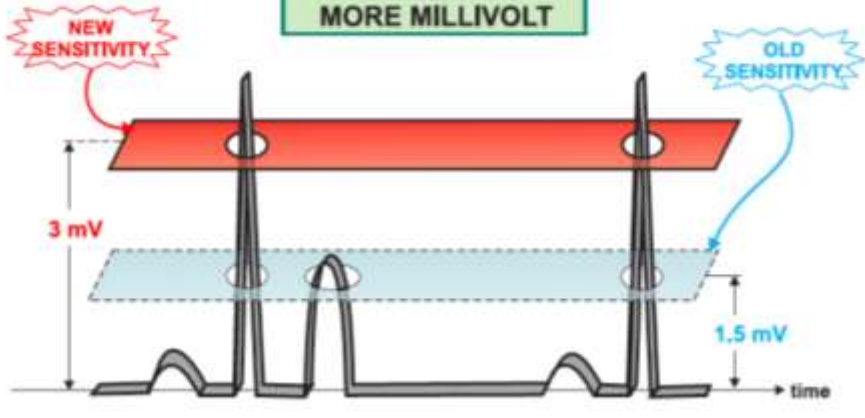


Sensing

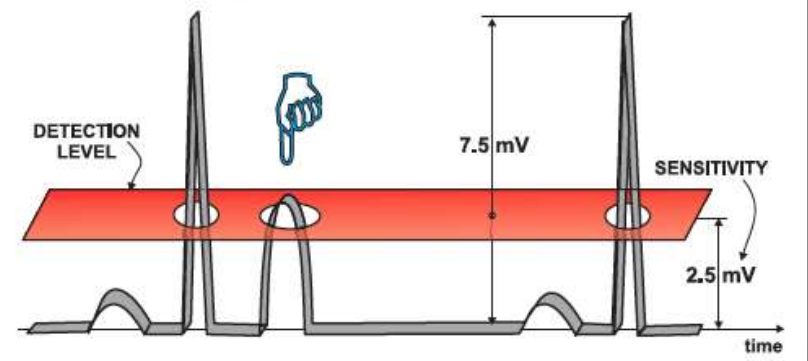
- Schopnost PM vidět depolarizaci
- Správný sensing vyžaduje odfiltrování nežádoucích signálů
 - Vlna T
 - Far-field (např. komorový signál v síni)
 - Myopotenciály

Sensing

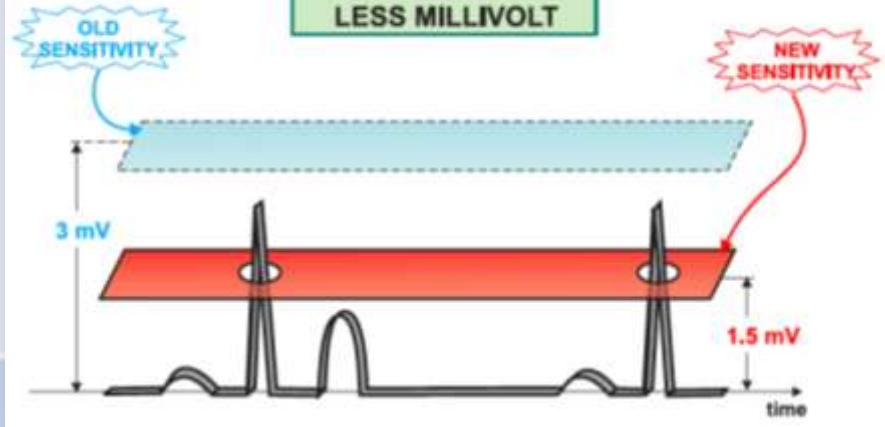
LOWER SENSITIVITY
means
MORE MILLIVOLT



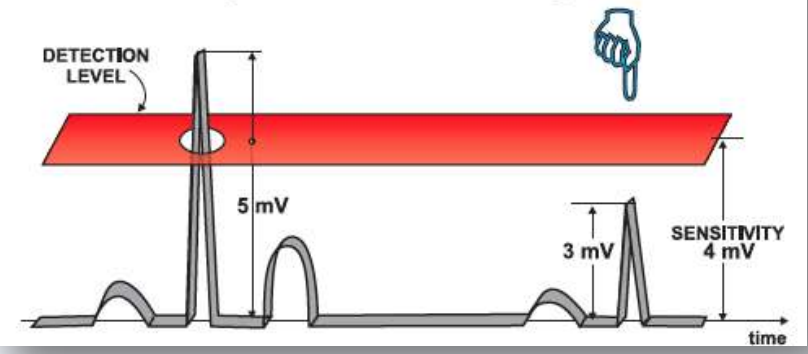
OVERSENSING



HIGHER SENSITIVITY
means
LESS MILLIVOLT



UNDERSENSING



Pacemakerový kód

Position	I	II	III	IV	V
Category	Chamber(s) Paced	Chamber(s) Sensed	Response to Sensing	Rate Modulation	Multisite Pacing
Letters Used	<p>O = None</p> <p>A = Atrium</p> <p>V = Ventricle</p> <p>D = Dual (A + V)</p>	<p>O = None</p> <p>A = Atrium</p> <p>V = Ventricle</p> <p>D = Dual (A + V)</p>	<p>O = None</p> <p>T = Triggered</p> <p>I = Inhibited</p> <p>D = Dual (T + I)</p>	<p>O = None</p> <p>R = Rate modulation</p>	<p>O = None</p> <p>A = Atrium</p> <p>V = Ventricle</p> <p>D = Dual (A + V)</p>
Manufacturers' Designation Only	S = Single (A or V)	S = Single (A or V)			



VOO

- Asynchronní komorová stimulace
- Není sensing

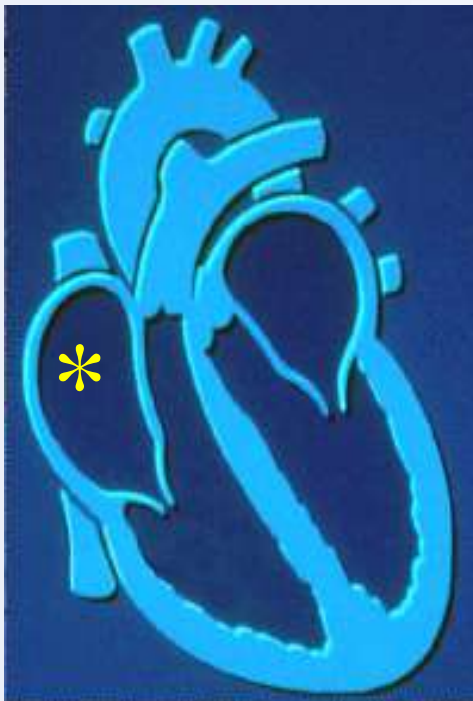




VVI

- Komorová stimulace
- Sensing v komoře
- Sensing inhibuje stimulaci





AOO

- Síňová asynchronní stimulace
- Není sensing v síni

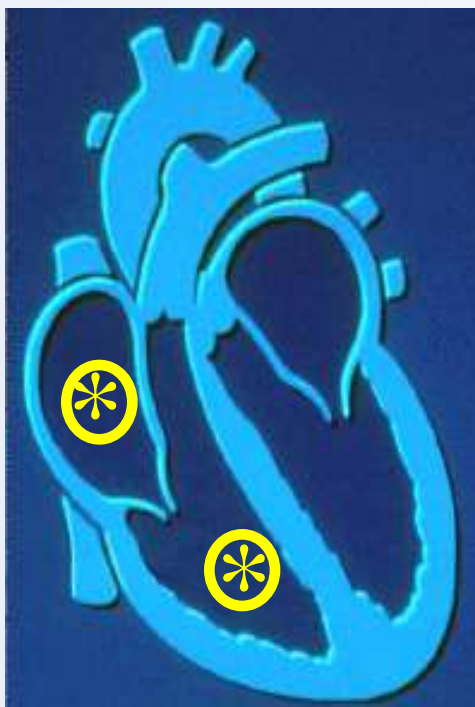




AAI

- Síňová stimulace
- Síňový sensing
- Vlastní P inhibuje stimulaci



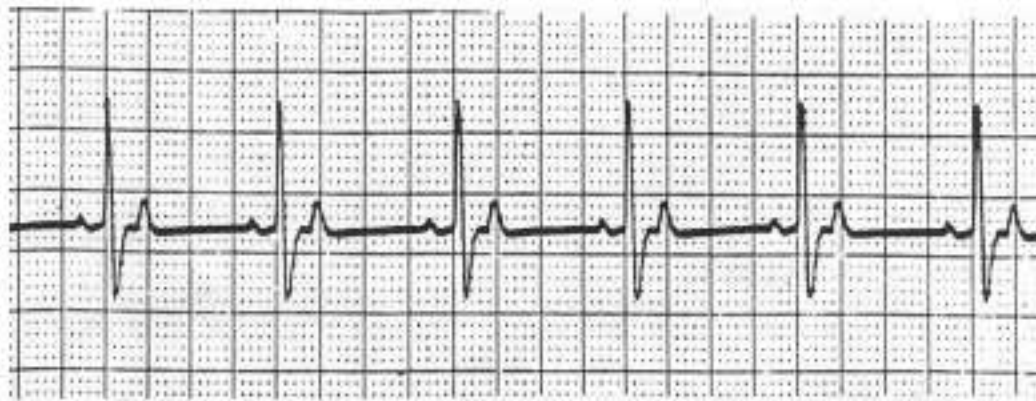


DDD

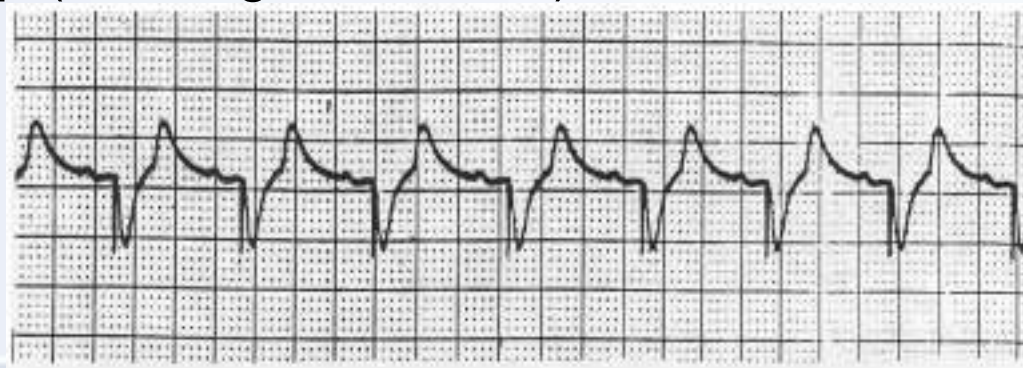
- Stimulace v síni a komoře
- Sensing v síni a komoře
- Vlastní P a vlastní QRS inhibují stimulace
- Vlastní P může spouštět stimulovaný QRS



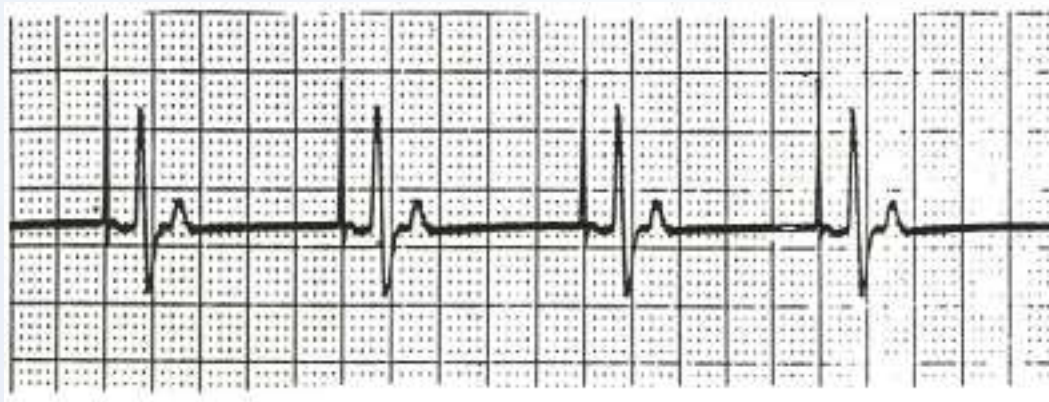
AsVs



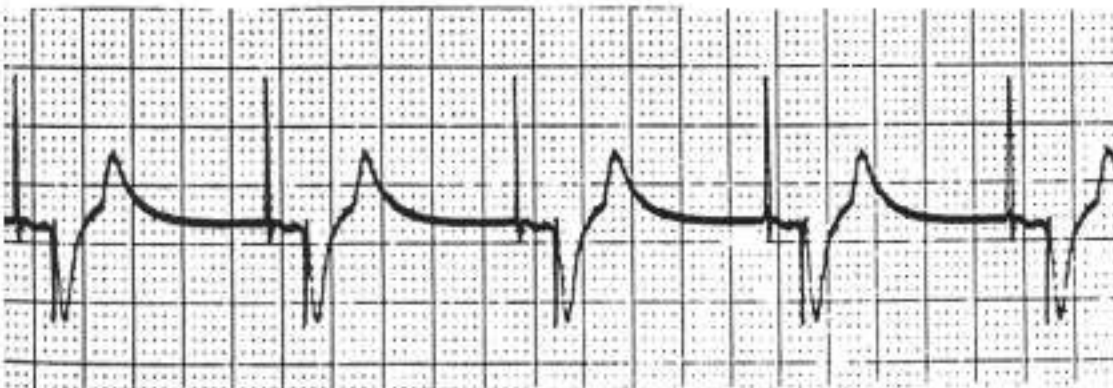
AsVp (tracking P vIn, VAT)

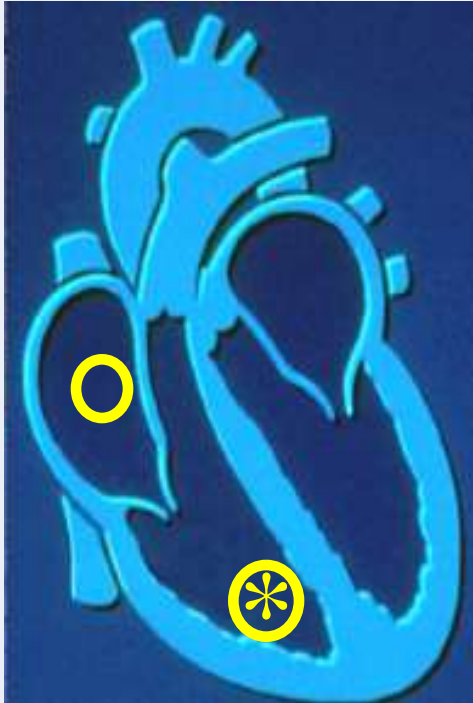


ApVs



ApVp





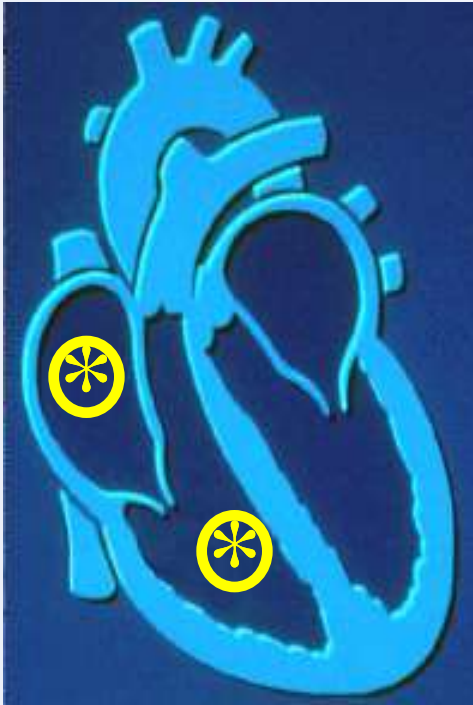
VDD

- Pacing in ventricle
- Sensing in both atrium and ventricle
- Intrinsic QRS inhibits ventricular pacing
- Intrinsic P wave can trigger ventricular pacing



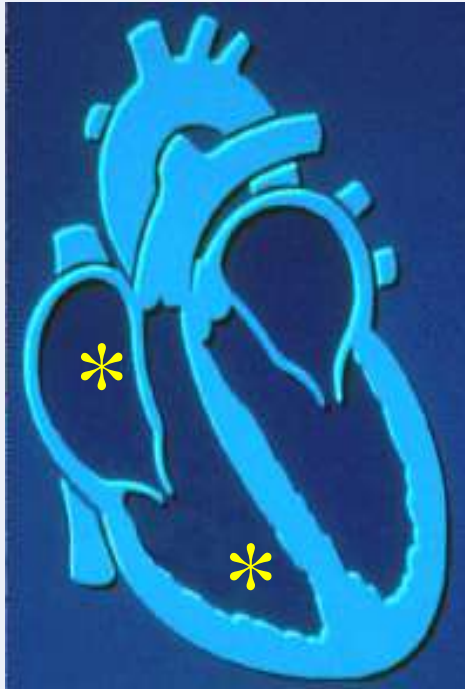
DDI

- Stimulace A V
- Sensing A V
- Není tracking P vln (není konstatní AV delay)



- Při vlastní P vlně není spouštěn AV delay (non-tracking)
- Kombinace AAI a VVI
- Primárně užit v mode-switch modu





DOO

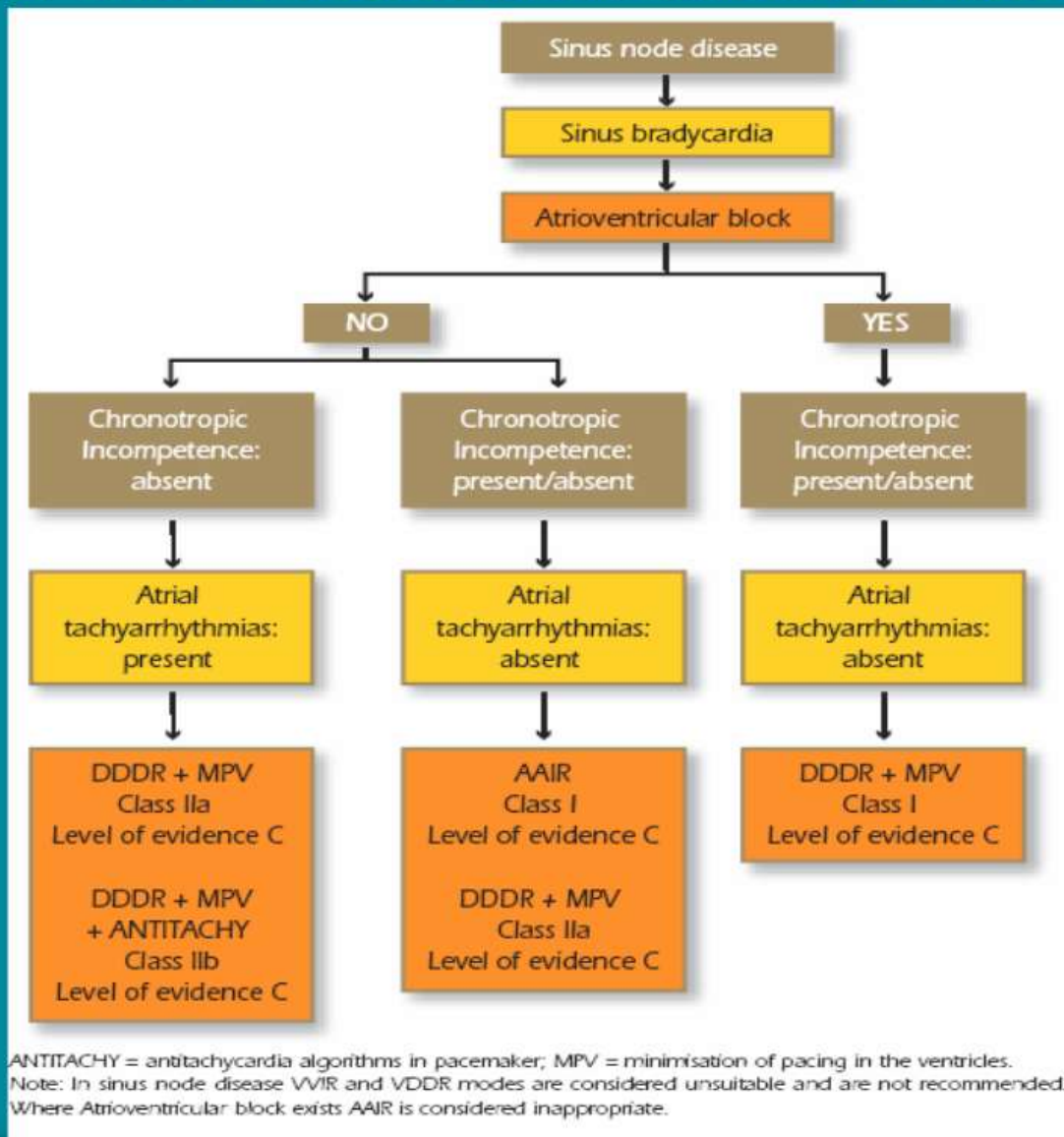
- Pacing in the atrium and ventricle
- Intrinsic P wave and QRS do not affect pacing
- Asynchronous pacing (always pace at lower pacing rate)



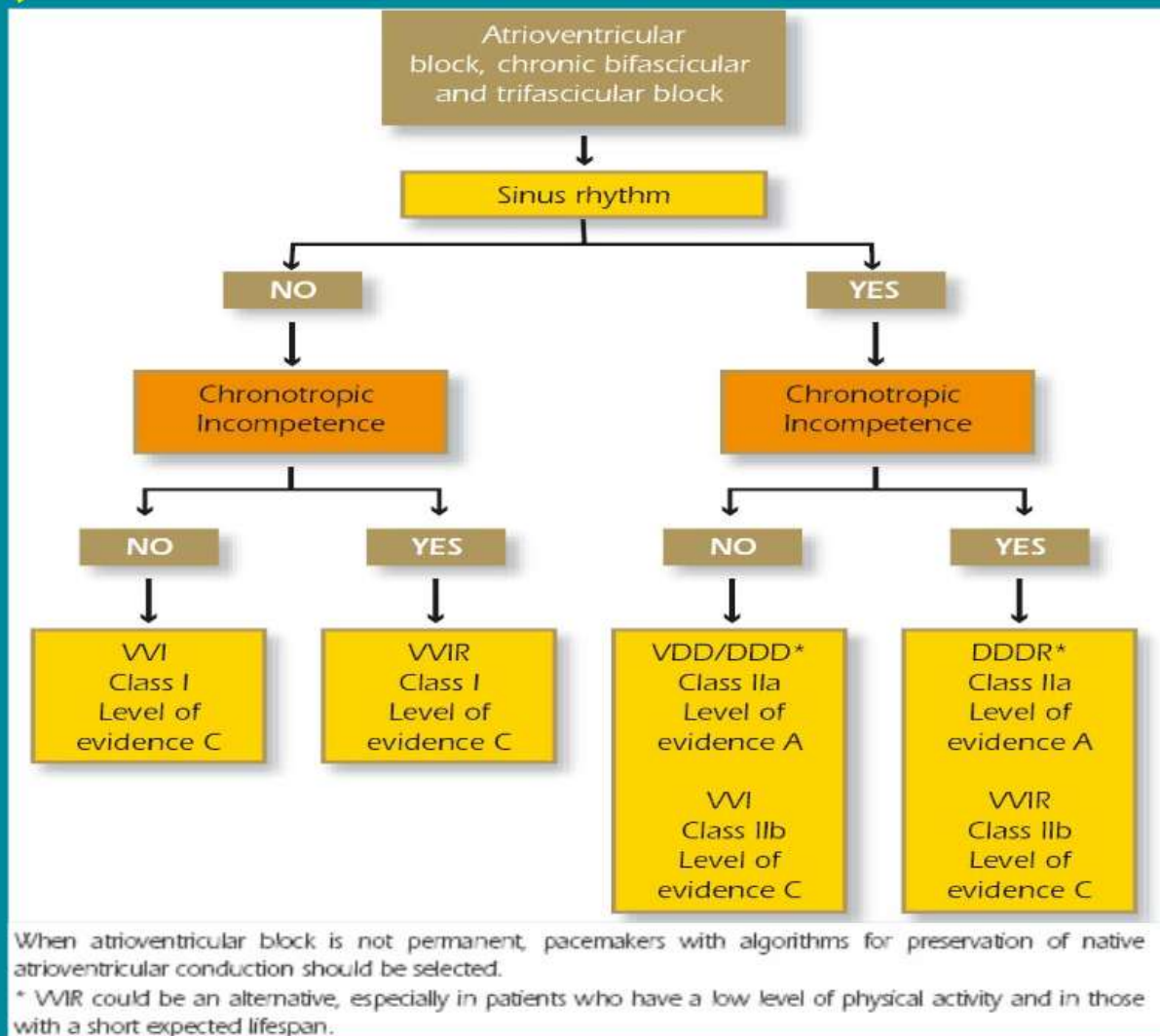
Frekvenční reakce kardiostimulátorů

- Zvýšení stimulační frekvence
- Senzory:
 - Metabolické
 - Pohybové (piezoelectrický krystal nebo akcelerometr)
 - Fyziologické (např. minutová ventilace)

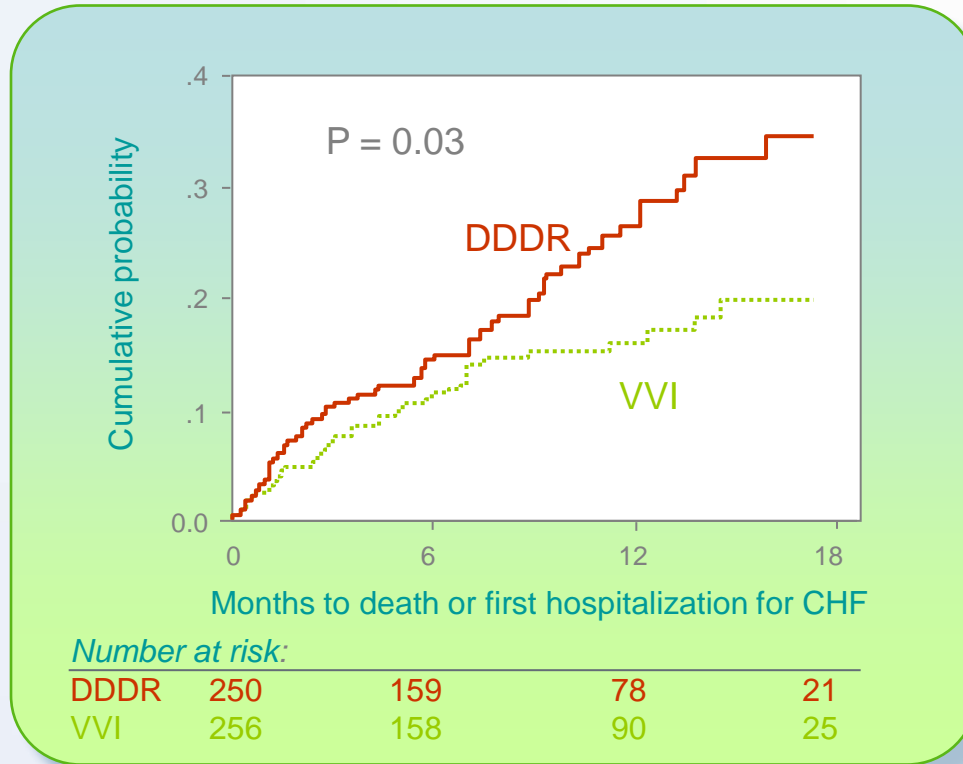
Pacemaker mode selection in sinus node disease



Pacemaker mode selection in acquired atrioventricular block, chronic bifascicular and trifascicular block

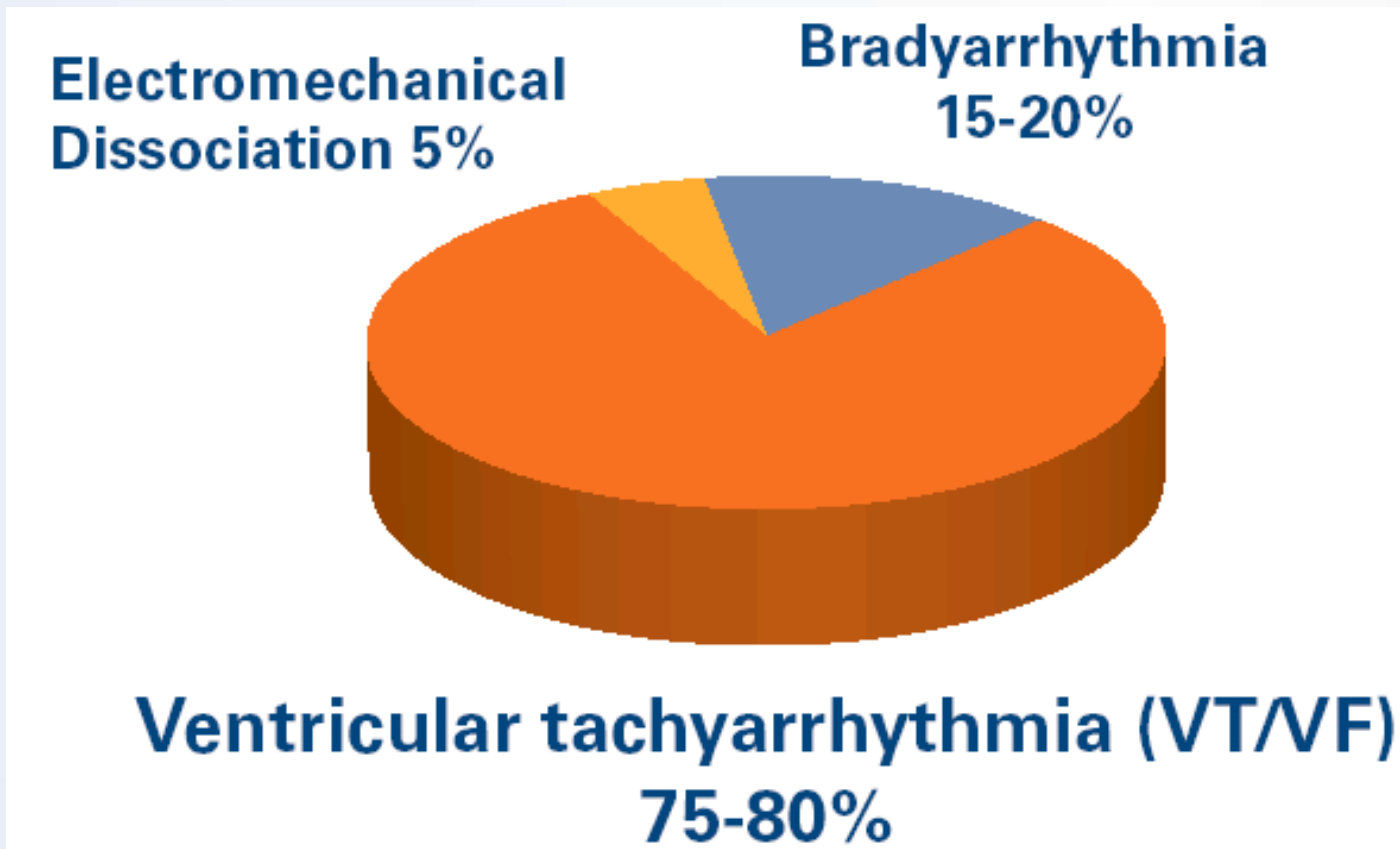


DAVID



DDDR-70 není lepší než VVI-40 a zvyšuje incidenci srdečního selhání a mortalitu

Příčiny NSS



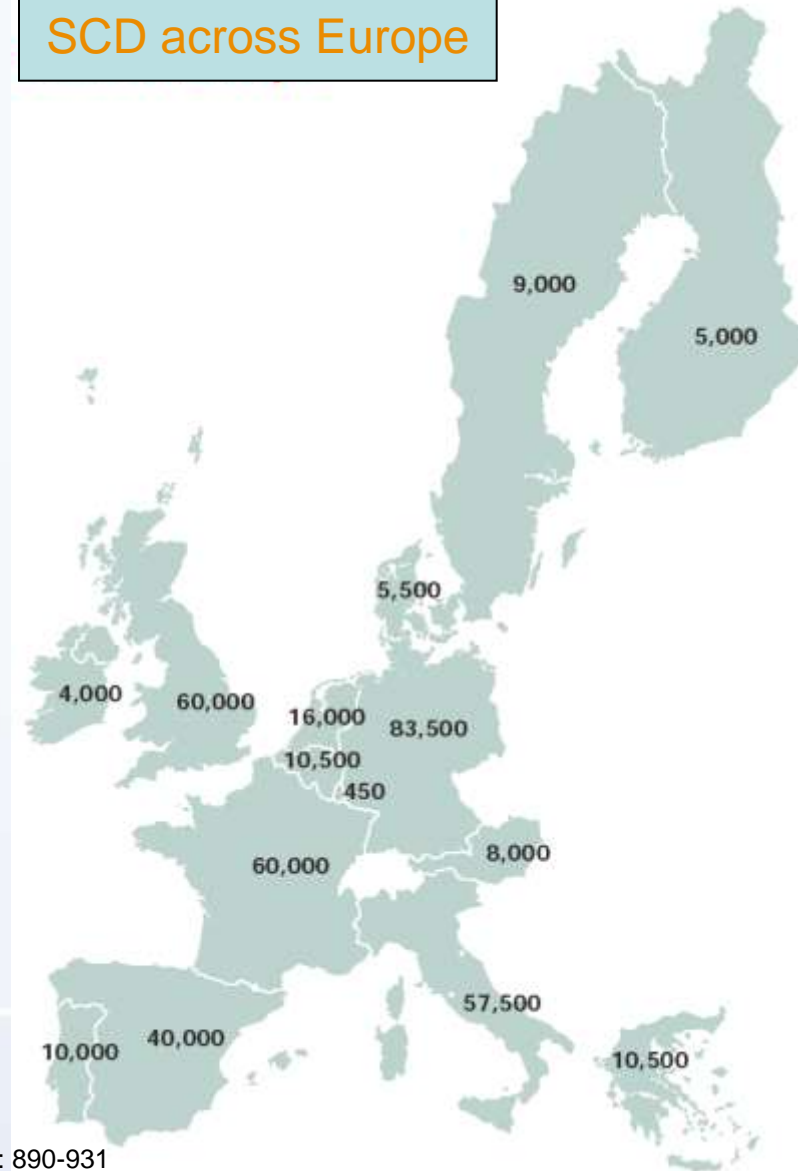
Incidence of SCD

SCD across Europe

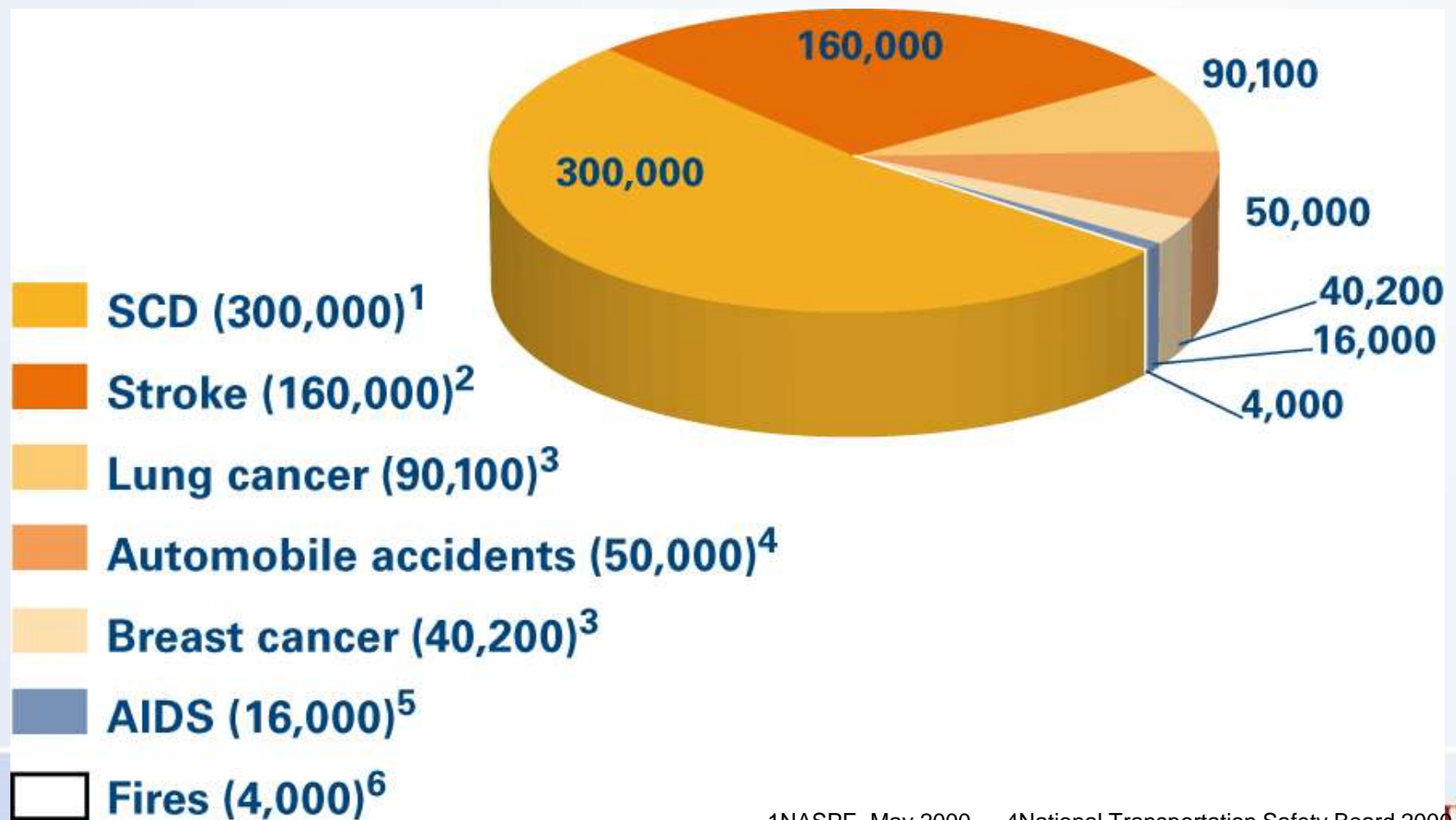
SCD is a worldwide epidemic:

- USA 300/400.000 death/year
- Europe 350.000 death/year

1st cause of death across developed countries



Size of the problem



¹NASPE, May 2000

²American Heart Association 2000

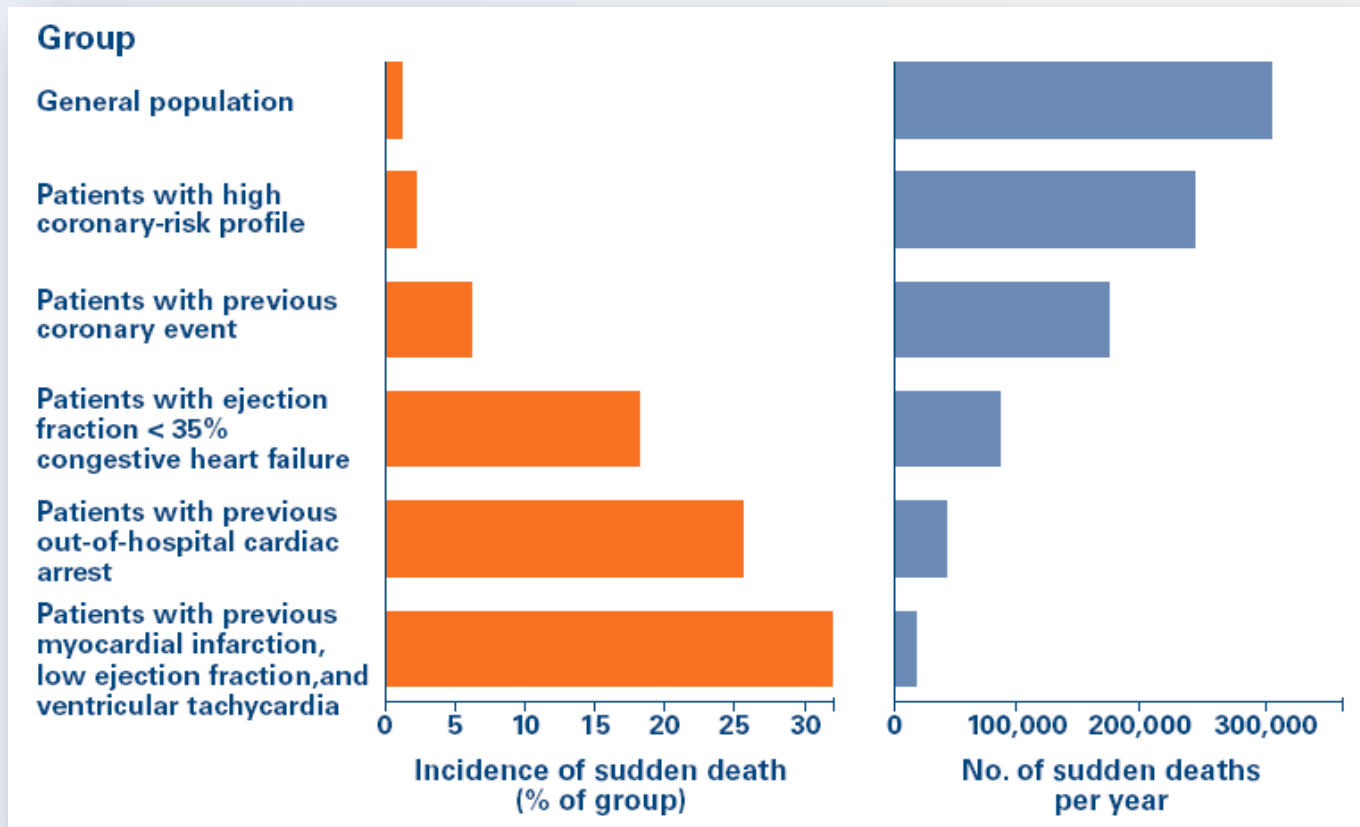
³National Cancer Institute 2001

⁴National Transportation Safety Board 2000

⁵Center for Disease Control 2001

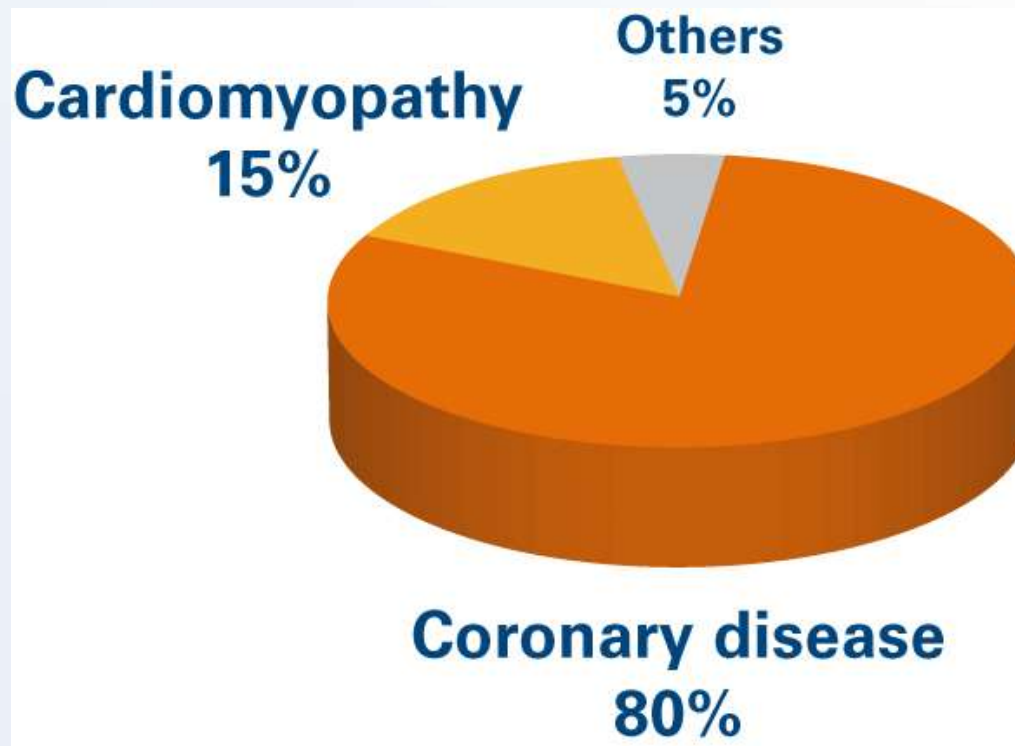
⁶NFPA, US Facts & Figures 2000

Meyerburgův paradox



Two major risk factors for SCD

Underlying causes of **fatal arrhythmias**

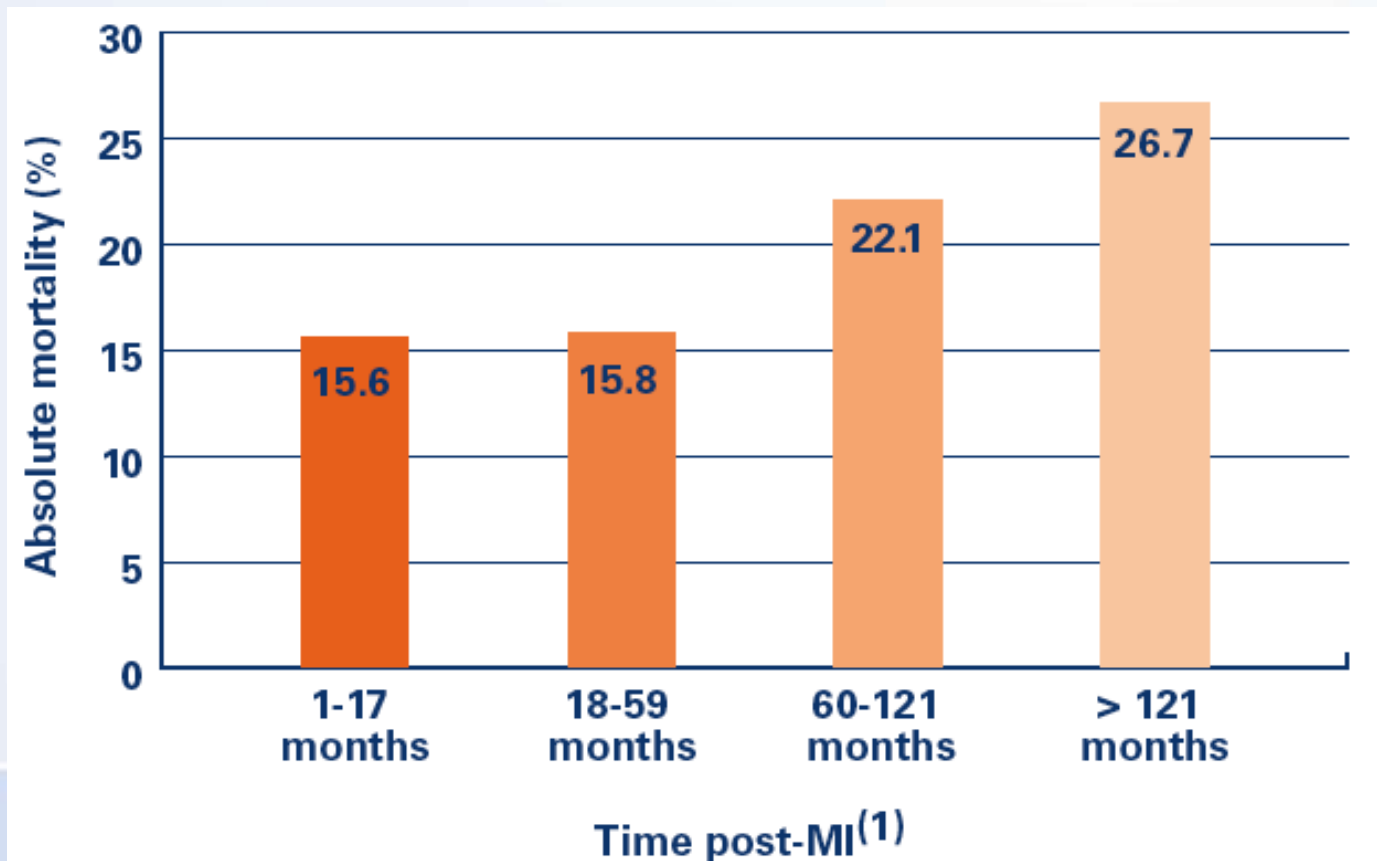


SCD and post-MI

- **People who have had a heart attack, have a sudden cardiac death rate that is 4-6 times that of the general population.**

Risk of SCD in post-MI patients

Mortality risk in contemporary post-MI patients with EF \leq 30%
tends to increase as a function of time from last MI

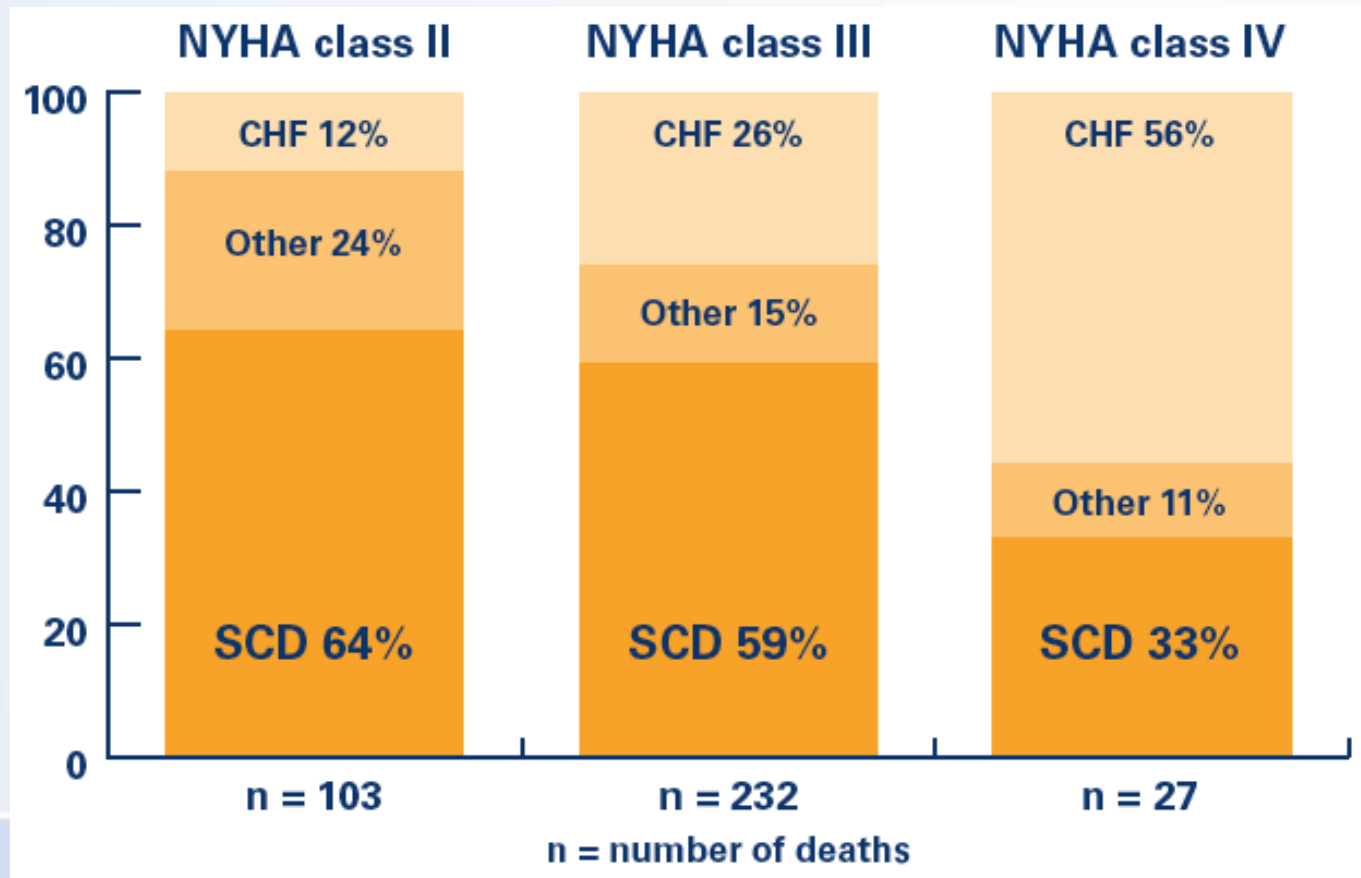


SCD and HF

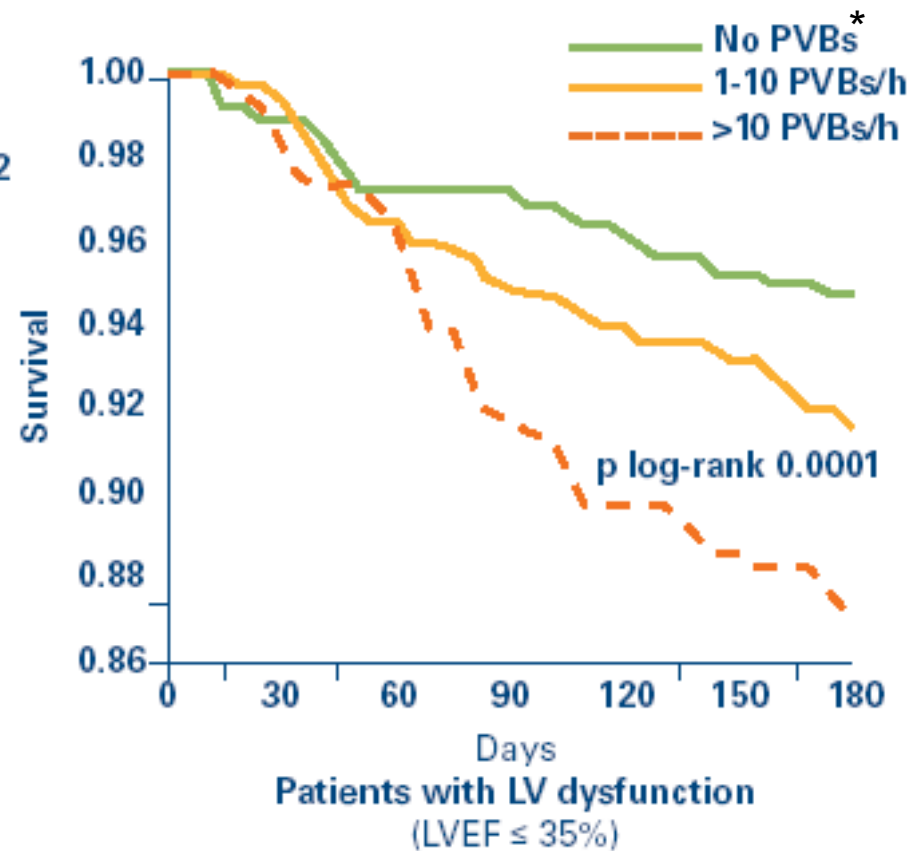
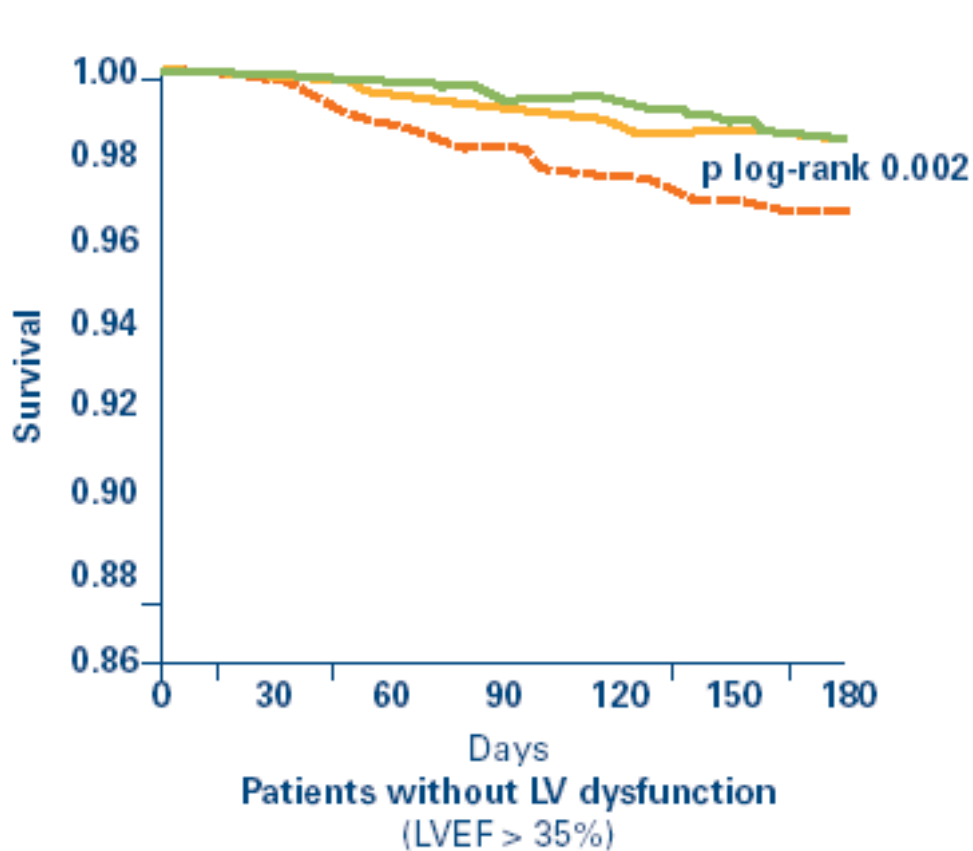
- In people diagnosed with heart failure, sudden cardiac death occurs at **6-9 times** the rate of the general population.

Risk of SCD in HF

SCD is **More Prevalent in NYHA class II/III**



Reduced LVEF : an important risk factor



Summary of Drug Trials

Trial	Patients	Trial Design	Result
CAST-I¹	1498	Encainide, Flecainide / Placebo	Terminated due to excessive death in treatment arm
CHF-STAT²	674	Amiodarone / Placebo	No change in overall mortality
SWORD³	546	d-Sotalol / Placebo	Terminated due to excessive death in treatment arm
ESVEM⁴	486	EPS-guided / Holter-guided	Mortality high in both arms
EMIAT⁵	1500	Amiodarone / Placebo	No change in overall mortality
CAMIAT⁶	1200	Amiodarone / Placebo	No change in overall mortality

1 Echt, et al. N Engl J Med. 1991;324:781–8.

2 Singh, et al. N Engl J Med. 1995;333:77–82 (supported by Sanofi & Wyeth).

3 Waldo A.L. The Lancet; 1996;348:7–12. (supported by Bristol-Myers Squibb).

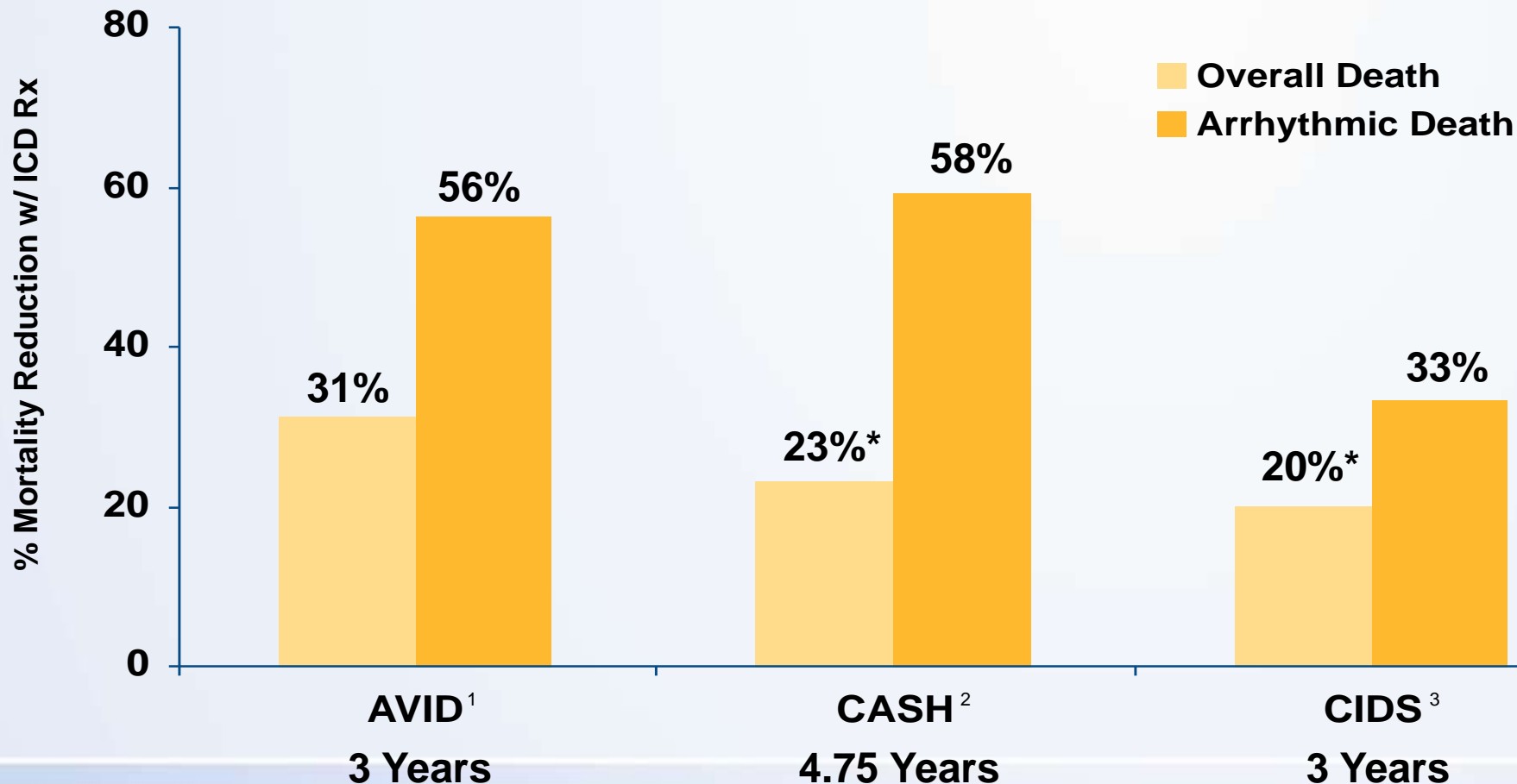
4 Mason J.W. N Engl J Med. 1993;329(7):452–8. (Supported by Bristol-Myers Squibb, Knoll Pharmaceutical, Boehringer-Ingelheim, Parke-Davis, and Ciba-Geigy).

5 Julian D.G. The Lancet. 1997;349:667–74. (Supported by Sanofi)

6 Cairns J.A. The Lancet. 1997;349:675–82.

Secondary Prevention Trials outcomes

Reduction in Mortality with ICD Therapy



* Non-significant results.

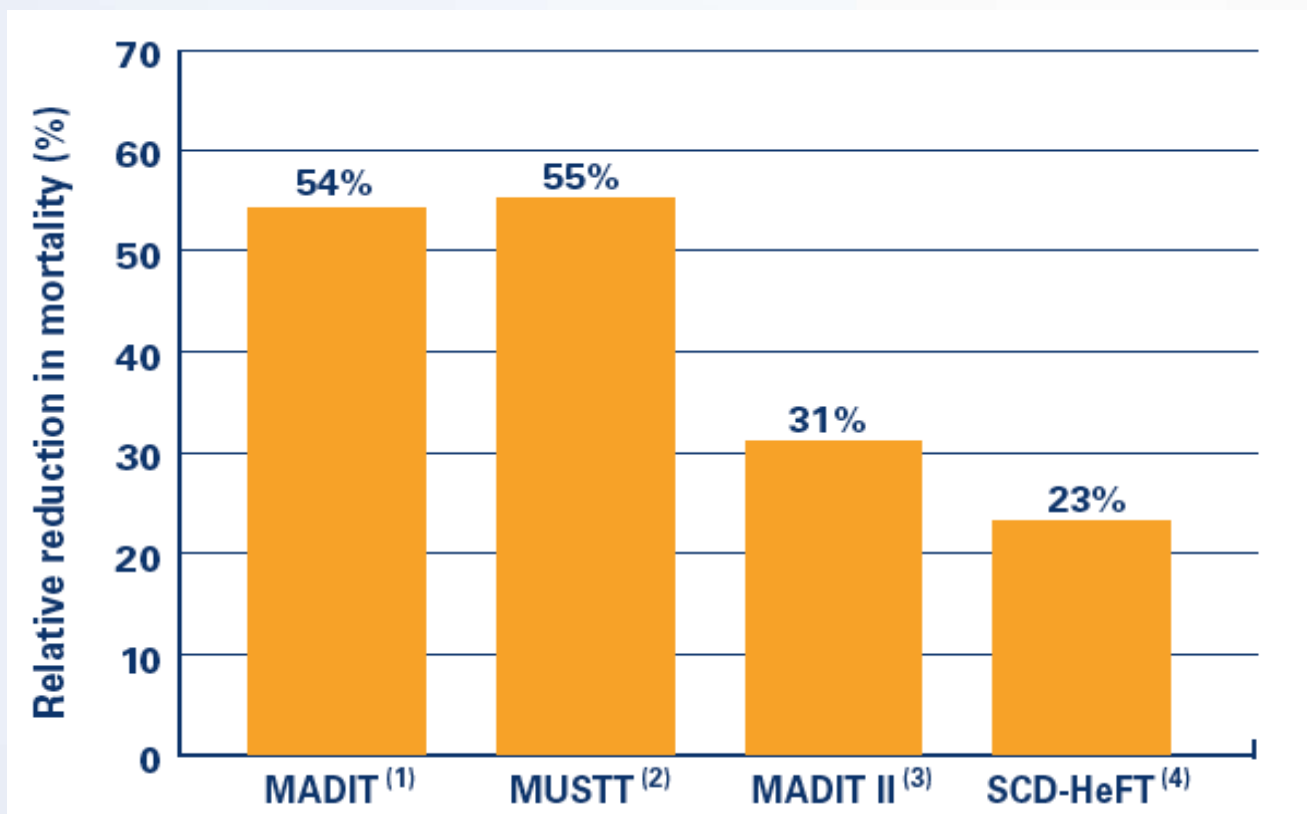
1 The AVID Investigators. N Engl J Med. 1997;337:1576-1583.

2 Kuck K. Circulation. 2000;102:748-754.

3 Connolly S. Circulation. 2000;101:1297-1302.

Primary Prevention Trials

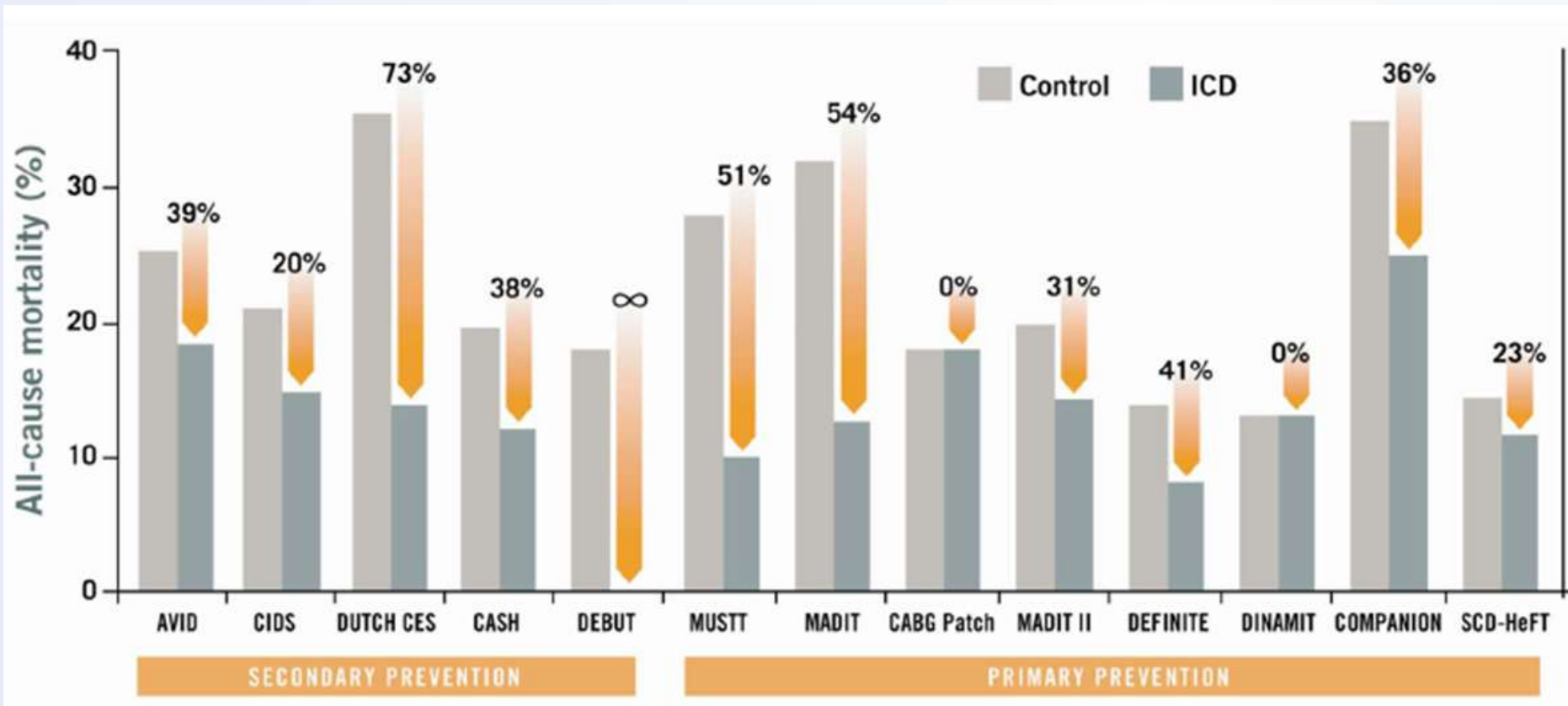
Reduction In All-cause Mortality with ICDs: Trials Summary



1. Moss AJ, *et al.* N Engl J Med. 1996;335:1933-1940.
2. Buxton AE, *et al.* N Engl J Med. 1999;341:1882-1890.
3. Moss AJ, *et al.* N Engl J Med. 2002;346:877-883.

ICD trials

Reduction in Mortality with ICD Therapy



ICD Trials Conclusions

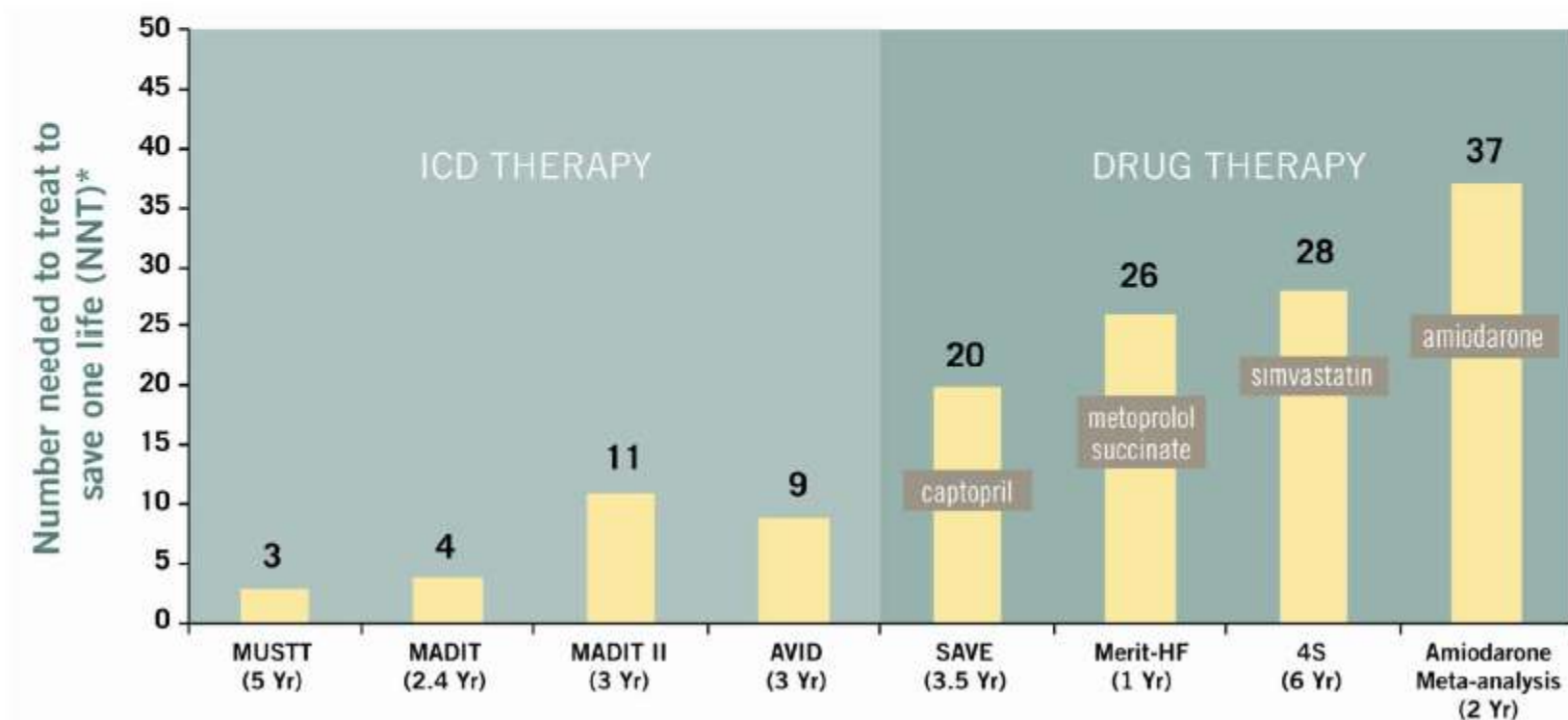
- **To summarize, prophylactic use of ICD therapy prevents SCD and saves lives in high-risk patients who are also on optimal pharmacologic therapies:**
 - Prior SCA (VT or VF)
 - Prior MI with LVEF $\leq 30\%$
 - HF patients (NYHA class II/III) with LVEF $\leq 35\%$

PERCEPTION

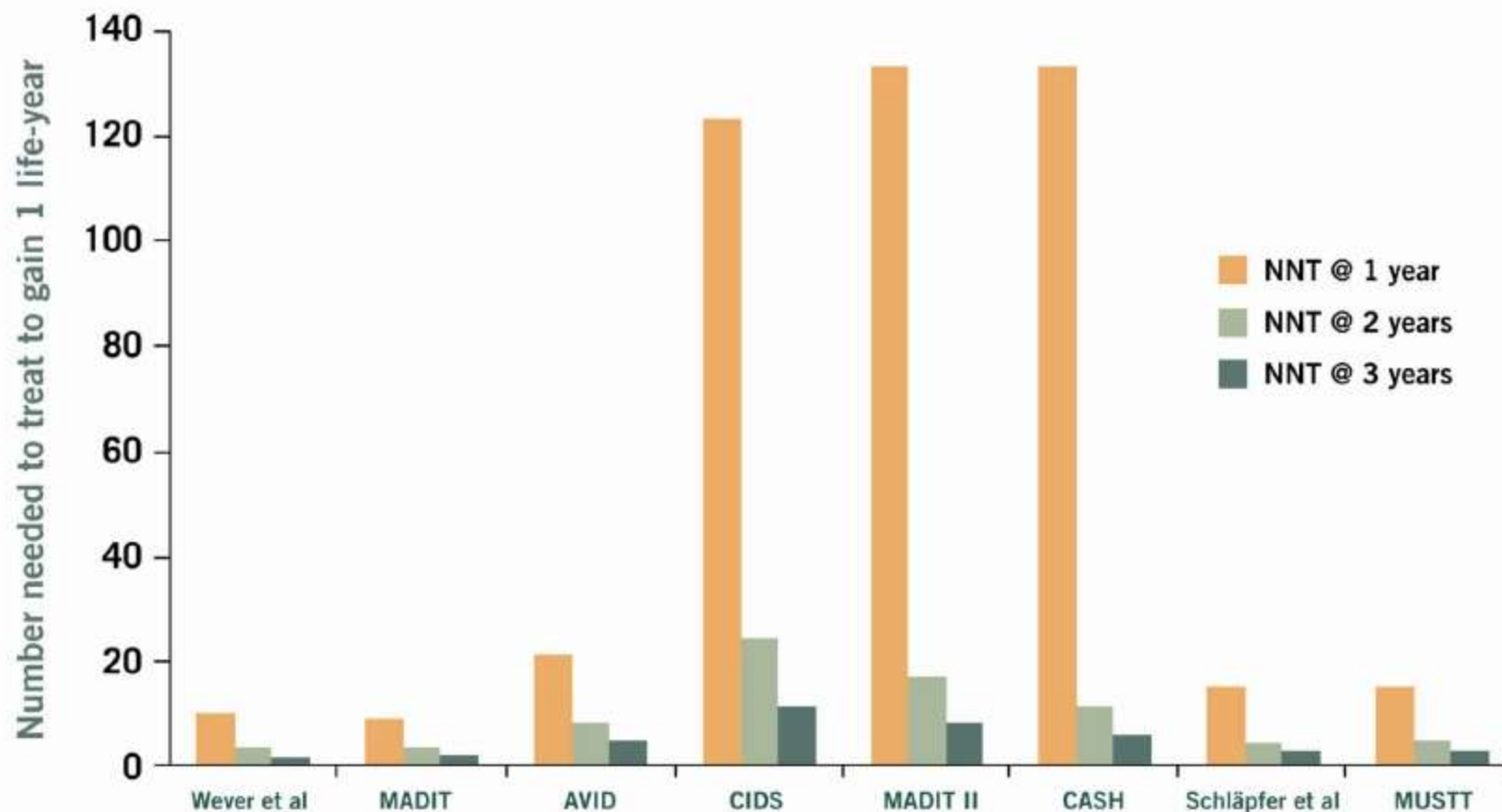
Number needed to treat (NNT)
to save one life is too high

FACTS

- NNT for ICDs is significantly lower compared to drug therapy



NNT “markedly decreases” with time



Drs. Mirowski and Mower

1970-71: úvahy o defibrilátoru



IMPLANTABLE CARDIOVERTER DEFIBRILLATOR



Fig. 3. First clinical model of the implantable cardioverter-defibrillator (ICD) shown with superior vena cava catheter and patch electrode.

1980

289 g., 150 ml, 22 mm

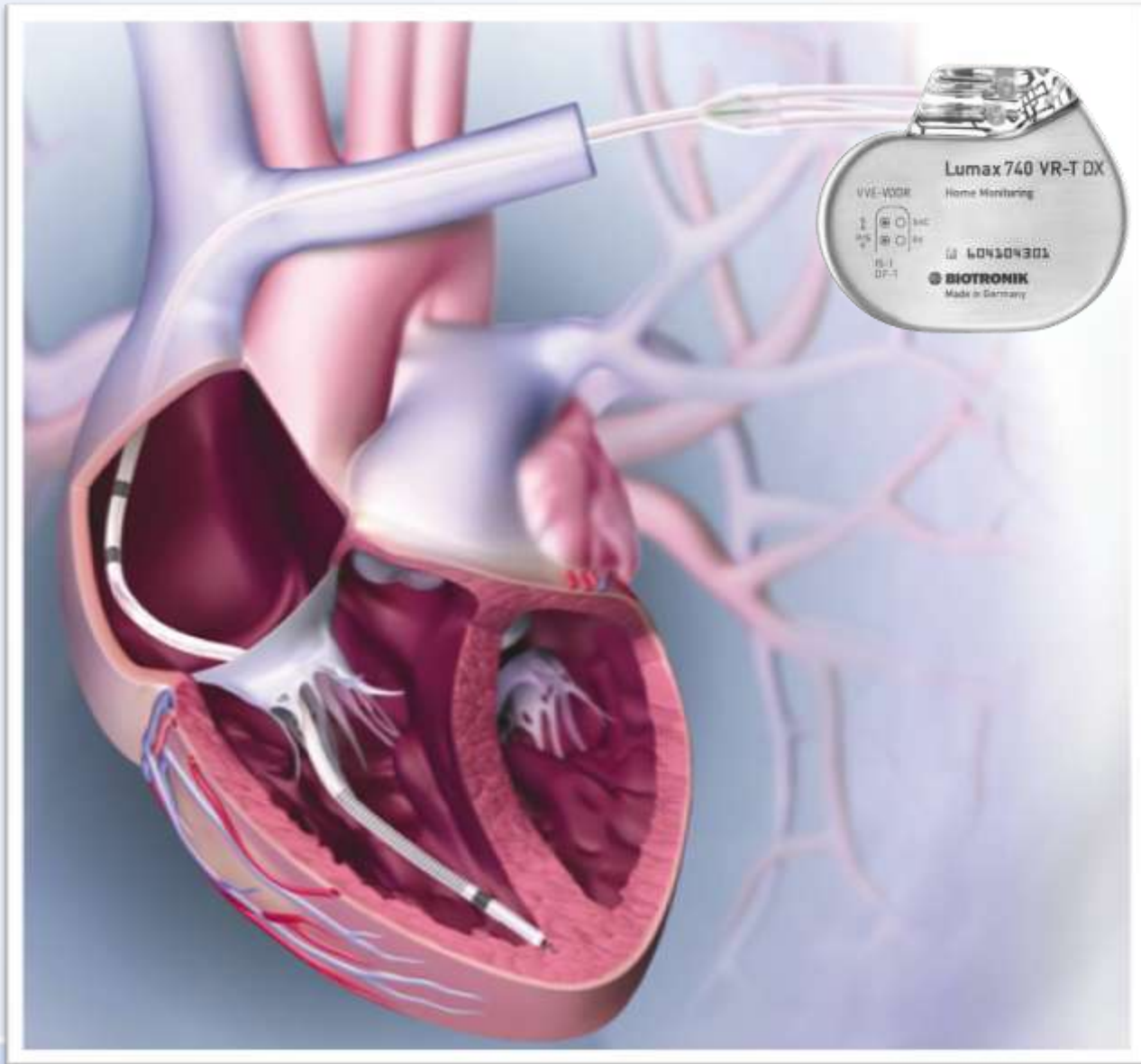


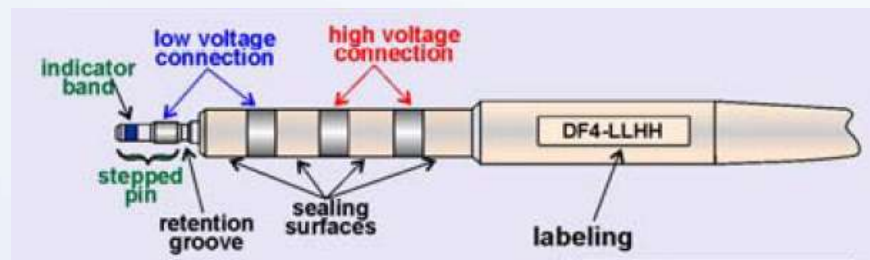
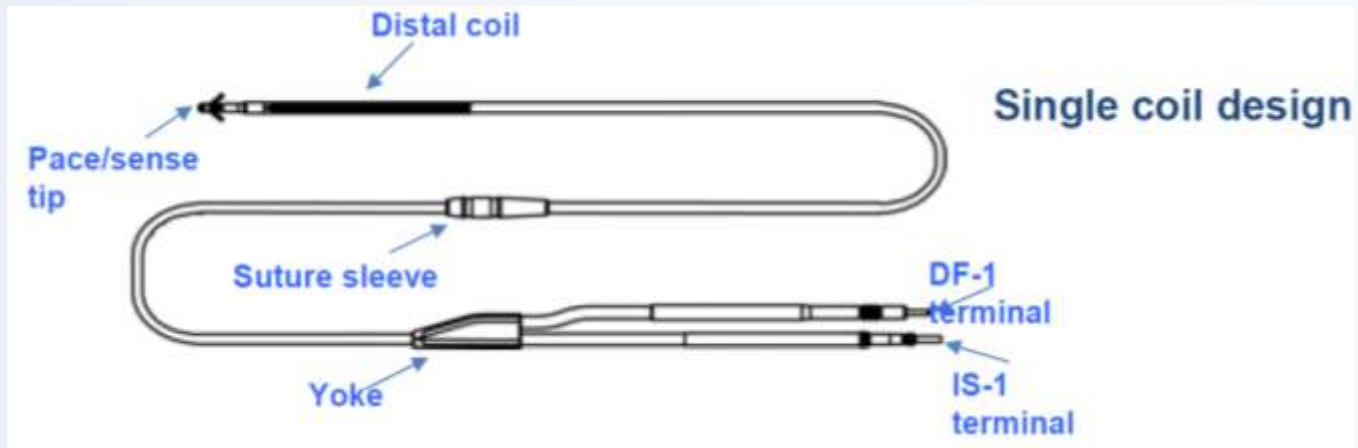
2008 device

72 g., 31.5 ml, 9.9 mm

Protecta XT VR

Volume*	37 cc
Weight	68 g
Charge Time BOS**	7.7 seconds
Charge Time RRT***	9.4 seconds

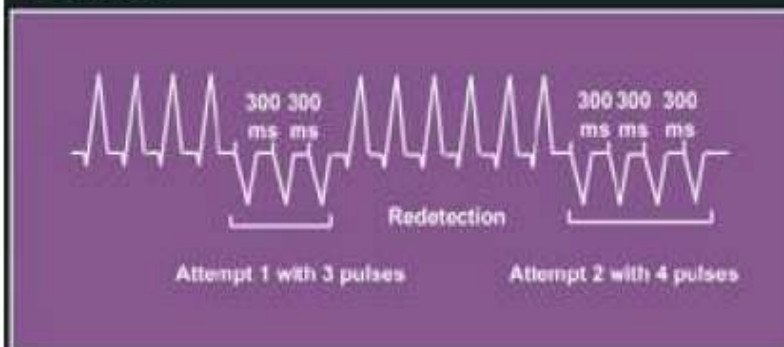




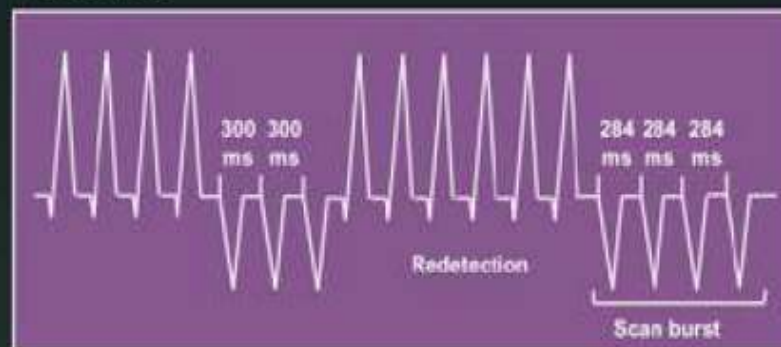
Tachycardia Therapy (ATP)

4 different types of schemes

Burst



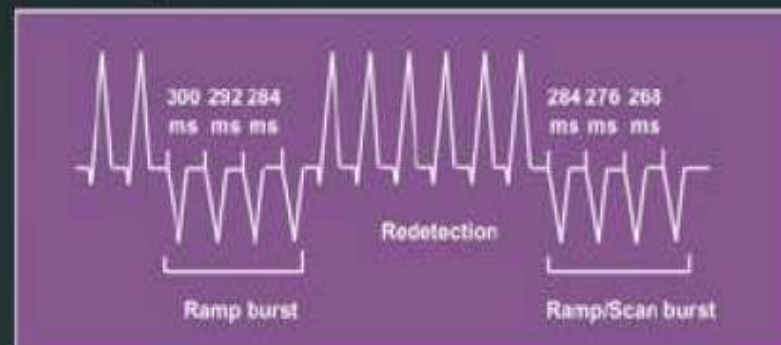
Scan



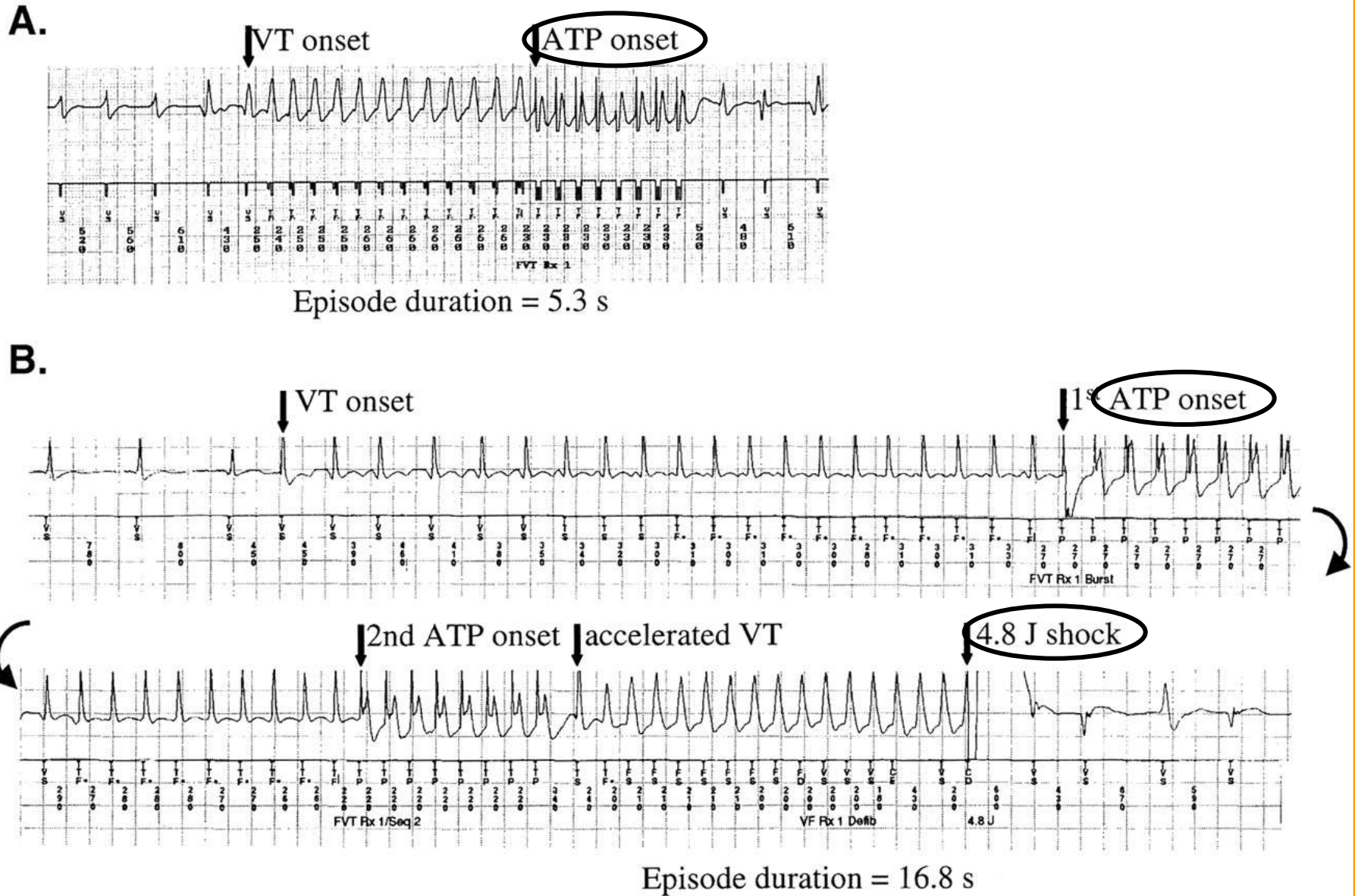
Ramp

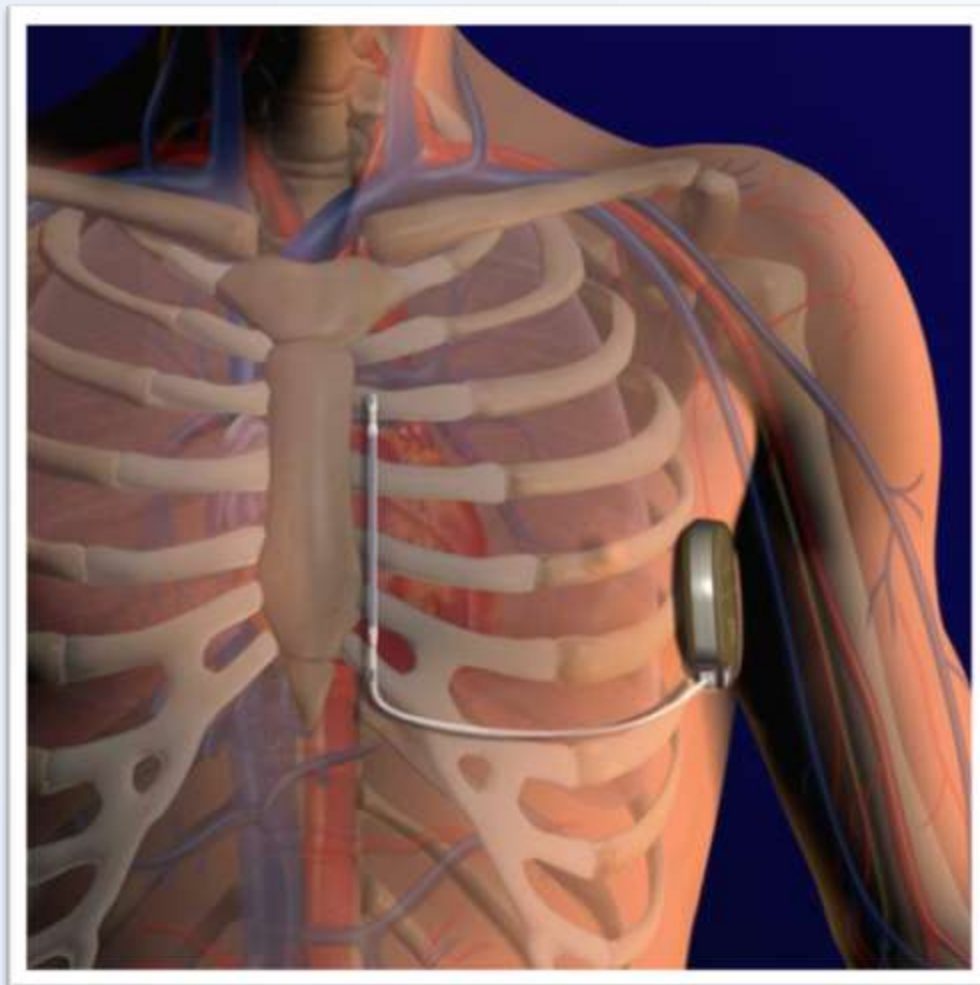


Ramp/Scan

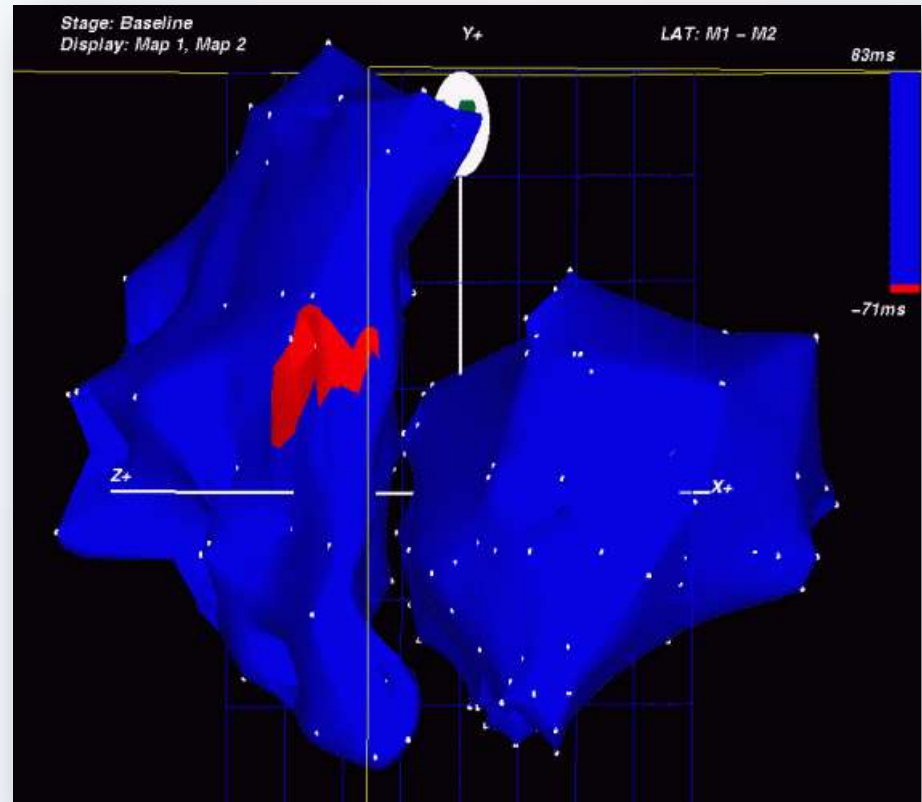
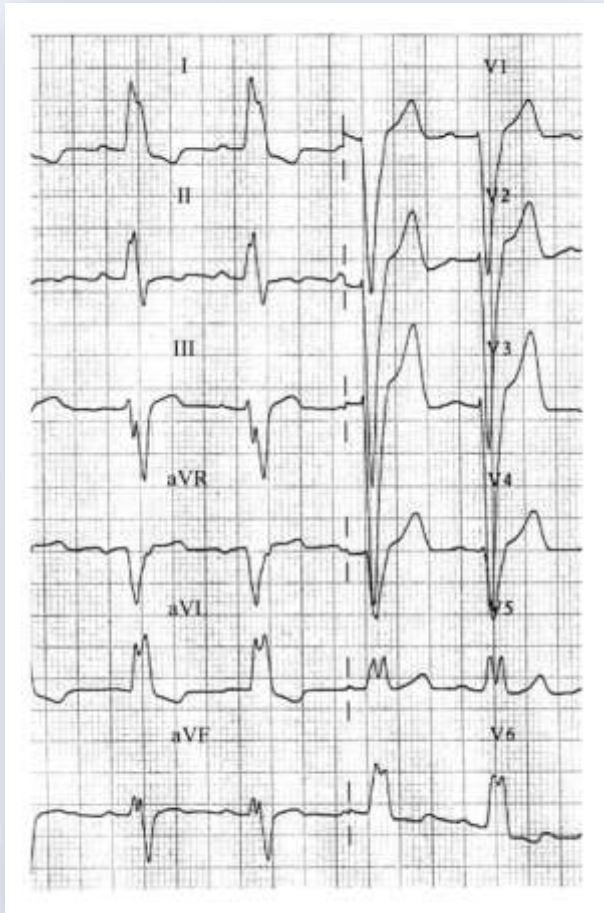


ECG - ICD therapies





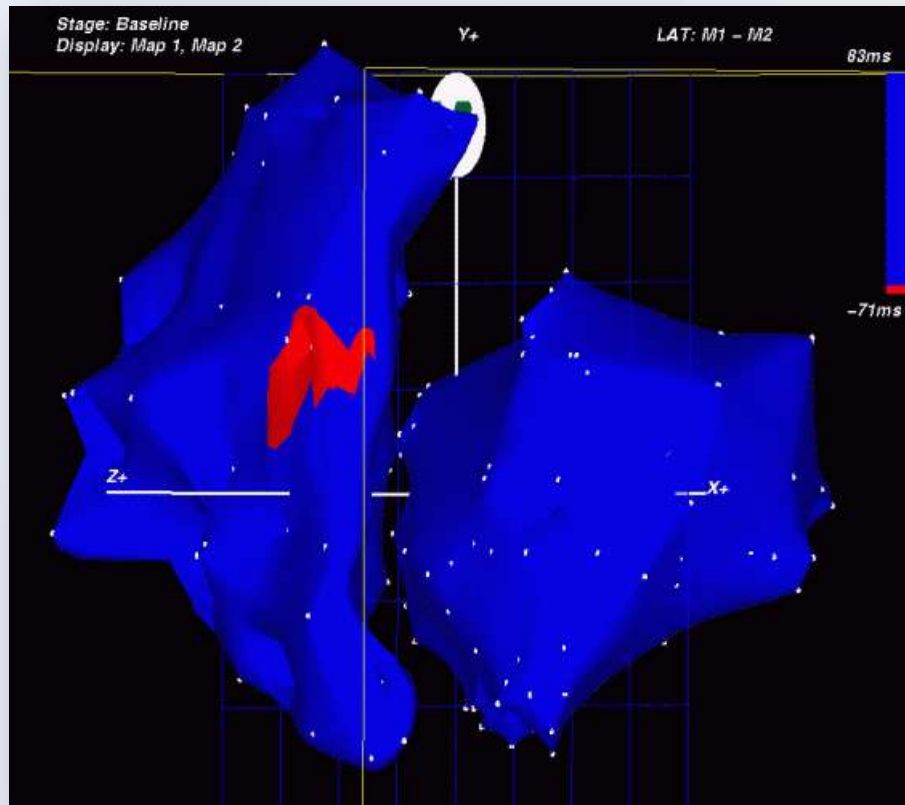
Co je SRL?



Peichl P, Kautzner J, 2006

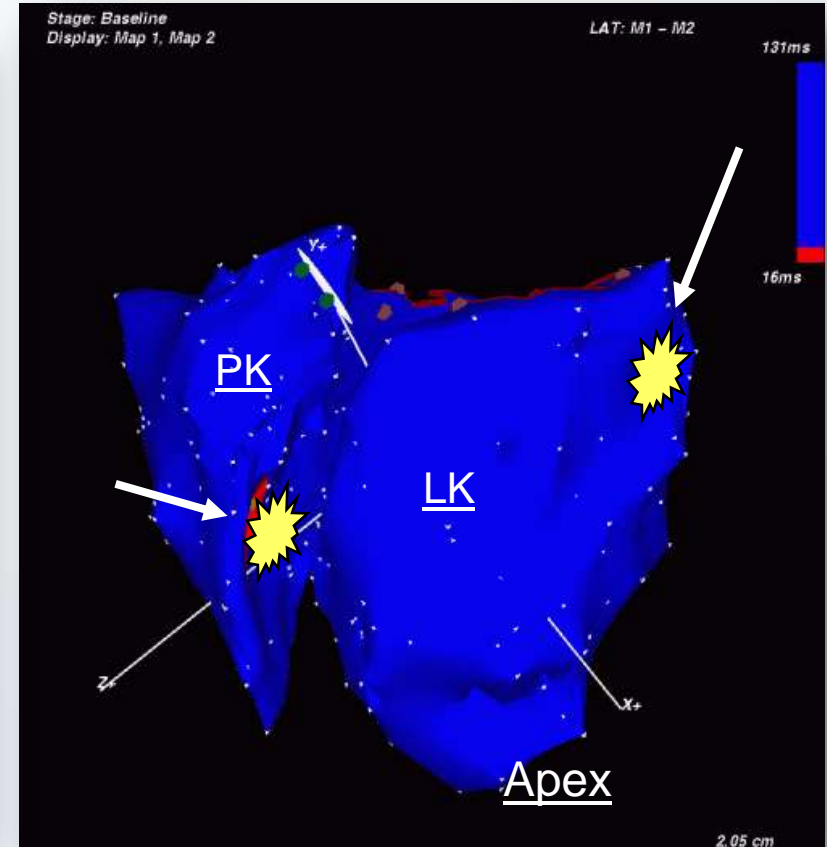
Elektrické (a mechanické) zpoždění při LBBB

Co je SRL?



Elektrická aktivace při LBBB

Peichl P, Kautzner J, 2006

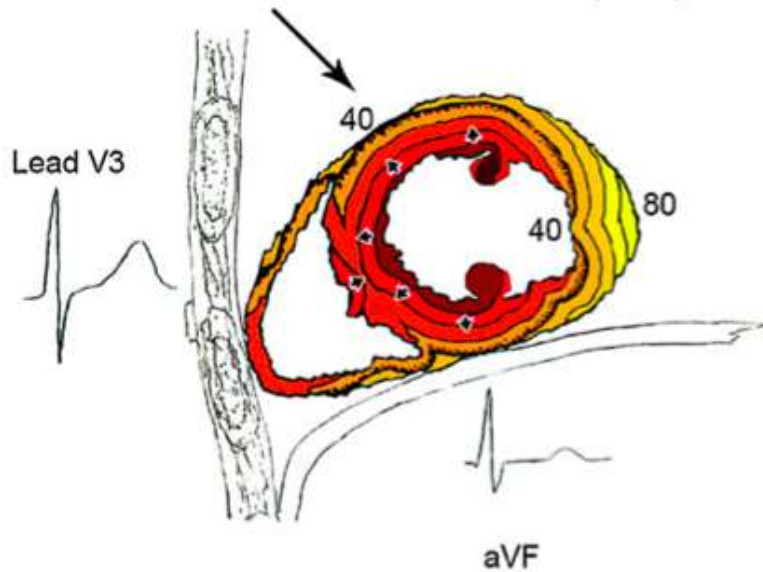


Biventrikulární stimulace

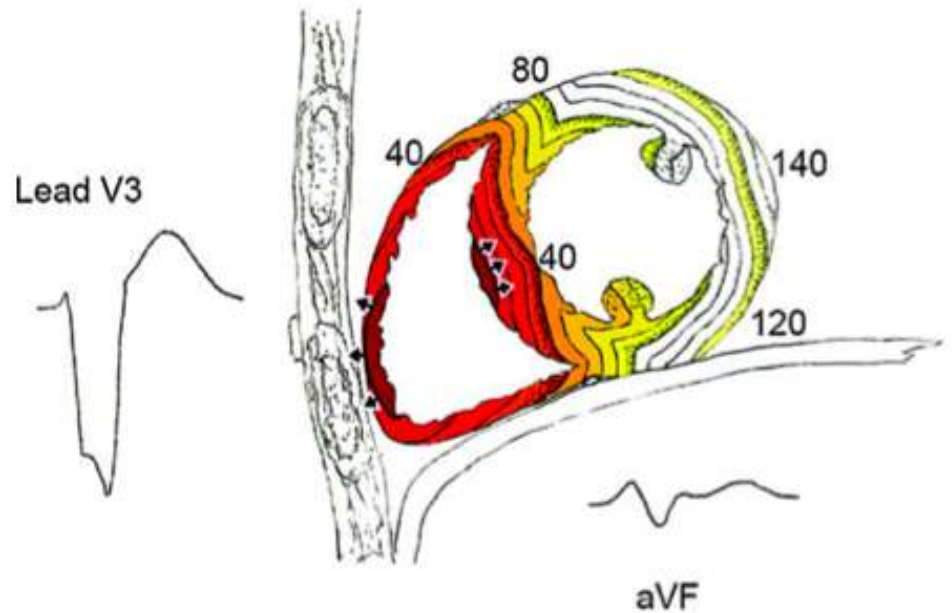
Časování elektrické srdeční aktivace

normal conduction

Electrical Activation Time (msec)



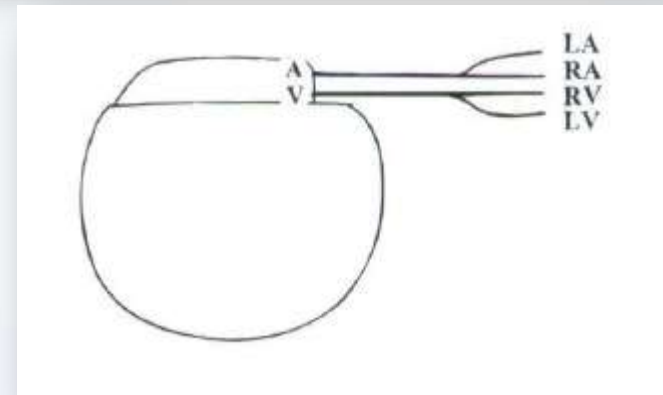
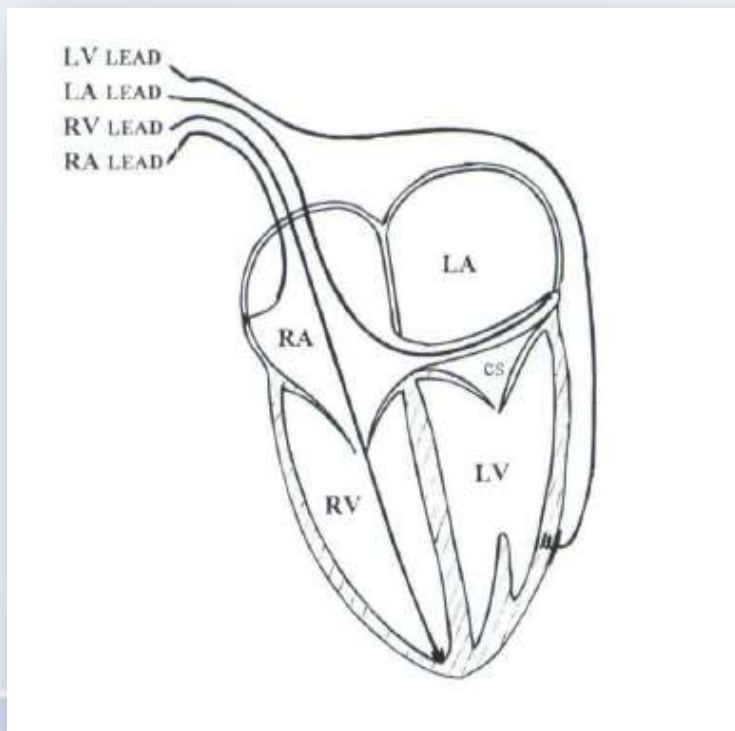
left bundle branch block



Four Chamber Pacing in Dilated Cardiomyopathy

S. CAZEAU, P. RITTER, S. BAKDACH, A. LAZARUS, M. LIMOUSIN,*
L. HENAO, O. MUNDLER,** J.C. DAUBERT,[†] and J. MUGICA

From the Val d'Or Surgical Centre, St. Cloud, the *Clinical Research Department, Ela Medical, Le Plessis Robinson, the **Department of Nuclear Medicine, University Hospital of Lariboisière, Paris, and the [†]University Hospital of Rennes, France



„We doubt that this technique will have an impact on long-term survival, but it could be of major importance to improve the patient's well-being and control heart failure..“.

Zařazovací kritéria studií se SRL

Trial	Patients	NYHA class	LVEF (%)	LVEDD (mm)	SR/AF	QRS (ms)	ICD
MUSTIC-SR ¹⁶	58	III	≤35	≥60	SR	≥150	No
MIRACLE ⁵	453	III, IV	≤35	≥55	SR	≥130	No
MUSTIC AF ³⁵	43	III	≤35	≥60	AF	≥200	No
PATH CHF ⁶	41	III, IV	≤35	NA	SR	≥120	No
MIRACLE ICD ⁸	369	III, IV	≤35	≥55	SR	≥130	Yes
CONTAK CD ⁵⁴	227	II, IV	≤35	NA	SR	≥120	Yes
MIRACLE ICD II ⁹	186	II	≤35	≥55	SR	≥130	Yes
PATH CHF II ⁵⁵	89	III, IV	≤35	NA	SR	≥120	Yes/no
COMPANION ¹⁰	1520	III, IV	≤35	NA	SR	≥120	Yes/no
CARE HF ¹¹	814	III, IV	≤35	≥30	SR	≥120	No
CARE HF ¹⁷	813	III, IV	≤35	≥30	SR	≥120	No
REVERSE ^{21,22}	610	I, II	≤40	≥55	SR	≥120	Yes/no
MADIT CRT ²⁰	1800	I, II	≤30	NA	SR	≥130	Yes
RAFT ⁵⁶	1800 Canada	II, III	≤30	>60	SR/AF	≥130 ≥200 ^a	Yes

2010 Focused Update of ESC Guidelines on device therapy in heart failure.
European Heart Journal (2010) 31, 2677–2687

Efekt SRL širě QRS

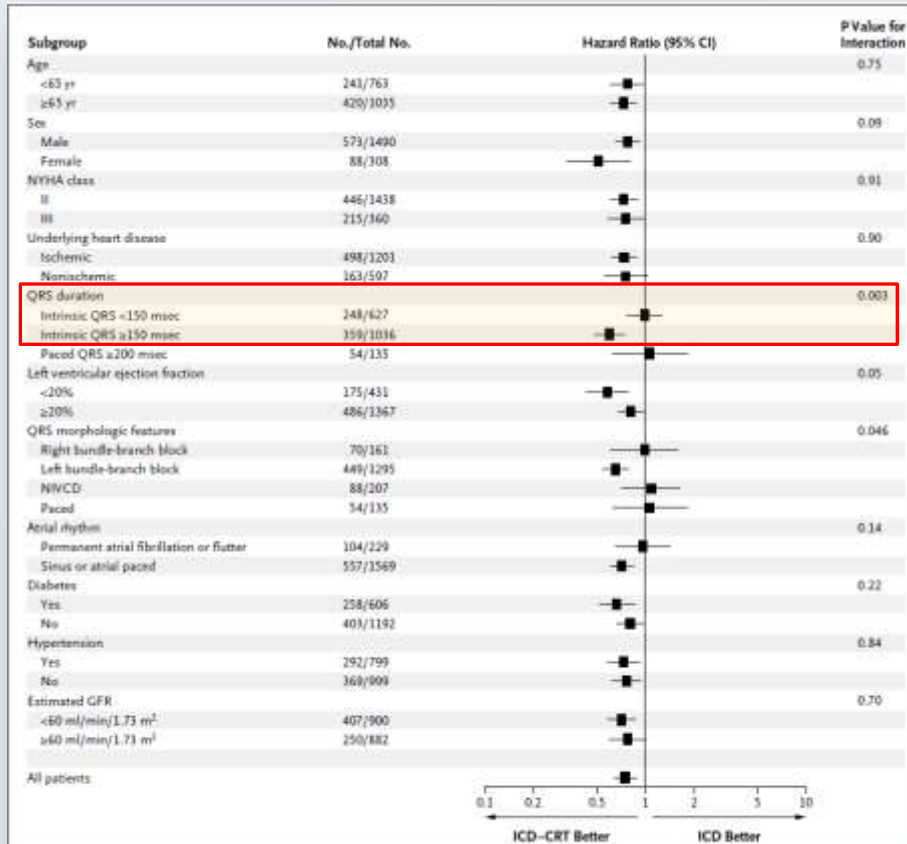
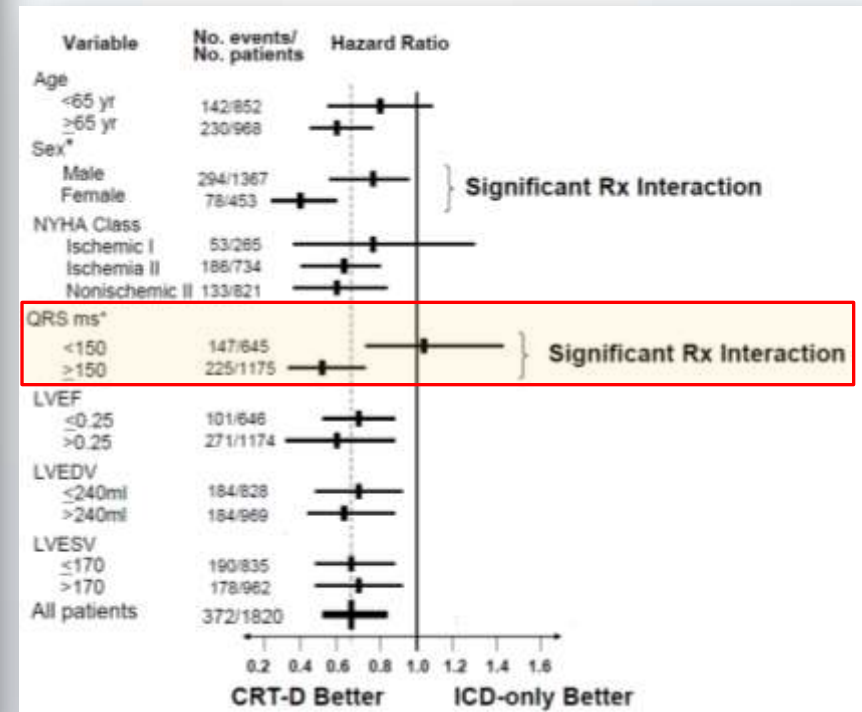


Figure 3. Subgroup Analyses of Death or Hospitalization for Heart Failure (Composite Primary Outcome). Hazard ratios and 95% confidence intervals are shown for the primary outcome in each prespecified subgroup. GFR denotes glomerular filtration rate, NIVCD nonspecific intraventricular conduction delay, and NYHA New York Heart Association.

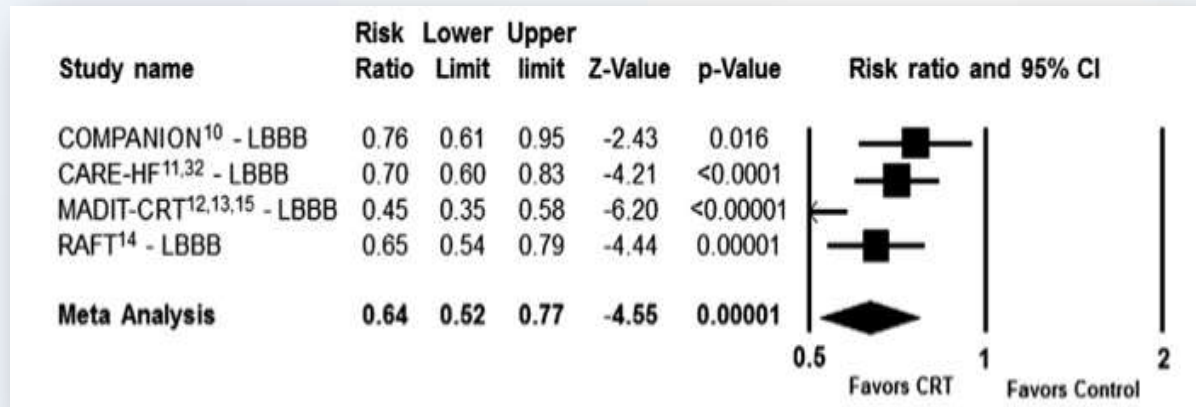


Moss et al. MADIT-CRT Trial. NEJM 2009

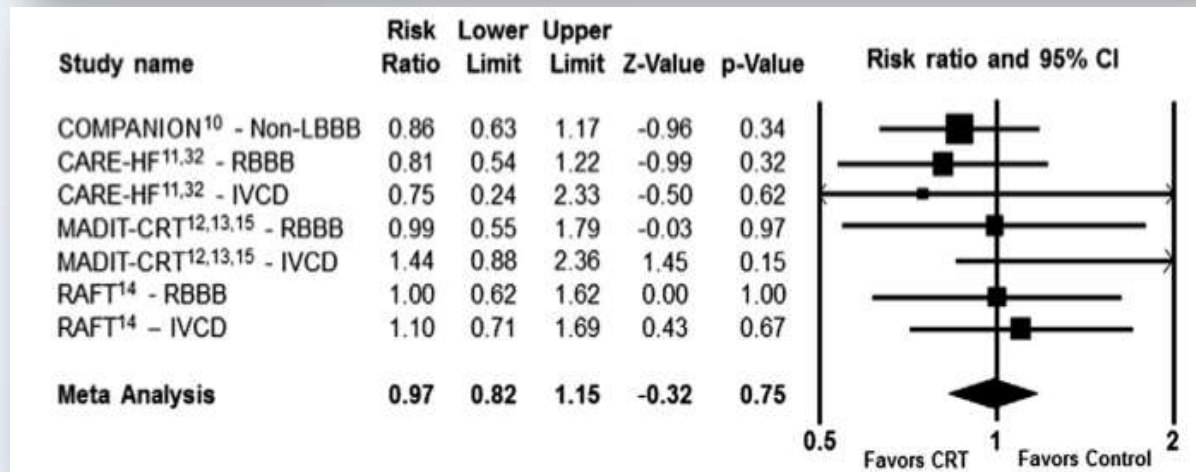
Tang et al. RAFT Trial. NEJM 2010

Efekt SRL podle typu blokády

BLRT



Non-BLRT



Sipahi I, et al. *Am Heart J* 2012;163:260-267.e3.)

Aditivní princip kardiovaskulární terapie posledních 20 let

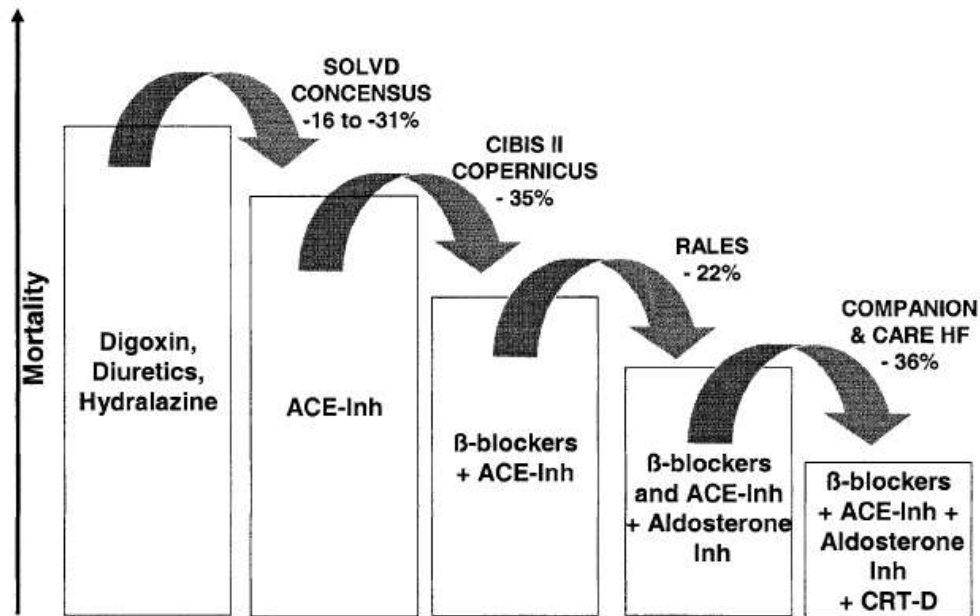


Figure 2. Add-on therapy in heart failure. Each added therapy incrementally decreases mortality when added on top of previous therapy. See text for explanation and references. ACE-Inh = acetylcholinesterase inhibitor; other abbreviations as in Figure 1.

Shrnutí doporučení pro CRT

NYHA III, IV

QRS BLRT

- QRS > 120 ms
- EF < 35 %
- Ambulantní režim

QRS non-BLRT

- QRS > 150 ms

NYHA II

QRS BLRT

- QRS 130 ms
- EF < 30 %

QRS non-BLRT

- QRS > 150 ms

Cíl a evidence

Redukce morbidity a mortality

I A

Redukce morbidity a mortality

IIa A

Další indikace SRL

Dysfunkce levé komory $EF \leq 35 \%$

+

Antibradykardická indikace pro AV blokádu

nebo

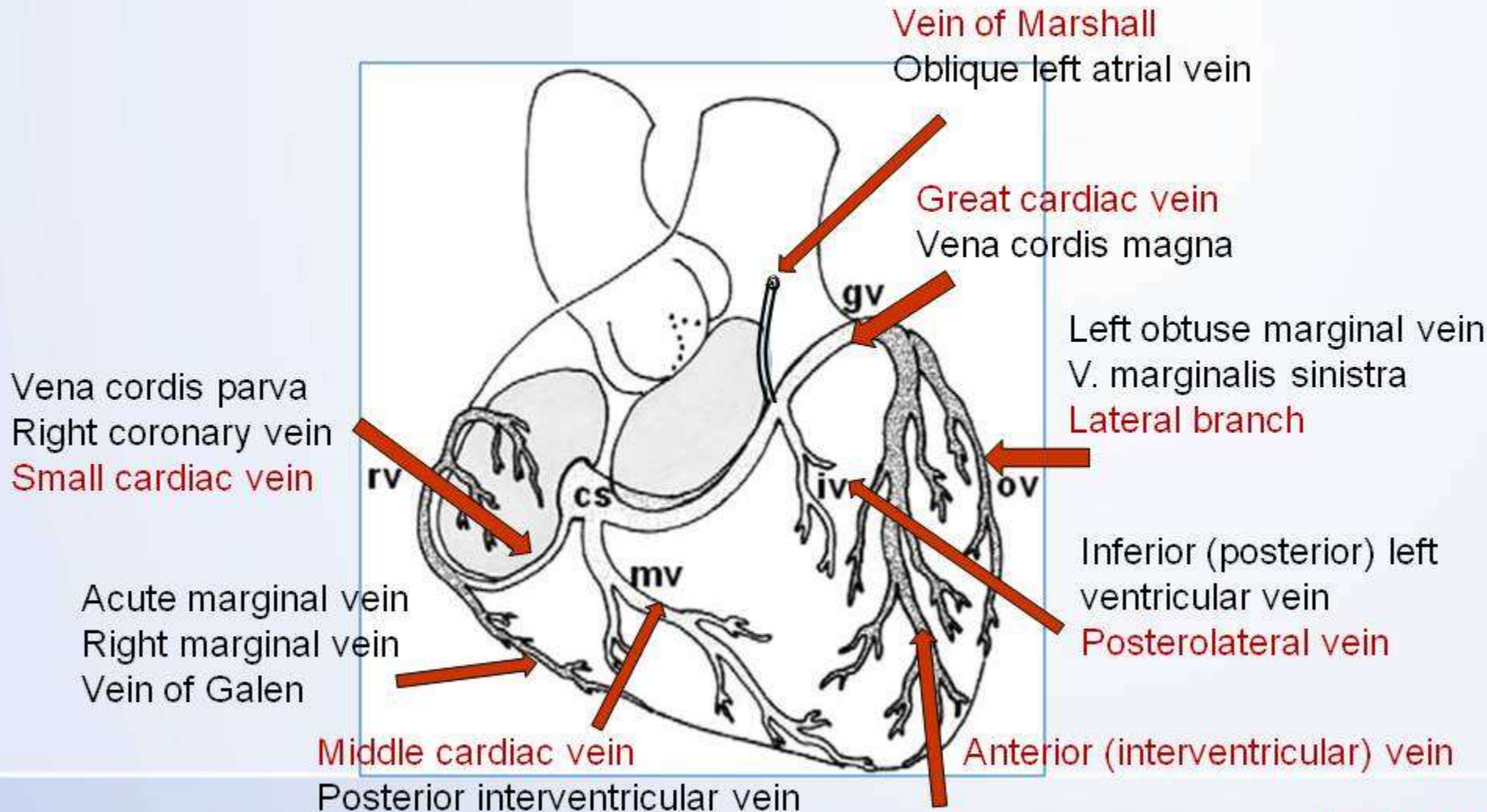
Indikace k ablaci AVN pro fibrilaci síní s rychlou komorovou odpovědí

Implantační výkon

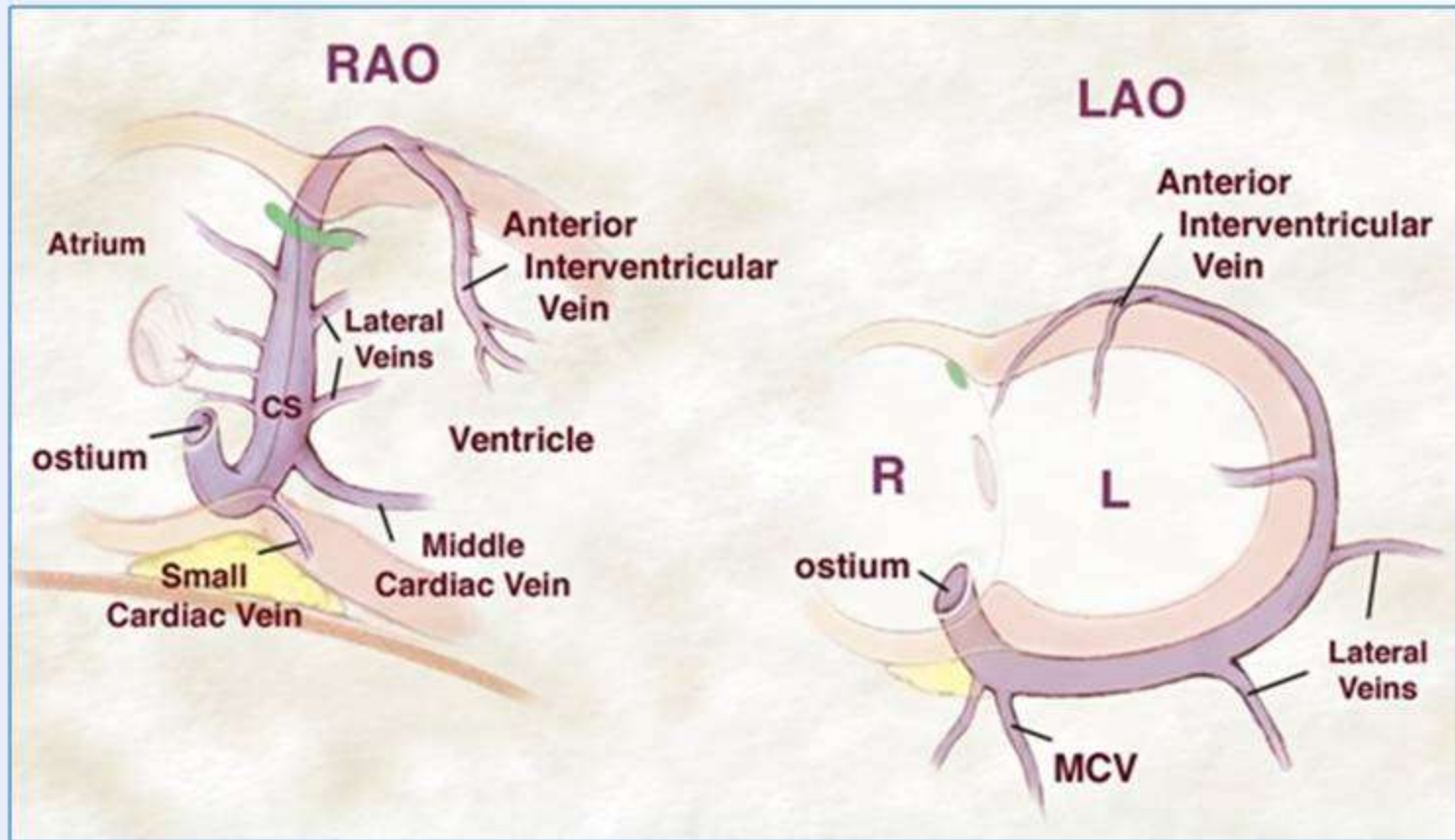
- 3-denní hospitalizace
- Analgosedace a lokální anestezie
- Délka výkonu kolem 90 min
- IKEM: od r. 2000, ročně kolem 150 výkonů

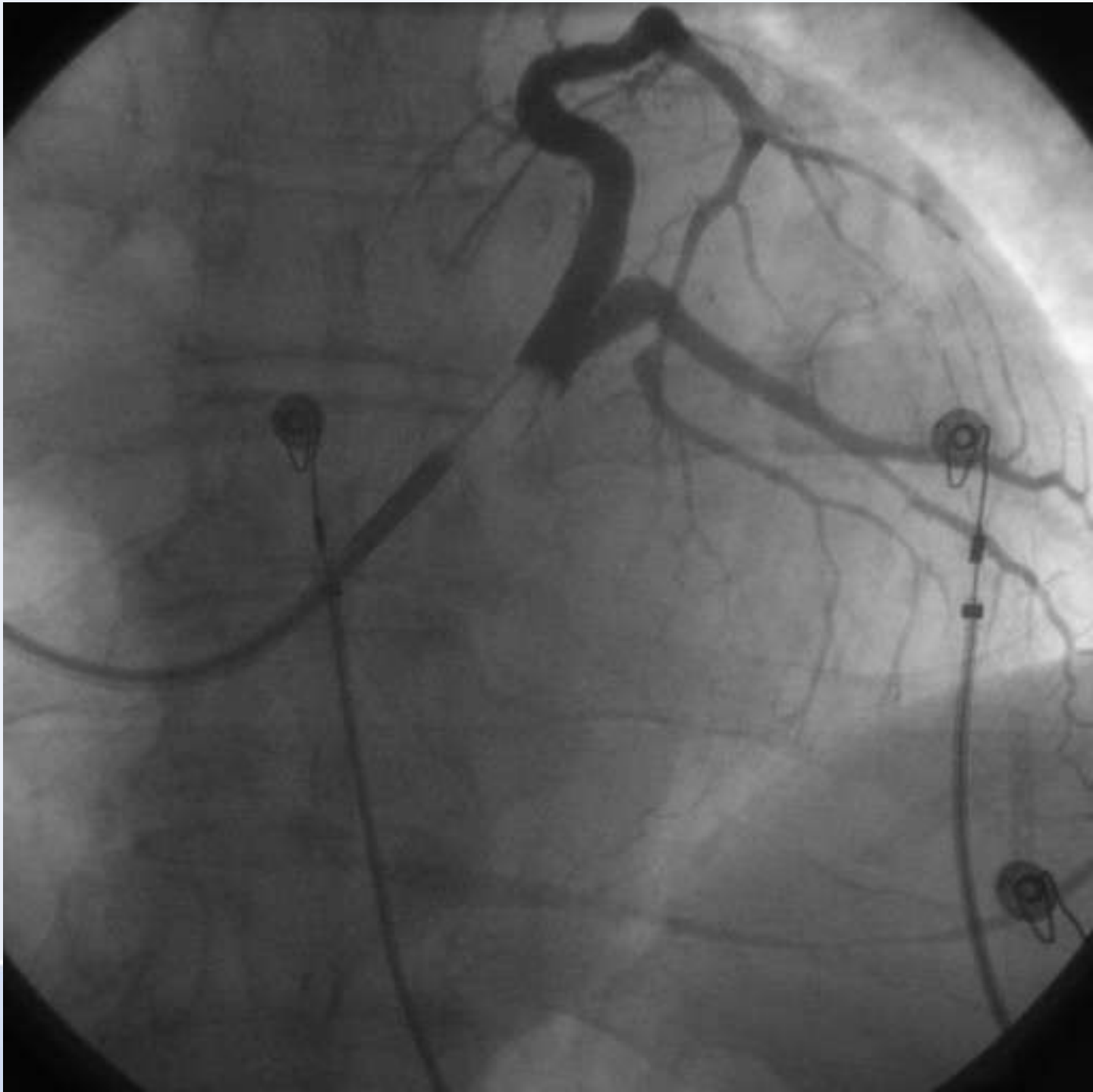


Gross anatomy and nomenclature

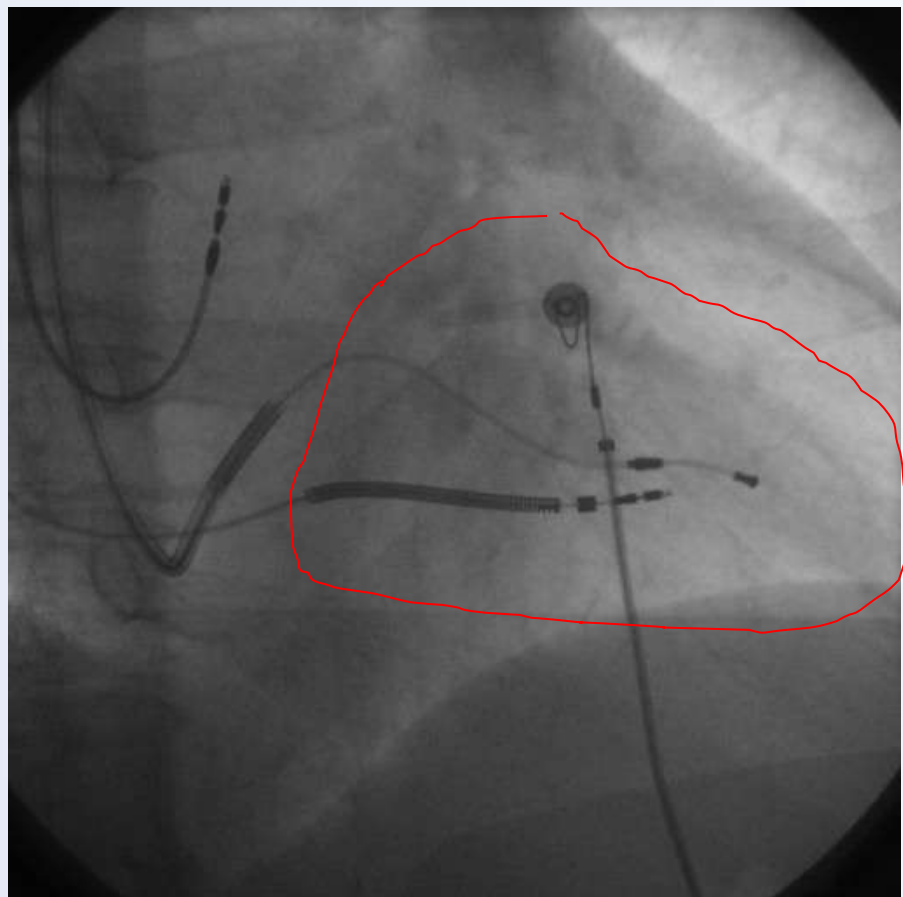


Fluoroscopic cardiac vein anatomy

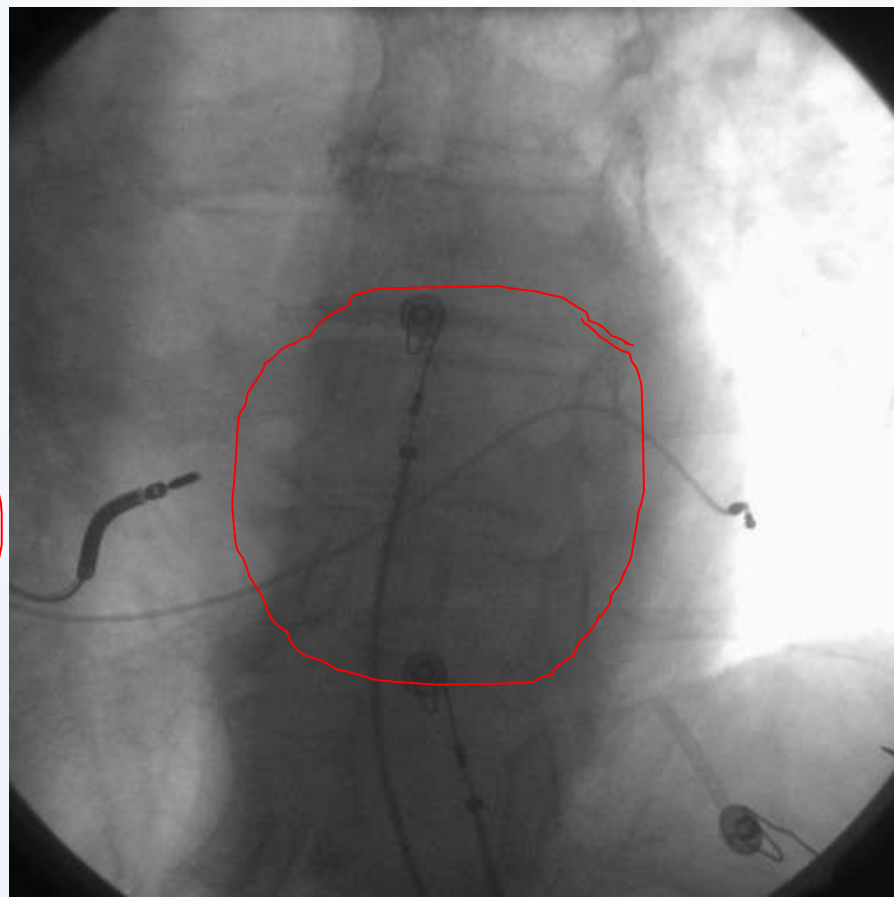




RAO



LAO



Pozdní komplikace

- Pozdní dislokace: 2 (0,2 %)
- Fatální endokarditida: 1 (0,1%)
- Život ohrožující endokarditida: 2 (0,2 %)
- Endokarditida dobře zvládnutá terapií: 2 (0,2%)

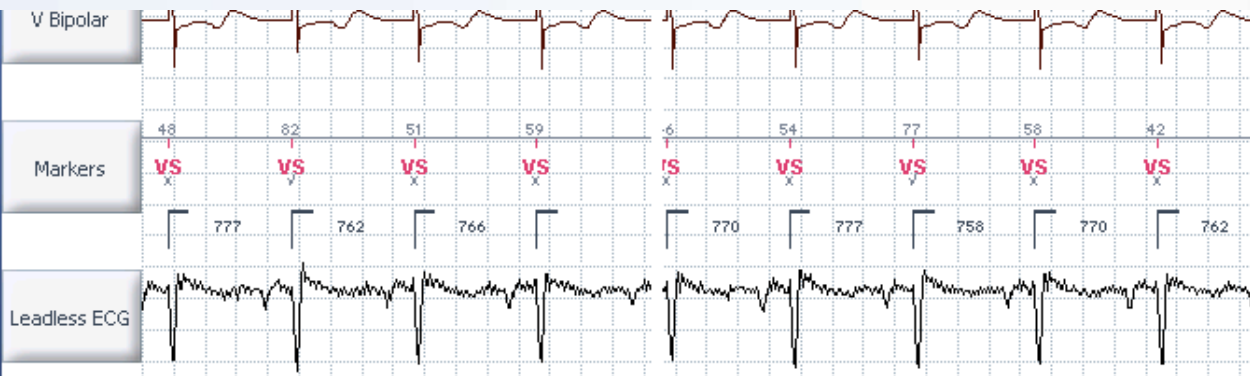
Sledování pacientů léčených implantabilními přístroji

- Zhodnocení klinického stavu
- Hodnocení a další optimalizace farmakoterapie
- EKG
- Interogace přístroje
- Řešení komplikací souvisejících s přístrojem

Tachy Therapy is ENABLED

POKORNA Hana
AnalyST Accel™ VR

Note:



78 min⁻¹

Ready

No Alerts

Longevity: 8,0 yrs

~ERI > 5 yrs

Last Max Charge: 10,9 sec (27-Feb-2013)

Voltage: 3,19 V

Mode **VVI**

Base Rate **45 min⁻¹**

V Pulse Amp **2,5 V**

V Pulse Width **0,5 ms**

- FastPath™ Summary**
- Episodes**
- Diagnostics**
- Tests**
- Parameters**
- Wrap-up™ Overview**

Test Results (Today's most recent results shown on top) Automatic

	Capture	Sense	Lead Impedance
V	Today: 0,5V@0.5ms (Bi) 5 Oct 2012: < 0,25V@0.5ms (Bi)	Today: 11,7mV (Bi) A 5 Oct 2012: 11,7mV (Bi)	Today: 540Ω (Bi) A 4 Oct 2012: 480Ω (Bi)
HV			Today: 60Ω (RV-SVC&Can) A 4 Oct 2012: 55Ω (RV-SVC&Can)

Tachy: 2 Zone Configuration

VT	VF
179 min⁻¹	222 min⁻¹
ATPx3, 15,0l, 25,0l, 36,0lx2	36,0l, 36,0l, 36,0lx4

VT/VF Episodes: 0

VT	VF
0	0

SVT Episodes: 0

VP: 1,1 %

rhythmiedetail

Episode: 8

Datum: Zeit:
20-SEP-98 20:10

Arrhythmie Auslöser
Maximal erreichte Frequenz
Arrhythmiedauer

V-TACHY
250 min-1
(HH:MM:SS)

speicherte EGM

Episode: 8

EGM

V-EGM



Ende des Berichts

Sledování pacientů s CRT

- Hodnocení přítomnosti biventrikulární stimulace
- Procento biventrikulární stimulace
 - CAVE fibrilace síní
- Diagnostika příčin při chybění odpovědi na terapii
- Další optimalizace terapie
- Monitorování na dálku

Typy odpovědi na SRT

zlepšení stavu (60 - 70%)

response (1-4)

bez odpovědi (30 %)

non-response (1-4)

výrazné zlepšení
funkčního stavu a
výrazná reverzní
remodelace LK

PK
hyper-response (5)
super-response

1. Abraham et al, N Engl J Med 2002
2. Bradley DJ et al., JAMA 2003
3. Cleland JCF et al, N Engl J Med 2005
4. van Bommel R.J. et al., EHJ 2009
5. Blanc JJ, Europace 2005

Prediktory

chybění odpovědi

- BPRT, nespecifická porucha vedení
- iKMP
- NYHA IV
- CHRI
- Diabetes
- Vysoké hladiny BNP
- Těžká mitrální regurgitace
- Vysoký věk

Saxon LA et al. Predictors of sudden cardiac death and appropriate shock in the COMPANION Trial. *Circulation* 2006;114(25):2766-72

Bilchick KC et al. Bundle-branch block morphology and other predictors of outcome after cardiac resynchronization therapy in Medicare patients. *Circulation*. 2010;122(20):2022-30

Richardson M et al.; CARE-HF Study Steering Committee and Investigators. Predictors and treatment response with cardiac resynchronization therapy in patients with heart failure characterized by dyssynchrony: a pre-defined analysis from the CARE-HF trial. *Eur Heart J* 2007;28(15):1827-34

Cappola TP et al. Predictors of remodeling in the CRT era: influence of mitral regurgitation, BNP, and gender. *J Card Fail* 2006;12(3):182-8.

Xu YZ et al. Cardiac resynchronization therapy: do women benefit more than men? *J Cardiovasc Electrophysiol* 2012;23(2):172-8

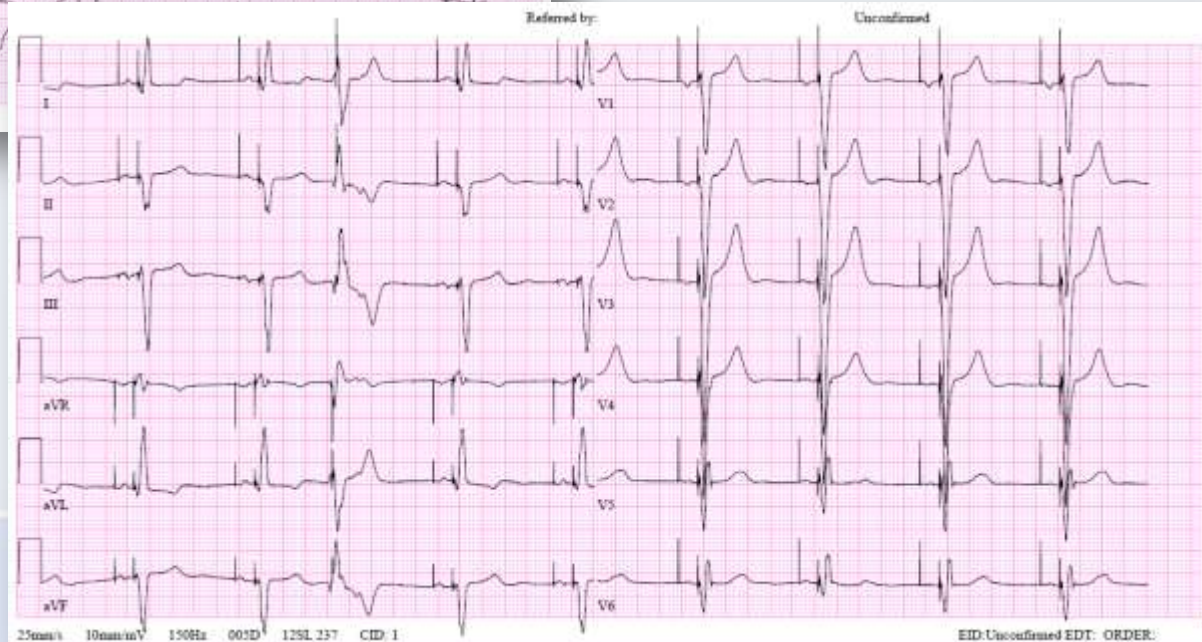
Hsing JM et al. Paced left ventricular QRS width and ECG parameters predict outcomes after cardiac resynchronization therapy: PROSPECT-ECG substudy. *Circ Arrhythm Electrophysiol* 2011;4(6):851-7

Goldenberg I et al.; MADIT-CRT Executive Committee. Predictors of response to cardiac resynchronization therapy in the MADIT-CRT. *Circulation* 2011;124(14):1527-36

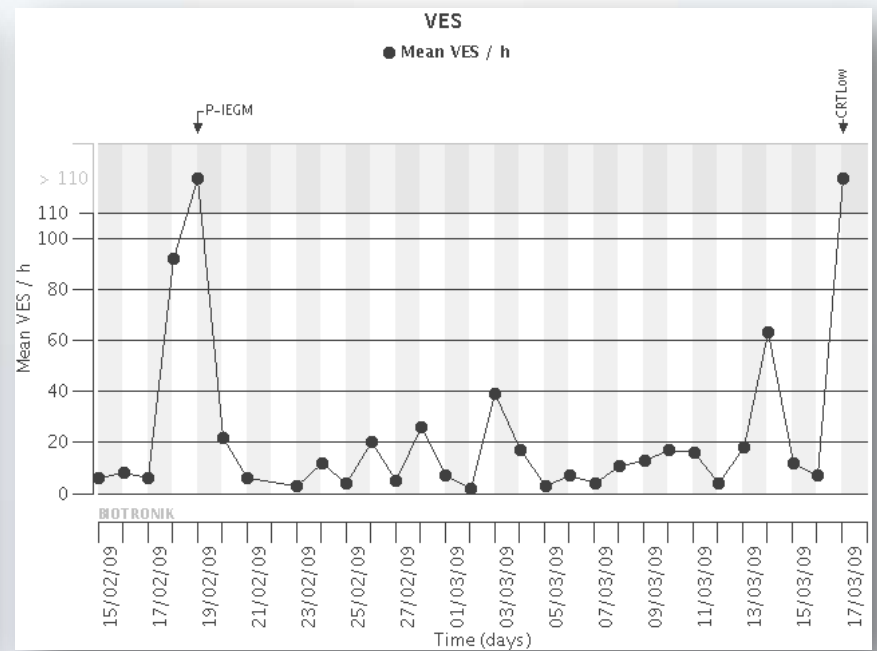
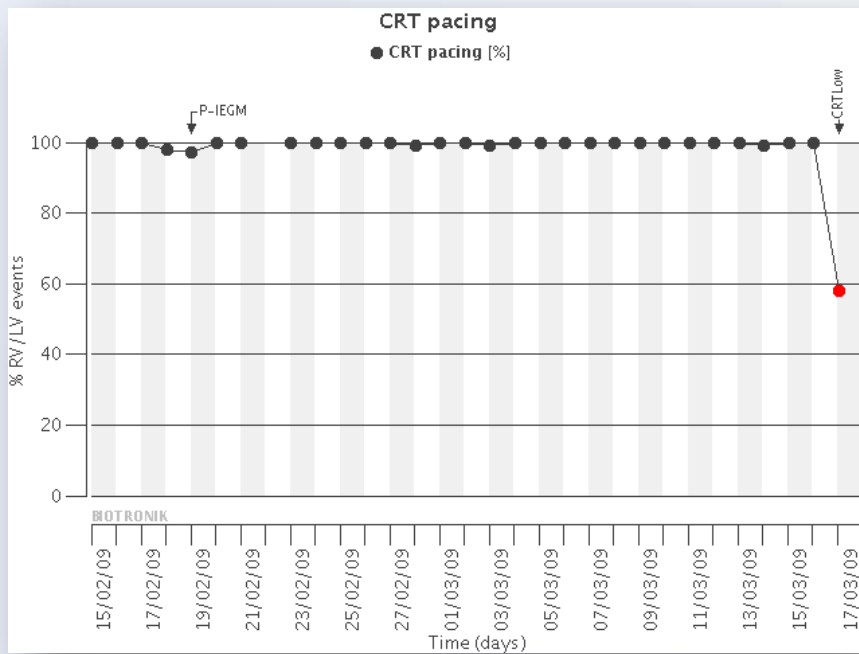
dobré odpovědi

- BLRT
- QRS > 150 ms
- NIDCM
- Ženské pohlaví
- Méně dilatovaná LK
- Objem levé síně < 40 ml/m²
- Echokardiografie (?)

Změna EKG při biventrikulární stimulaci

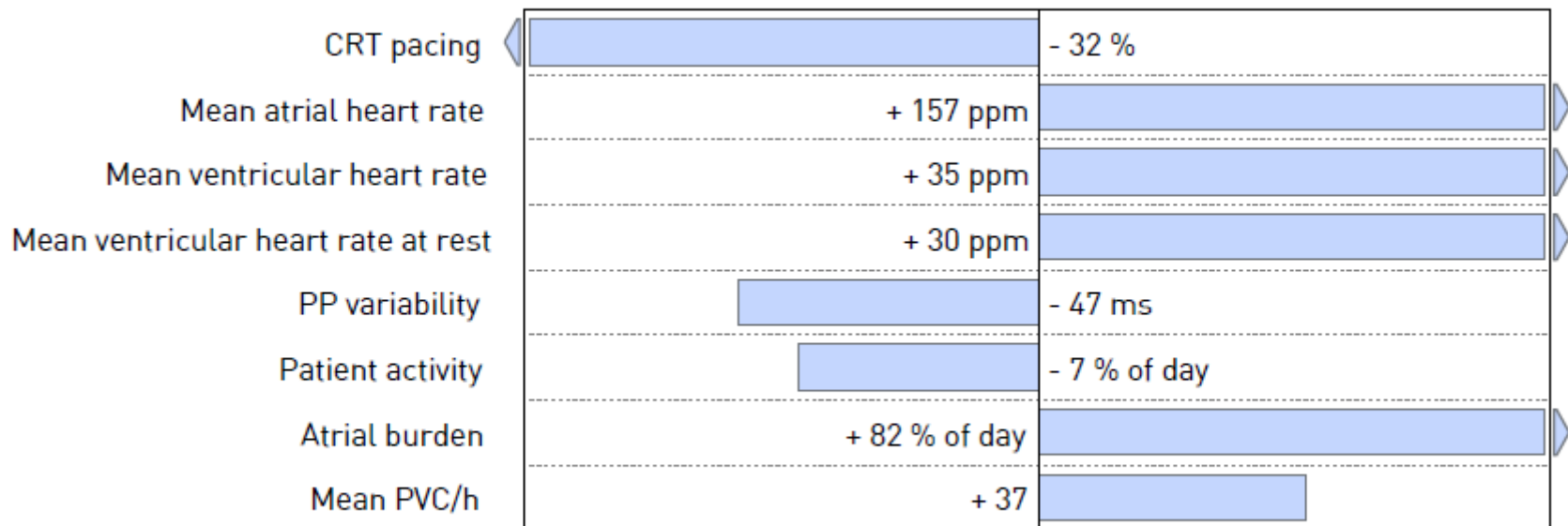


Monitorování na dálku



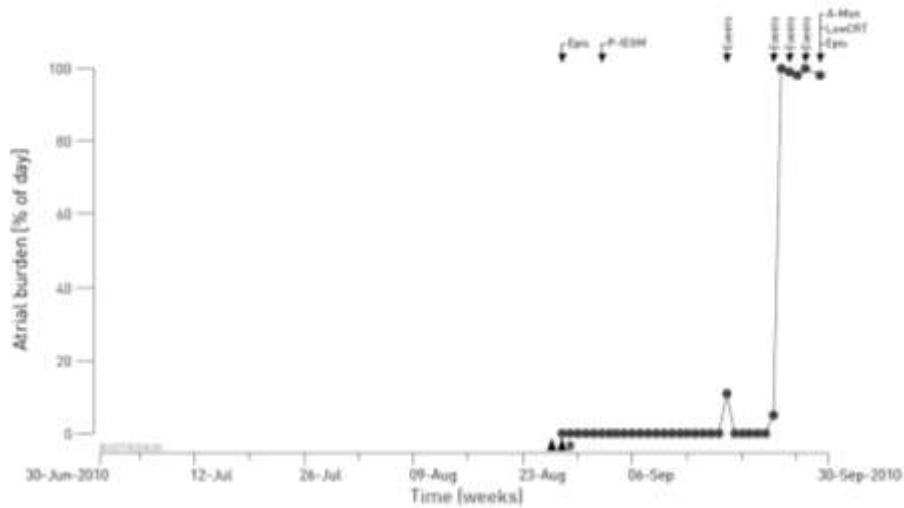
Monitorování na dálku

HF Monitor Guide



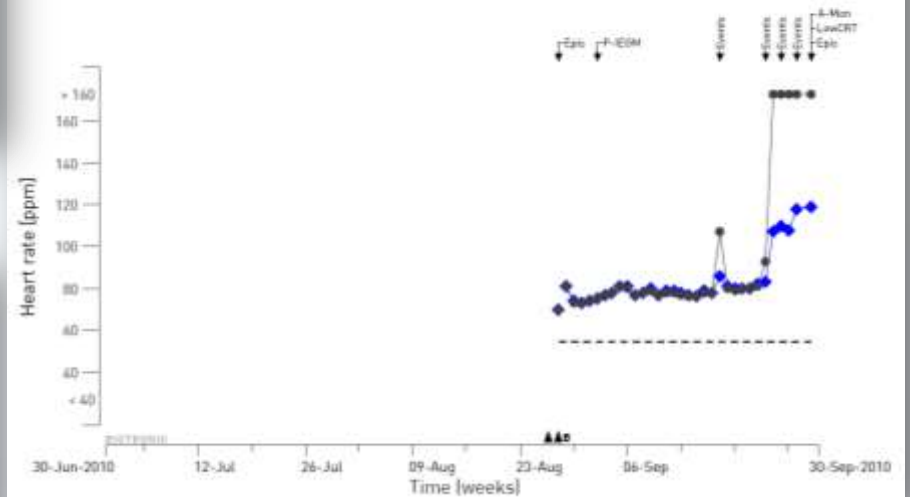
Difference to mean since 28-Aug-2010 00:00:36

• Atrial burden [% of day]



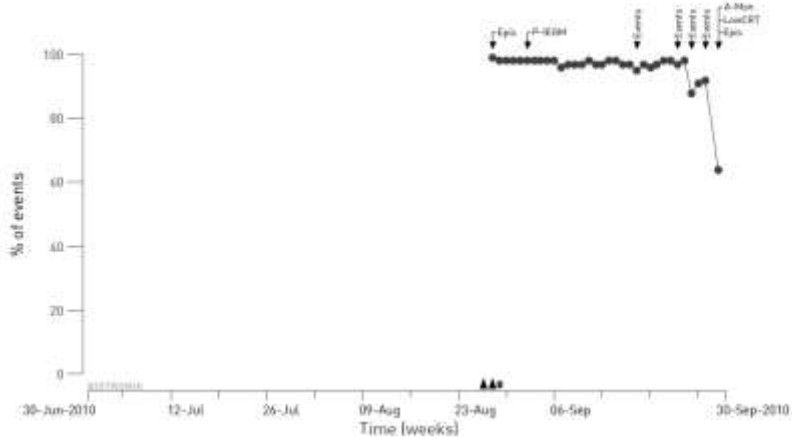
Mean heart rate

• Mean atr. heart rate [ppm] ♦ Mean ven. heart rate [ppm] = Progr. basic rate [ppm]



CRT pacing

• CRT pacing [%]



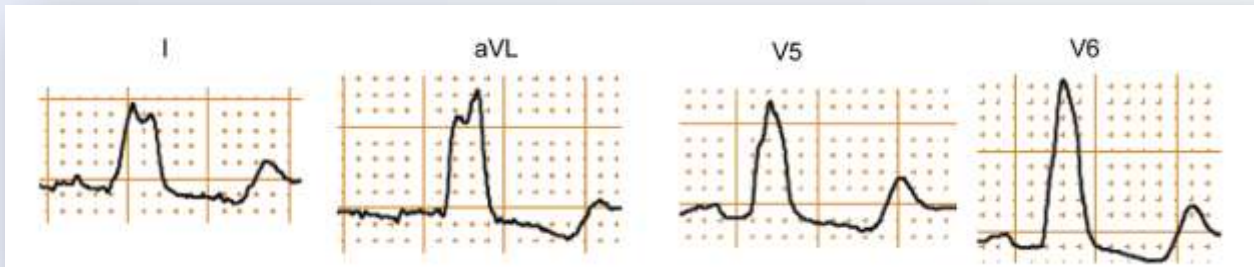
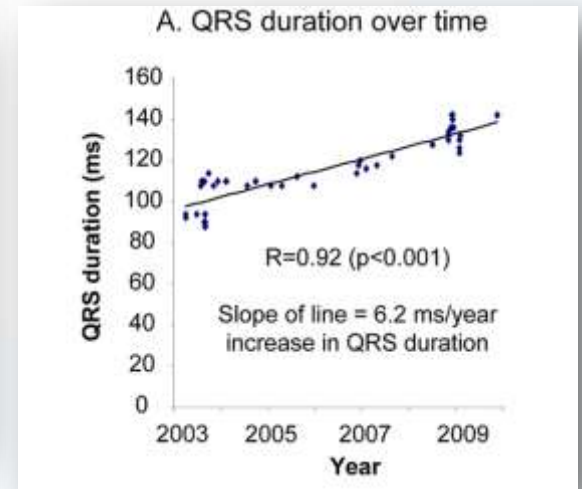
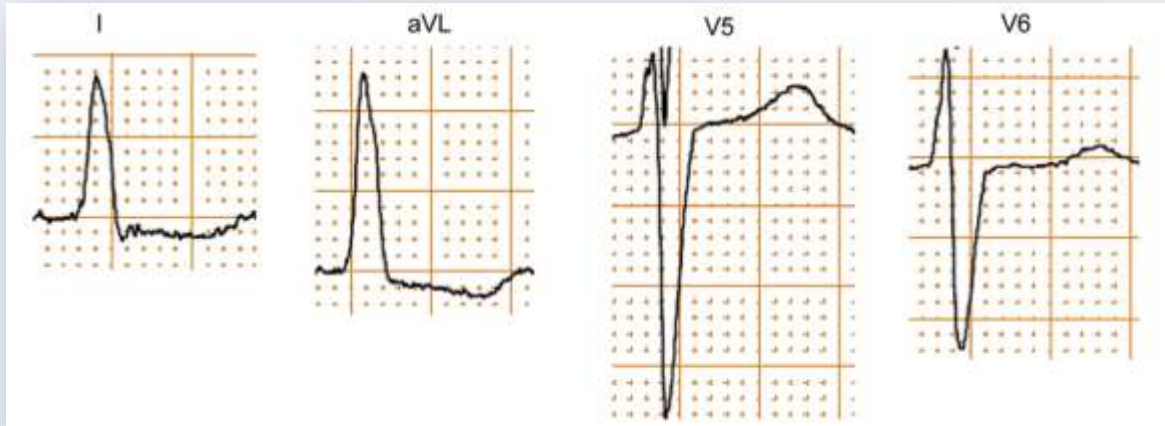
Závěr

- Přístrojová terapie je dnes integrální součástí péče o kardiologické pacienty.
- Zahrnuje bradykardickou kardiostimulaci, prevenci náhlé srdeční smrti (ICD) a léčbu srdečního selhání u pacientů se širokým QRS (CRTD, CRTP)
- Implantační výkony jsou bezpečné a dnes trvají kolem 30-90 min
- Život ohrožující komplikace související s implantátem jsou vzácné a patří mezi ně především infekce v chronické fázi terapie.

LBBB

- Experimentálně vytvořený LBBB: 1909
- 1914: Carter et al. – série EKG
- 1920: kritéria BBB: Wilson @ Hermann – široký QRS
- 1920: Oppenheimer, Pardee – vyměnili (napravili) RBBB a LBBB
- 1930: EP potvrzení LBBB a RBBB
- 1941: Wilson: BBB: QRS > 120 ms

NIVC, LVH, LBBB



Návrh nové definice LBBB

- QRS > 140 ms u mužů, 130 ms u žen
- QS n. rS V1, V2
- „notching“ n. „slurring“ QRS komplexu v jeho střední části (50 – 90 ms)

