

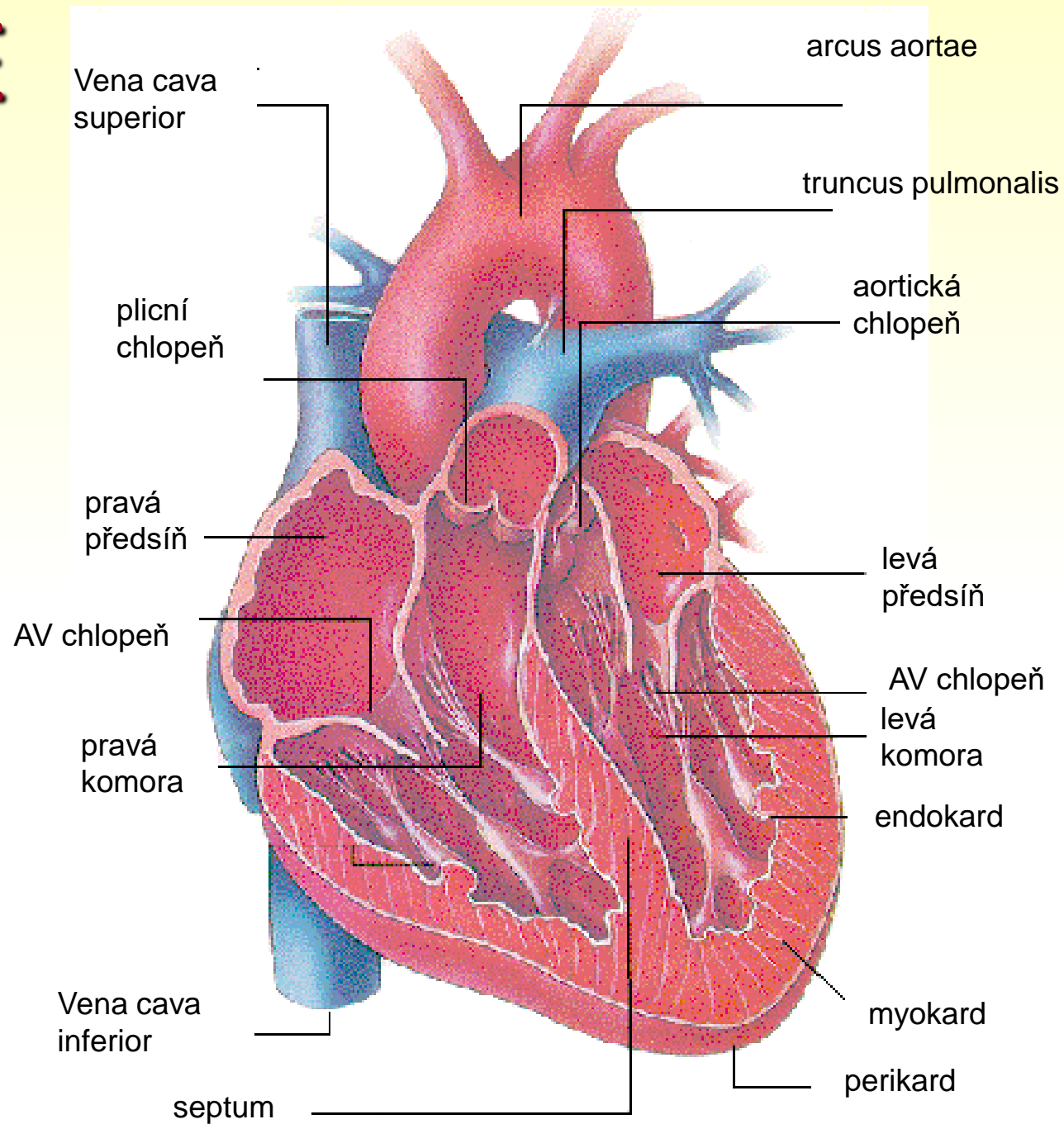
# 3. PŘEDNÁŠKA

13. října 2022

## SIGNÁLY SRDCE I.

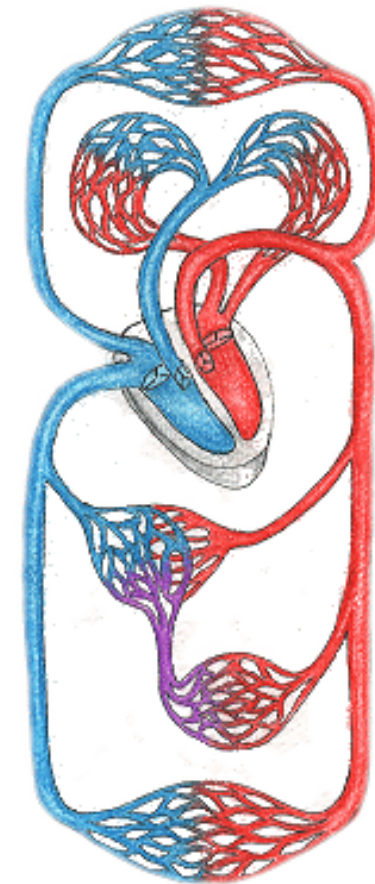
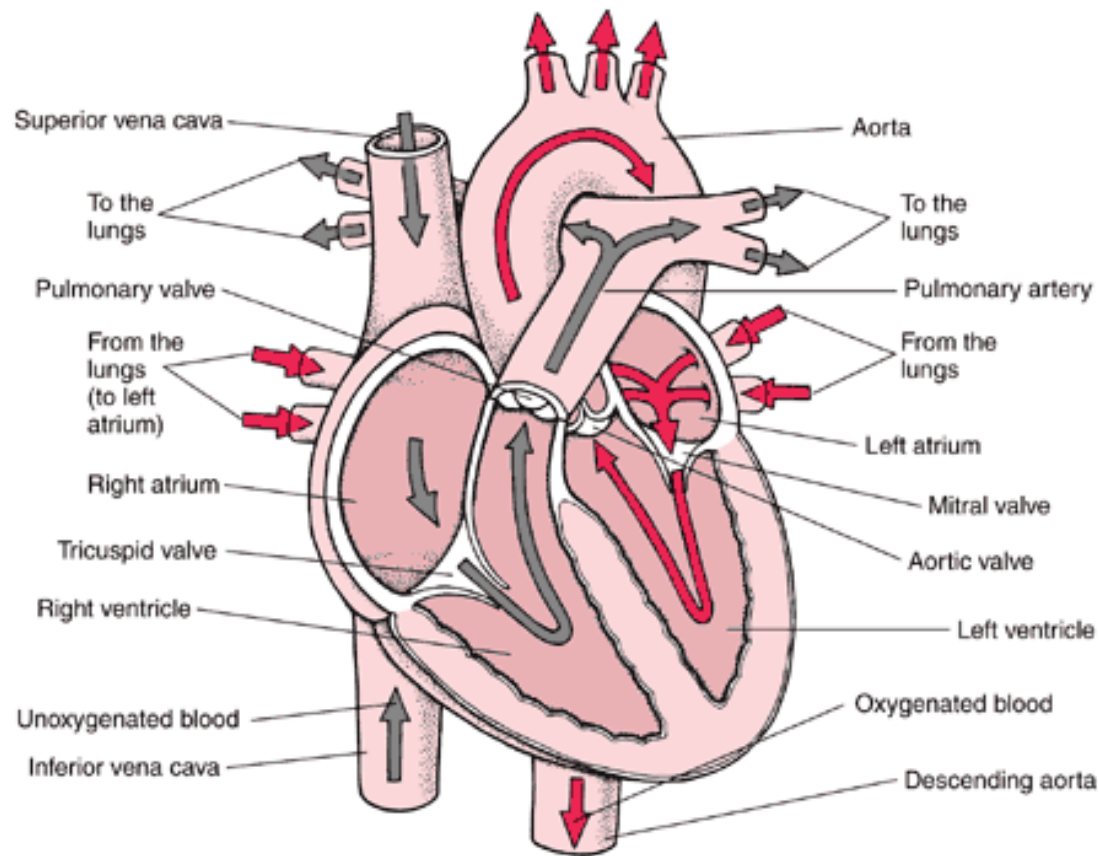
- **Základy EKG**
  - převodní systém srdeční
  - svodové systémy
  - geneze EKG křivky
- **Analýzy EKG**
  - EKG desatero
  - elektrická osa srdeční
- **Další typy EKG**
- **Základní obrazy EKG**
- **Zpracování signálů EKG**
  - rušení a filtrace EKG
  - detekce hrotů a vln

# SRDCE



# KREVNÍ OBĚH

[http://pie.med.utoronto.ca/heart\\_physiology/module/blood-flow.html](http://pie.med.utoronto.ca/heart_physiology/module/blood-flow.html)



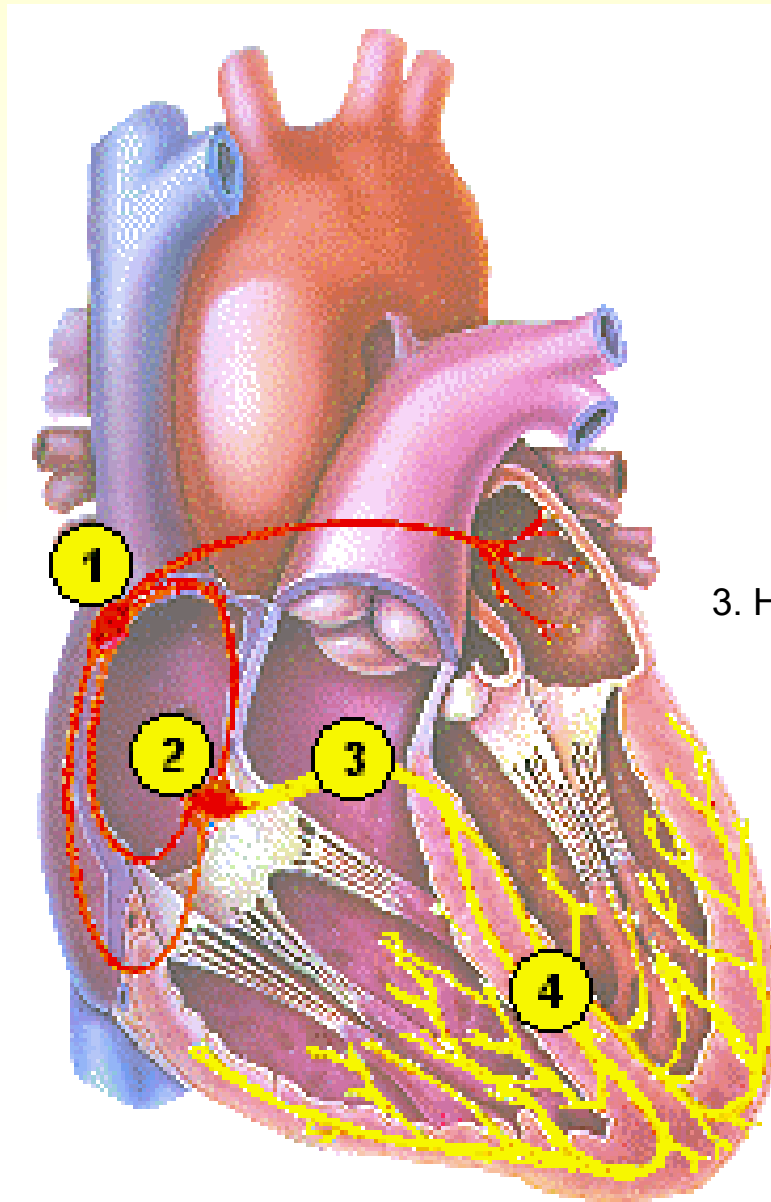
# PŘEVODNÍ SYSTÉM SRDEČNÍ

1. SA uzel

2. AV uzel

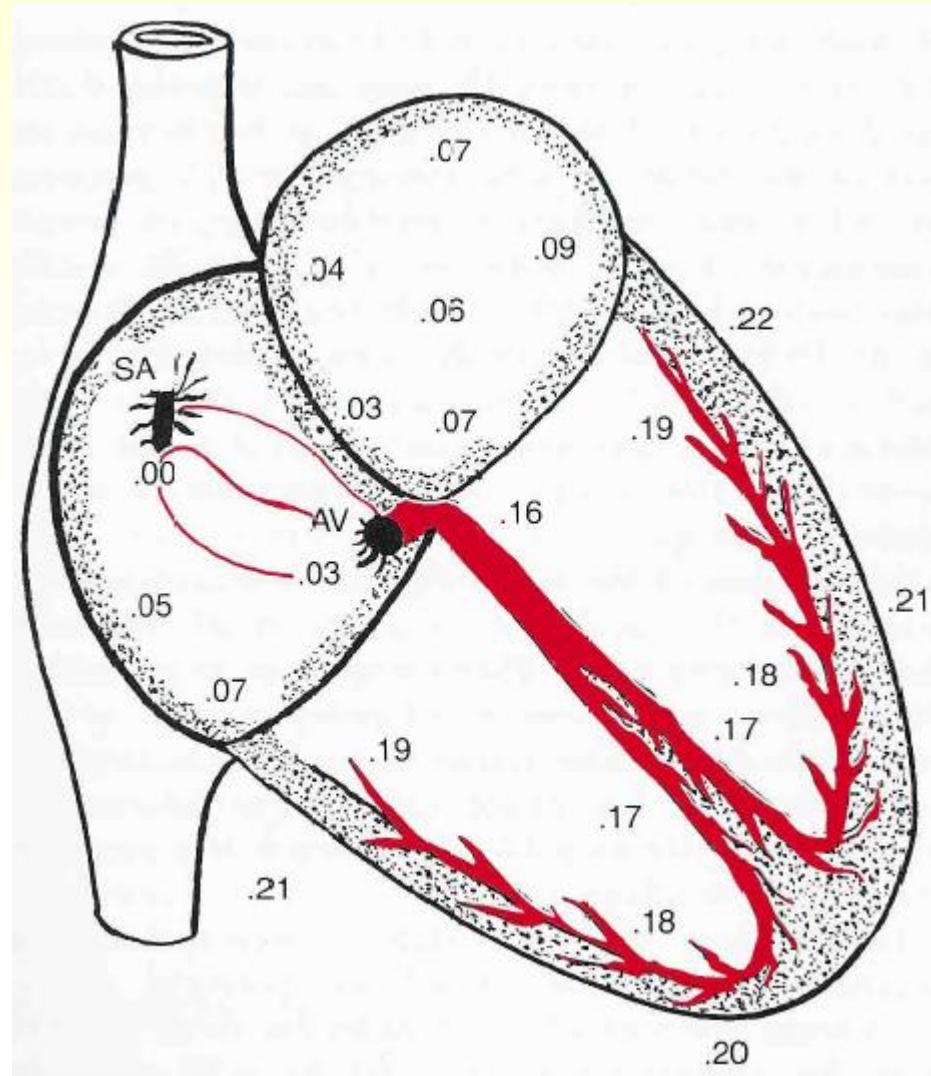
3. Hisův svazek

4. Purkyňova vlákna



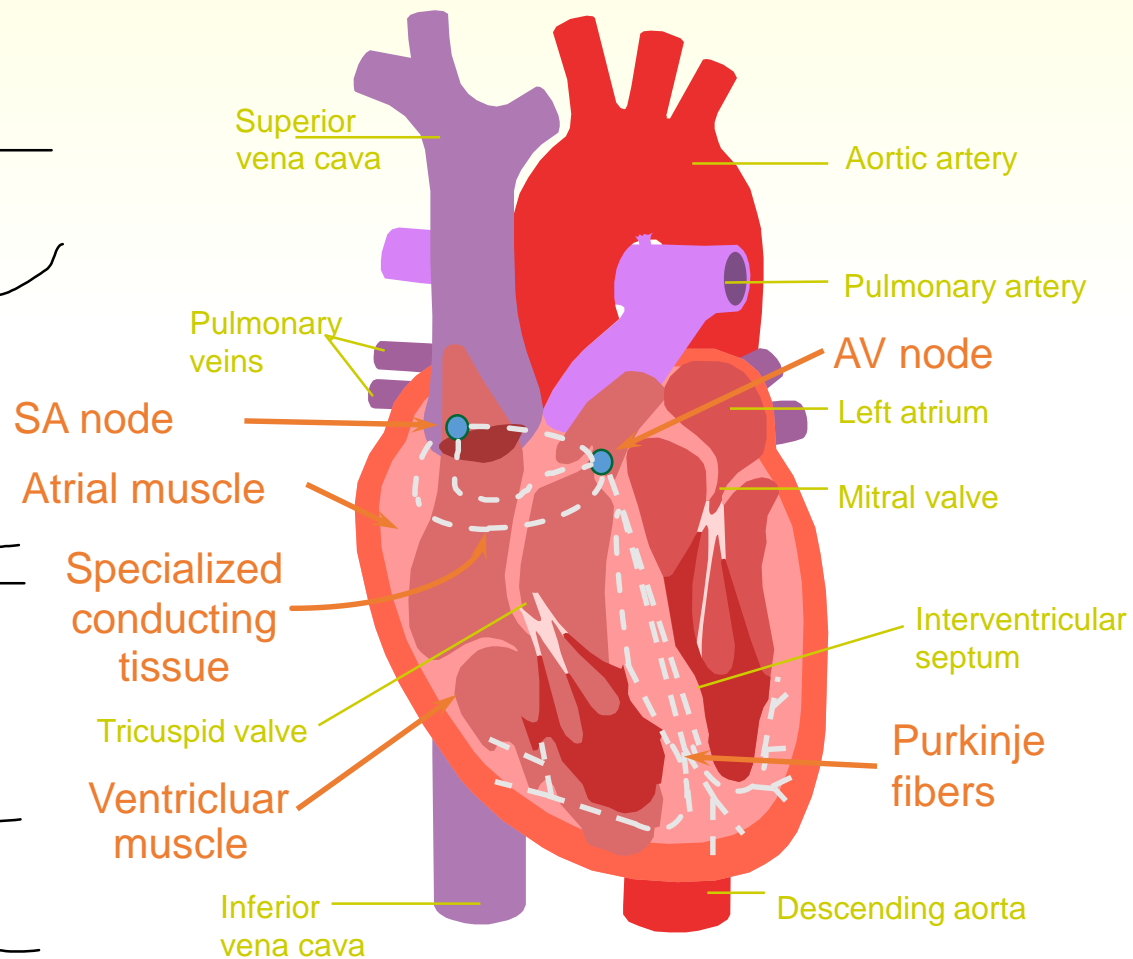
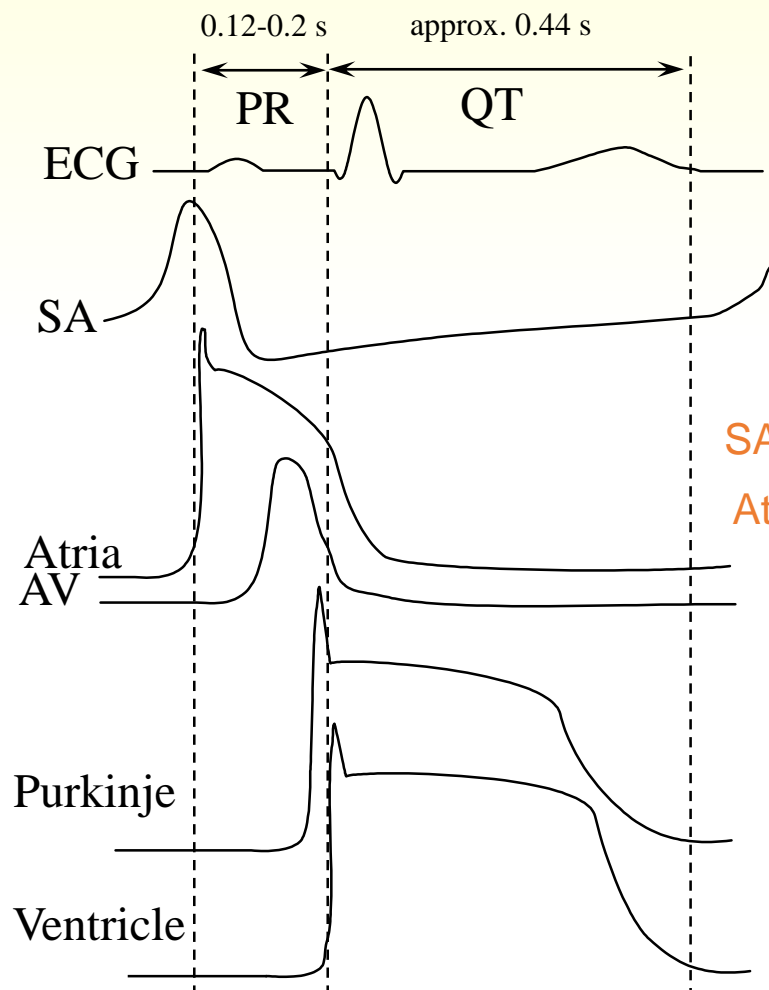


# ŠÍŘENÍ DEPOLARIZACE

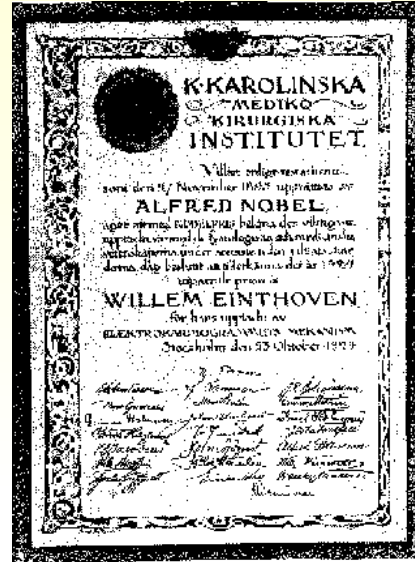


# EKG – geneze vzniku

- buňky převodního systému nemají klidový potenciál
- dochází zde ke spontánní depolarizaci



# EKG – svodové systémy



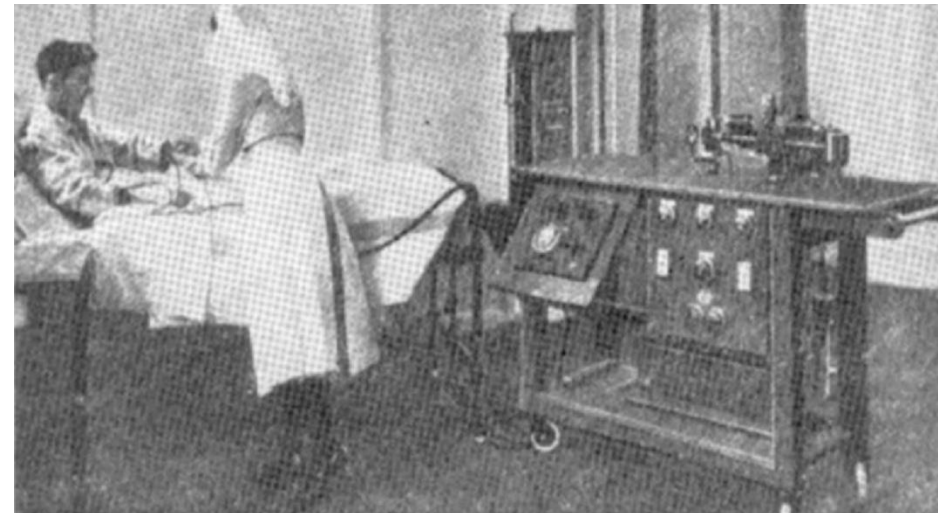
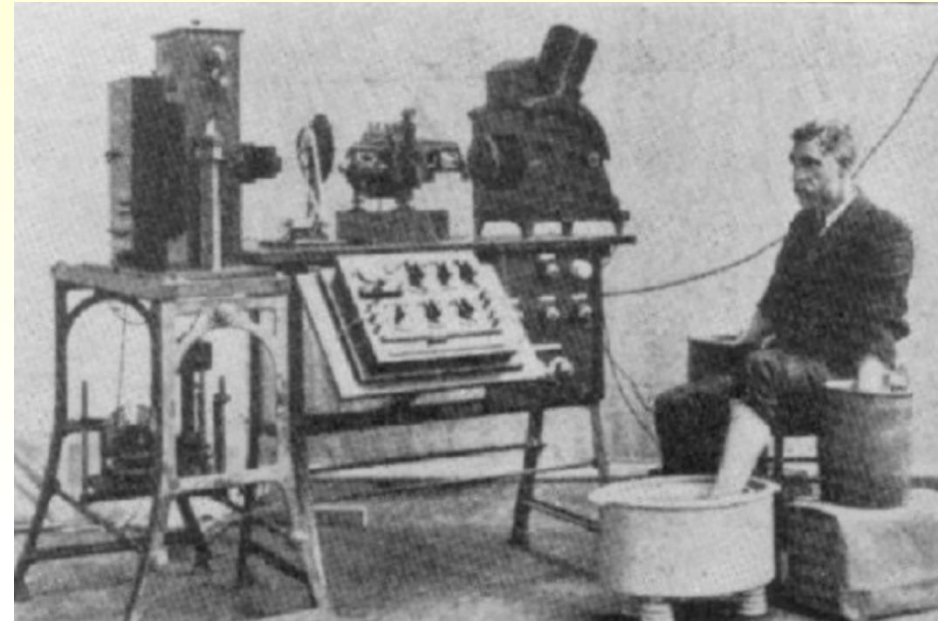
## Willem Einthoven

(\* 22.V.1860 - † 29.IX.1927)

1924 Nobelova cena za vynález  
elektrokardiografu



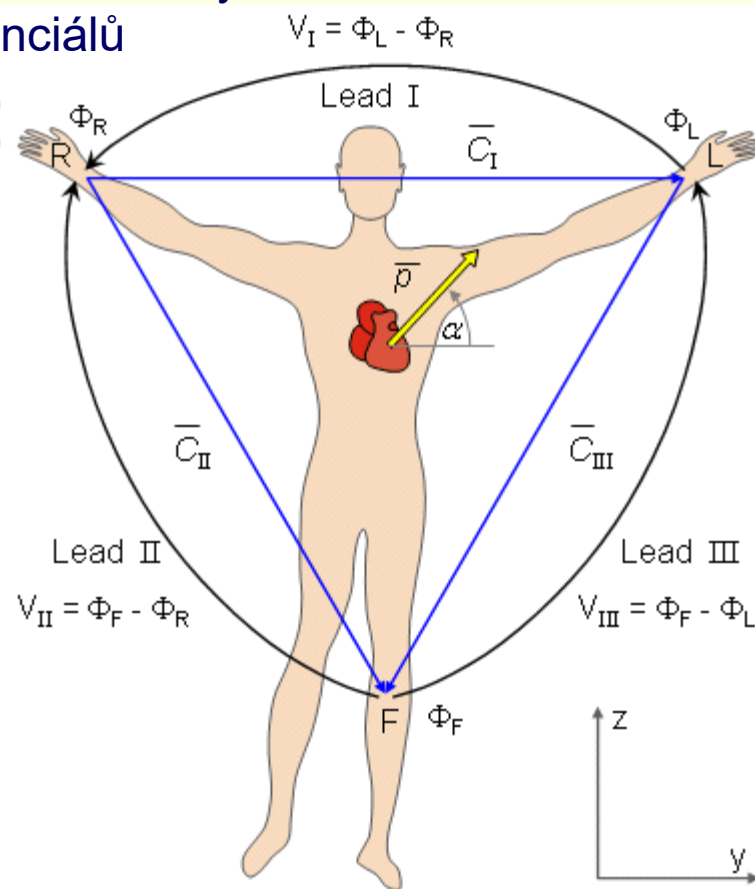
Jeden z typů kovových elektrod



mobilní EKG z roku 1920

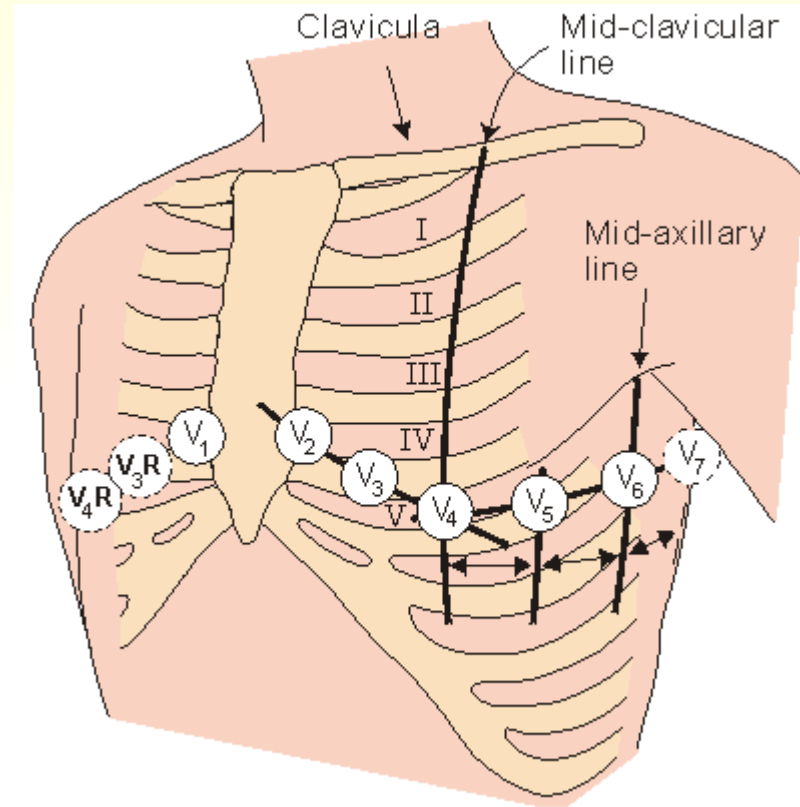
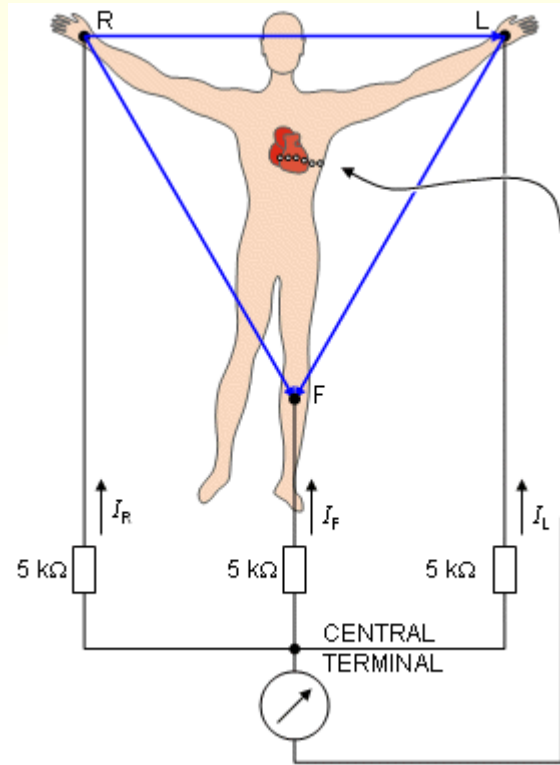
# EKG svody

- 3 standardní končetinové svody
- snímáme rozdíl potenciálů



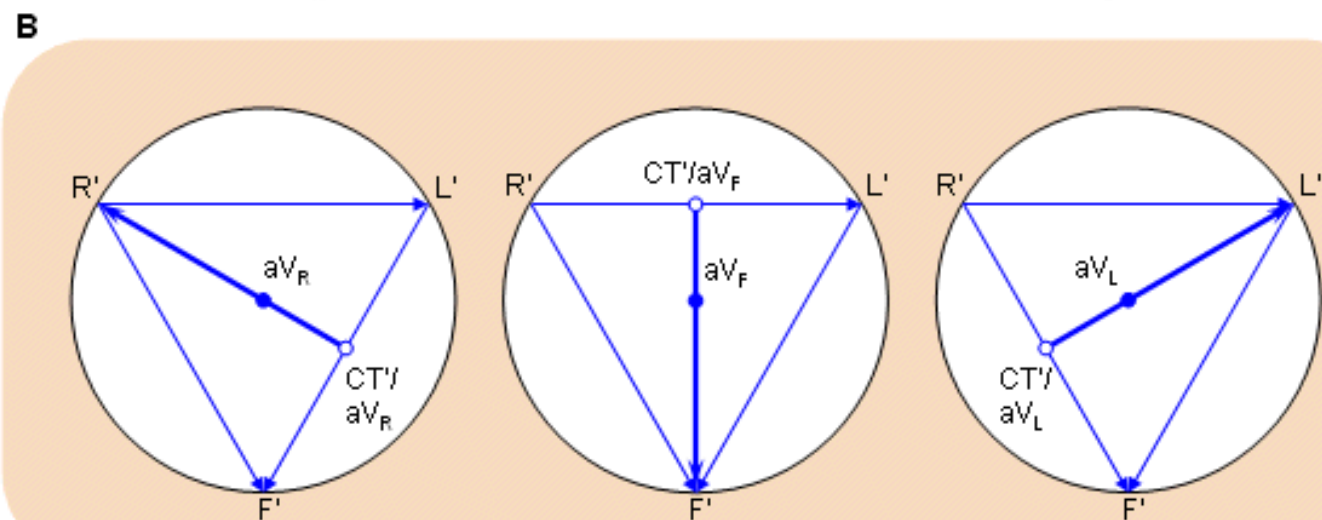
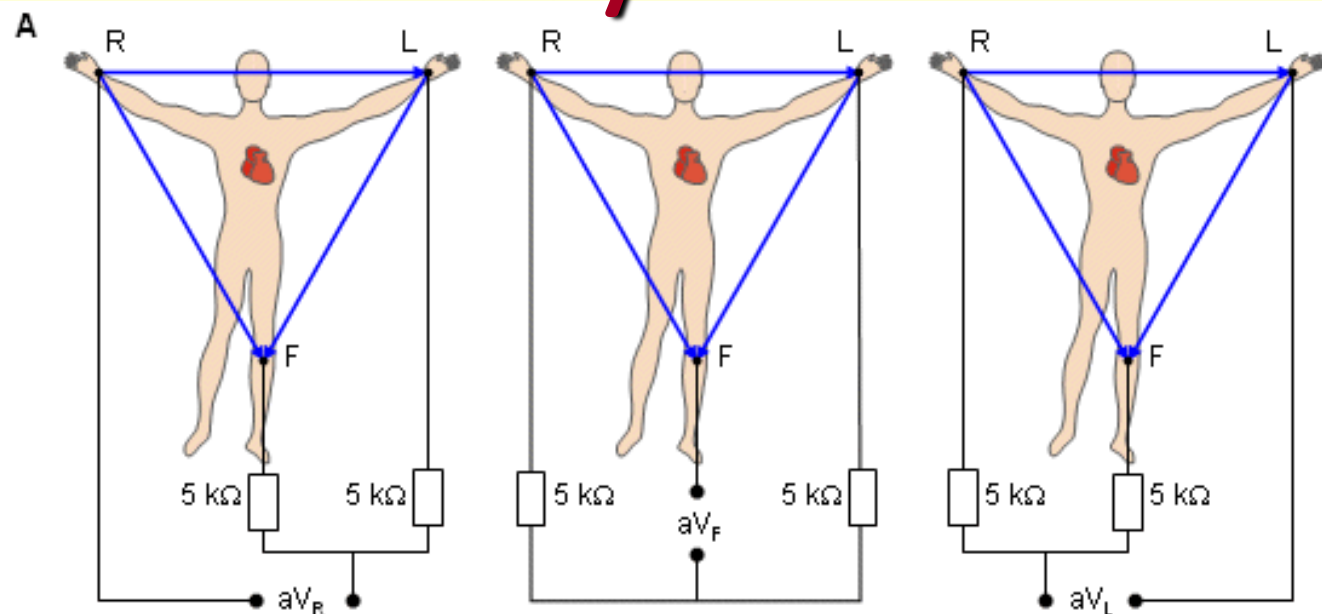
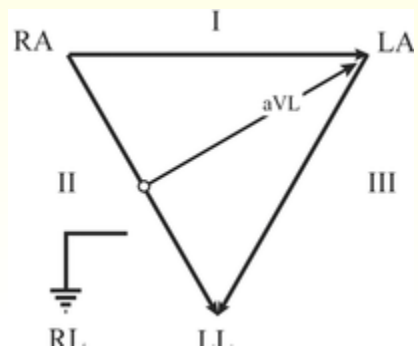
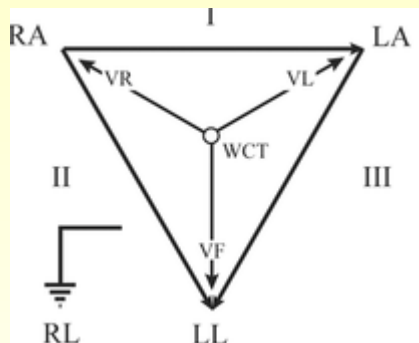
**Einthovenovy bipolární končetinové svody**

# EKG svody



**Hrudní unipolární Wilsonovy svody**

# EKG svody



**Goldbergerovy zesílené svody**



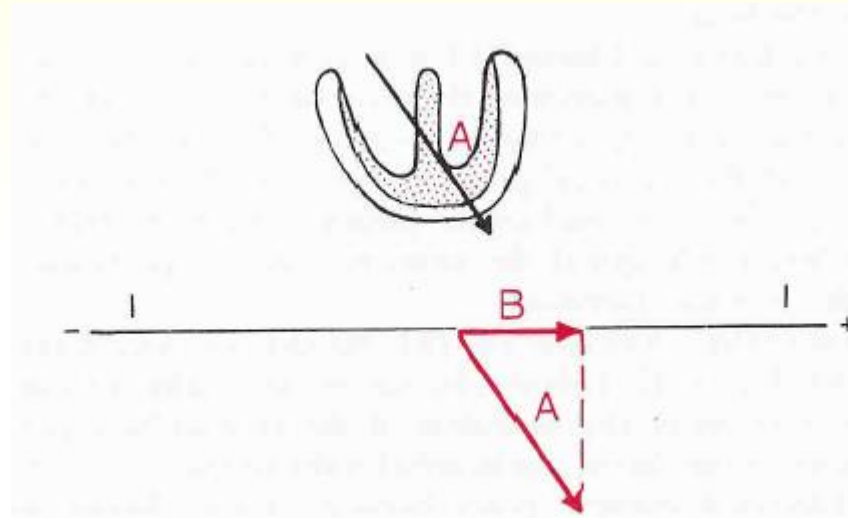
# EKG – svodové systémy

## STANDARDNÍ 12 SVODOVÝ SYSTÉM

- **končetinové svody – I, II, III**
- **Wilsonovy svody – V1, V2, V3, V4, V5, V6**
- **Goldbergerovy (zesílené) svody – aVL, aVR, aVF**

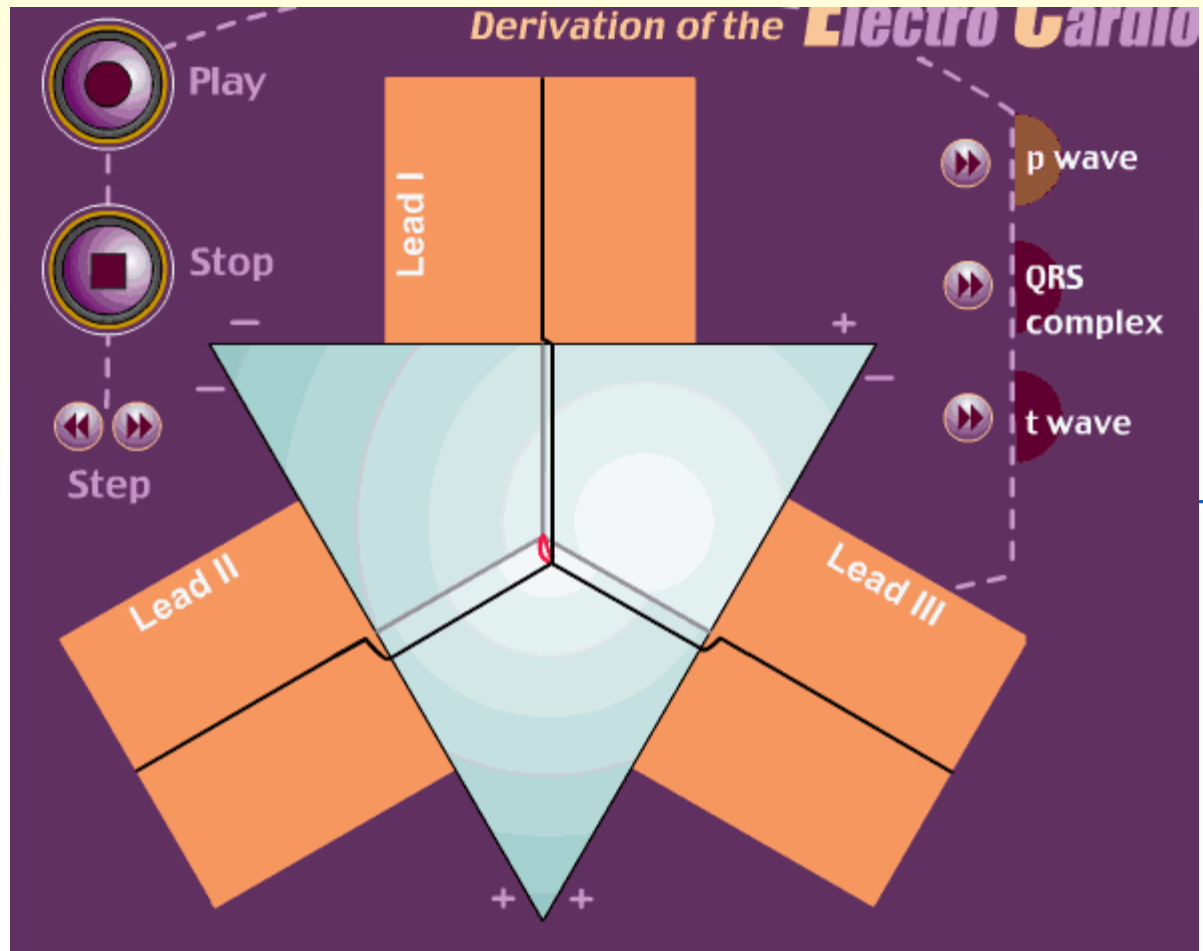
# VEKTOR DEPOLARIZACE

Směr elektrického  
vektoru při částečné  
depolarizaci

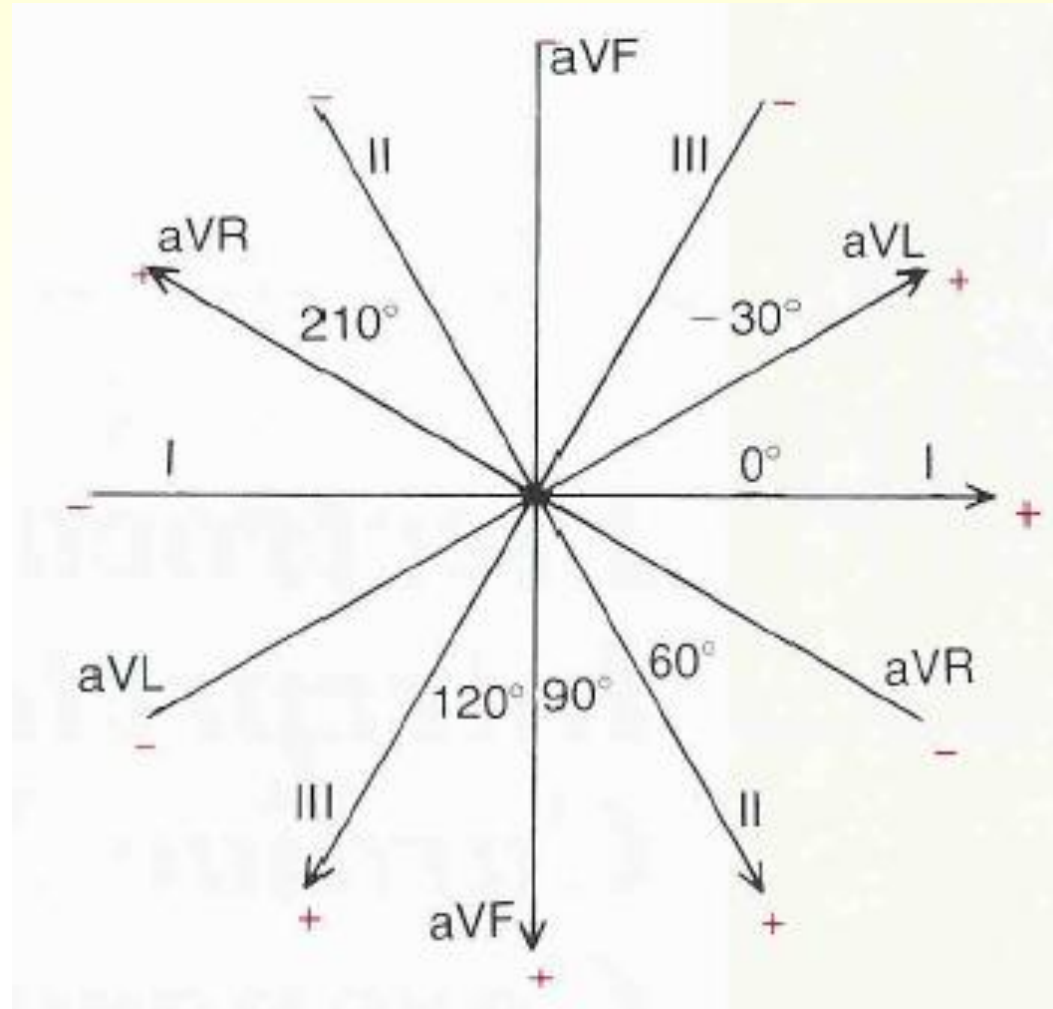


Znázornění vektoru





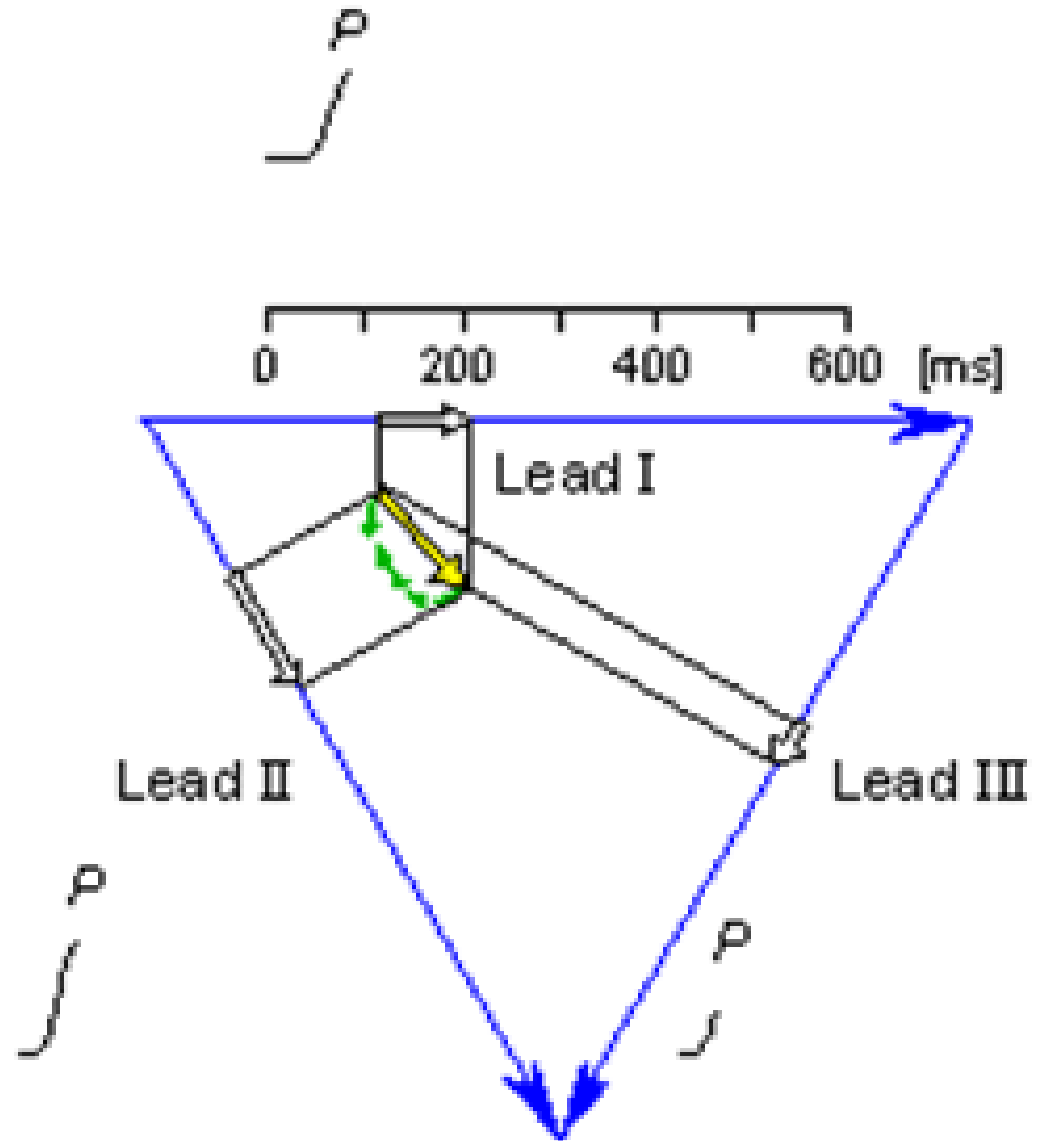
# EKG SVODY



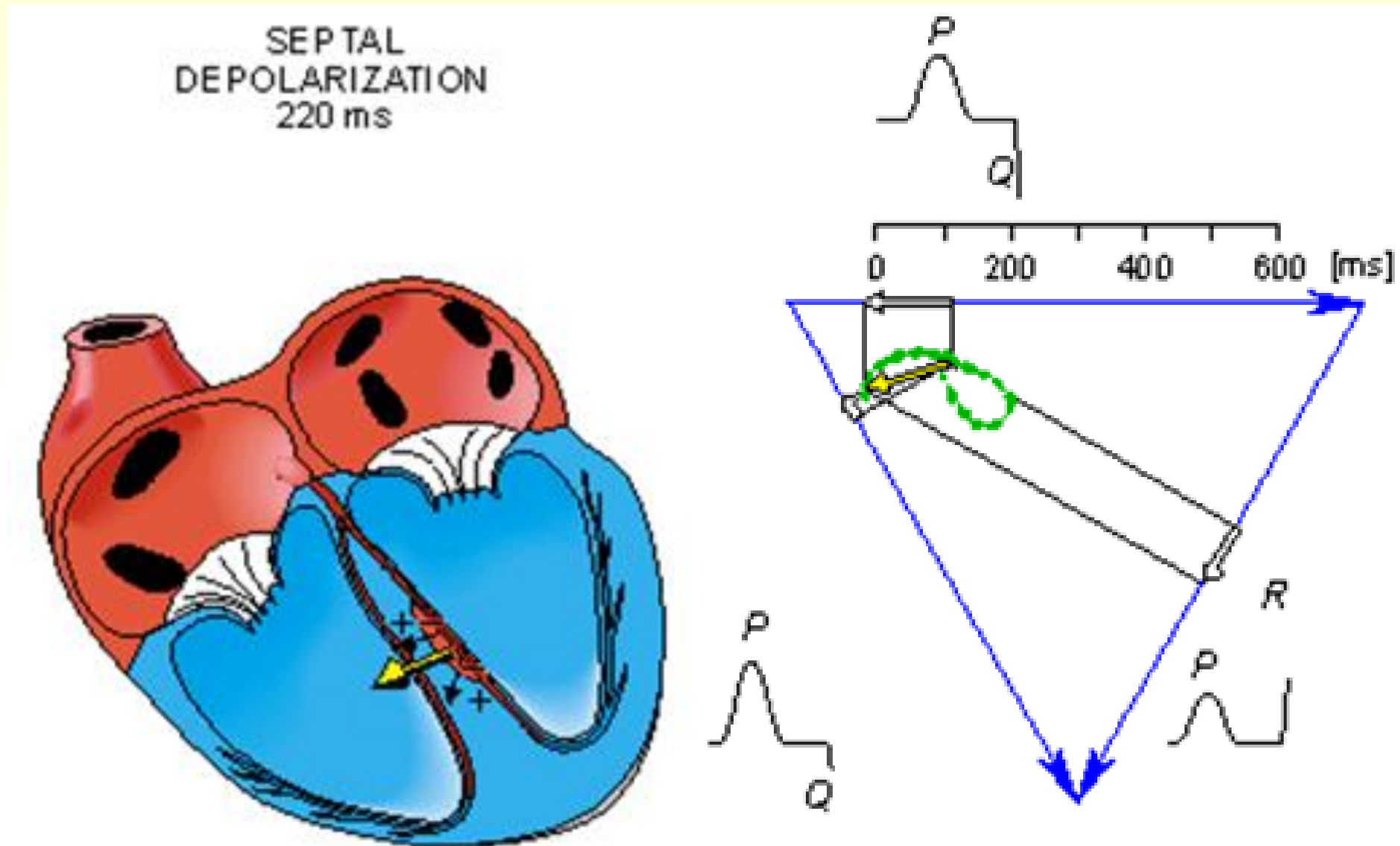
Vzájemné úhlové poměry různých svodových systémů  
Cabrerův kruh

# Depolarizace síní

ATRIAL  
DEPOLARIZATION  
80 ms

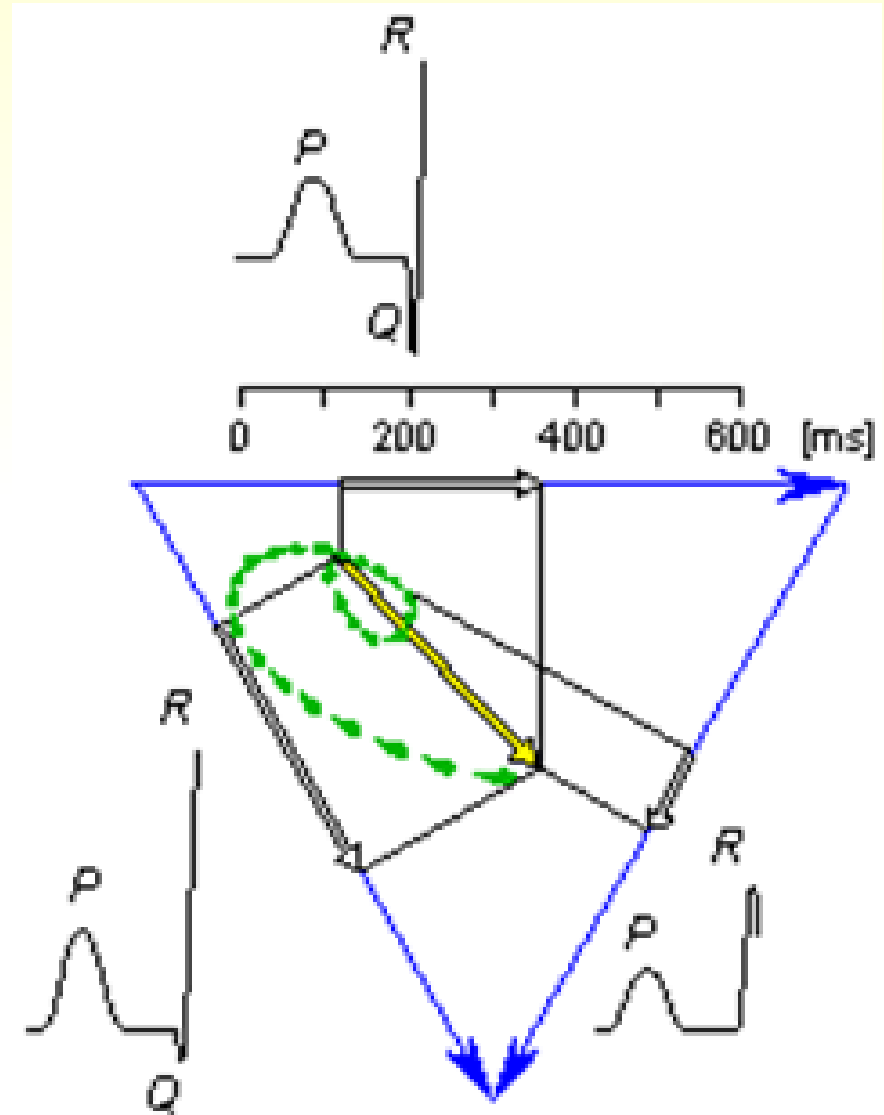


# Depolarizace septa

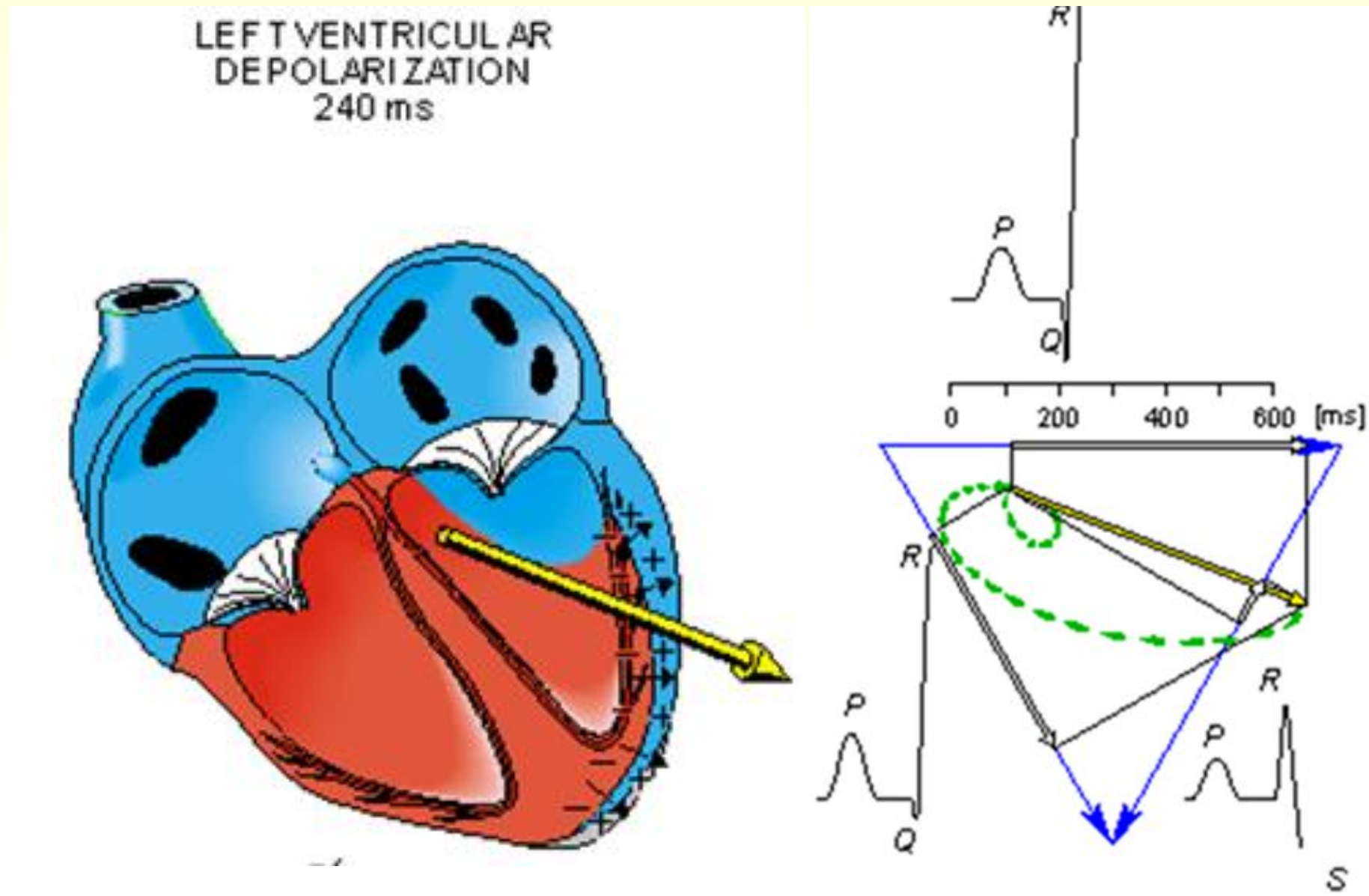


# Vrcholná depolarizace

APICAL  
DEPOLARIZATION  
230 ms



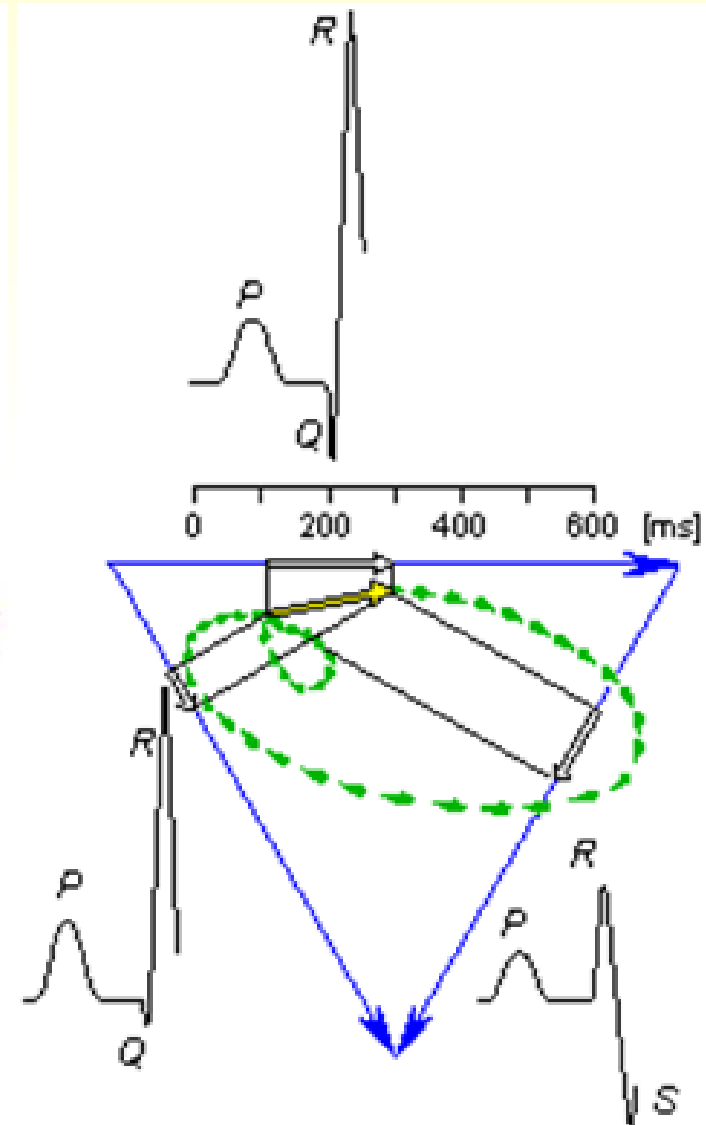
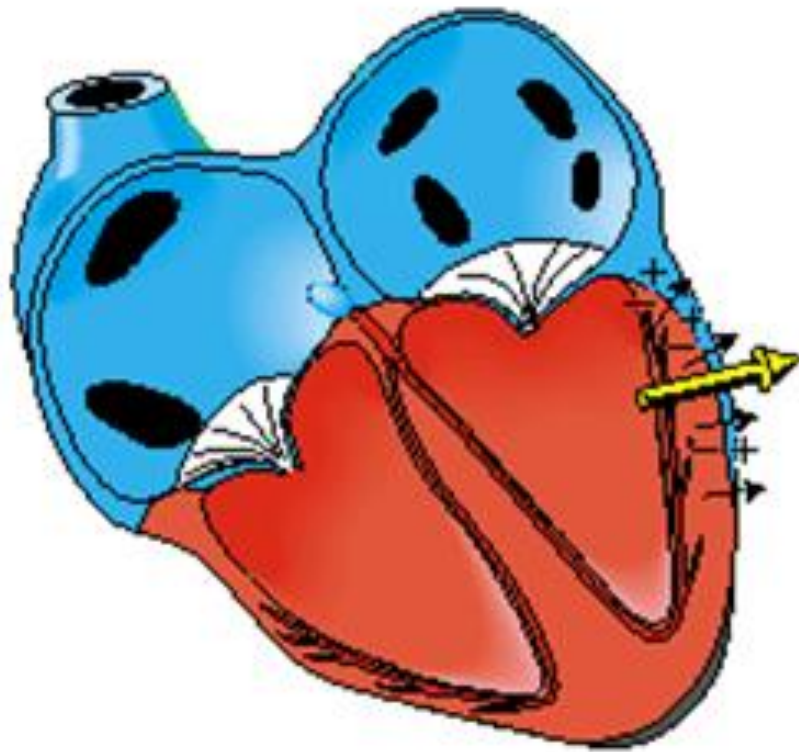
# Depolarizace levé komory



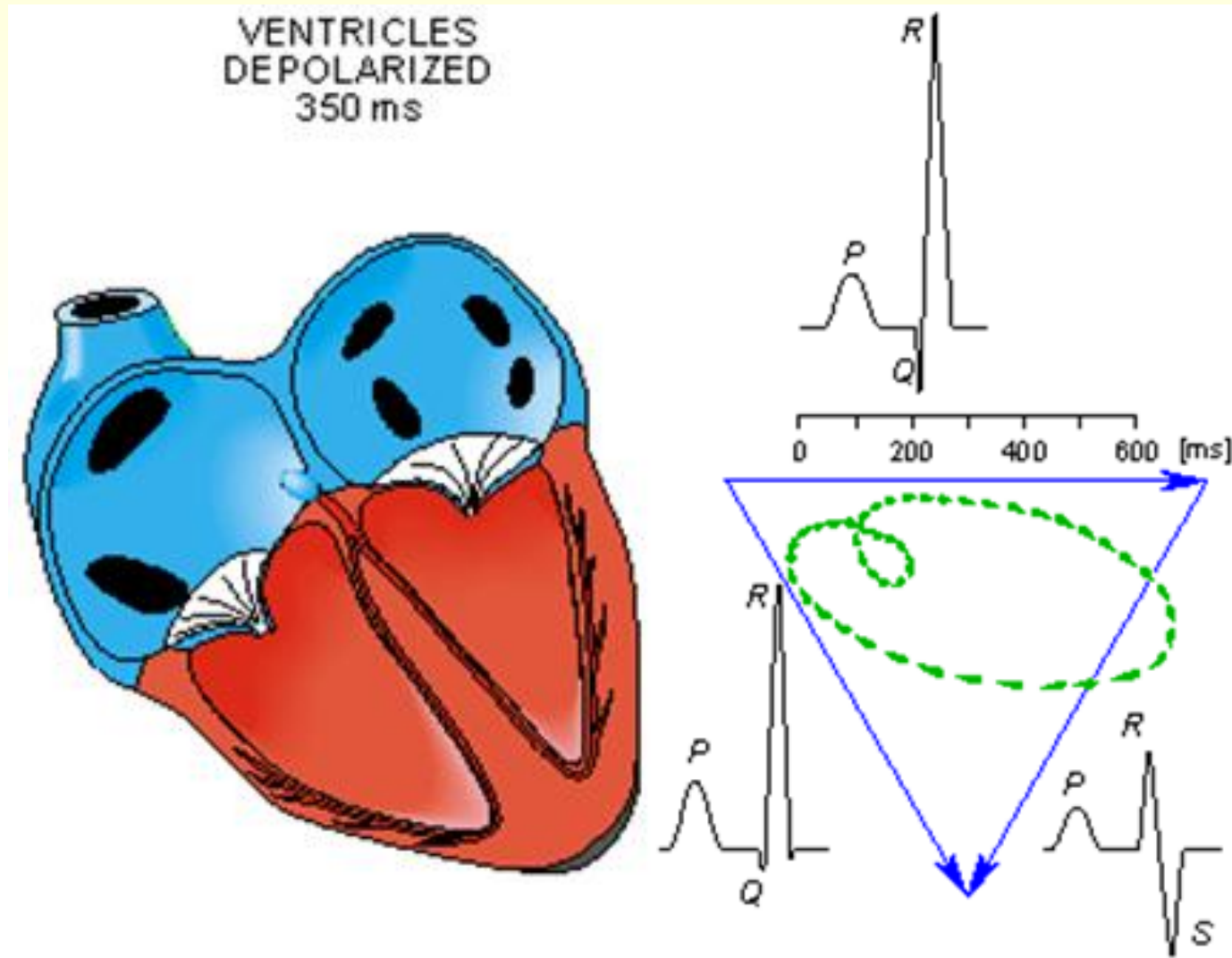


# Pozdní depolarizace levé komory

LATE LEFT VENTRICULAR  
DEPOLARIZATION  
250 ms

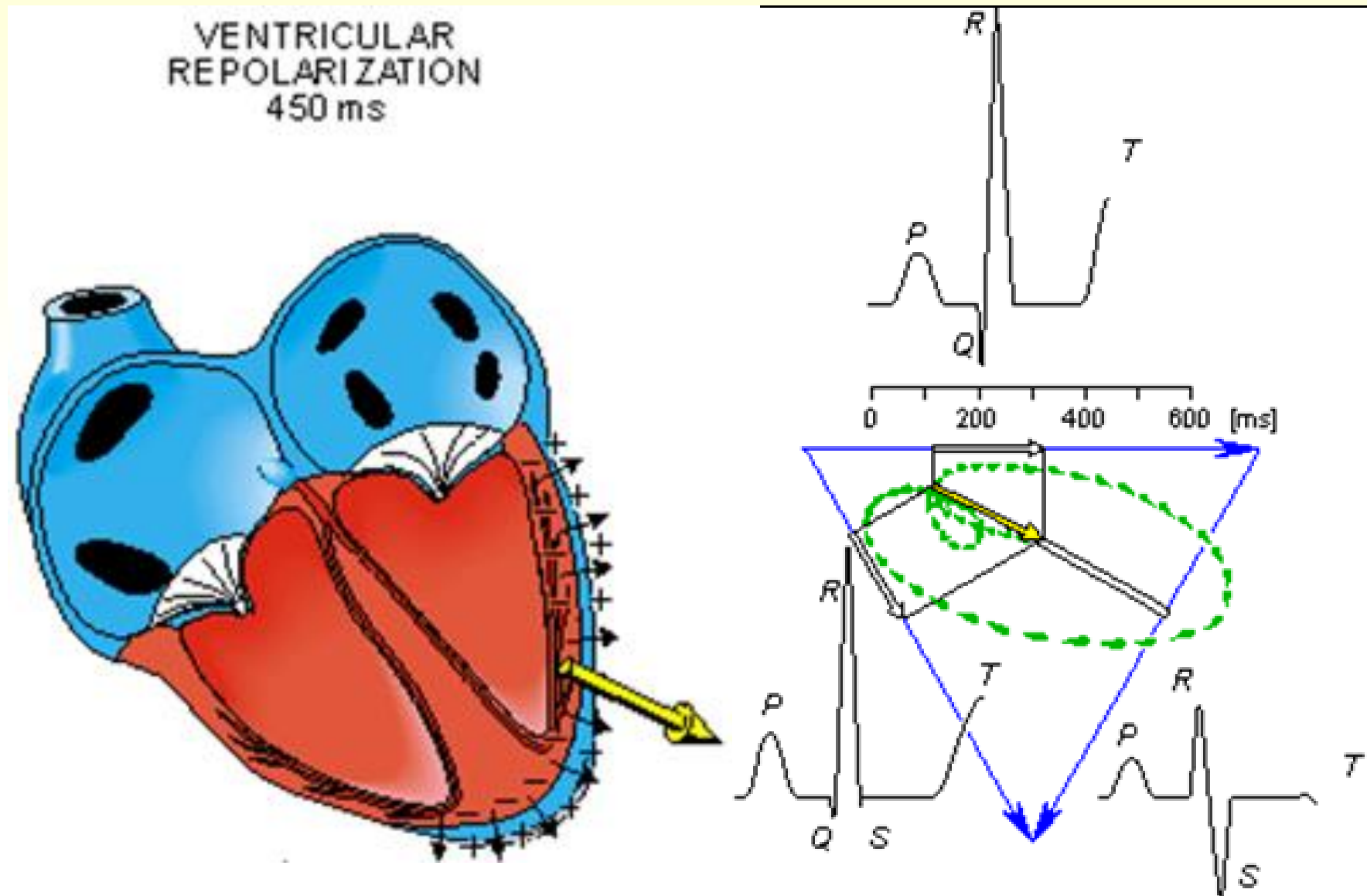


# Depolarizace komor

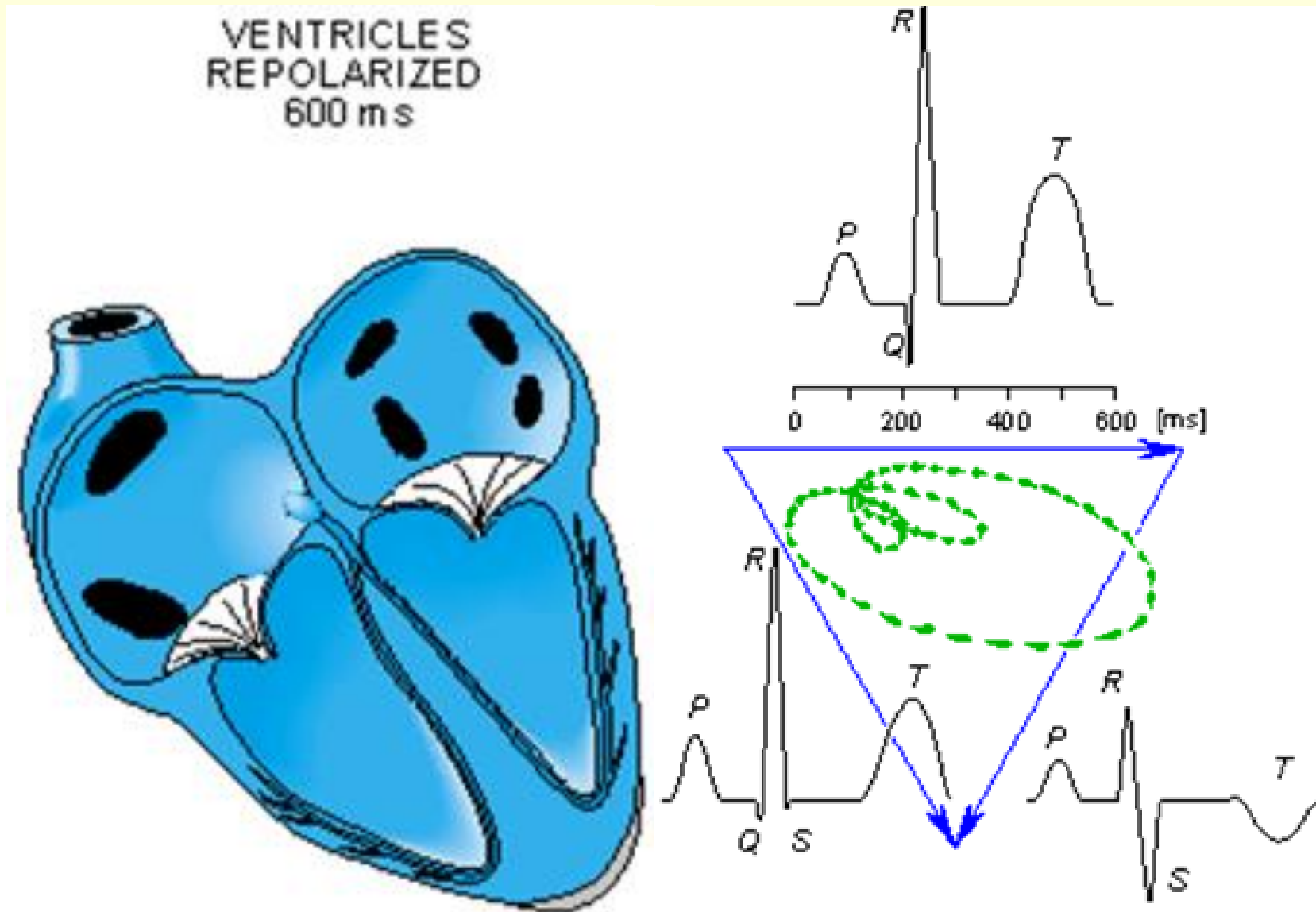




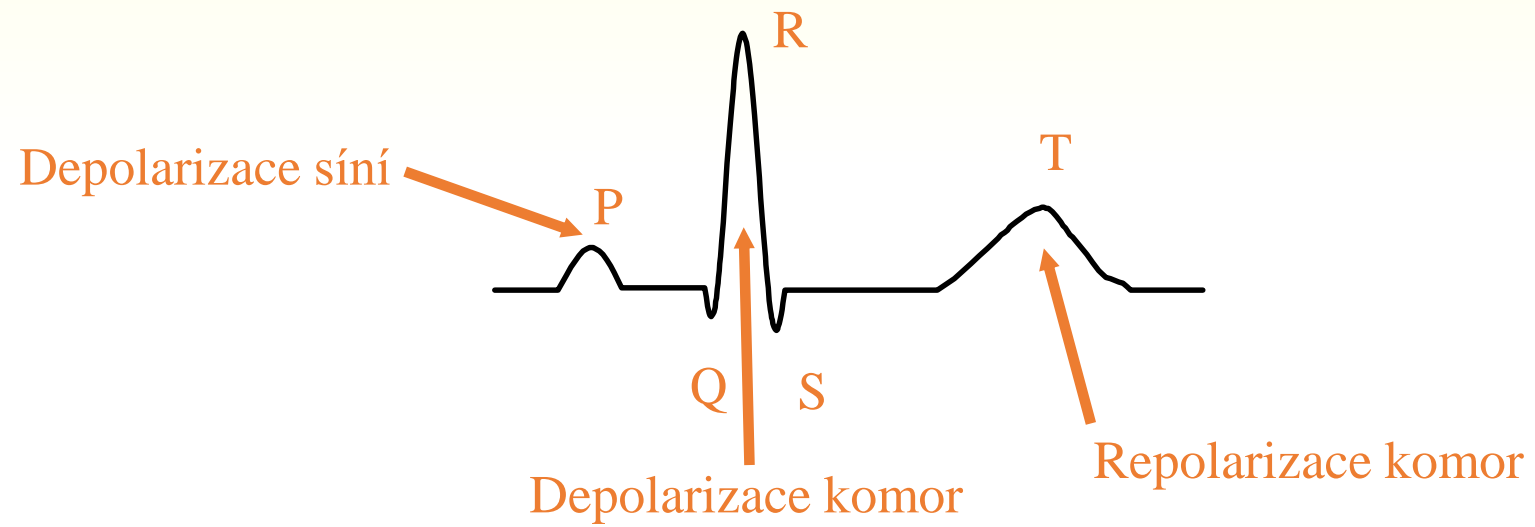
# Repolarizace komor



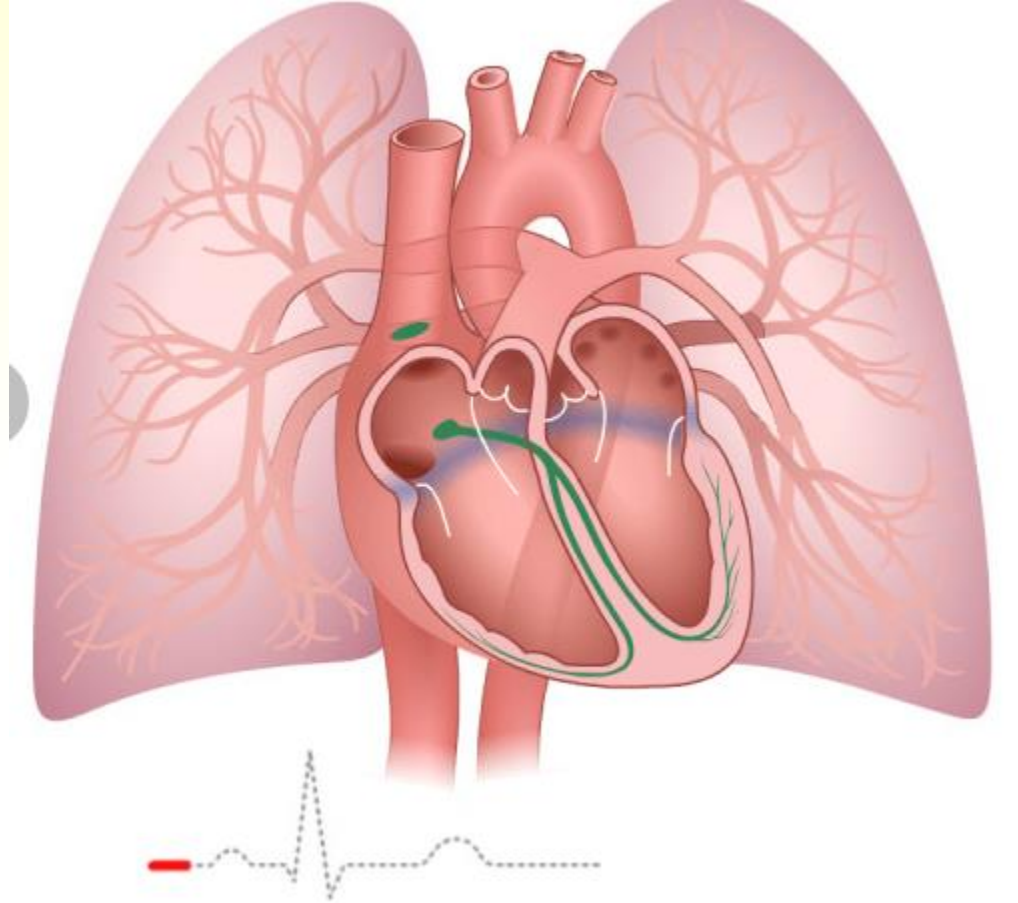
# Repolarizace komor



# EKG křivka

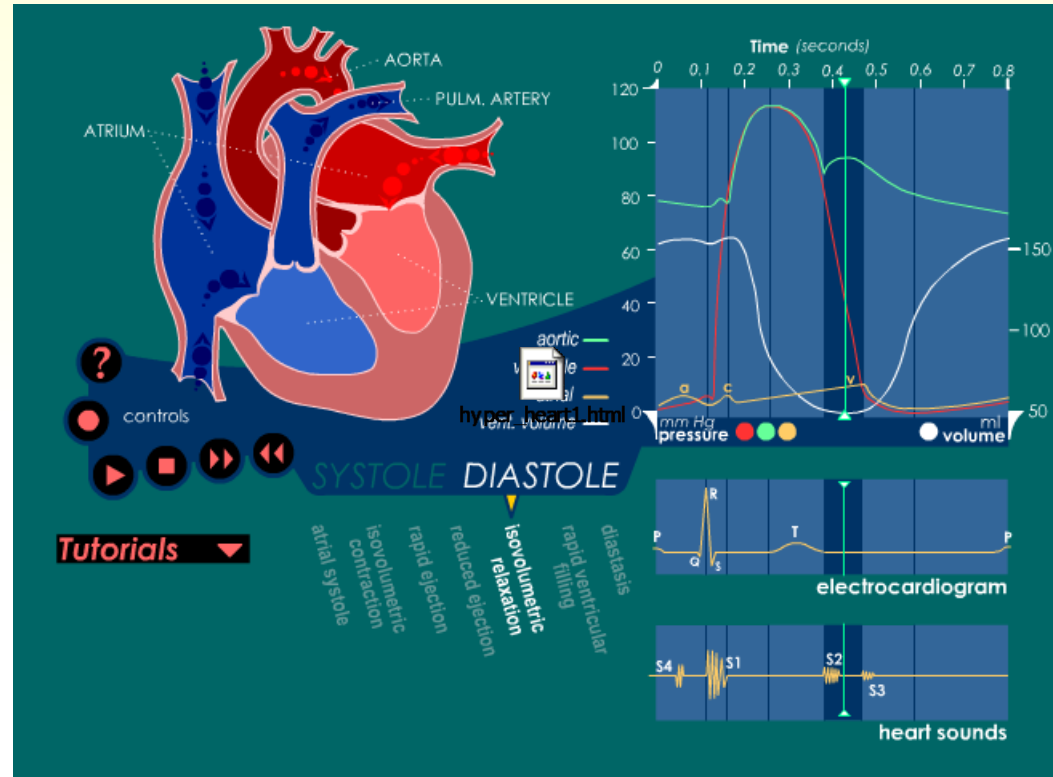


# EKG animace



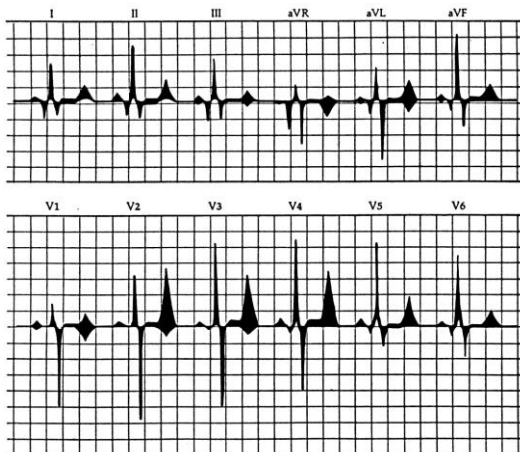
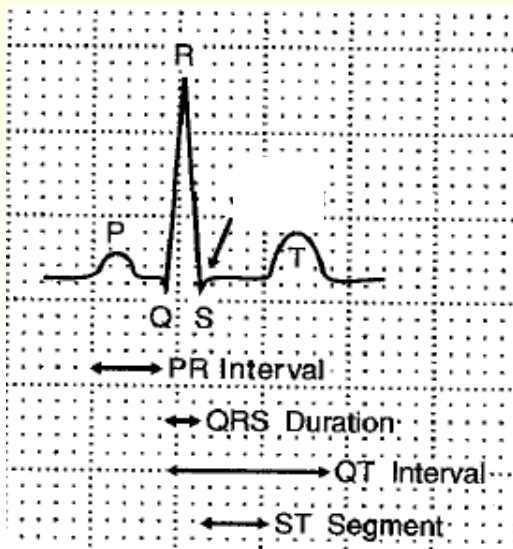
[http://pie.med.utoronto.ca/heart\\_physiology/module/ecg.html](http://pie.med.utoronto.ca/heart_physiology/module/ecg.html)

# EKG animace



[https://library.med.utah.edu/kw/pharm/hyper\\_heart1.html](https://library.med.utah.edu/kw/pharm/hyper_heart1.html)

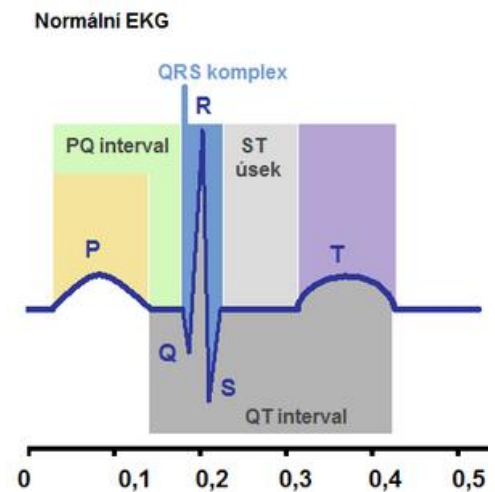
# Analýza EKG



- Na EKG se hodnotí:
  - srdeční frekvence
  - pravidelnost srdeční akce
  - směr elektrické osy srdeční
  - velikost a délka vln P, Q, R, S, T
  - velikost a délka úseků P-Q, Q-R-S, S-T, Q-T

- Fyziologické EKG ovlivňuje:

- věk
- konstituce
- poloha
- dýchání
- fyzická zátěž

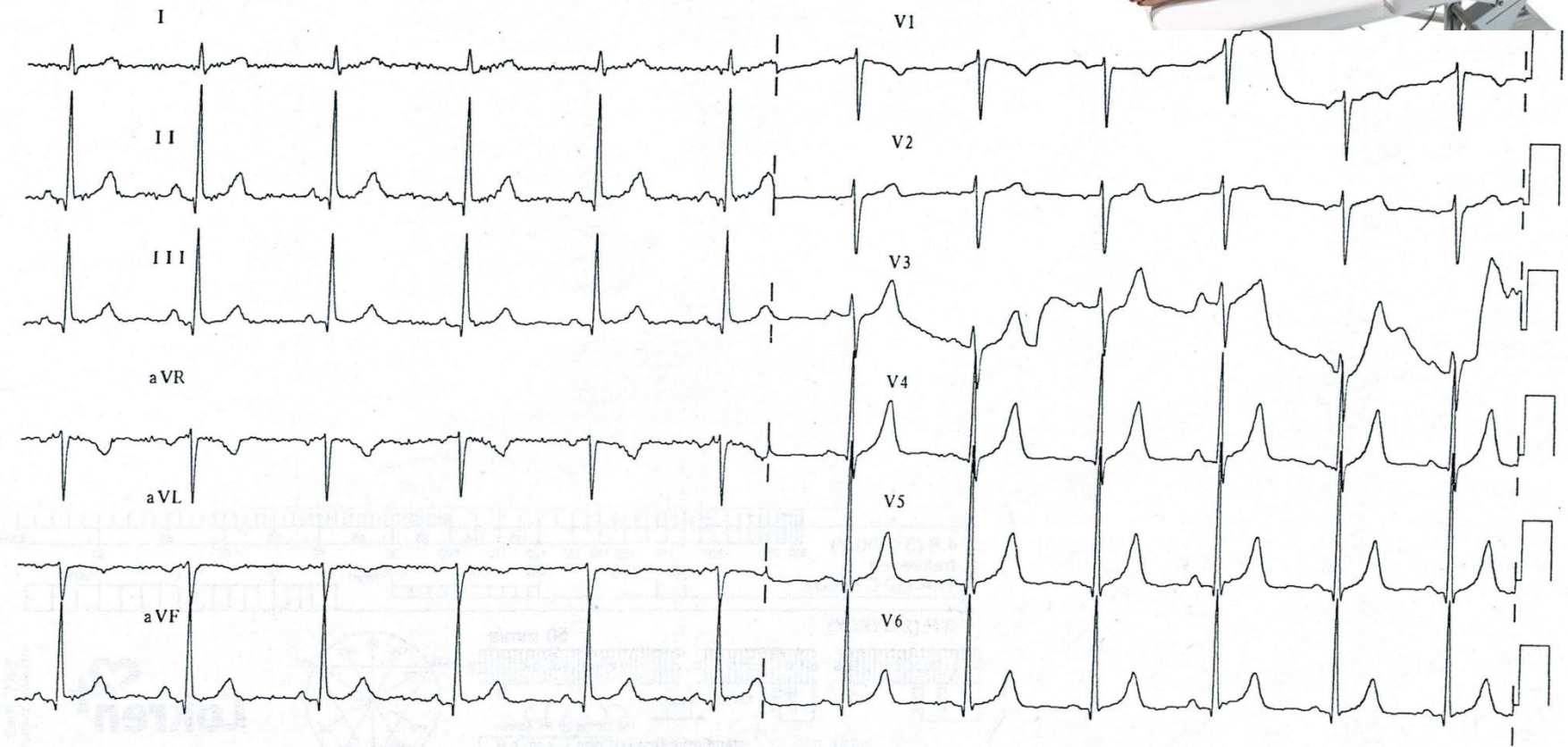




# Klidové EKG

Rate 70  
PR 141  
QRSD 96  
QT 393  
QTc 424

--Axis--  
P 70  
QRS 88  
T 71



# Hodnocení EKG křivky

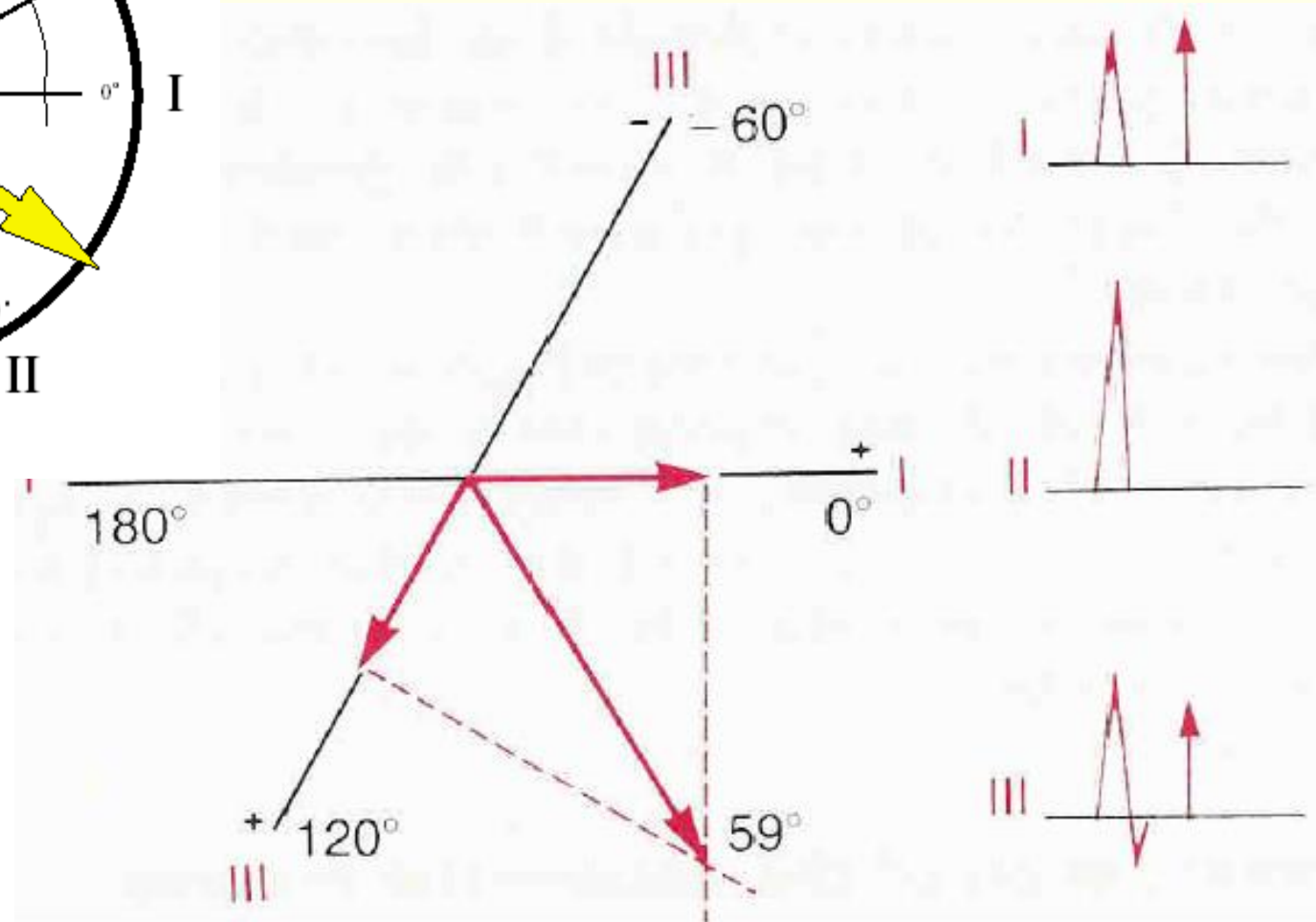
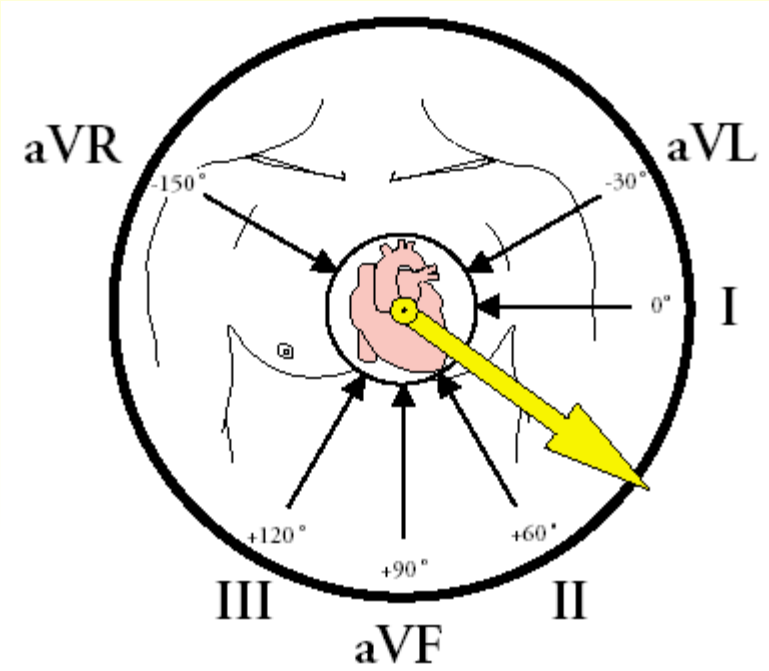
## EKG desatero

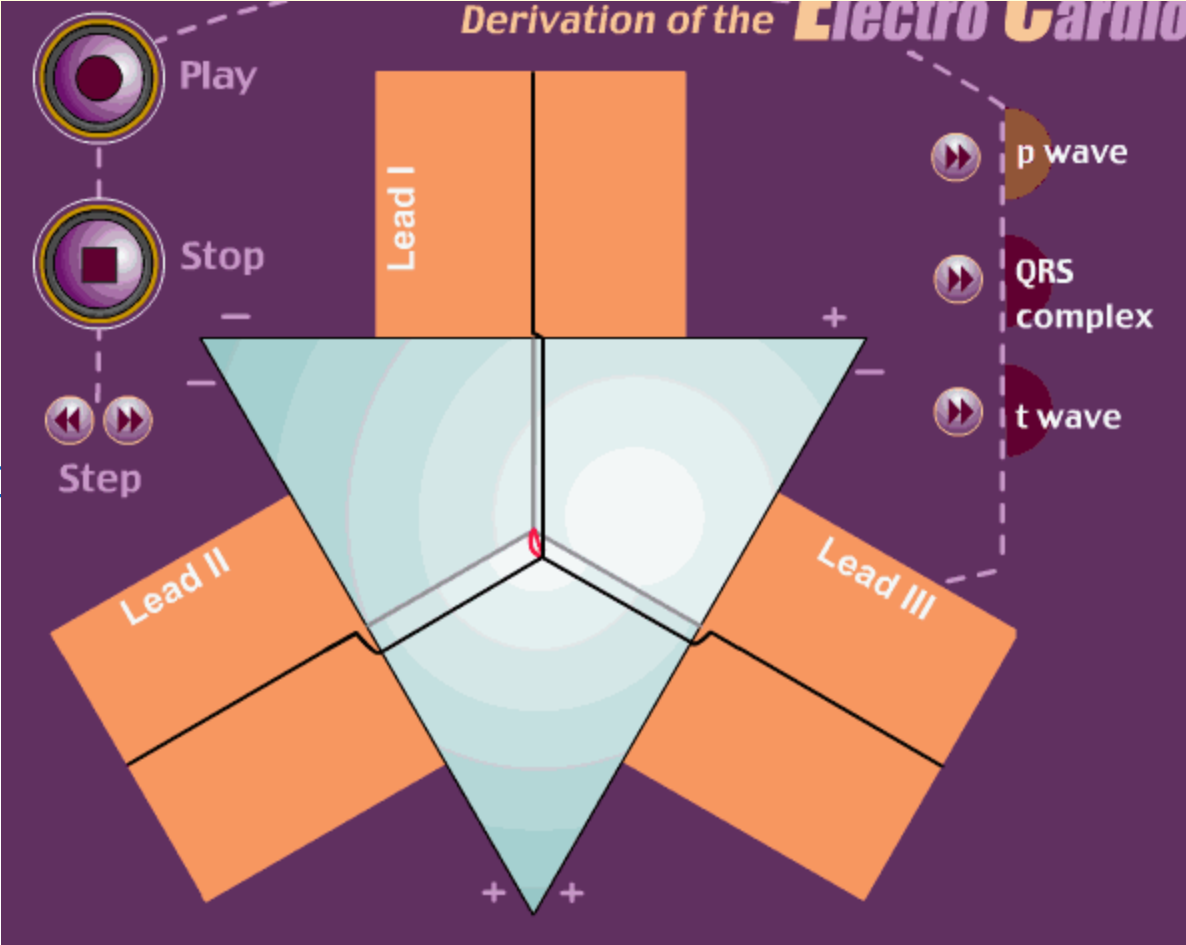
viz předchozí snímek

|     |                        |                       |
|-----|------------------------|-----------------------|
| 1.  | srdeční akce           | pravidelná            |
| 2.  | srdeční rytmus         | pravidelný sinusový   |
| 3.  | srdeční frekvence      | v normě, 70 cyklů/min |
| 4.  | P vlna                 | normální              |
| 5.  | PQ interval            | v normě, 4 mm, 160 ms |
| 6.  | QRS komplex            | v normě, 96 ms        |
| 7.  | ST úsek                | normální v izolinii   |
| 8.  | T vlna                 | norma                 |
| 9.  | QT interval            | norma, 393 ms         |
| 10. | elektrická osa srdeční | fyziologicky, 88°     |



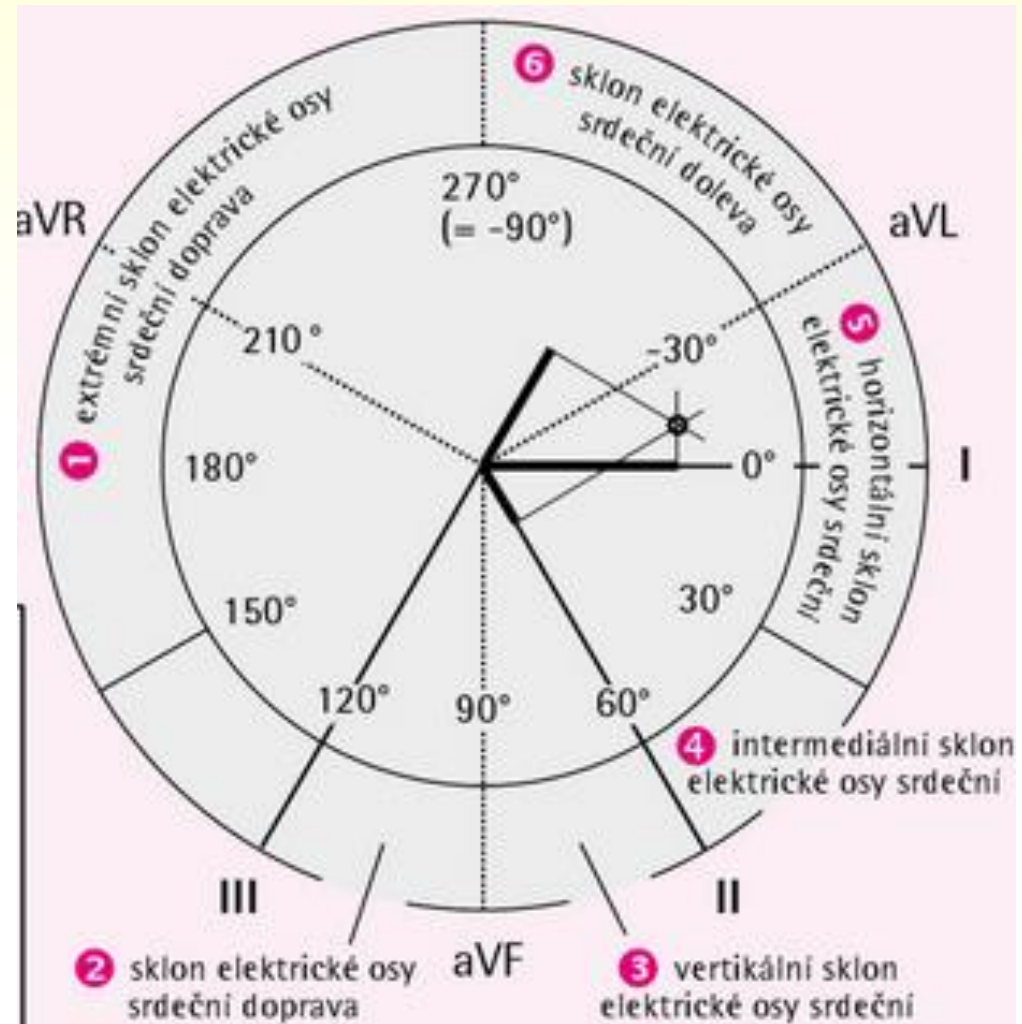
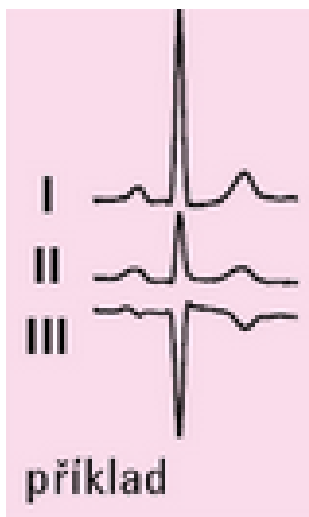
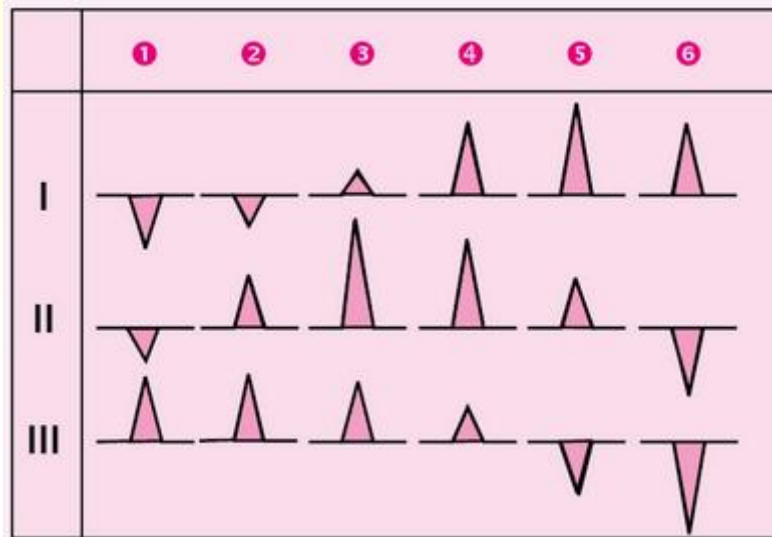
# ELEKTRICKÁ SRDEČNÍ OSA



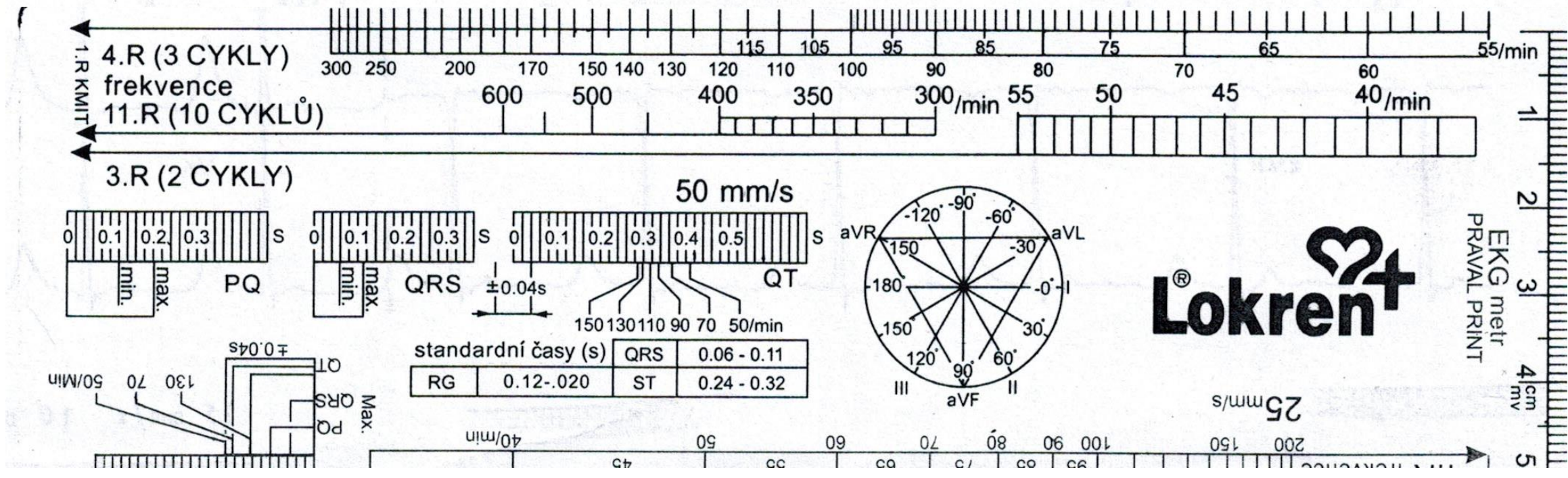
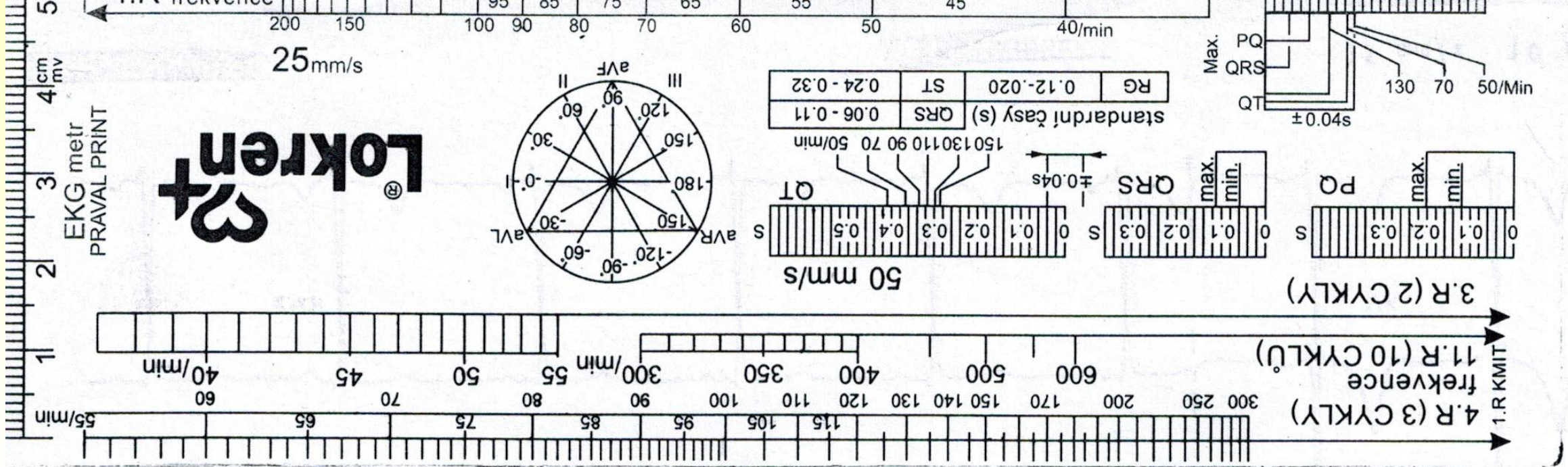


# Cabrerův kruh

## určení sklonu elektrické osy srdeční









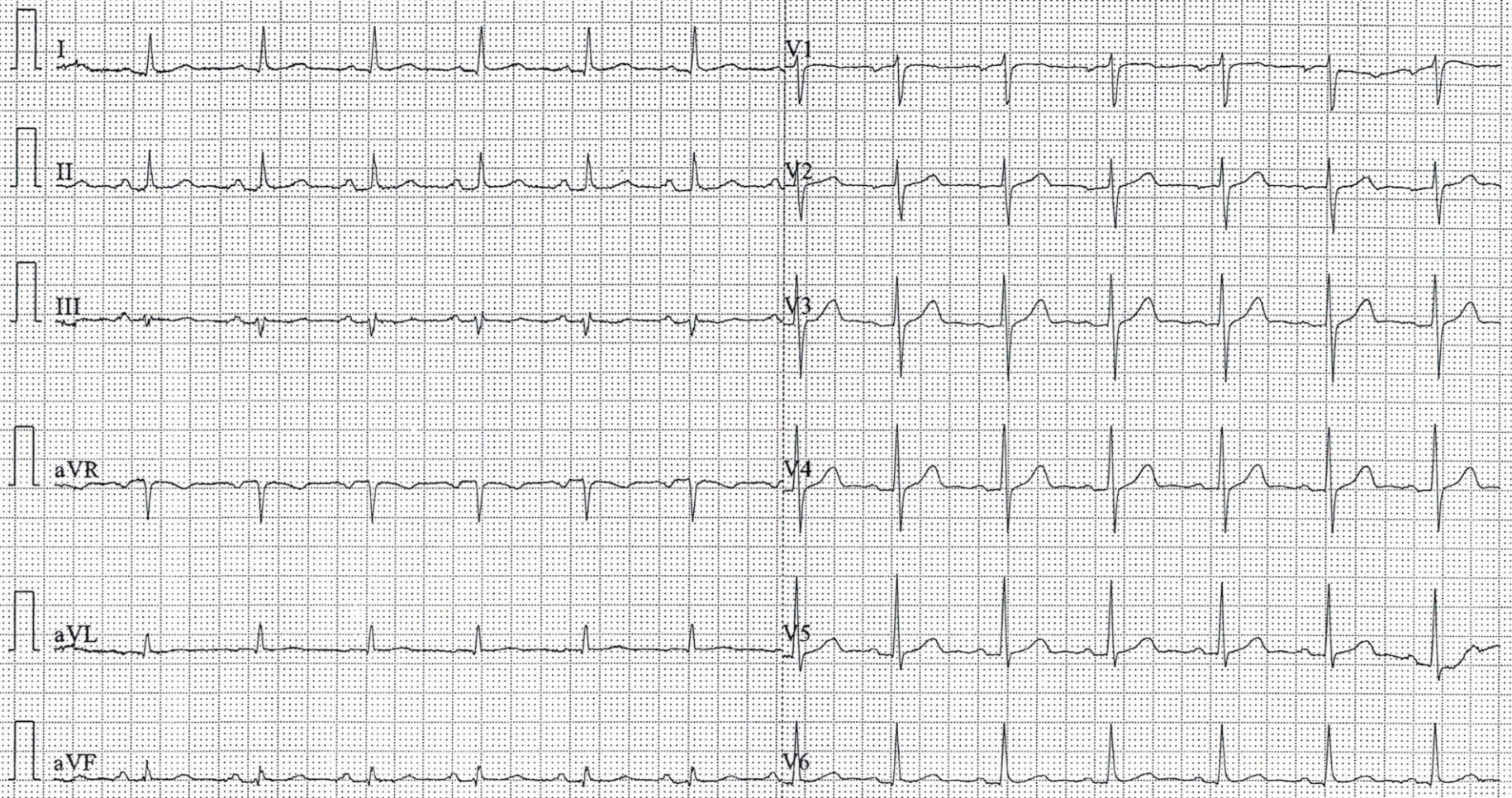
ID: 133

Muž Roky

HR 80 bpm  
P 119 ms  
PR 196 ms  
QRS 84 ms  
QT/QTc 375/435 ms  
P/QRS/T 69/27/45 °  
RV5/SVI 1.282/0.679 mV

Diagnostické Informace:  
Sinusový rytmus  
\*\*\*Normální EKG\*\*\*

Report potvrdil:





## Corrección. Fórmulas

|  |   |
|--|---|
| Bazett modificada por Taran y Szilagyi | $QTc = \frac{QT}{\sqrt{RR}}$                        |
| Fridericia                             | $QTc = \frac{QT}{\sqrt[3]{RR}}$                     |
| Framingham-Sagie                       | $QTc = QT + 0,154 (1 - RR)$                         |
| Hodges                                 | $QTc = QT + 1.75 (FC - 60)$                         |
| Sarma                                  | $QTc = QT (RR)^{\frac{1}{2}}$                       |
| Normograma                             | $QTc = 237 + 0.158 \times RR$ (para FC 60 -100 lpm) |
| Cobos                                  | $QTc = \frac{QT}{(1+RR)/2}$                         |



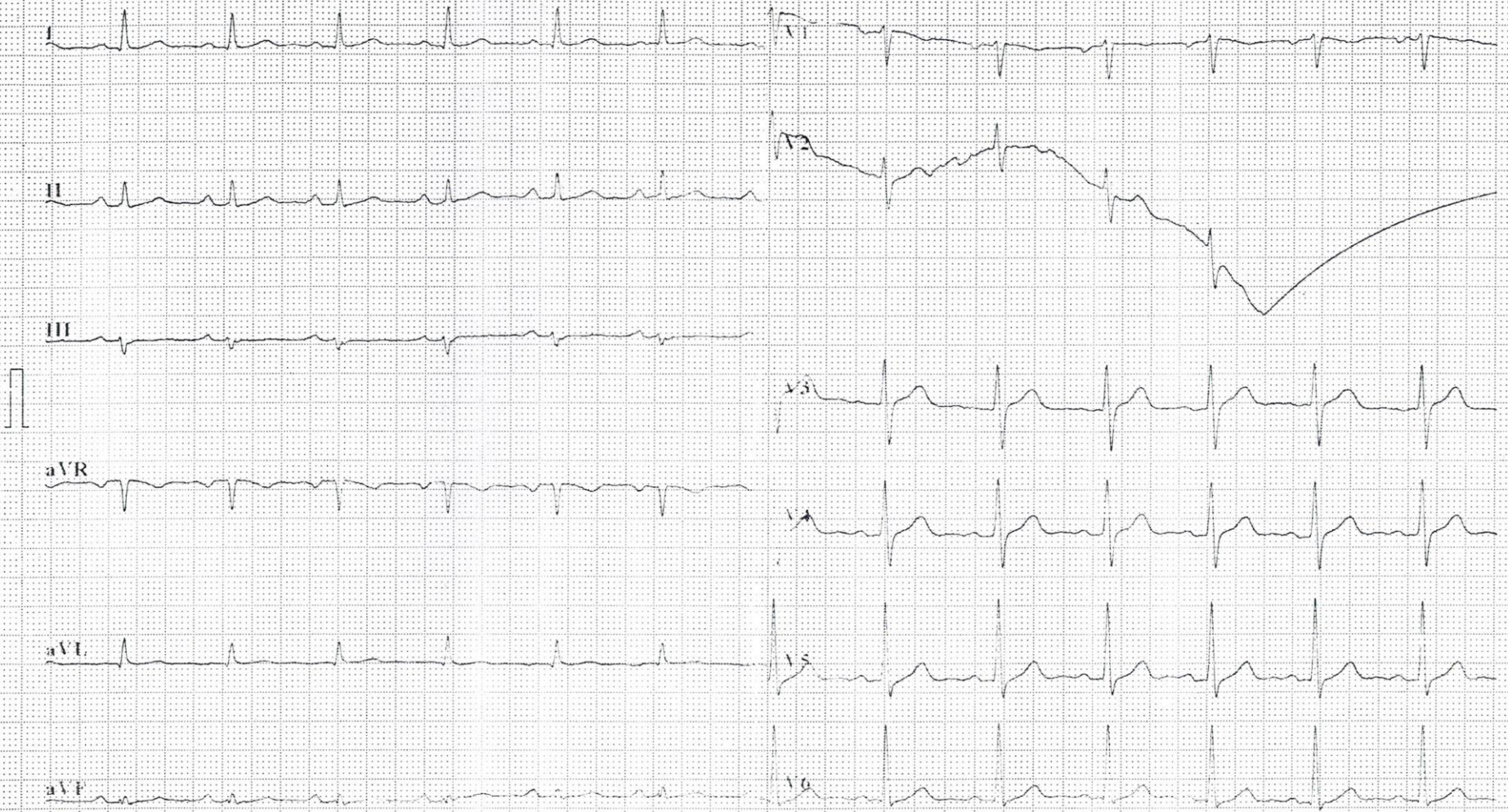
Name :  
ID : 2380  
Age : years  
Height : cm  
BP : / mmHg  
Gender : Male  
Weight : kg  
Race : Unknown

Minnesota Code:  
9-4-1(V3)

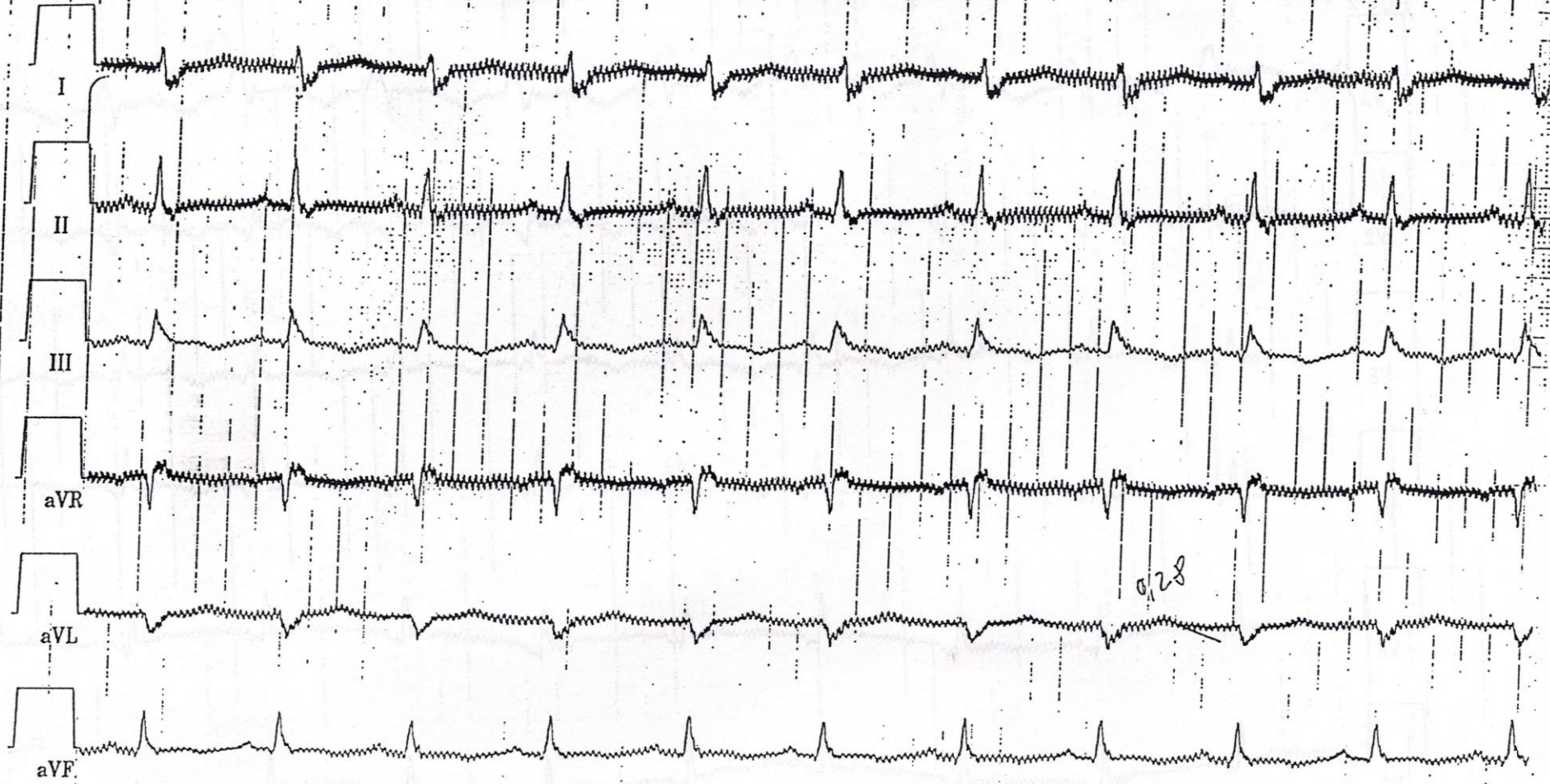
HR : 80 BPM  
P Dur : 114 ms  
PR int : 191 ms  
QRS Dur : 105 ms  
QT/QTc int : 358/414 ms  
P/QRS/T axis : 64/11/38 °  
RV5/SV1 amp : 1.459/0.554 mV  
RV5+SV1 amp : 2.013 mV  
RV6/SV2 amp : 1.380/0.448 mV

Diagnosis Information:  
800: Sinus Rhythm  
\*\*\*Normal ECG\*\*\*

Report Reviewed by:







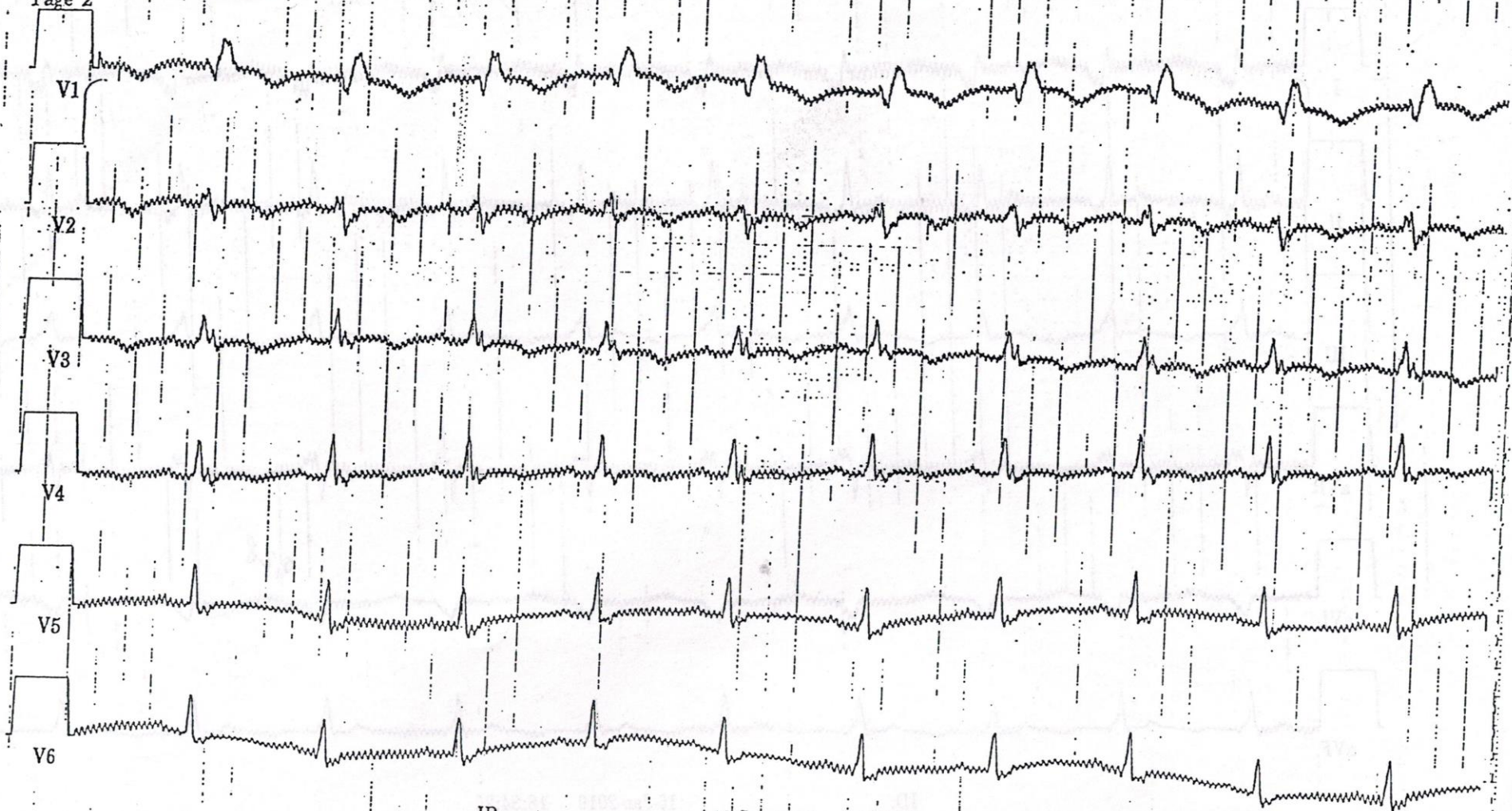
ID: 16-Jan-2010 18:34:26

Vent. rate 126 bpm  
 PR interval 124 ms  
 QRS duration 96 ms  
 QT/QTc 320/463 ms  
 P-R-T axes 56 88 -6

Sinus tachycardia  
 Low voltage QRS  
 Incomplete right bundle branch block  
 T wave abnormality, consider anterior ischemia  
 Abnormal ECG

Unconfirmed



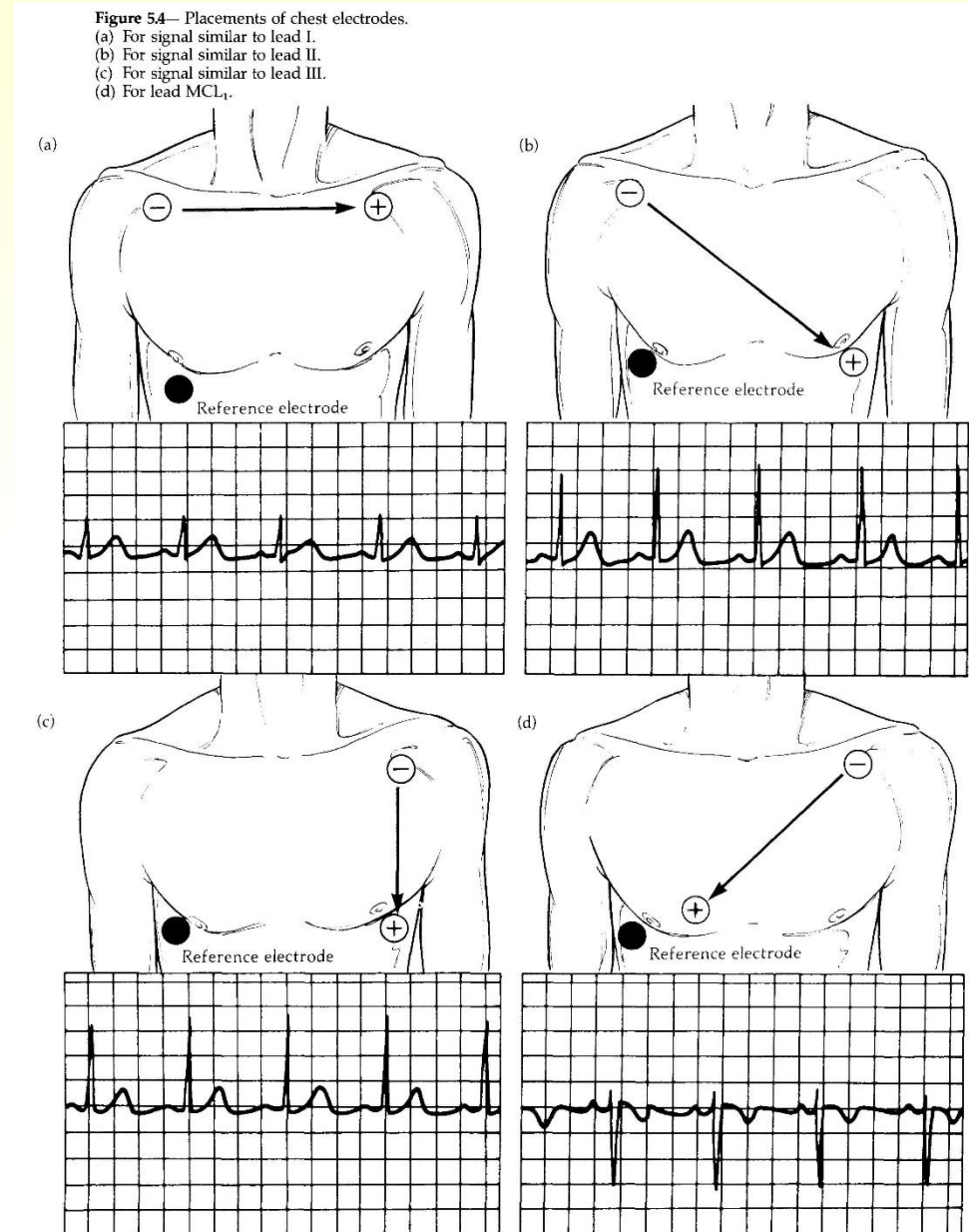
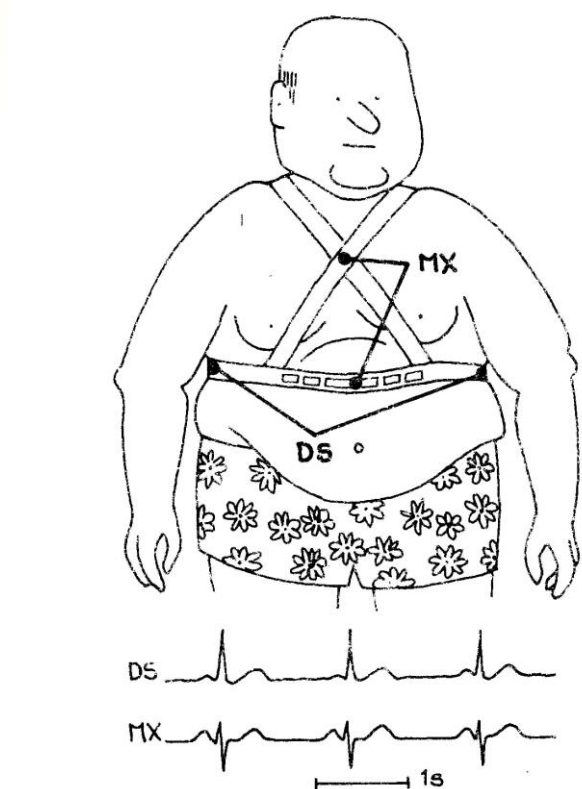


ID: 16-Jan-2010 18:34:26

|              |            |
|--------------|------------|
| Vent. rate   | 126 bpm    |
| PR interval  | 124 ms     |
| QRS duration | 96 ms      |
| QT/QTc       | 320/463 ms |
| P-R-T axes   | 56 88 -6   |

# Nahradní umístění elektrod

- co nejmenší vliv pohybu  
vyšetřovaného na kvalitu signálu –  
pohybové artefakty,  
myopotenciály;
- co nejmenší vliv vodičů na mobilitu  
vyšetřovaného



# Nahradní umístění elektrod

- končetinové definoval Einthoven (historický aspekt)
- končetinové dávají obecně větší biosignály
- končetinové svody jsou obecně více rušeny
- snadnost připojení

Present state-of-the-art is often based on historical quirks rather than on a profound scientific basis.

*Encyclopedia of Medical Devices and Instrumentation,  
Second Edition, edited by John G. Webster  
2006 John Wiley & Sons, Inc*

# Hrudní svody

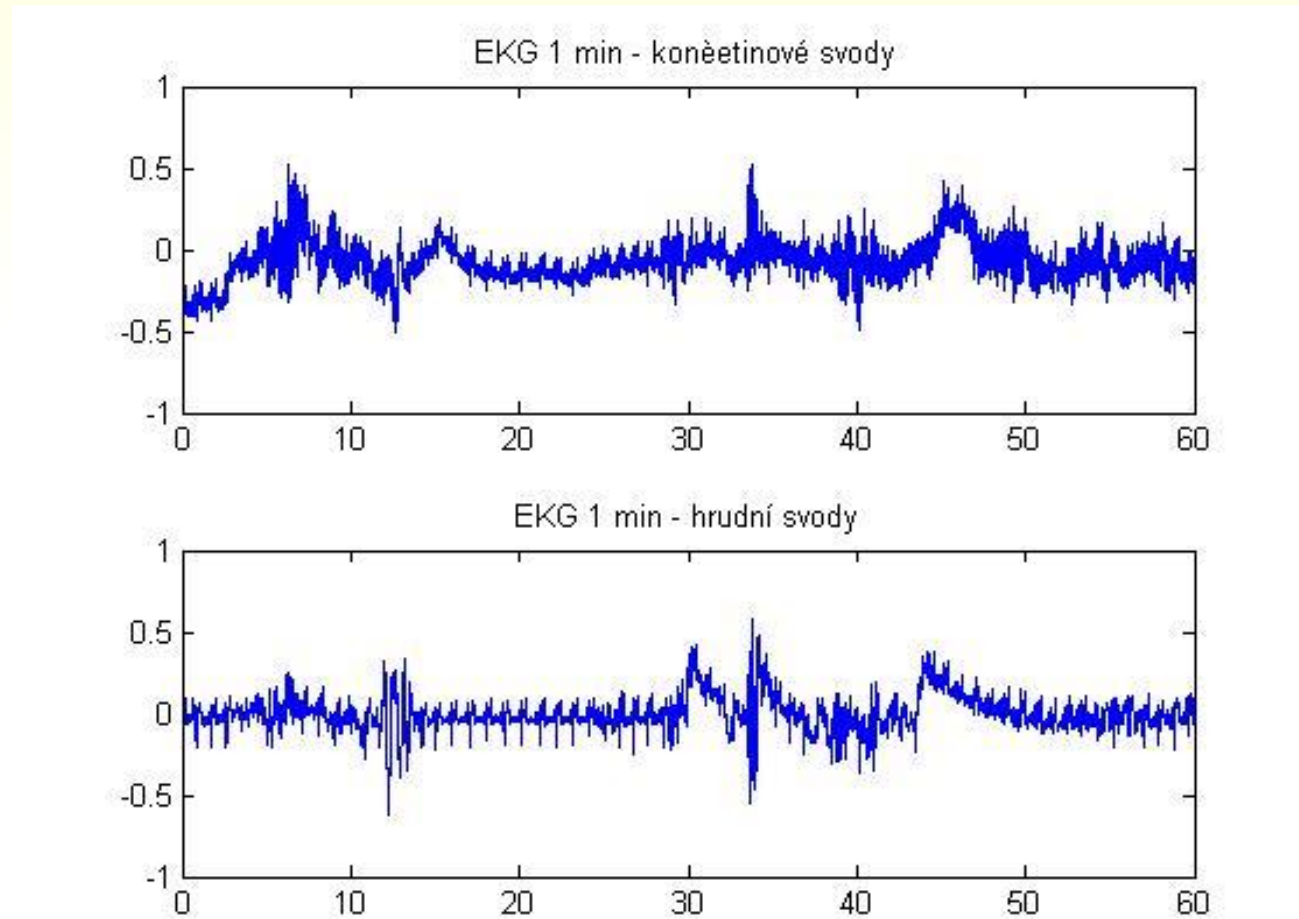
- jsou považovány za nejspolehlivější
- dávají nejčistší signál

# Končetinové svody

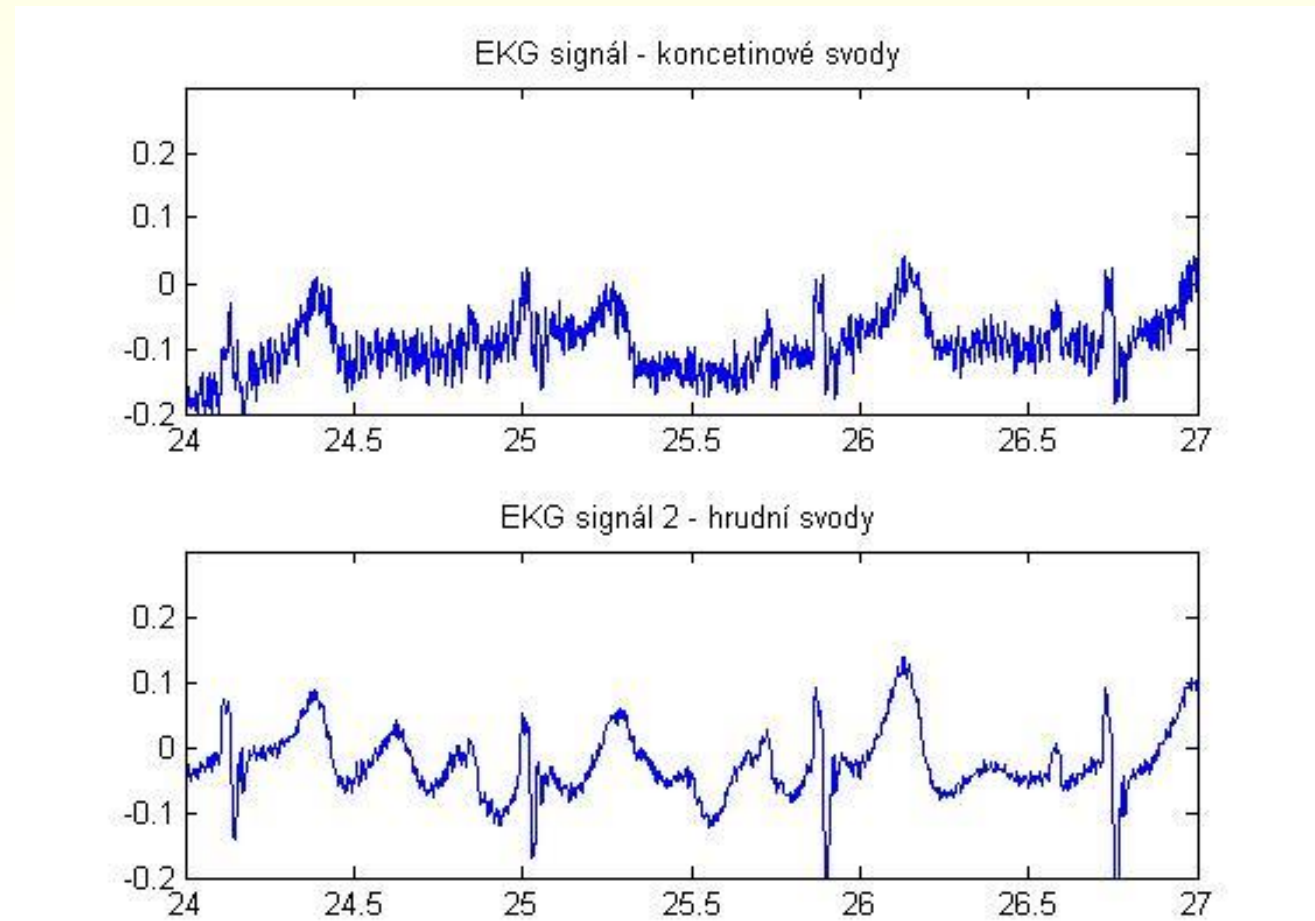
- pro redukci rušení doporučeno dávat elektrody výše na ruku
- více citlivé na pohybové artefakty



# Experiment

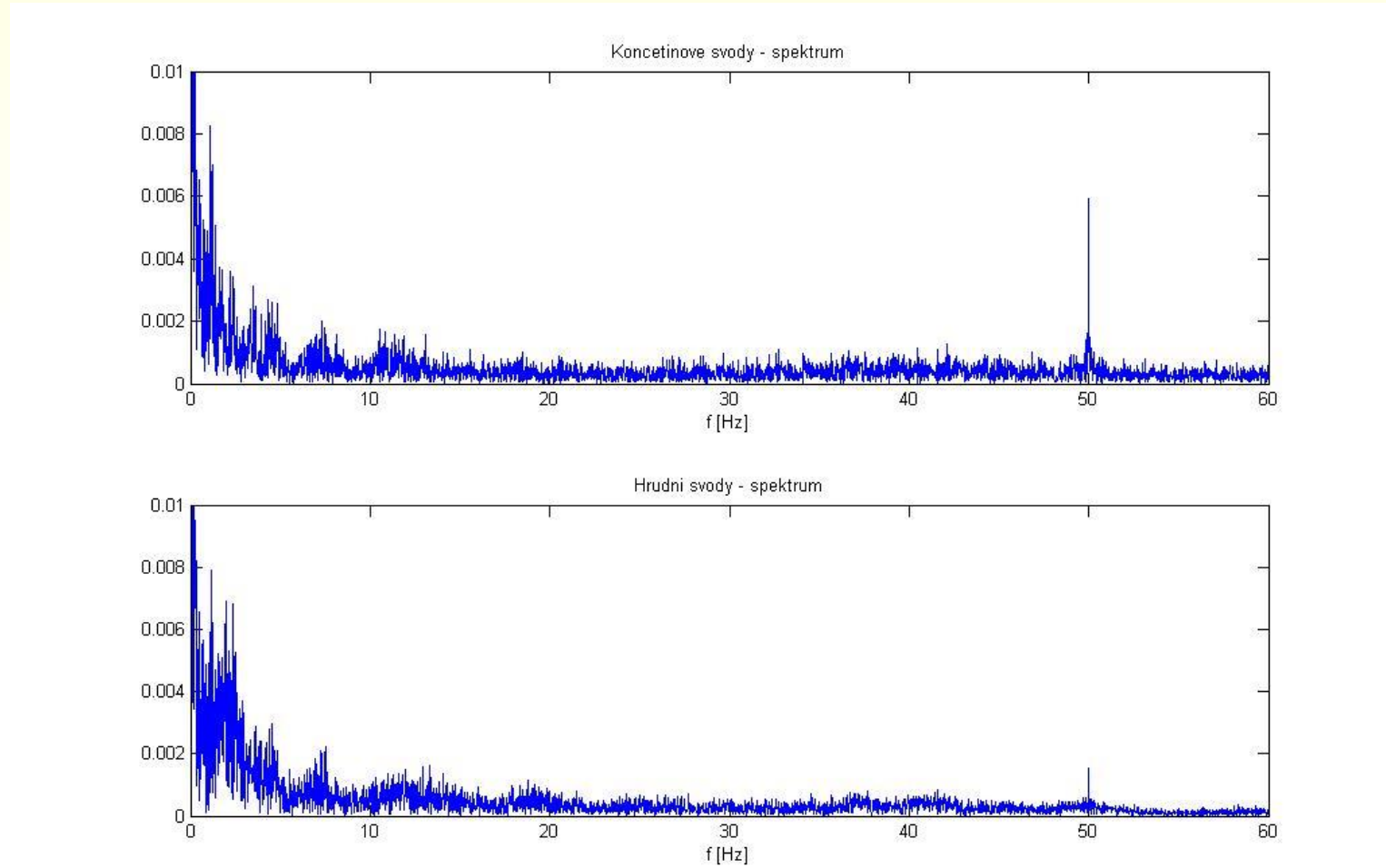


# Experiment





# Experiment



# EKG zátěžové

## bicyklová ergometrie, ergometrie



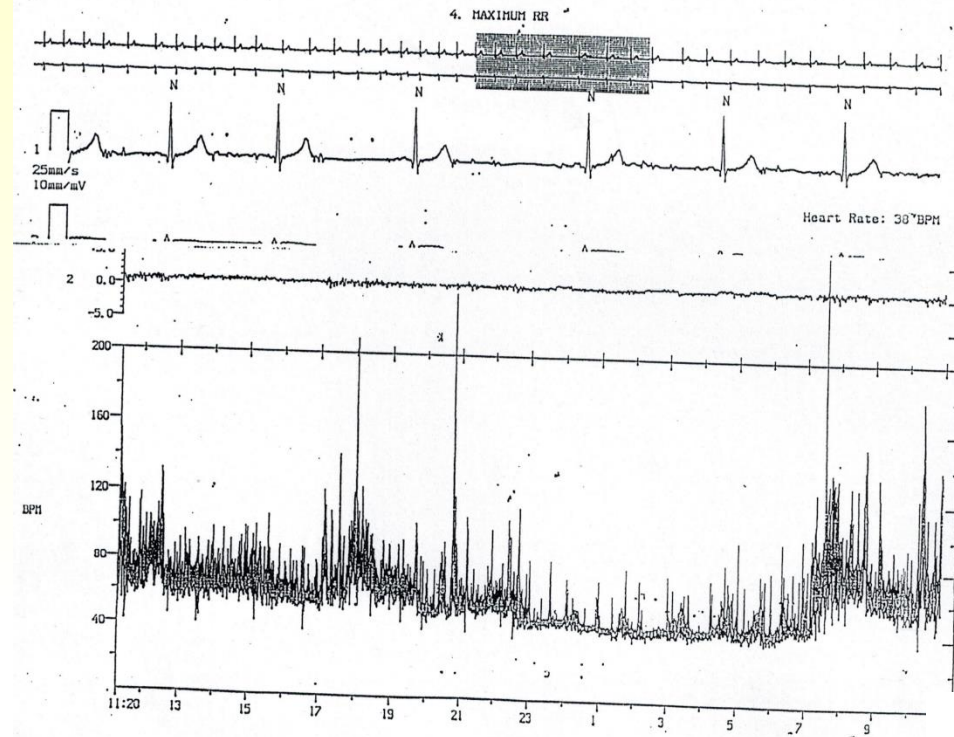
Sportovní, pracovní lékařství

- fyzická zátěž
- standardní protokoly
- zastaví se při vysoké tepové frekvenci



Stanovení maximální možné hodnoty srdeční frekvence při zátěžovém testu  
 $MHR = 220 - \text{věk}$

# Holterovská monitorace



## SUMMARY

A total of 83122 beats were observed for the entire recording period of 23 hours, 39 minutes.  
The maximum heart rate during this period was 200 BPM during minute 7:33.  
The minimum heart rate was 35 BPM, during minute 1:59.  
Atrial Fibrillation was present for 0X of the recording. Atrial Flutter for 0X. Junctional Rhythm for 0X.

## SUPRAVENTRICULAR REPORT

A total of 0 supraventricular ectopic beats were observed; with 0 isolated single events, 0 couplets, and 0 runs.

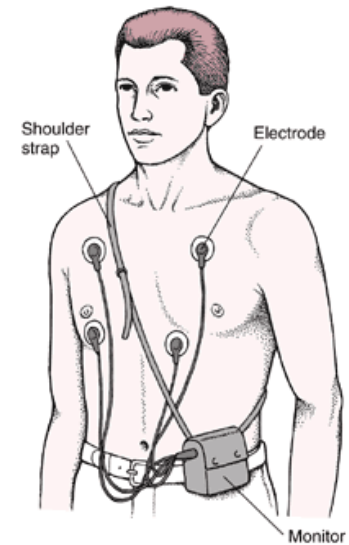
## VENTRICULAR REPORT

A total of 0 ventricular ectopic beats were observed; with 0 isolated single events, 0 couplets, and 0 runs.

## ST SEGMENT REPORT

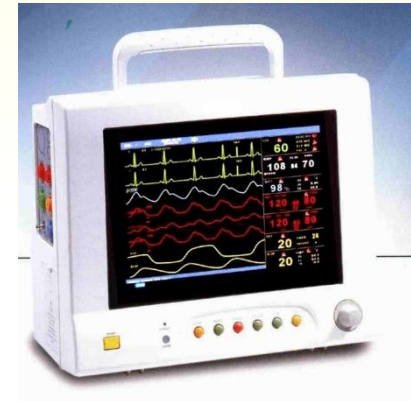
For channel 1, the maximum ST segment elevation/depression observed was + 2.0 mm during minute 8:12.  
For channel 2, the maximum ST segment elevation/depression observed was + 1.4 mm during minute 10:56.

Závěr: 1<sup>o</sup> vale sín.ř. s přiměřenými tep.fr. při klidném bdění s akcelerací na max. 135/min.  
Ve spánku nejnižší tep.fr. 35-38 při RR int. 1,6 sec. - sinusová bradykardie.  
Jiné formy bradykardie nezastiženy - nemá AV blok.



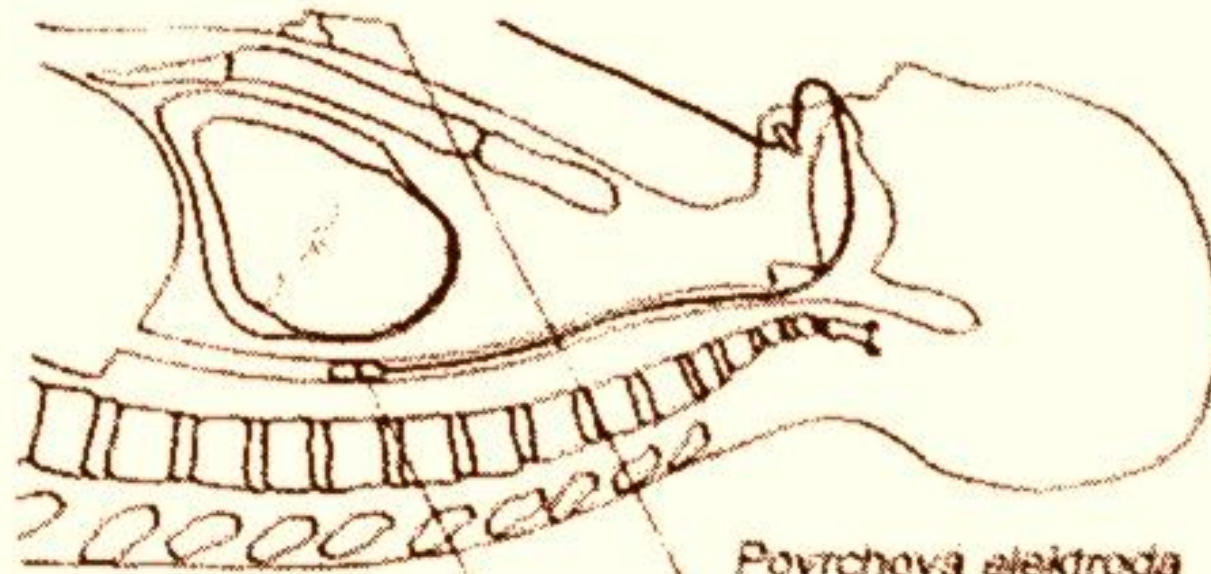
# Monitorování EKG v intenzivní péči

- **monitorování** (dlouhodobé)
  - „bedside“ – monitorování jednoho svodu v reálném čase + dechová frekvence
  - změna rytmu
  - výskyt extrasystoly – začne houkat alarm



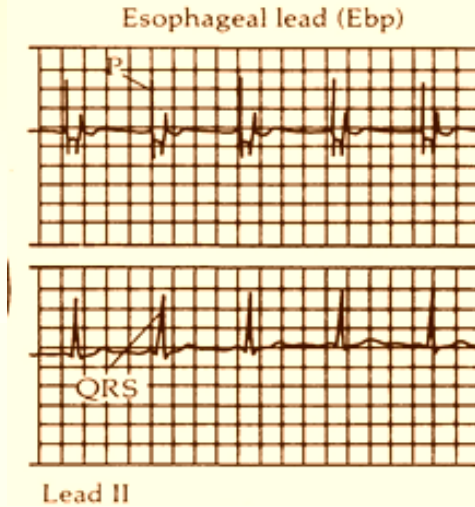


# Jícnová elektrokardiografie

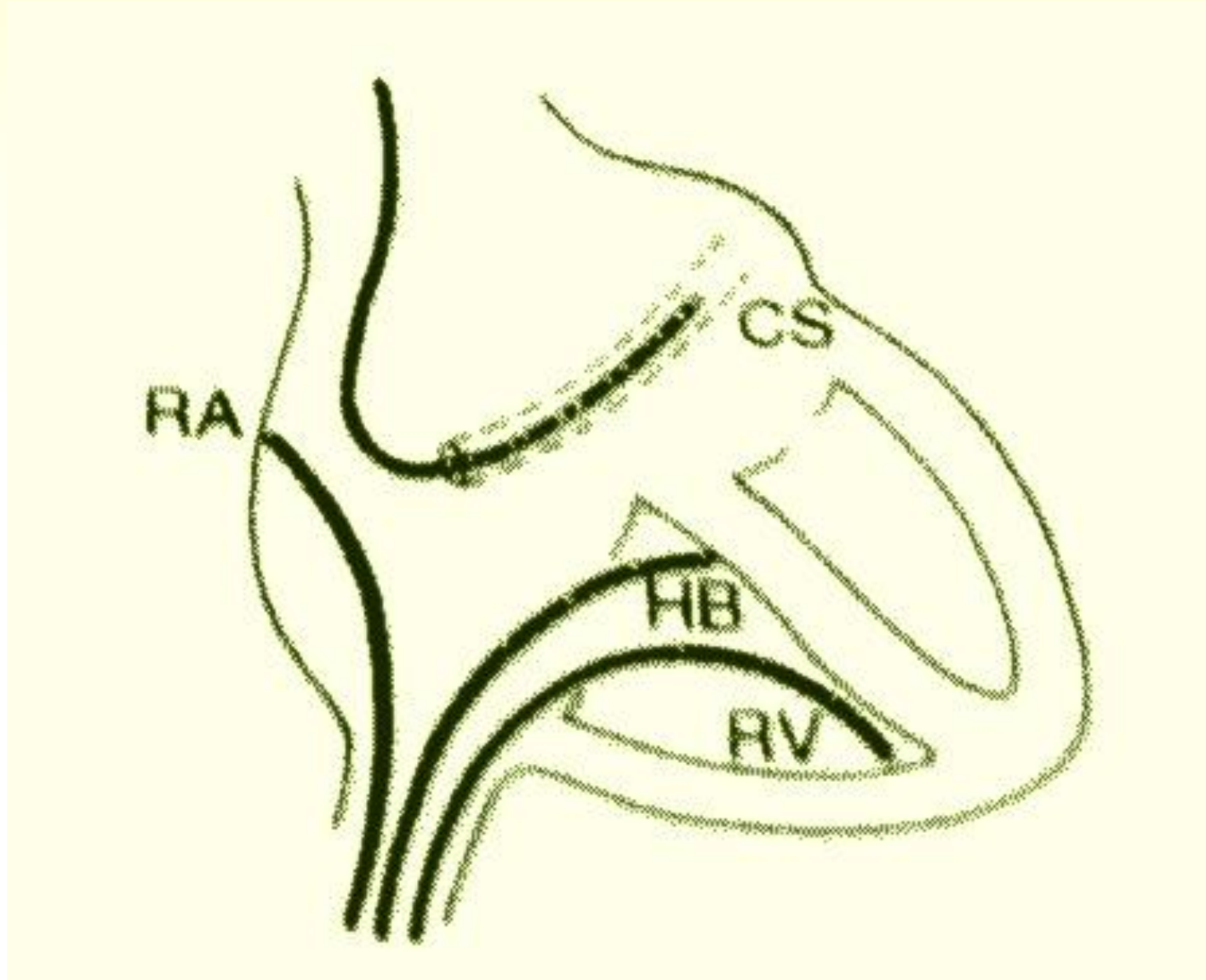


Jícnová elektroda  
pro snímání EKG  
a srdeční stimulaci

Povrchová elektroda  
pro snímání povrchového EKG



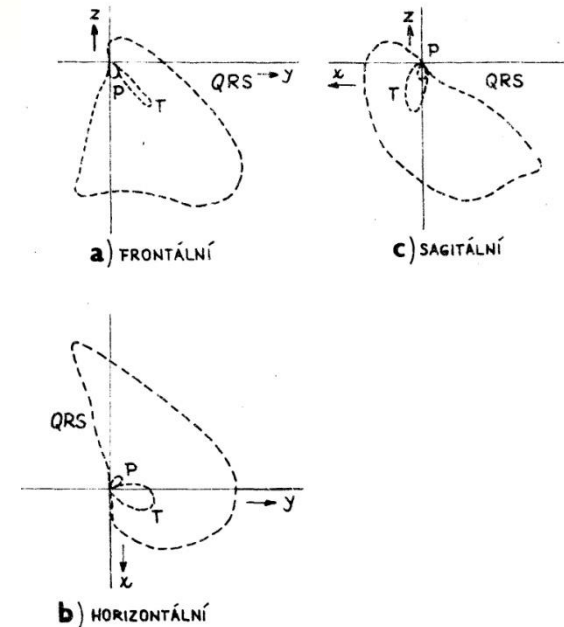
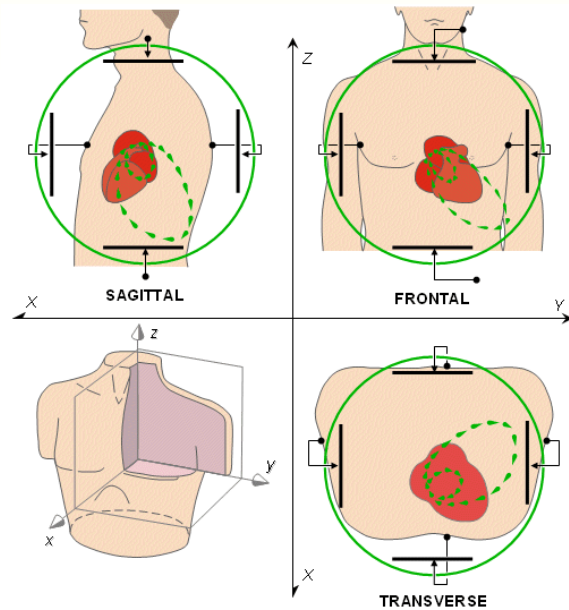
# Intrakardiální EKG





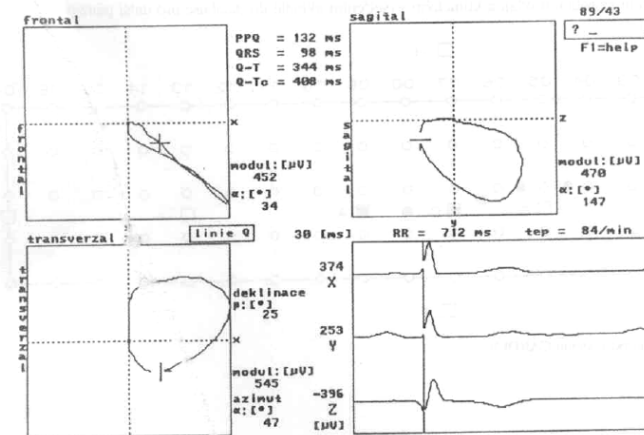
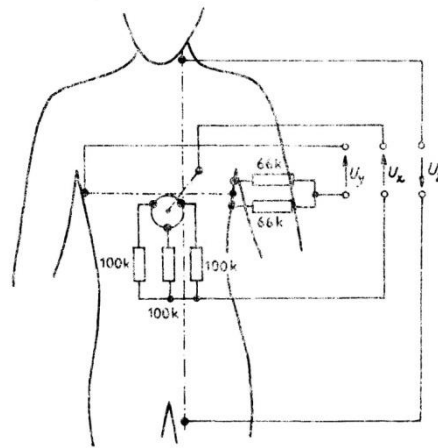
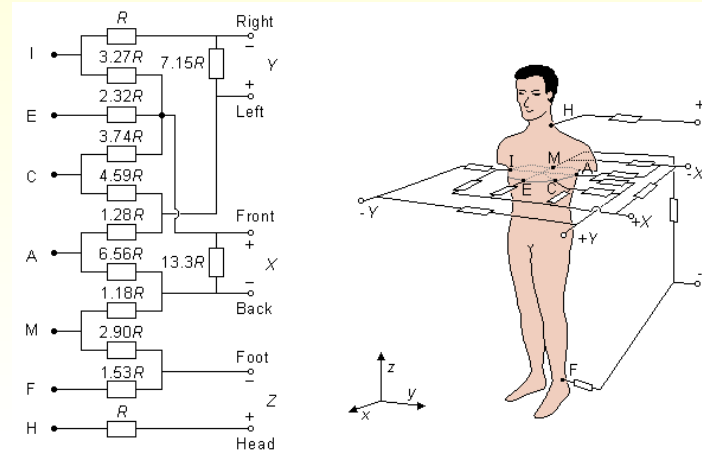
# Vektorkardiografie (ortogonální svody)

- vyjadřují prostorové vlastnosti elektrického pole kolem srdce (hrudníku) pomocí tří ortogonálních signálů;
- zobrazení pomocí tří rovinných smyček;

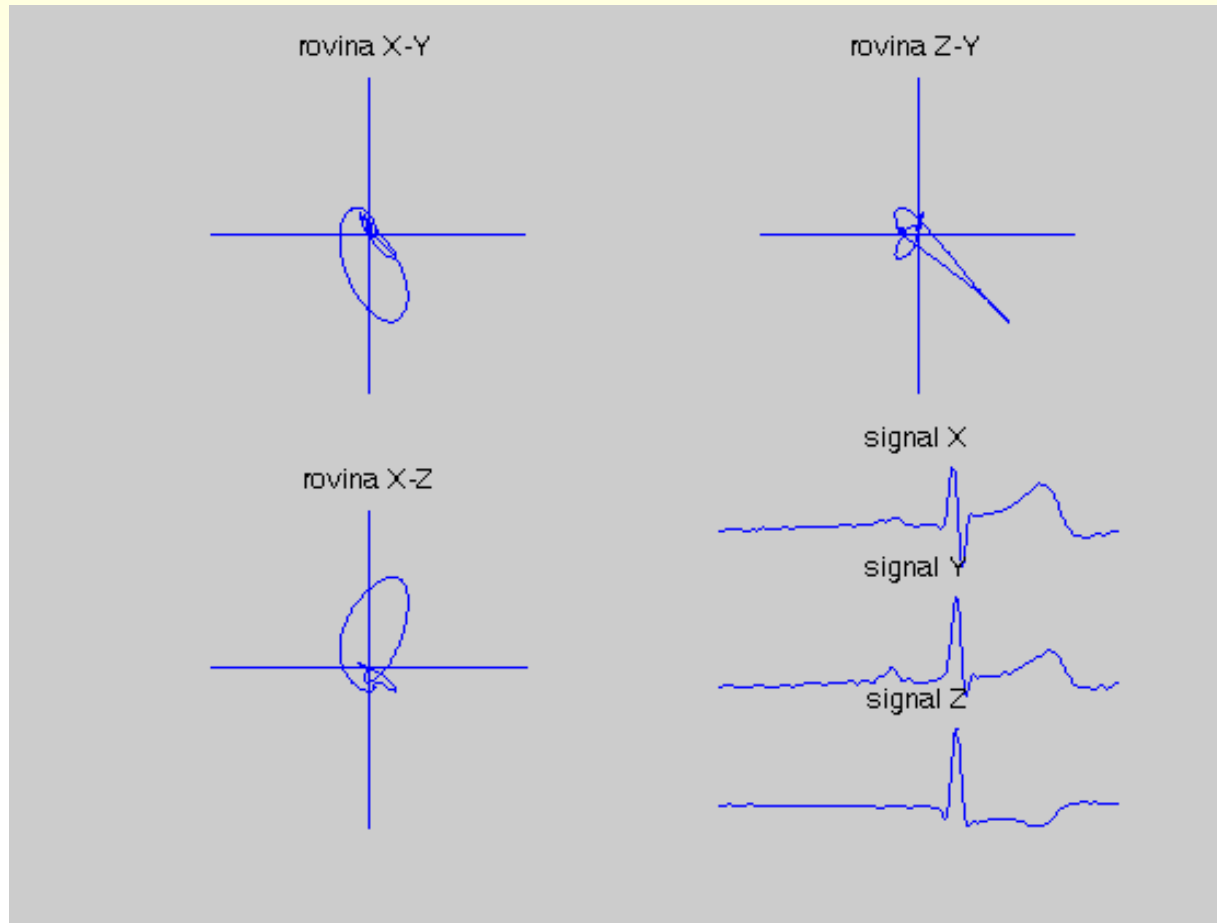


# Vektorkardiografie

- Frankův systém
- McFee systém



# Laboratorní úloha

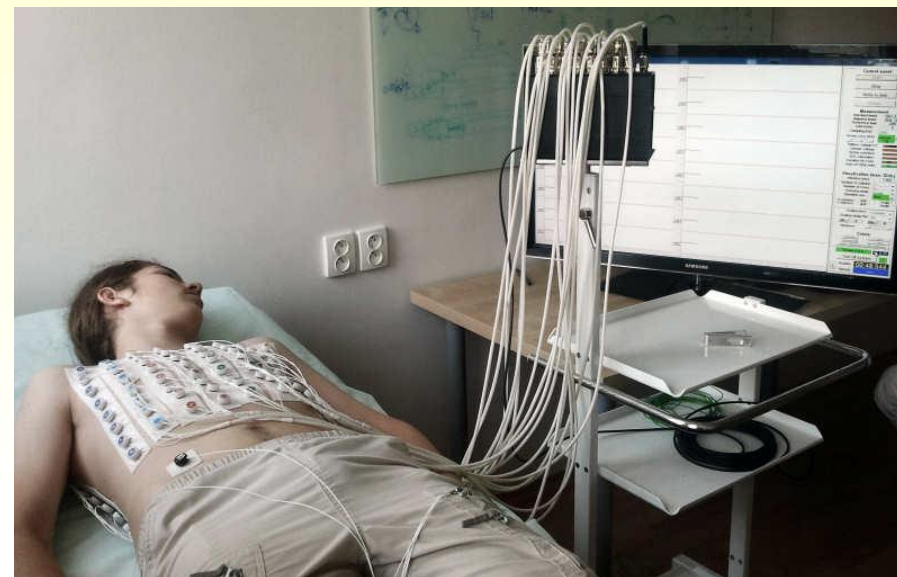
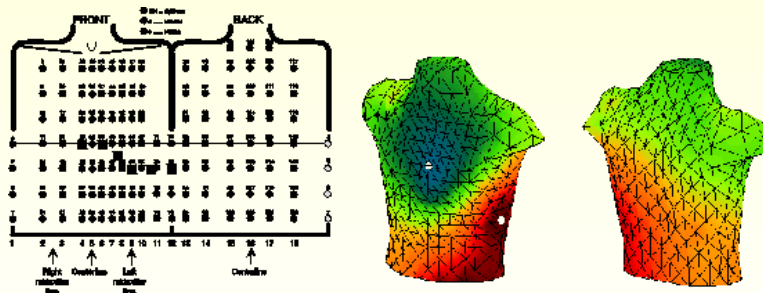


frontální x-y

horizontální x-z

sagitální z-y

# Izopotenciálové mapování



# EKG ve veterinární medicíně

## 6 končetinových svodů :

snímají srdce ze stran a zezadu v horizontální rovině

I,II,aVL „se dívají“ na levý laterální povrch

III, aVF zezadu

aVR na pravou síň

## 6 hrudních svodů:

snímají srdce v transverzální rovině

C1 „se dívá“ na pravou síň a komoru

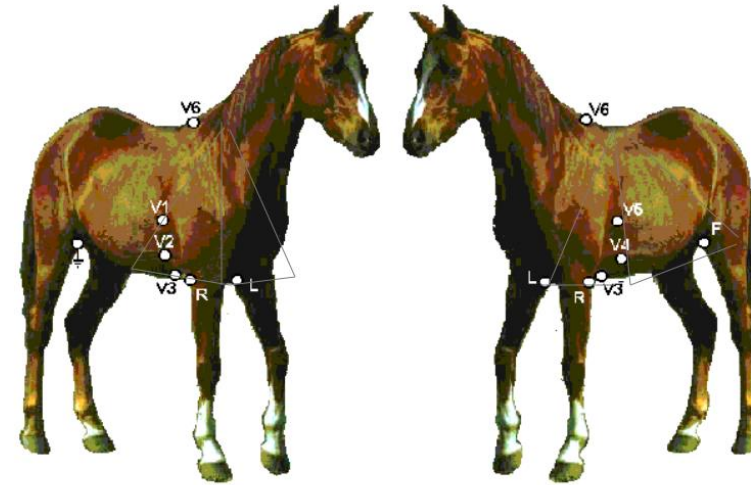
C4 na septum a levou komoru

C5 na levou komoru

C6 levou síň

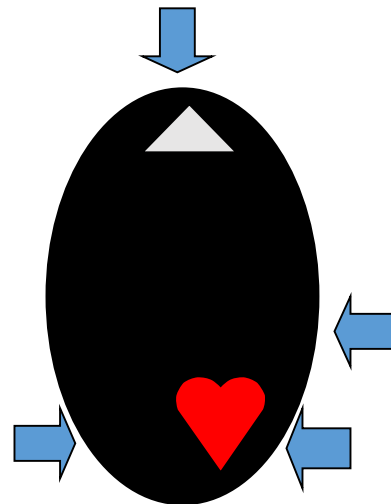
## Tetraedronový svodový systém

(Hanák a Jagoš, 1983)



## Poloha zvířete

- v sedě
- v náruči majitele
- na pravém boku  
(ve stoje vznikají ARTEFAKTY !)





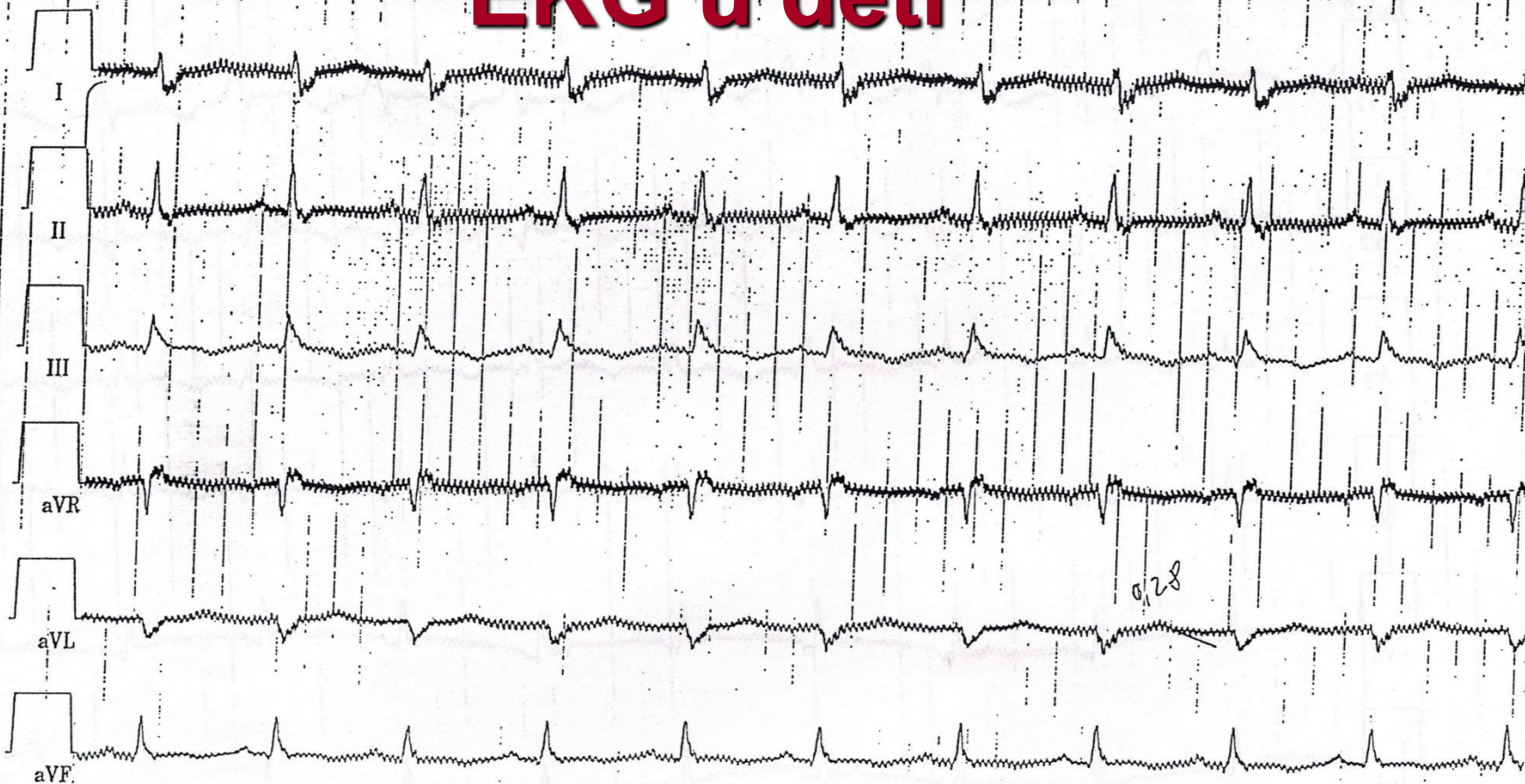
# EKG u dětí

| Age         | Mean (range) Heart Rate (beats/min) | Mean (max) PR Interval (s) | Mean (range) QRS Axis (degrees) | Mean (max) QRS Interval (s) |
|-------------|-------------------------------------|----------------------------|---------------------------------|-----------------------------|
| 0-4 weeks   | 145 (95-180)                        | 0.10 (0.12)                | +110 (30-180)                   | 0.05 (0.07)                 |
| 1-6 months  | 145 (110-180)                       | 0.11 (0.14)                | +70 (10-125)                    | 0.05 (0.075)                |
| 6-12 months | 135 (110-170)                       | 0.11 (0.14)                | +60 (10-110)                    | 0.05 (0.075)                |
| 1-3 years   | 120 (90-150)                        | 0.11 (0.15)                | +60 (10-110)                    | 0.05 (0.075)                |
| 4-5 years   | 110 (65-135)                        | 0.13 (0.15)                | +60 (0-110)                     | 0.06 (0.075)                |
| 6-8 years   | 100 (60-130)                        | 0.14 (0.16)                | +60 (-15- +110)                 | 0.06 (0.075)                |
| 9-11 years  | 85 (60-110)                         | 0.14 (0.15)                | +60 (-30- +105)                 | 0.06 (0.085)                |
| 12-16 years | 65 (60-110)                         | 0.15 (0.17)                | +60 (-30- +105)                 | 0.07 (0.085)                |
| > 16 years  | 80 (60-100)                         | 0.15 (0.20)                | +60 (-30- +105)                 | 0.08 (0.10)                 |

Reproduced from: Amieva-Wang NE. *A Practical Guide to Pediatric Emergency Medicine*. New York: Cambridge University Press; 2011.



# EKG u dětí



ID:

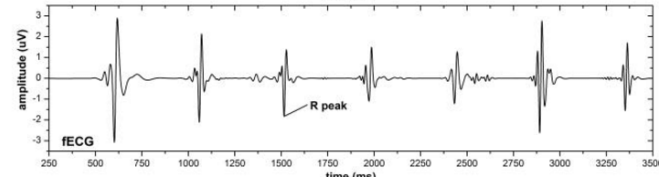
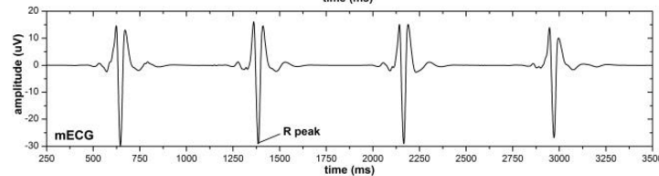
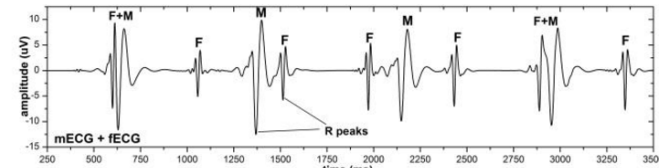
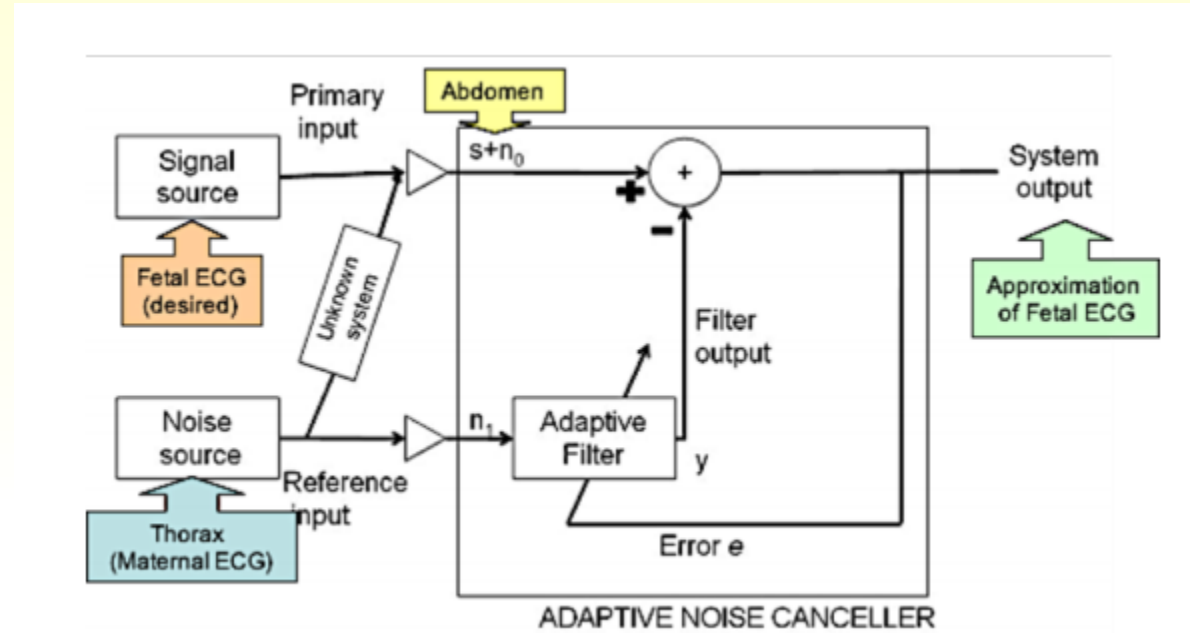
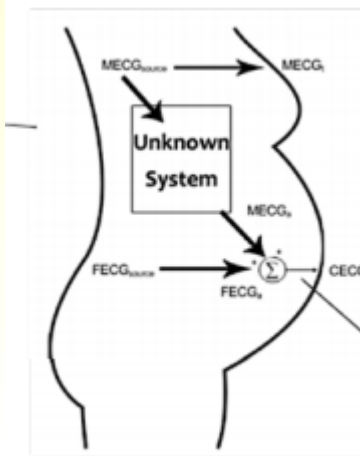
16-Jan-2010 18:34:26

Vent. rate 126 bpm  
PR interval 124 ms  
QRS duration 96 ms  
QT/QTc 320/463 ms  
P-R-T axes 56 88 -6

Sinus tachycardia  
Low voltage QRS  
Incomplete right bundle branch block  
T wave abnormality, consider anterior ischemia  
Abnormal ECG

Unconfirmed

# Fetální EKG

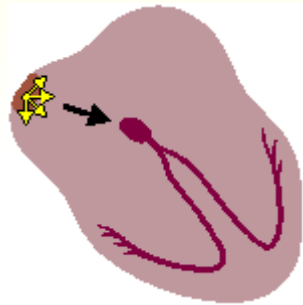


# Základní EKG obrazy

# Normální sinusový rytmus

## NORMAL SINUS RHYTHM

Impulses originate at S-A node at normal rate



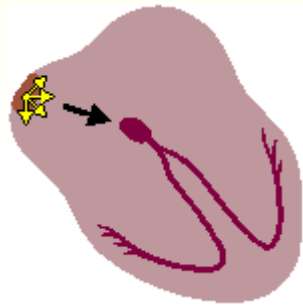
All complexes normal, evenly spaced  
Rate 60 - 100/min



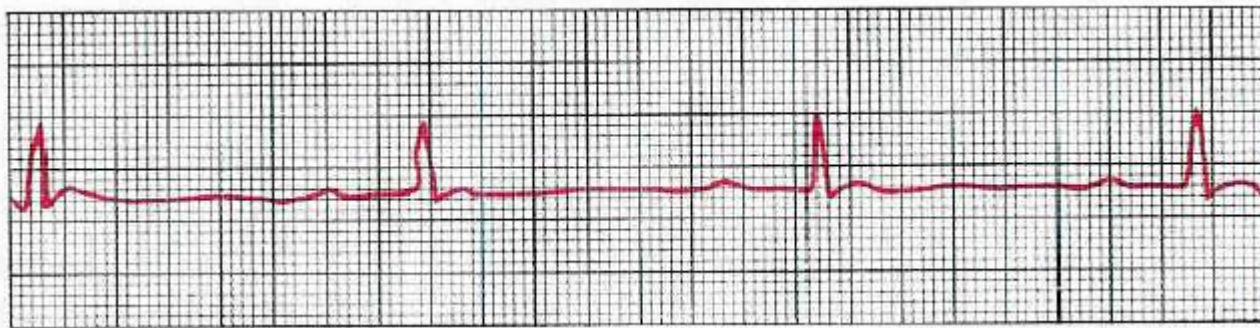
# Sinusová bradykardie

## SINUS BRADYCARDIA

Impulses originate at S-A node at slow rate



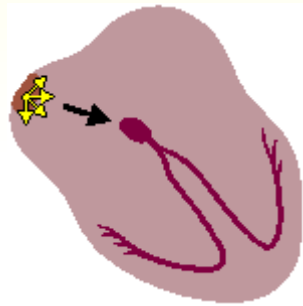
All complexes normal, evenly spaced  
Rate < 60 - 100/min



# Sinusová tachykardie

## SINUS TACHYCARDIA

Impulses originate at S-A node at rapid rate



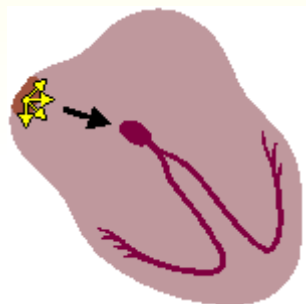
All complexes normal, evenly spaced  
Rate > 100/min



# Respirační arytmie

## SINUS TACHYCARDIA

Impulses originate at S-A node at rapid rate

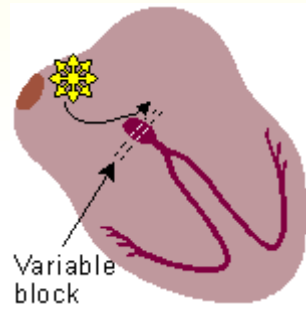


All complexes normal, rhythm is irregular  
Longest R-R interval exceeds shortest > 0.16 s

# Flutter síní

## ATRIAL FLUTTER

Impulses travel in circular course in atria



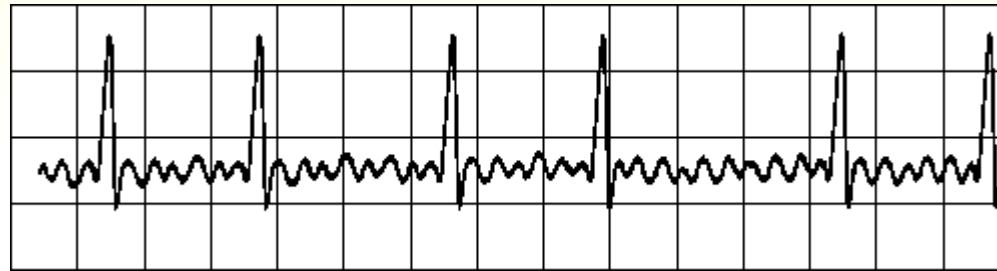
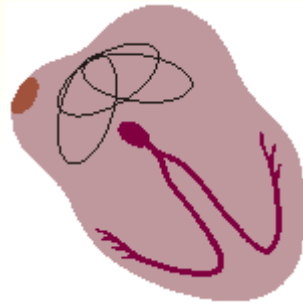
Rapid flutter waves, ventricular response irregular



# Fibrilace síní

## ATRIAL FIBRILLATION

Impuses have chaotic, random pathways in atria



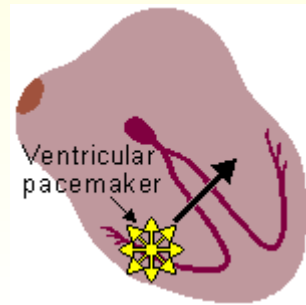
Baseline irregular, ventricular response irregular

# Komorová extrasystola

(premature ventricular contraction, PVC)

## PREMATURE VENTRICULAR CONTRACTION

A single impulse originates at right ventricle



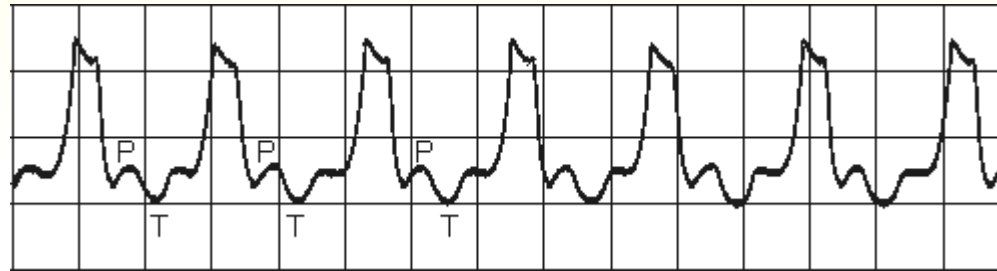
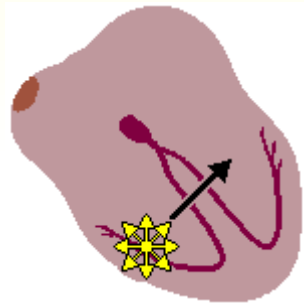
Time interval between normal R peaks  
is a multiple of R-R intervals



# Komorová tachykardie

## VENTRICULAR TACHYCARDIA

Impulse originate at ventricular pacemaker

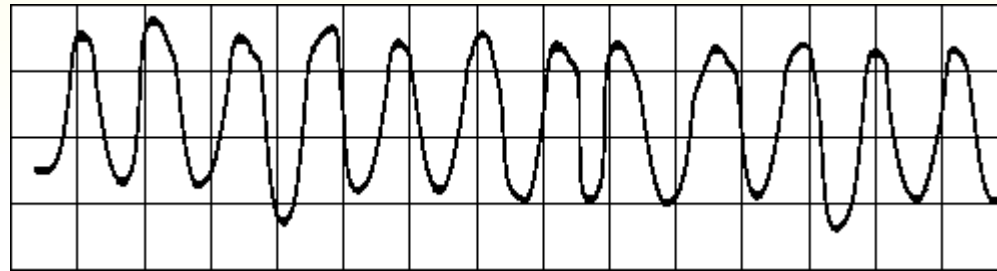
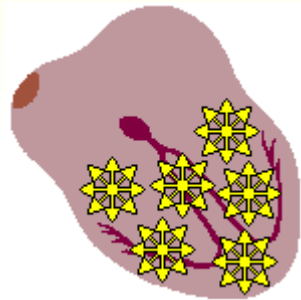


Wide ventricular complexes  
Rate > 120/min

# Fibrilace komor

## VENTRICULAR FIBRILLATION

Chaotic ventricular depolarization



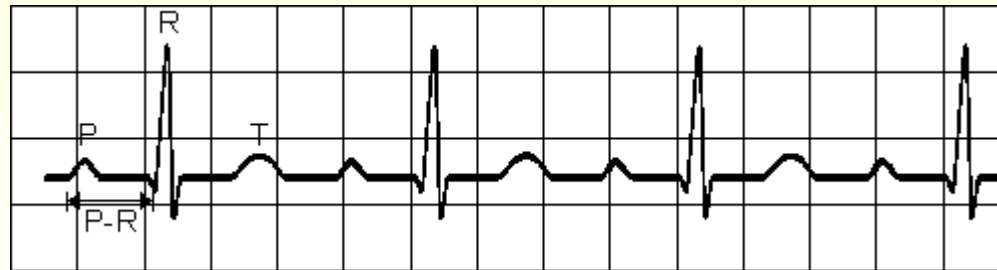
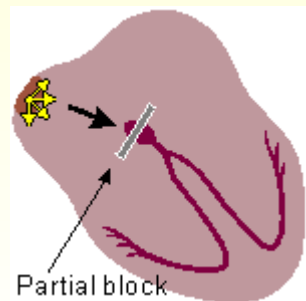
Rapid, wide, irregular ventricular complexes



# A-V blokáda, 1. stupeň

## A-V BLOCK, FIRST DEGREE

Atrio-ventricular conduction lengthened



P-wave precedes each QRS-complex but PR-interval is  $> 0.2$  s

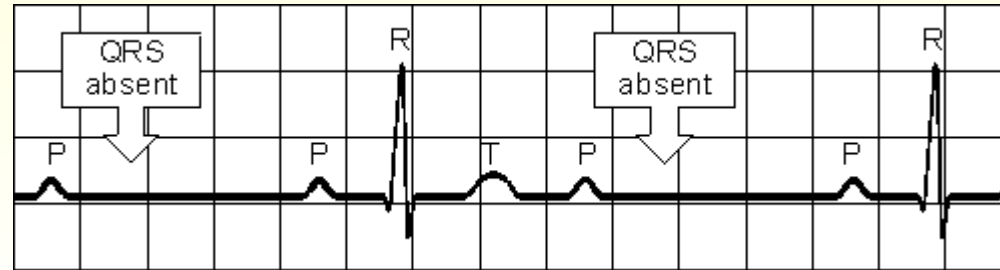
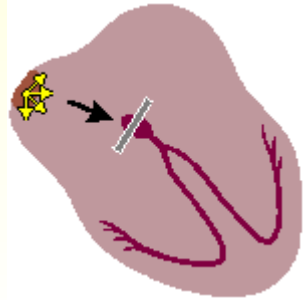
Prodloužení srdečního cyklu při 1.-stupňové blokádě AV uzlu



# A-V blokáda, 2. stupeň

## A-V BLOCK, SECOND DEGREE

Sudden dropped QRS-complex



Intermittently skipped ventricular beat

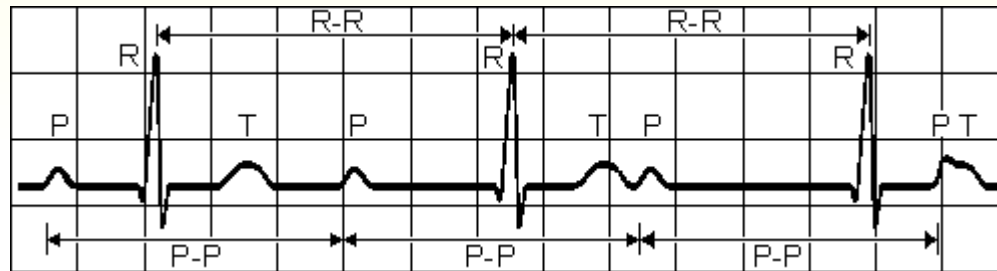
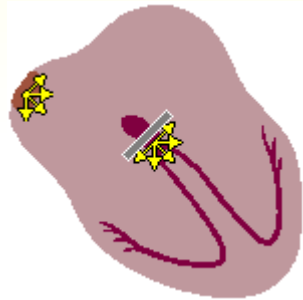
## Blokáda AV uzlu 2. řádu, III. svod



# A-V blokáda, 3. stupeň

## A-V BLOCK, THIRD DEGREE

Impulses originate at AV node and proceed to ventricles  
Atrial and ventricular activities are not synchronous



P-P interval normal and constant,  
QRS complexes normal, rate constant, 20 - 55 /min

## Úplná AV blokáda

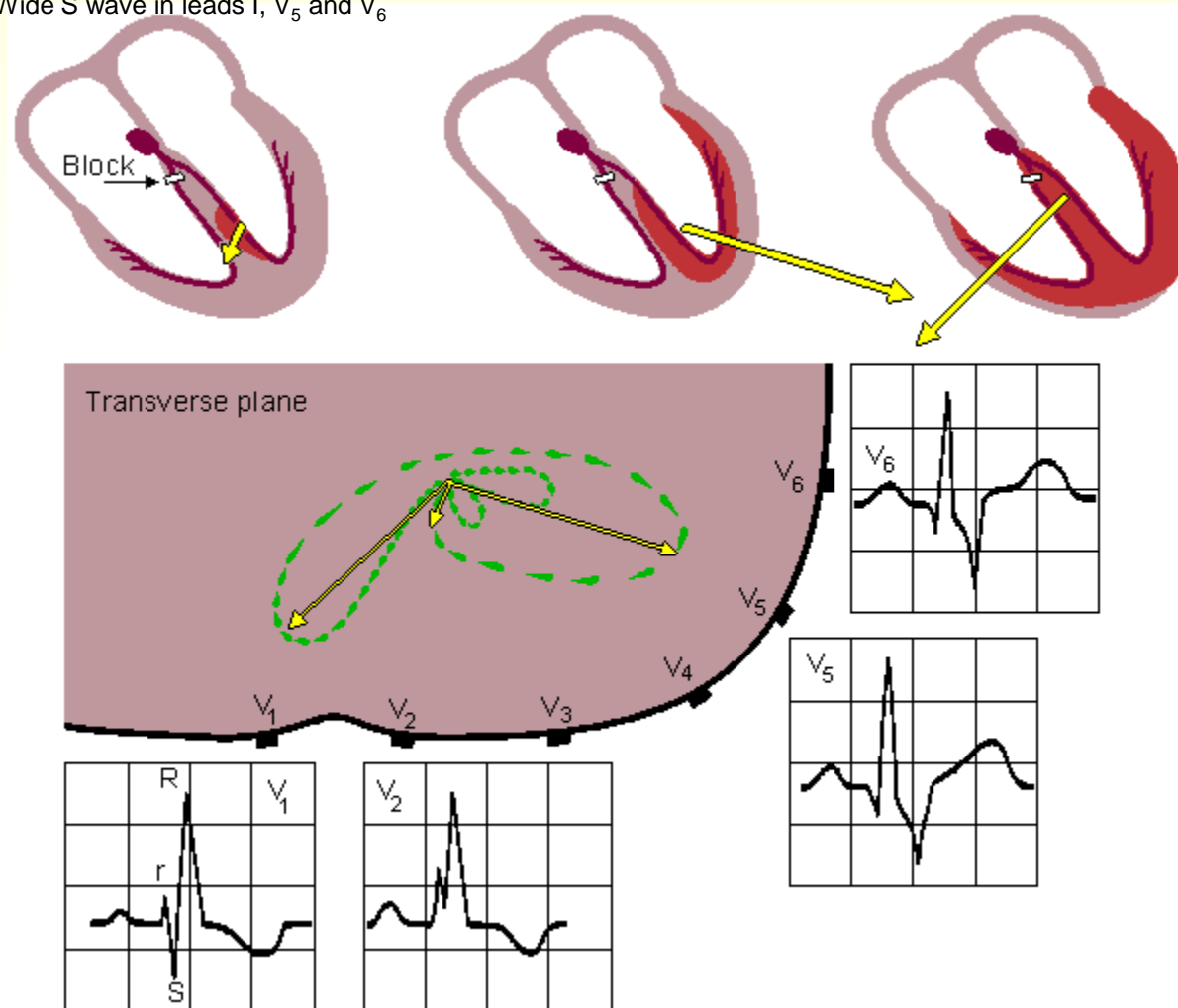


# Blokáda pravého Tawarova raménka

## RIGHT BUNDLE-BRANCH BLOCK

QRS duration greater than 0.12 s

Wide S wave in leads I, V<sub>5</sub> and V<sub>6</sub>



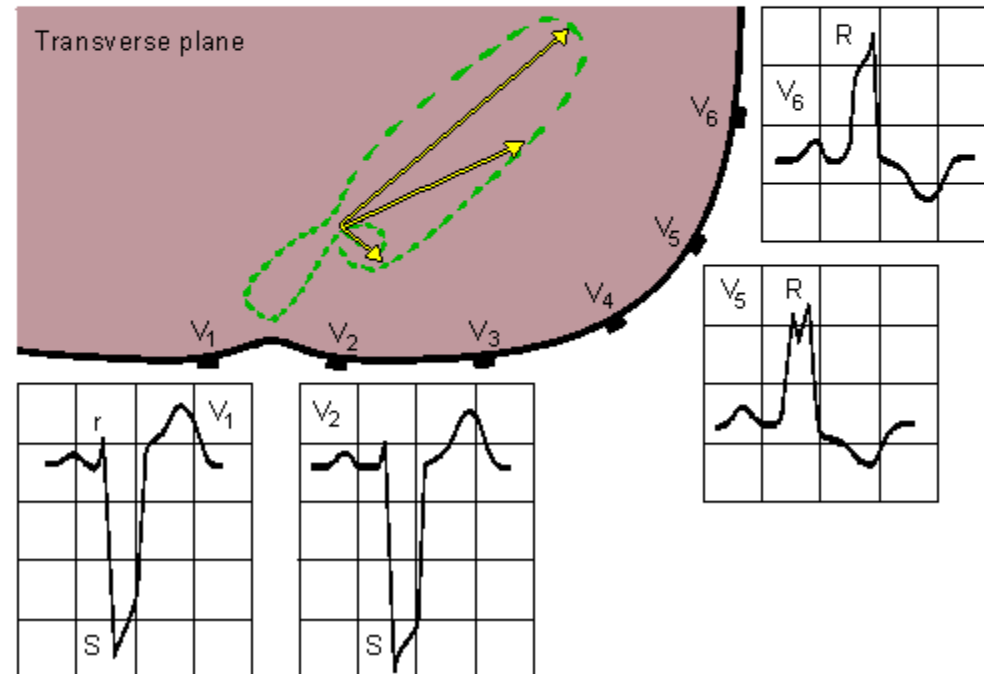
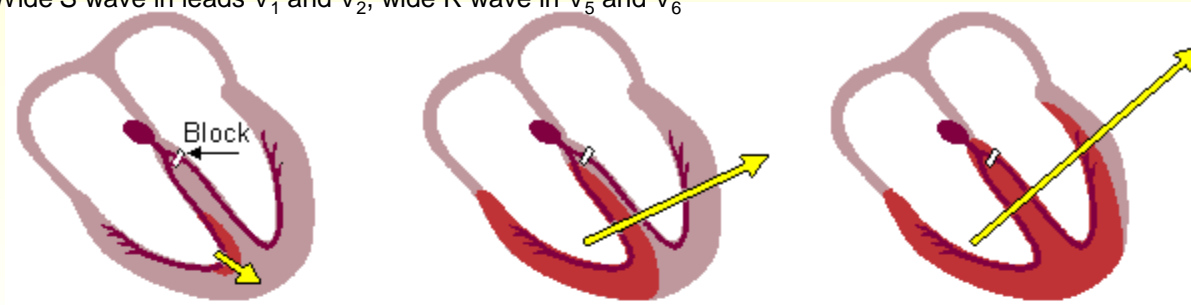


# Blokáda levého Tawarova raménka

## LEFT BUNDLE-BRANCH BLOCK

QRS duration greater than 0.12 s

Wide S wave in leads V<sub>1</sub> and V<sub>2</sub>, wide R wave in V<sub>5</sub> and V<sub>6</sub>



# Síňová hypertrofie

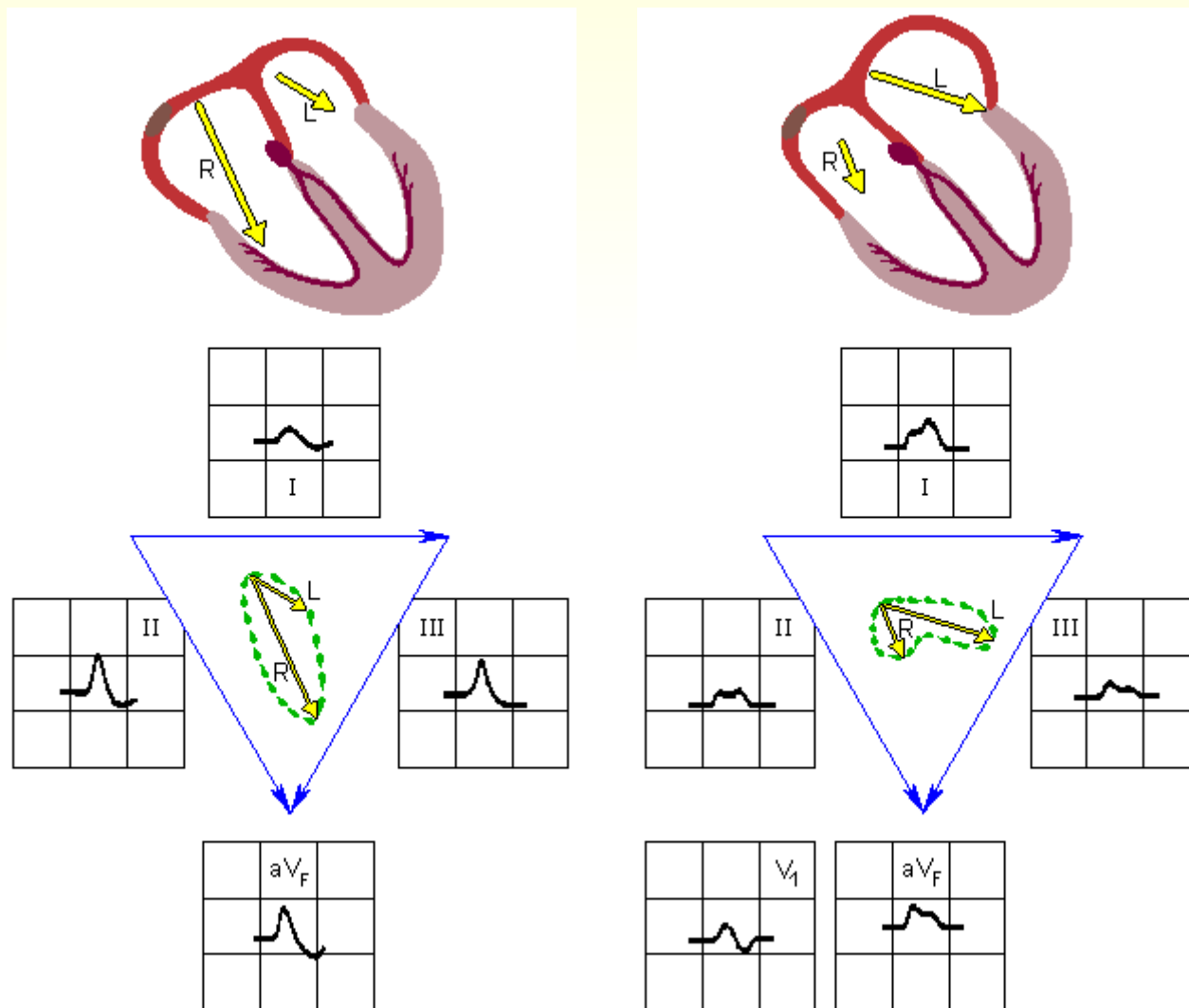
## RIGHT ATRIAL HYPERTROPHY

Tall, peaked P wave in leads I and II

## LEFT ATRIAL HYPERTROPHY

Wide, notched P wave in lead II

Diphasic P wave in  $V_1$

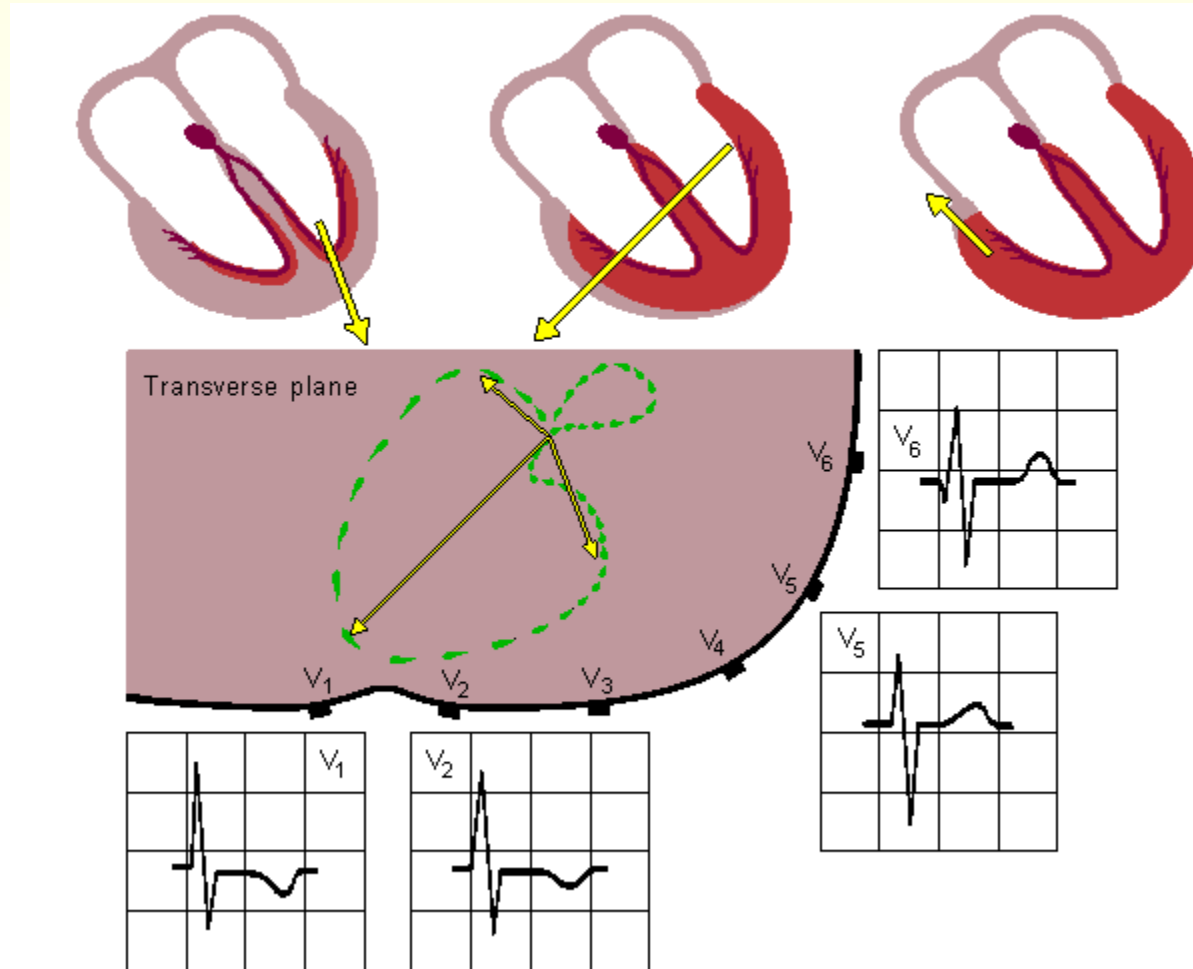


# Hypertrofie pravé komory

## RIGHT VENTRICULAR HYPERTROPHY

Large R wave in leads V<sub>1</sub> and V<sub>3</sub>

Large S wave in leads V<sub>5</sub> and V<sub>6</sub>

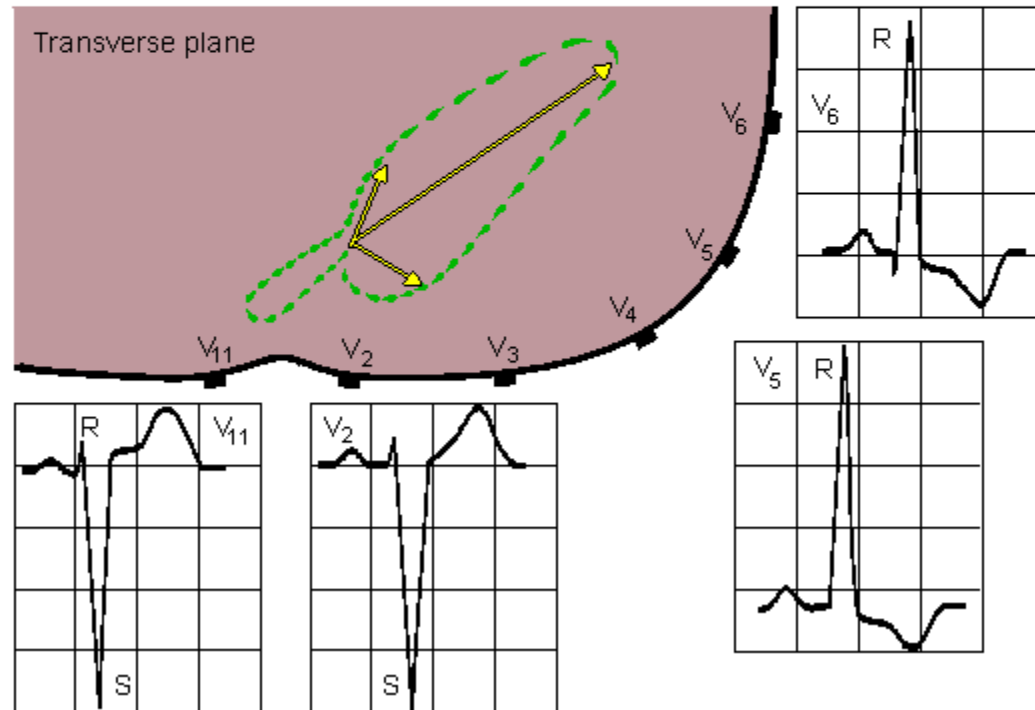
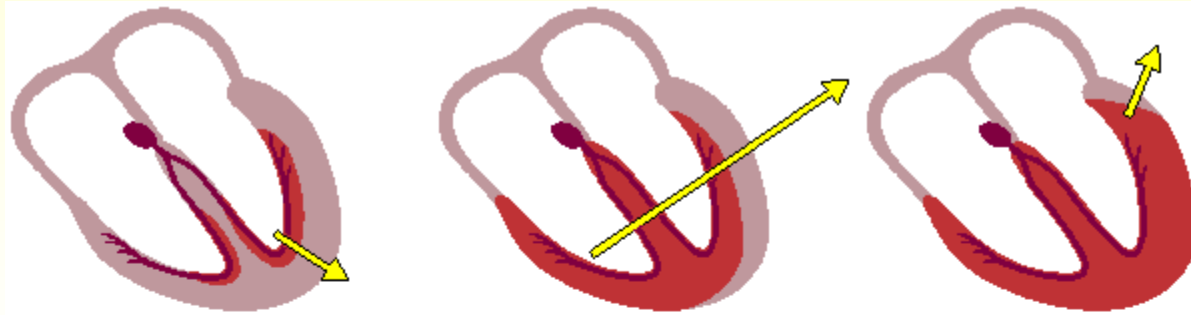


# Hypertrofie levé komory

## LEFT VENTRICULAR HYPERTROPHY

Large S wave in leads V<sub>1</sub> and V<sub>2</sub>

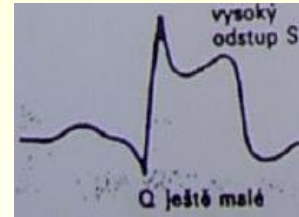
Large R wave in leads V<sub>5</sub> and V<sub>6</sub>



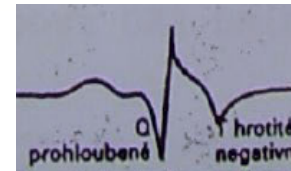


# Infarkt myokardu

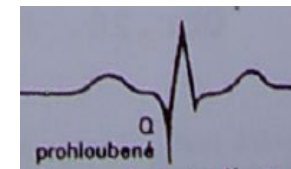
1. Akutní stadium  
(po hodinách)

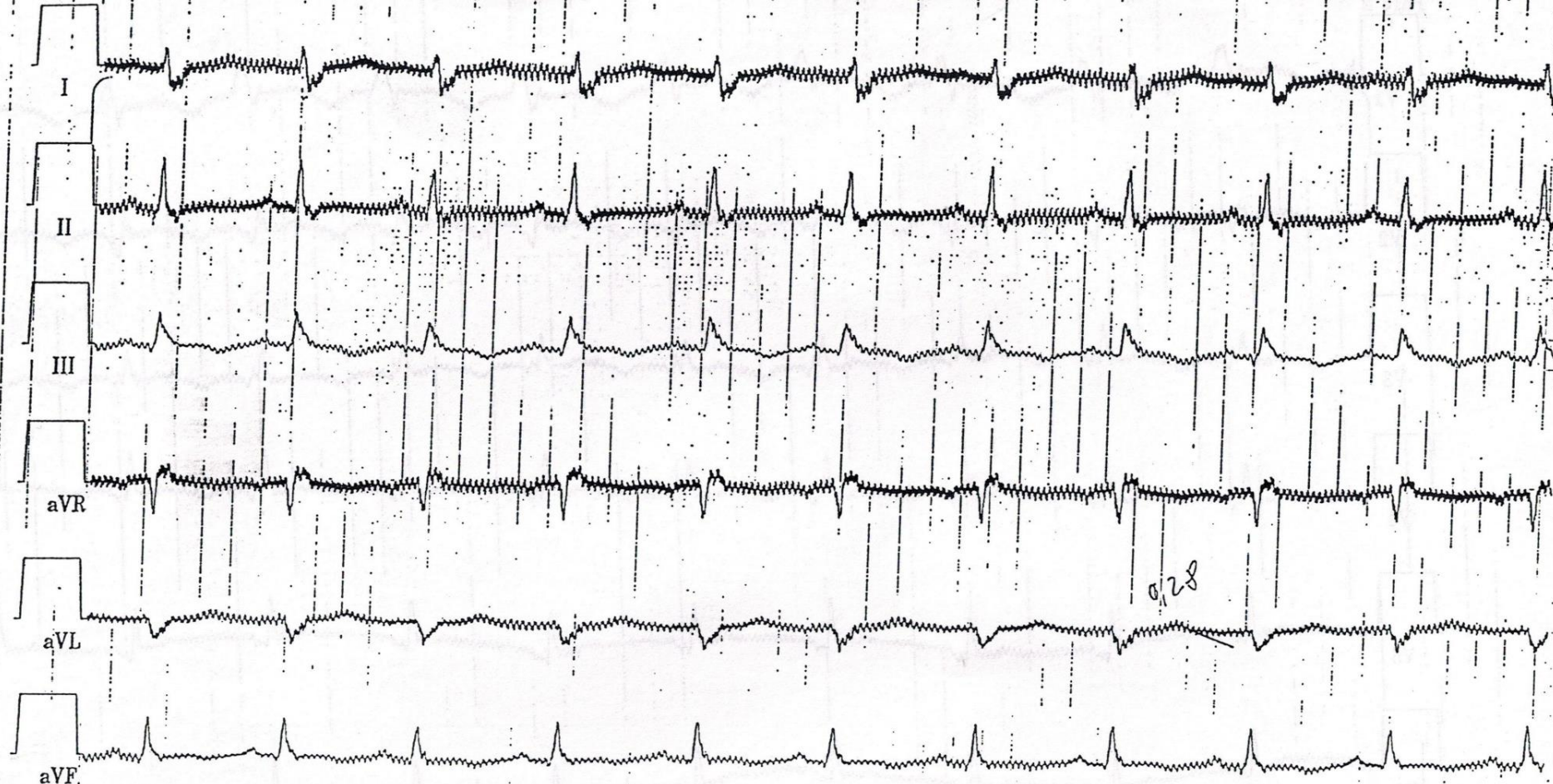


2. Následné stadium  
(po dnech až týdnech)



3. Pozdní stadium  
(po měsících až letech)





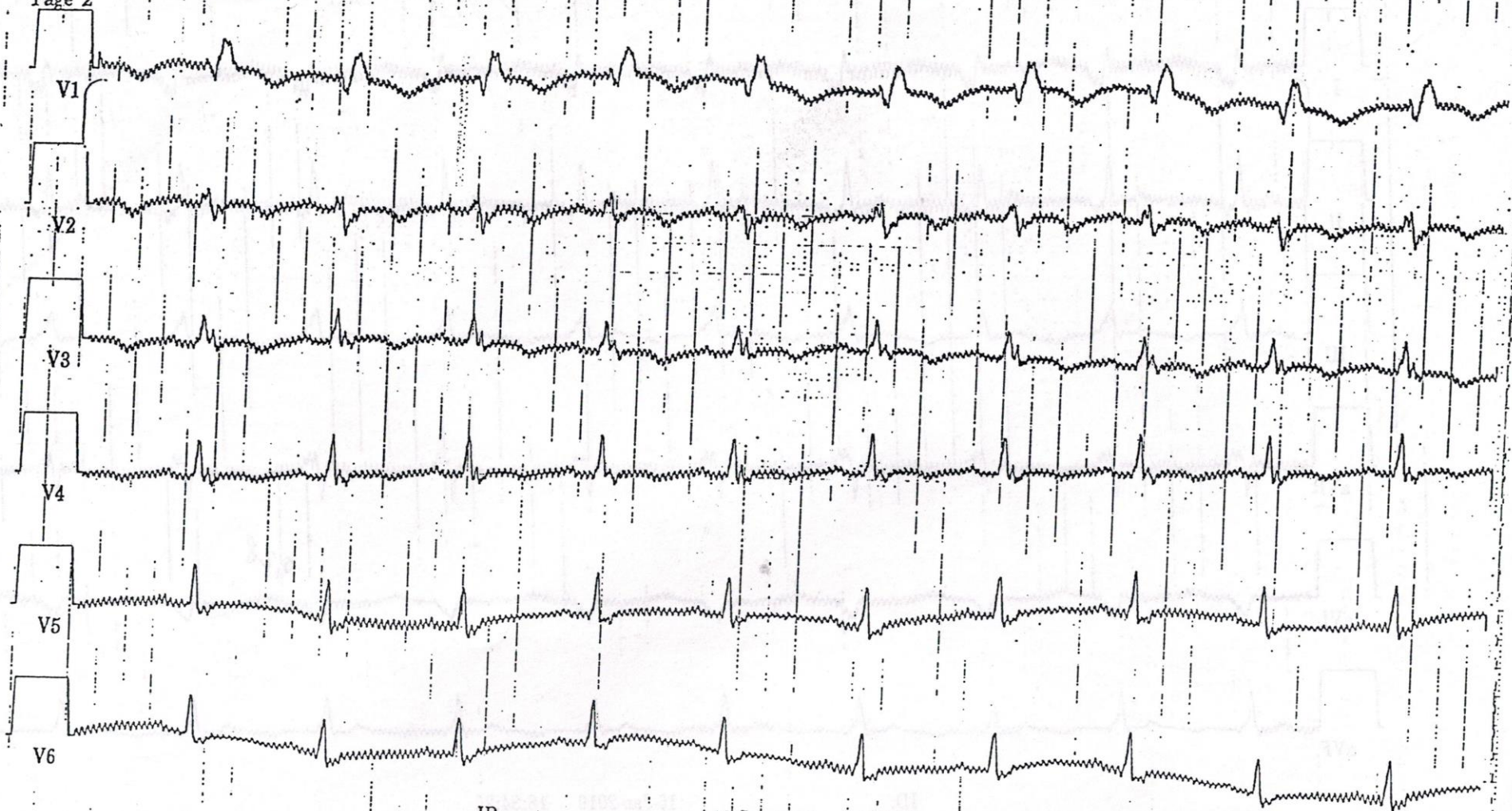
ID: 16-Jan-2010 18:34:26

Vent. rate 126 bpm  
 PR interval 124 ms  
 QRS duration 96 ms  
 QT/QTc 320/463 ms  
 P-R-T axes 56 88 -6

Sinus tachycardia  
 Low voltage QRS  
 Incomplete right bundle branch block  
 T wave abnormality, consider anterior ischemia  
 Abnormal ECG

Unconfirmed





ID: 16-Jan-2010 18:34:26

|              |            |
|--------------|------------|
| Vent. rate   | 126 bpm    |
| PR interval  | 124 ms     |
| QRS duration | 96 ms      |
| QT/QTc       | 320/463 ms |
| P-R-T axes   | 56 88 -6   |


# Základní EKG obrazy

The 6 Second ECG



# Attempts: # Correct: % Correct: Time / ECG: 01:00  PLAY

|                   |                     |                 |                     |                   |
|-------------------|---------------------|-----------------|---------------------|-------------------|
| Sinus Rhythm      | NSR with PAC        | NSR with 1° AVB | NSR with PJC        | NSR with PVC      |
| Sinus Bradycardia | SVT                 | 2° AVB Type I   | Junctional Rhythm   | Idioventricular   |
| Sinus Tachycardia | Atrial Fibrillation | 2° AVB Type II  | Accel Junctional    | Accelerated IVR   |
| Sinus Arrhythmia  | Atrial Flutter      | 2° AVB 2:1      | Junctional Tachy    | VTach             |
| Sinus Exit Block  | Paced Atrial        | 3° AV Block     | Wandering Pacemaker | VFib              |
| Sinus Arrest      |                     |                 |                     | Paced Ventricular |

 SKILLSTAT LEARN GAME   

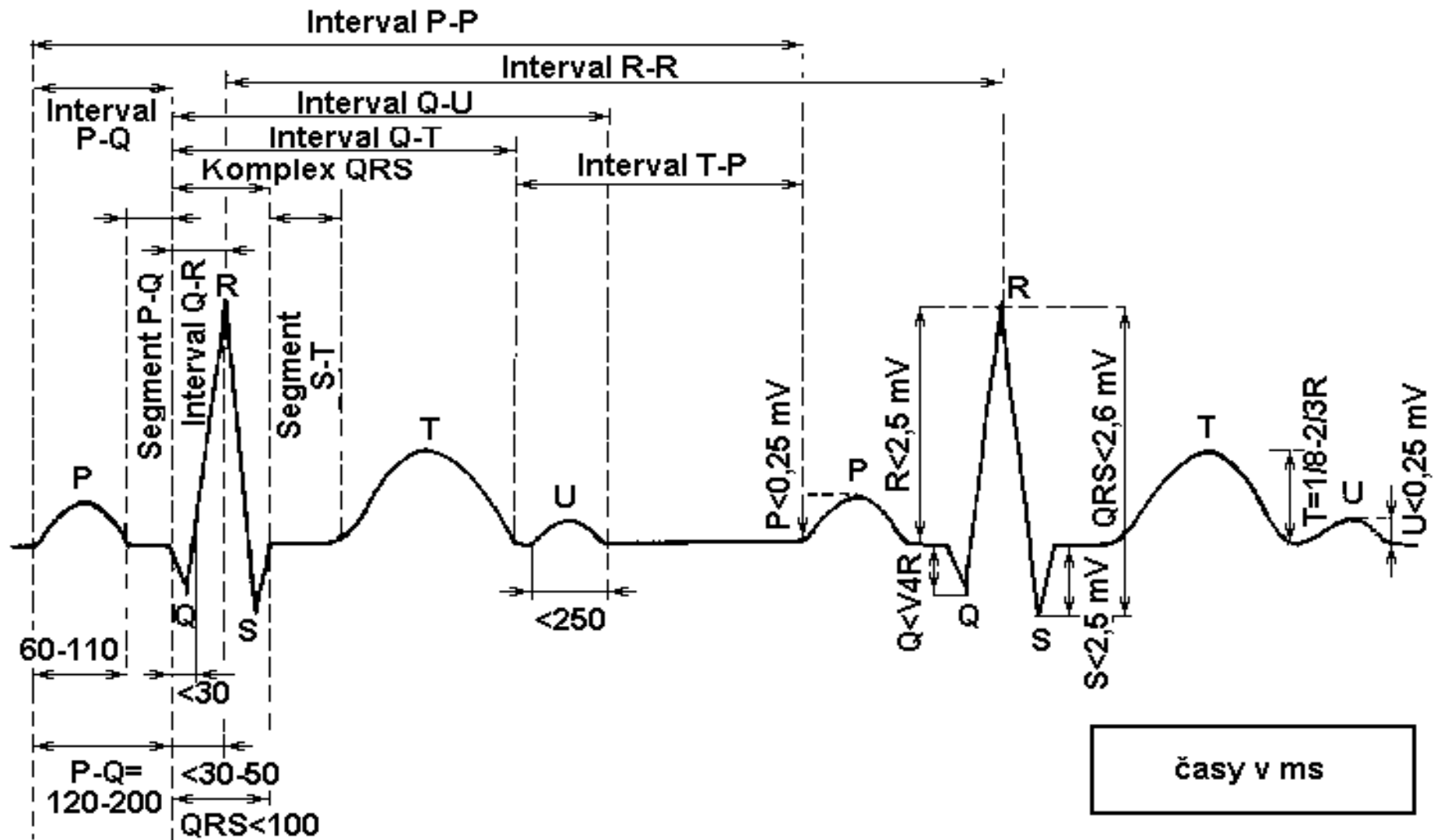
<https://www.skillstat.com/tools/ecg-simulator>

# Zpracování a analýza signálu EKG

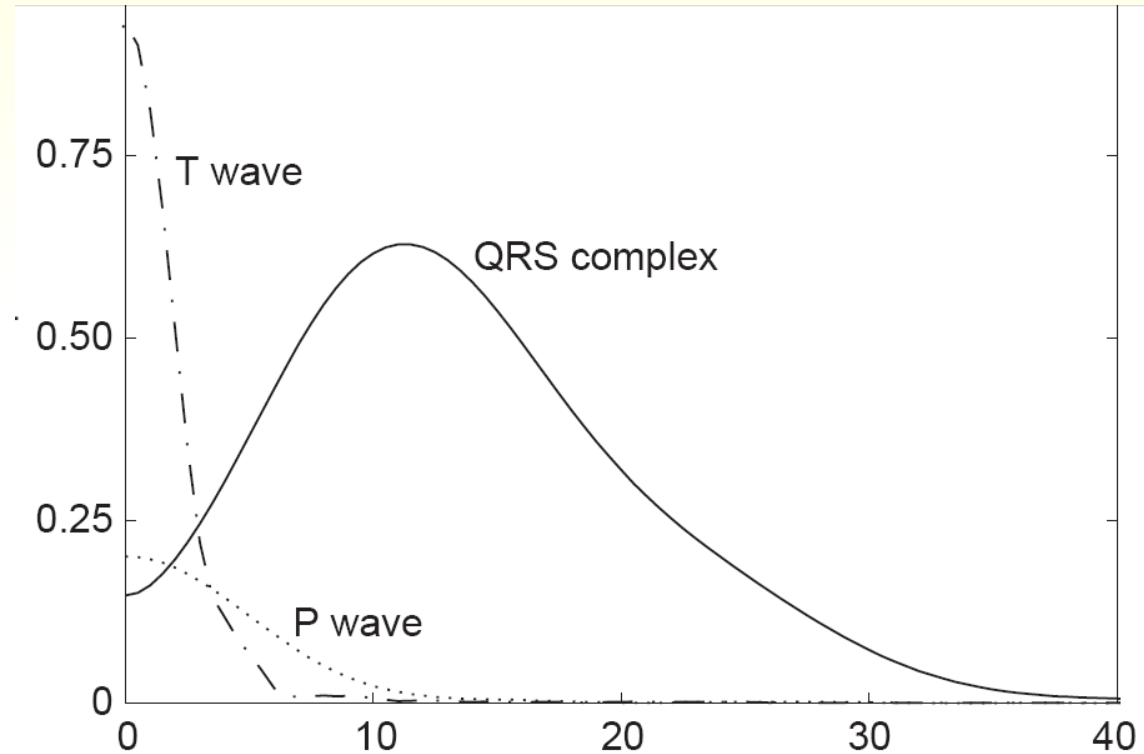
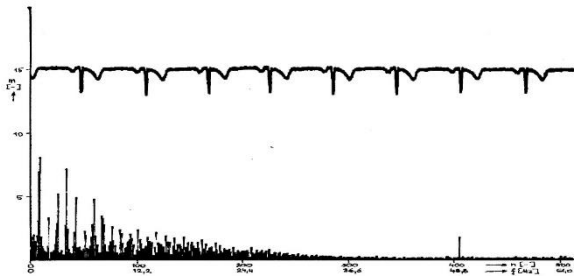
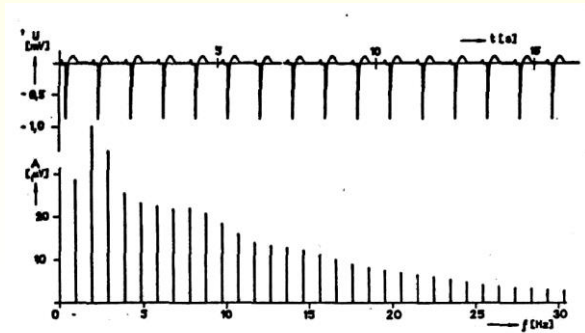
- **potlačení rušení**
- **výběr charakteristik** (detekce hrotů a vln)
- klasifikace
- interpretace



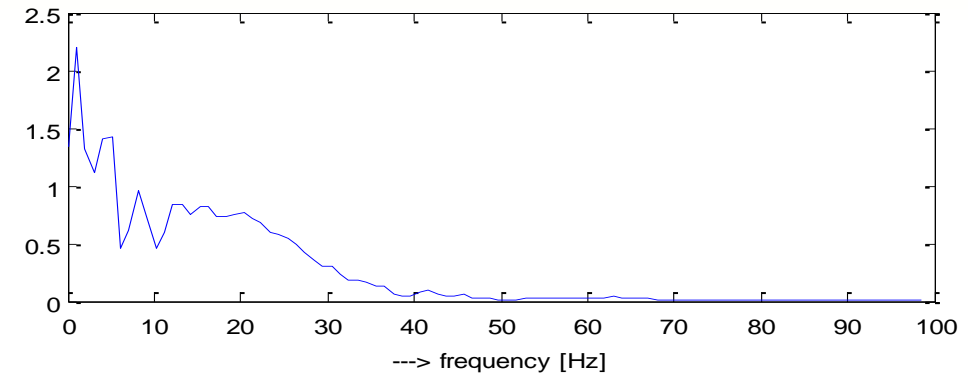
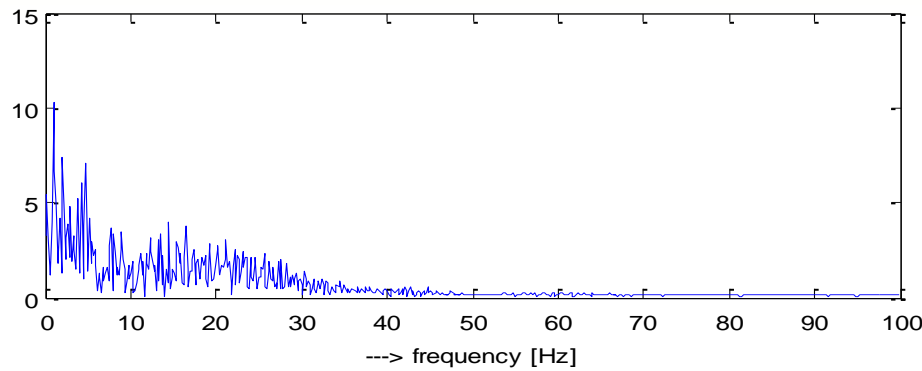
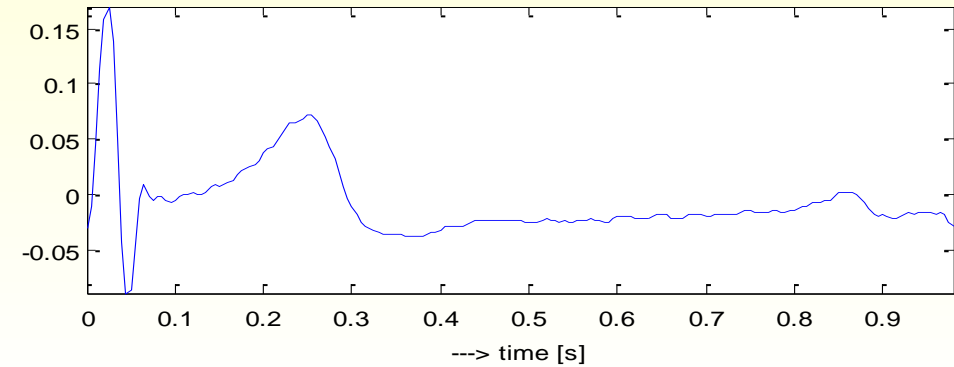
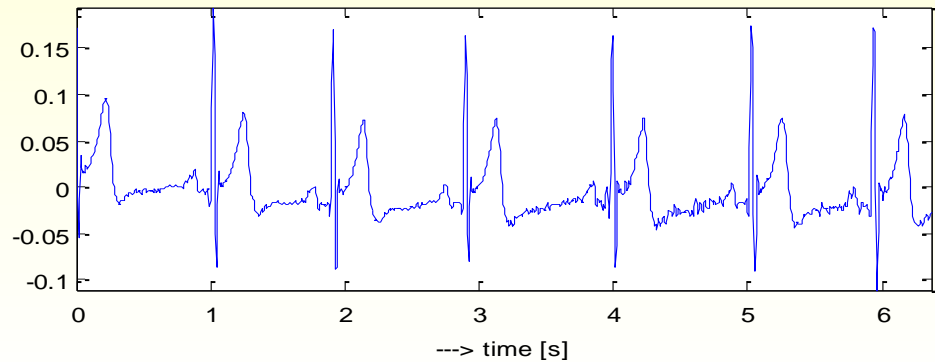
# Vlastnosti signálu EKG v časové oblasti



# Vlastnosti signálu EKG ve frekvenční oblasti



# Analýza EKG ve frekvenční oblasti



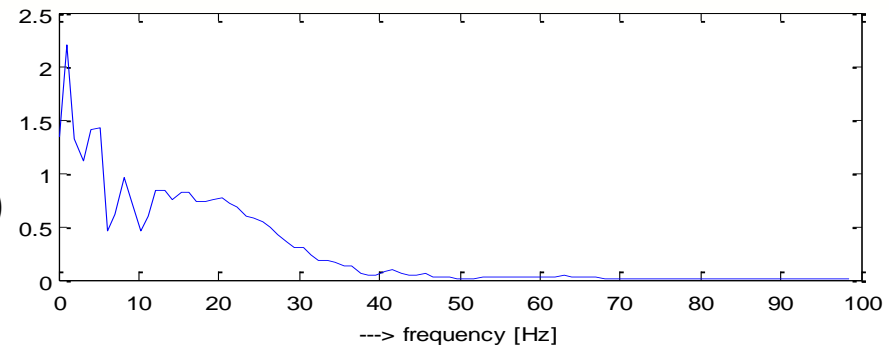
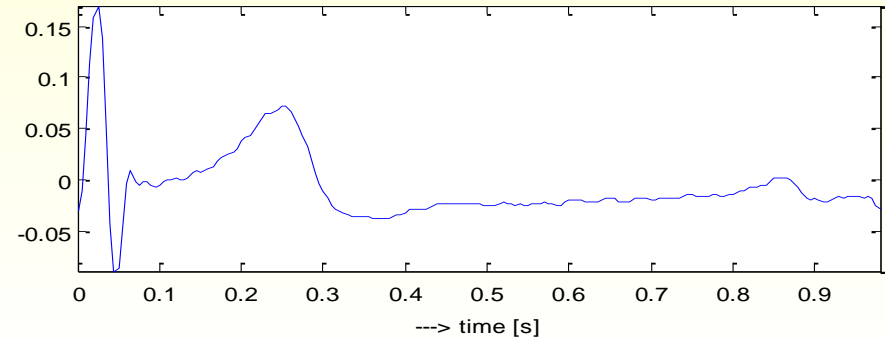
několik period signálu a odpovídající  
rozmazané spektrum

jedna perioda (jeden cyklus)

# Analýza EKG ve frekvenční oblasti

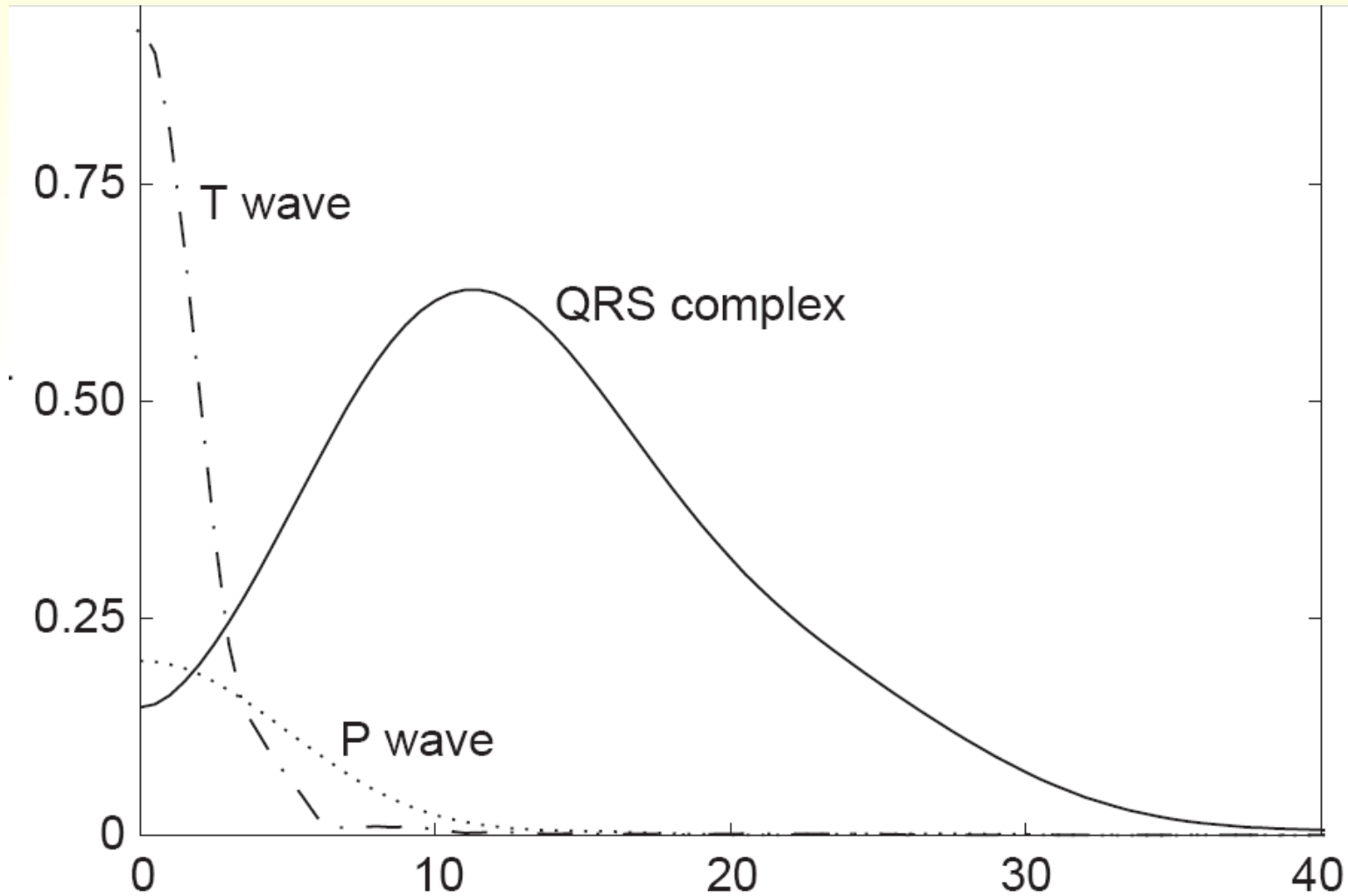
## Zaver:

spicky ve spektru jsou „zpusobeny“:  
1 Hz tepovou frekvenci  
2 Hz S-T usekem  
4 az 5 Hz T vlnou  
kolem 8 Hz P vlnou  
od 12 Hz vyse QRS komplexem (úzkým  
impulsum odpovídají sirsi spektra a naopak)





# Analýza EKG ve frekvenční oblasti



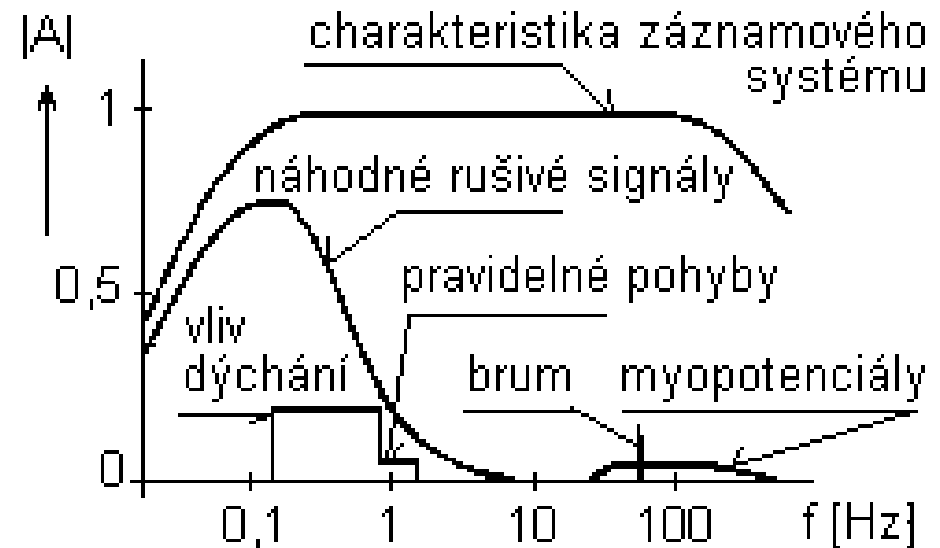
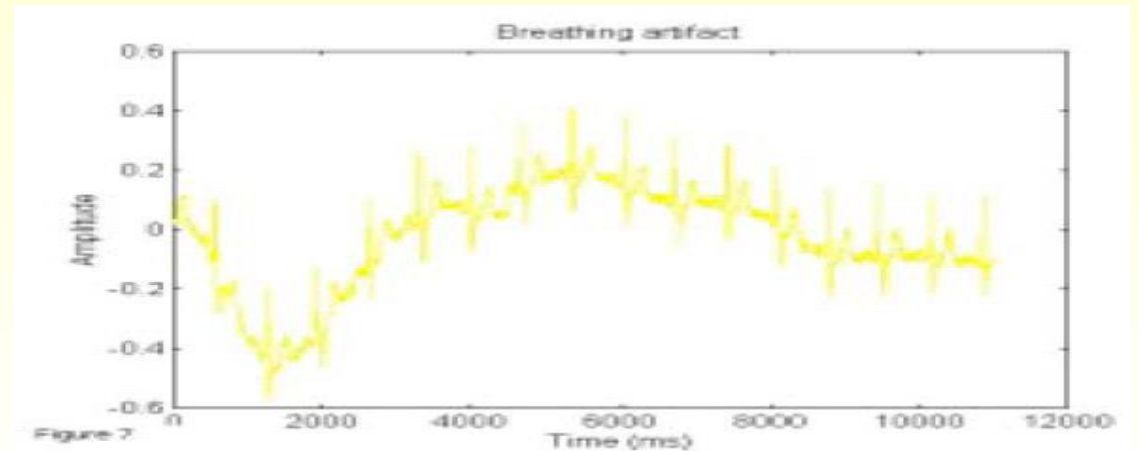
# Rušení signálu EKG

- **ÚZKOPÁSMOVÉ RUŠENÍ**

- kolísání (drift) základní izoelektrické linie
- síťové rušení (50 Hz)

- **ŠIROKOPÁSMOVÉ RUŠENÍ**

- myopotenciály
- rychlé (skokové) změny izoline
- impulsní rušení

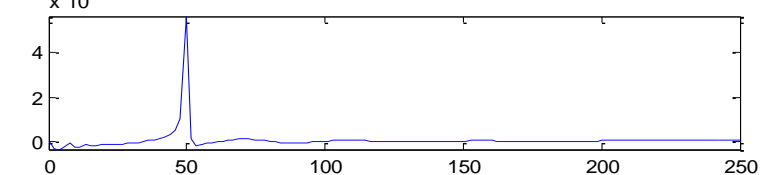
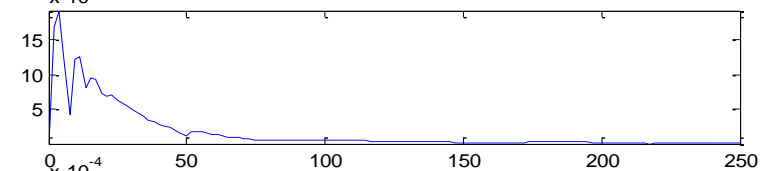
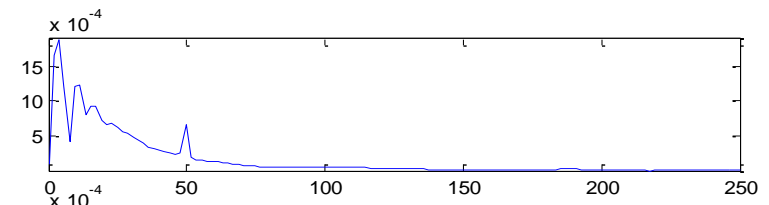
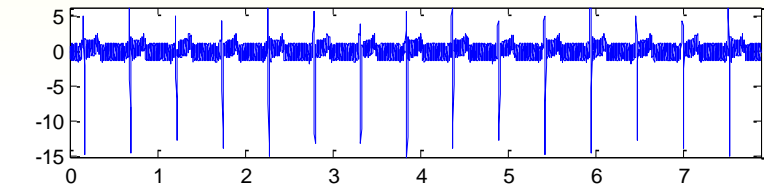
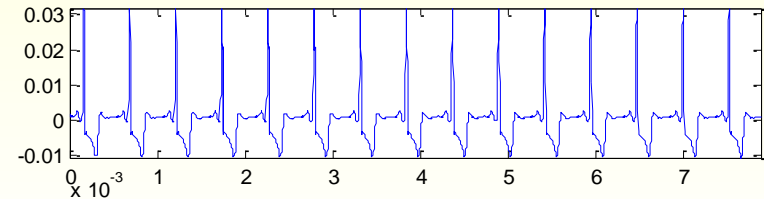
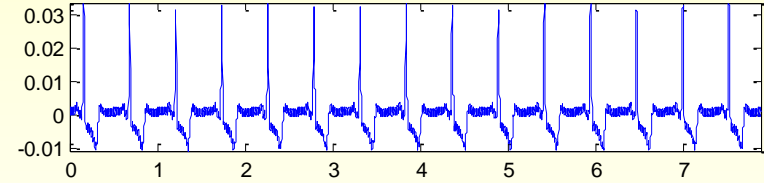
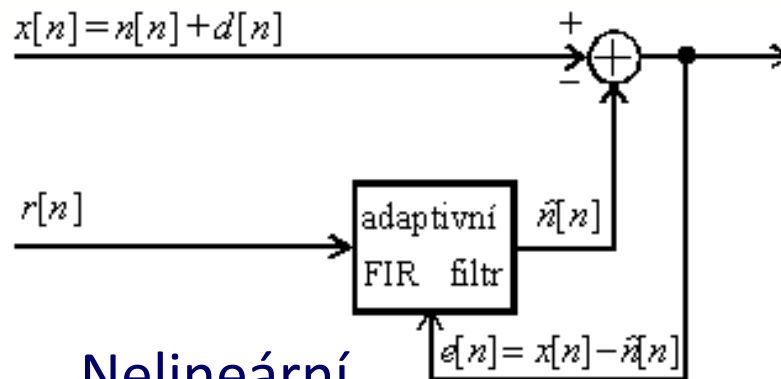


# 50 Hz

# Potlačení rušení

## Filtrace síťového brumu 50 Hz

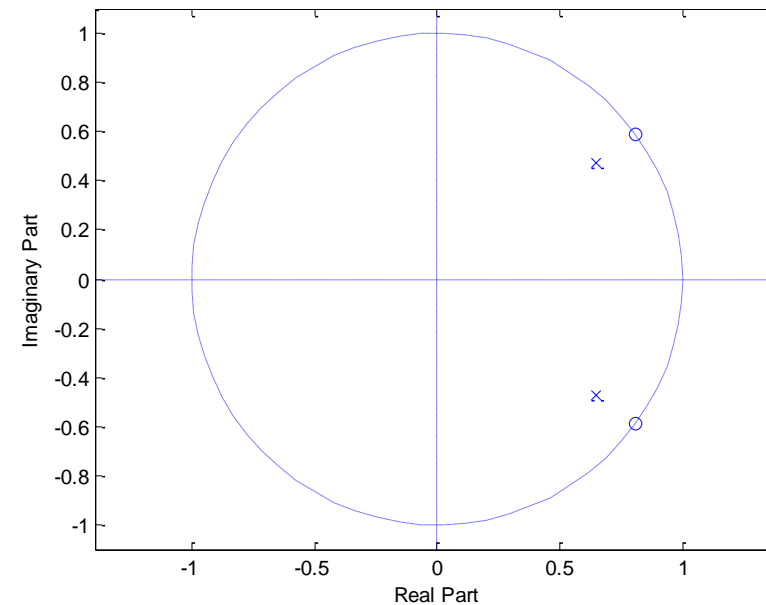
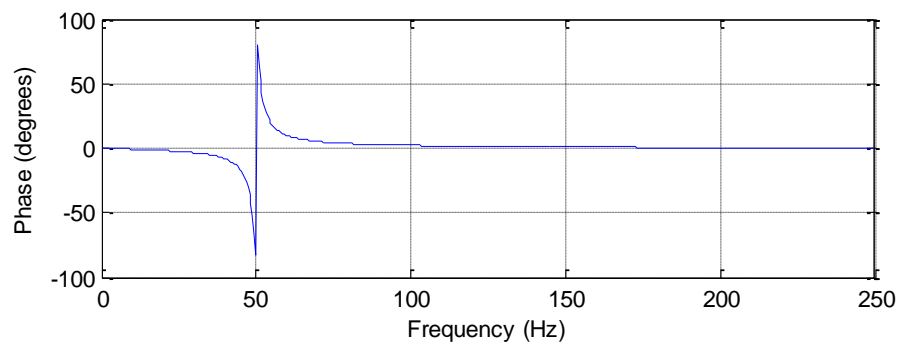
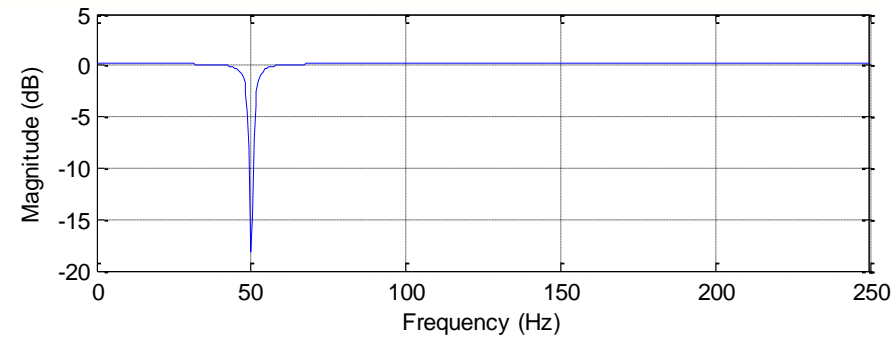
- Lineární filtrace
- Adaptivní filtrace
- Nelineární heuristické algoritmy



# 50 Hz

## Úzkopásmové filtry – bikvády

$$H(z) = \frac{1 - 2R \cos \hat{\omega}_0 z^{-1} + R^2 z^{-2}}{1 - 2r \cos \hat{\omega}_0 z^{-1} + r^2 z^{-2}} = \frac{z^2 - 2R \cos \hat{\omega}_0 z + R^2}{z^2 - 2r \cos \hat{\omega}_0 z + r^2}$$



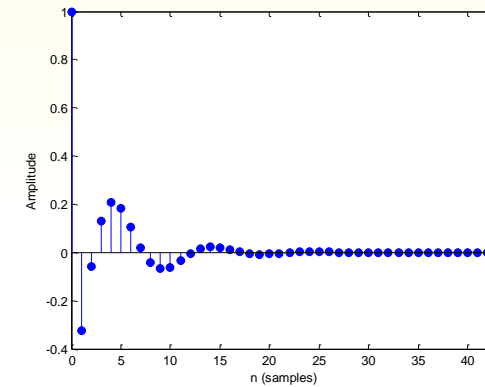
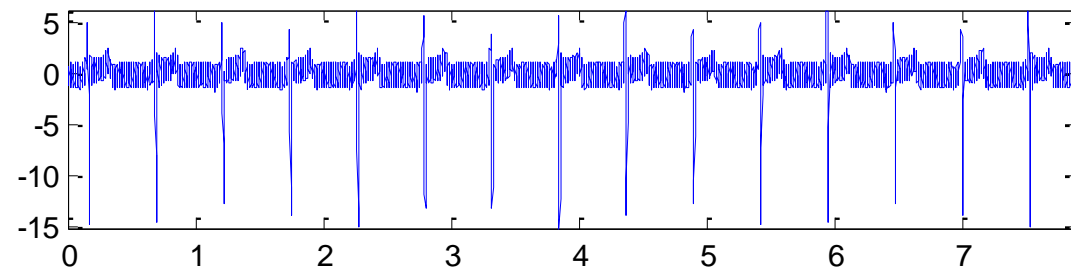
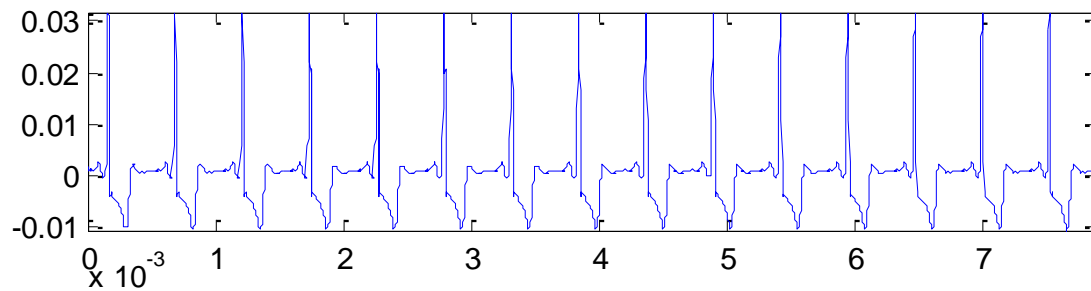
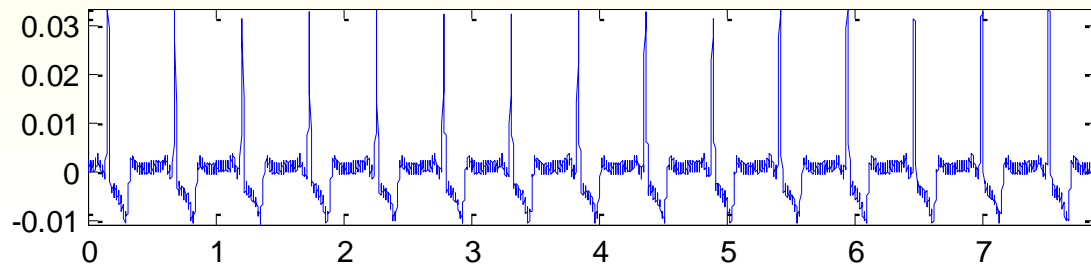
# 50 Hz

## Úzkopásmové filtry – bikvády

$$R = 1; r = 0.98;$$

$$b = [1 -2 \cdot R \cdot \cos(2 \cdot \pi \cdot f_0 / f_s) R \cdot R];$$

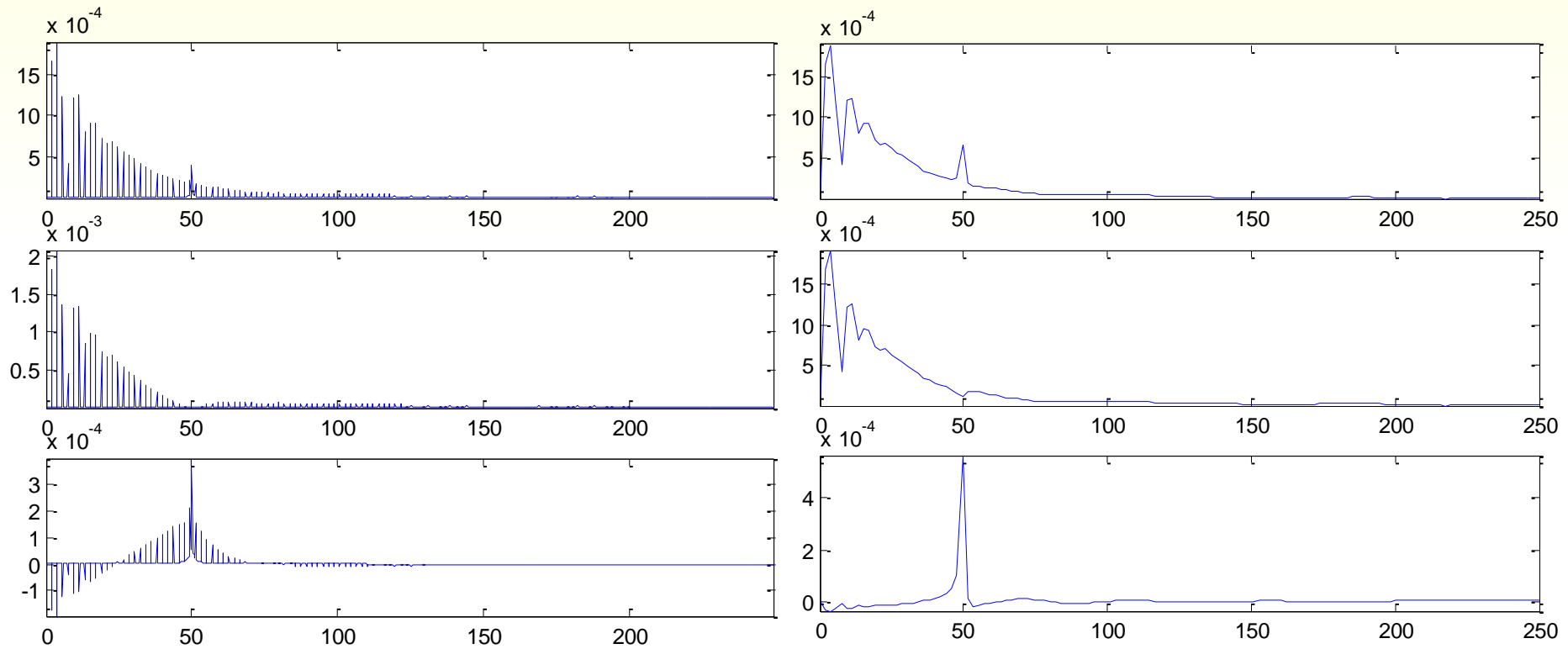
$$a = [1 -2 \cdot r \cdot \cos(2 \cdot \pi \cdot f_0 / f_s) r \cdot r];$$





# 50 Hz

## Úzkopásmové filtry – bikvády

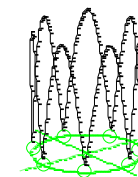
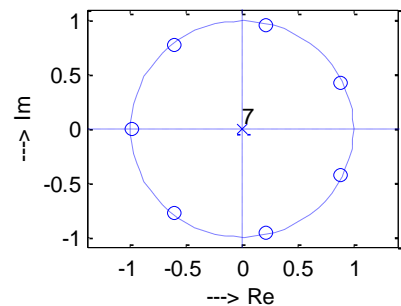
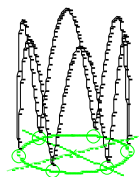
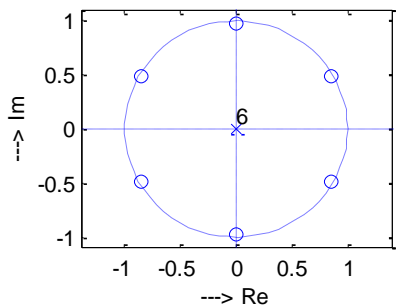
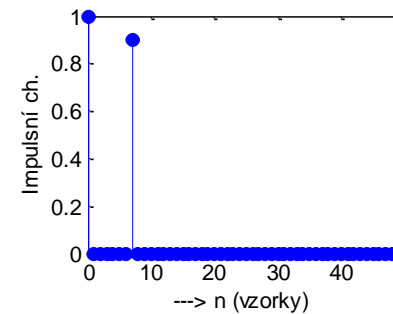
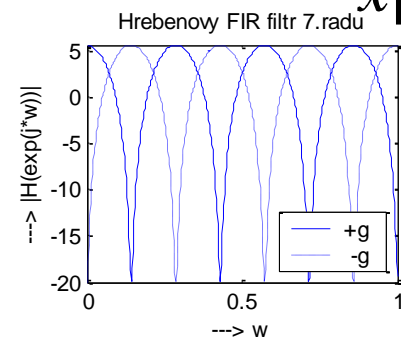
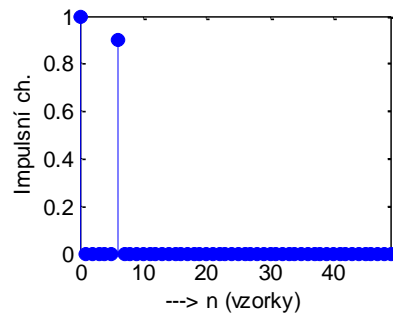
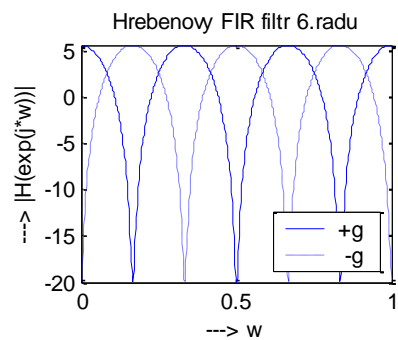
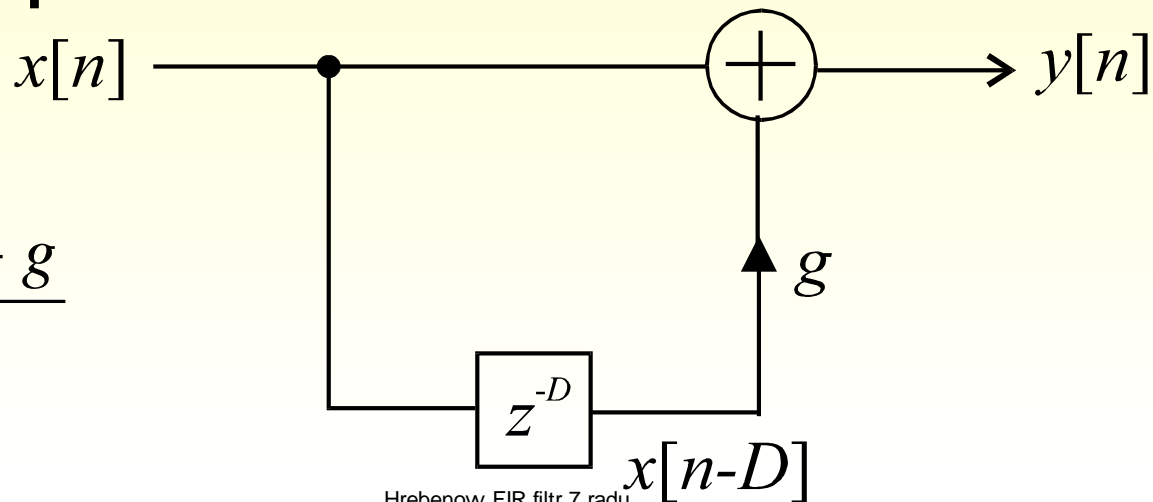


# 50 Hz

## Hřebenový FIR filtr pro potlačení

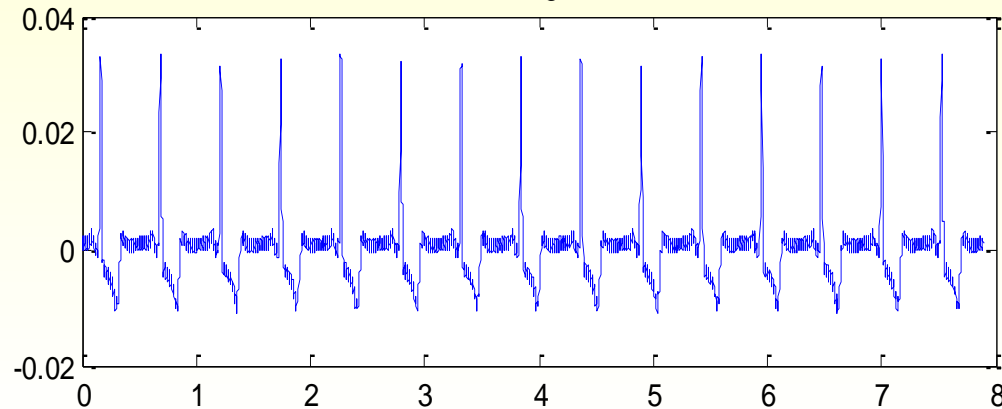
$$y[n] = x[n] + g \cdot x[n - D]$$

$$H(z) = 1 + g \cdot z^{-D} = \frac{z^D + g}{z^D}$$

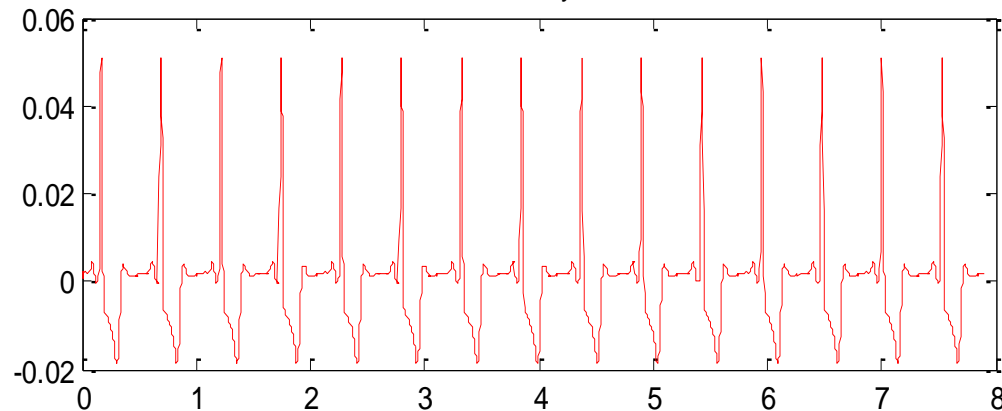


# 50 Hz

## Hřebenový FIR filtr pro potlačení ecg

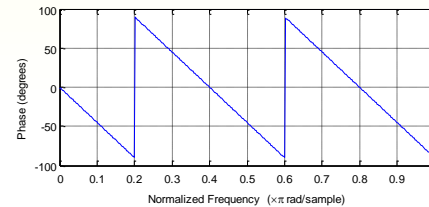
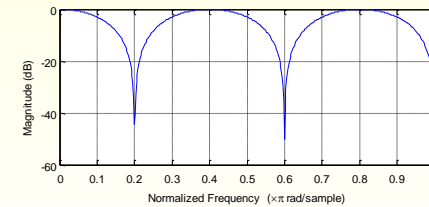


hřebenový filtr

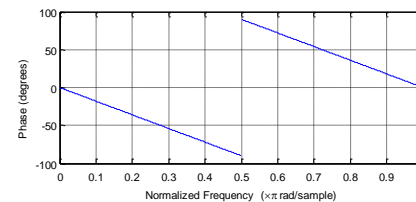
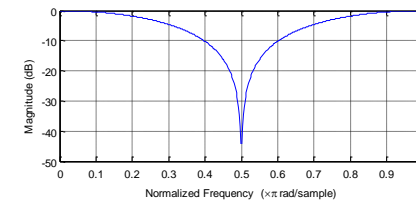


```
>> freqz(0.5* [1 zeros(1,9) 1],1,1000,1000)  
>> freqz(0.5* [1 zeros(1,4) 1],1,1000,500)  
>> freqz(0.5* [1 zeros(1,1) 1],1,1000,200)
```

$b = 0.5 * [1 \ 0 \ 0 \ 0 \ 0 \ 1]$   
% pro  $f_s = 500$  Hz



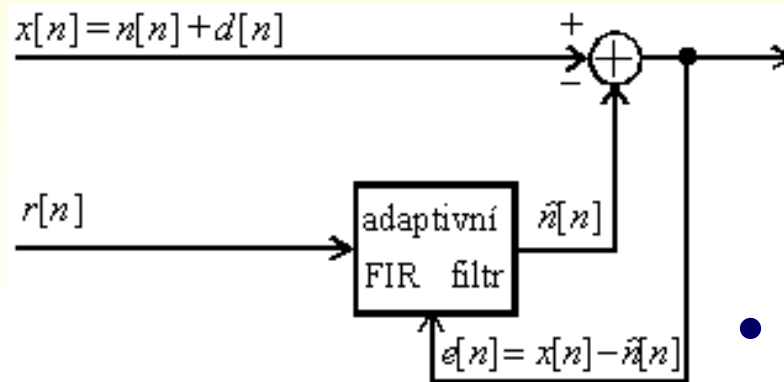
$b = 0.5 * [1 \ 0 \ 1]$ ;  
% pro  $f_s = 200$  Hz



# 50 Hz

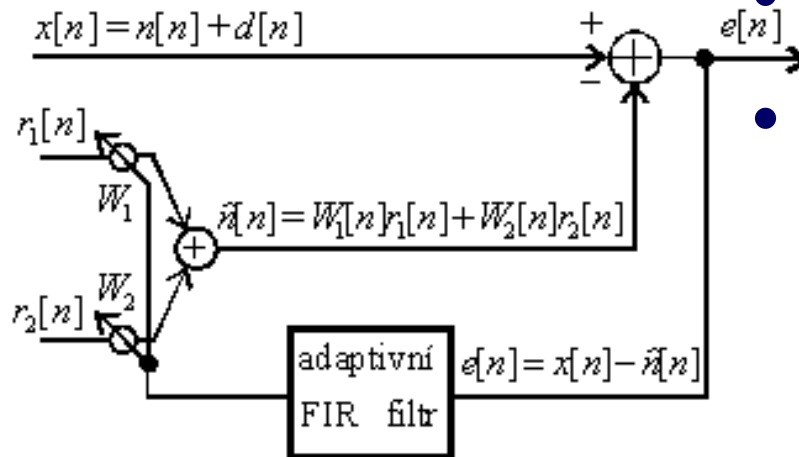
% Adaptive Noise Canceling - ANC

## ADAPTIVNÍ FILTRY



CO CHCEME ?

- rychlou konvergenci;
- robustnost vůči šumu;
- malé výpočetní nároky;



LMS

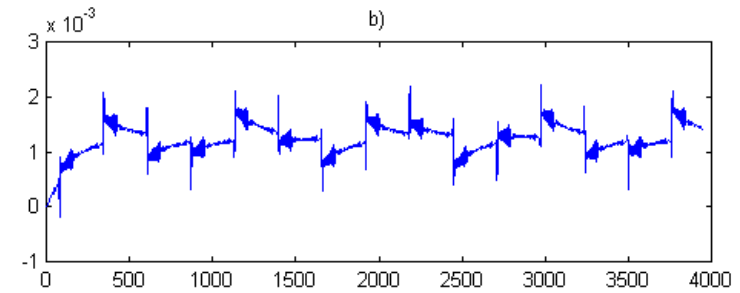
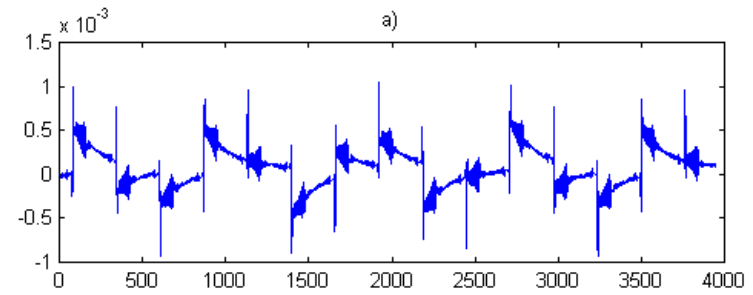
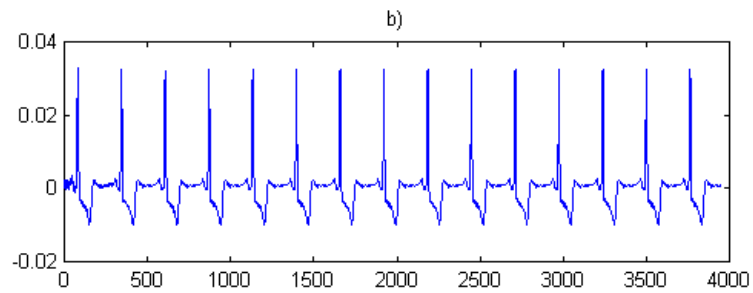
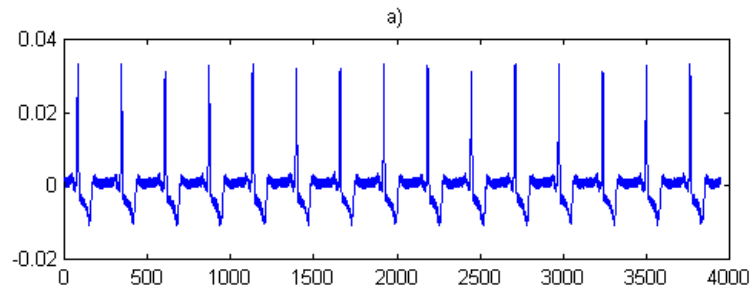
FIR

:

$$W(n+1) = W(n) + 2\mu \cdot e(n) \cdot x(n)$$

# 50 Hz

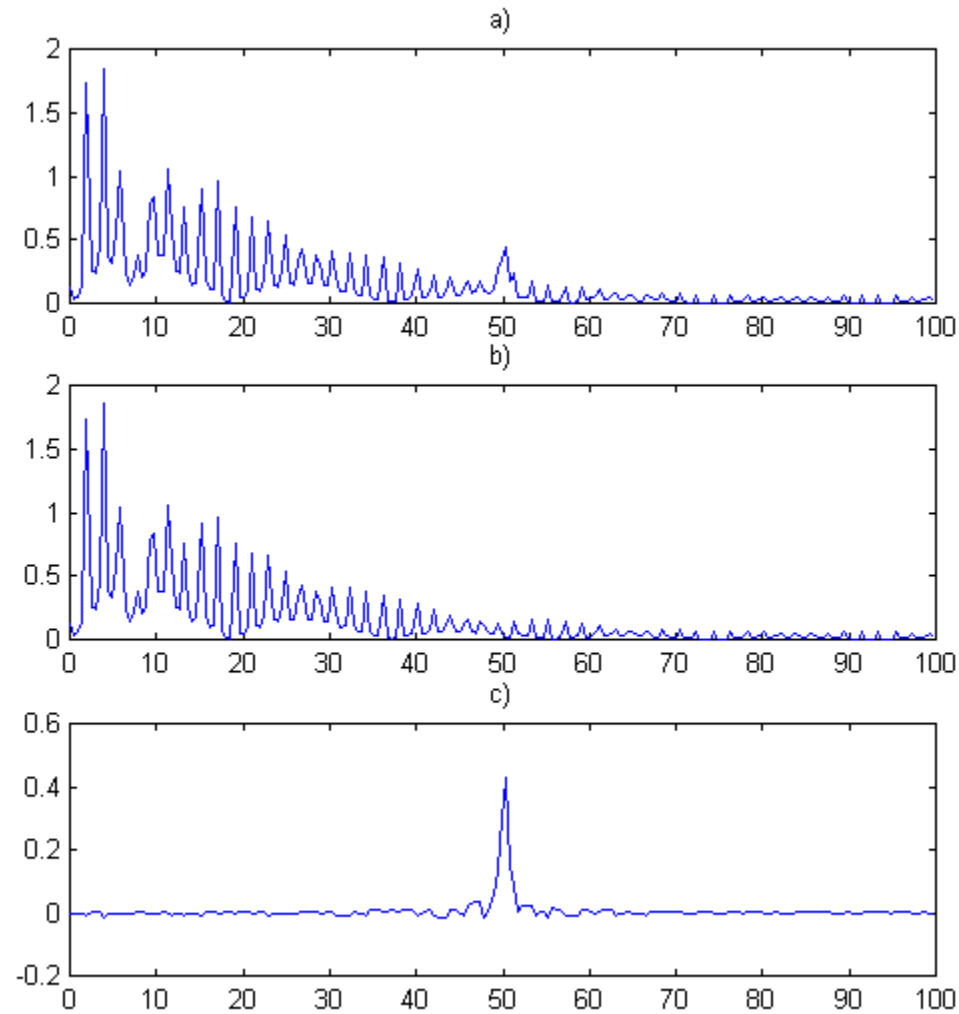
## ADAPTIVNÍ FILTRY





# 50 Hz

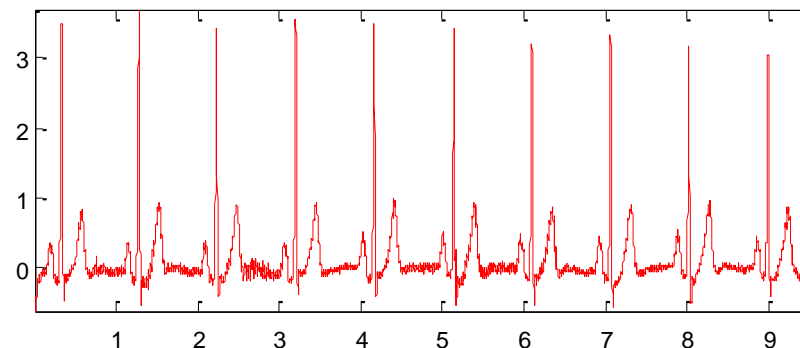
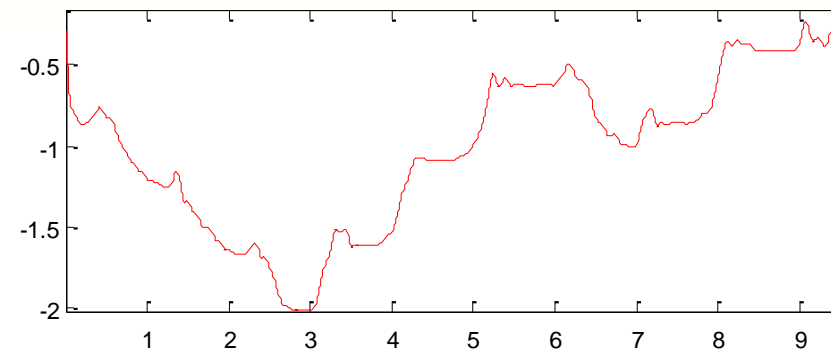
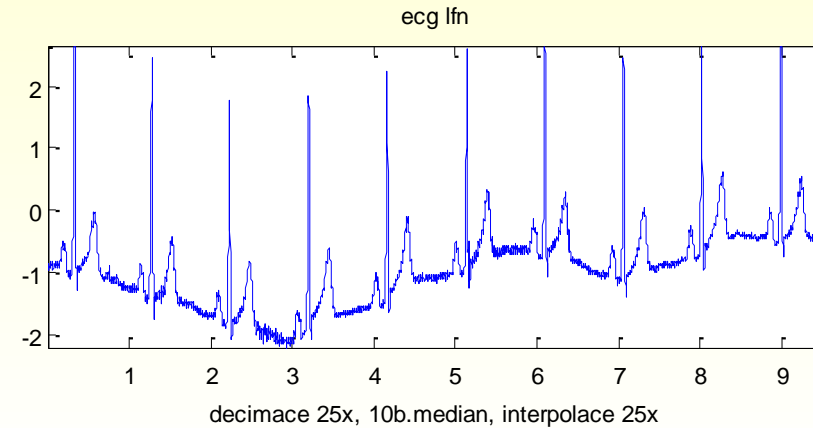
## ADAPTIVNÍ FILTRY



# drift

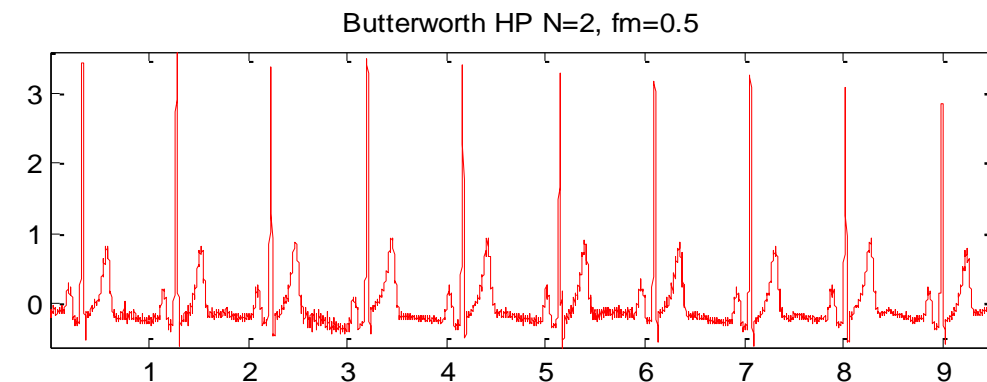
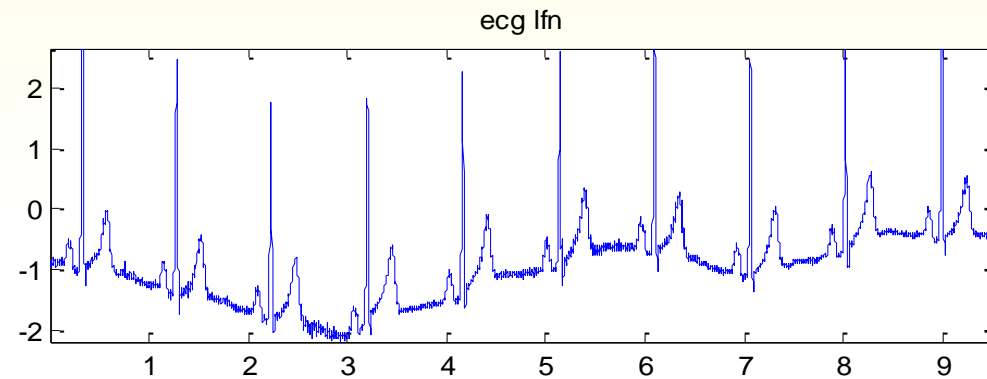
## Potlačení rušení Filtrace driftu izoelektrické linie

- lineární filtrace horní propustí
- odečtení odhadu kolísání driftu
- heuristické algoritmy



## Jednoduchá horní propust 2.řádu

```
[b,a] = butter(2,0.5/(fs/2),'high')
```



# drift

- filtry s FIR

- Hřebenové filtry

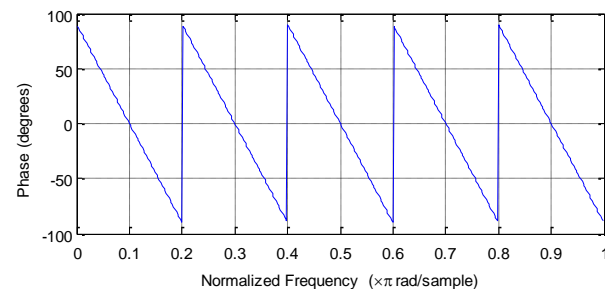
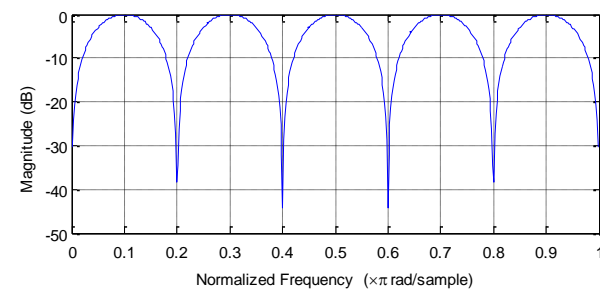
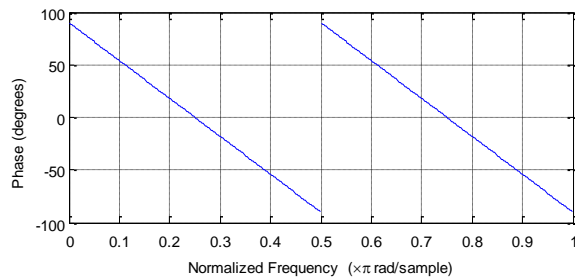
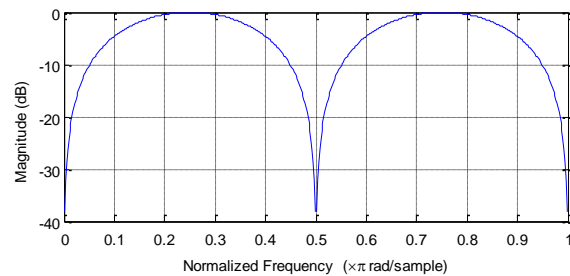
společné odstranění driftu s brumem

```
>> freqz(0.5* [1 zeros(1,19) -1],1,1000,1000)
```

```
>> freqz(0.5* [1 zeros(1,9) -1],1,1000,500)
```

```
>> freqz(0.5* [1 zeros(1,4) -1],1,1000,250)
```

```
>> freqz(0.5* [1 zeros(1,3) -1],1,1000,200)
```



# drift

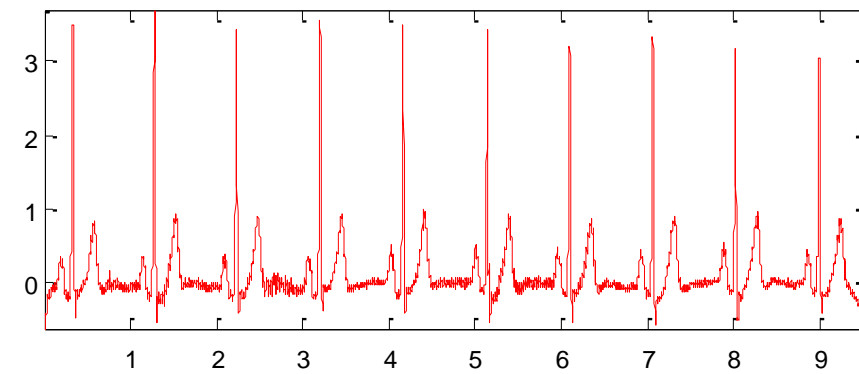
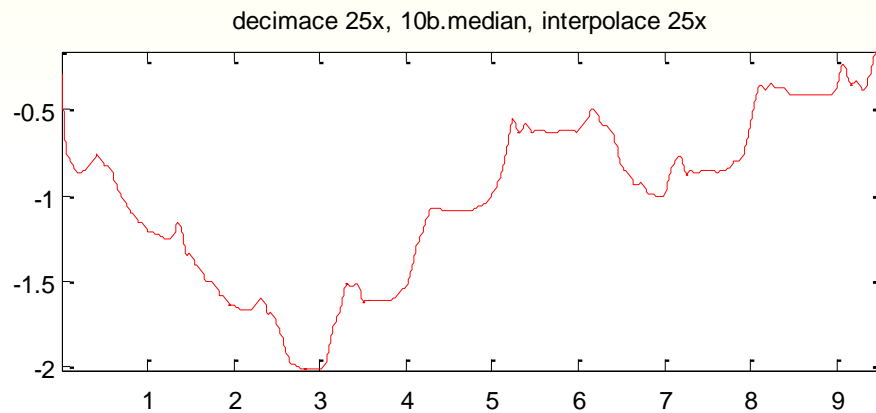
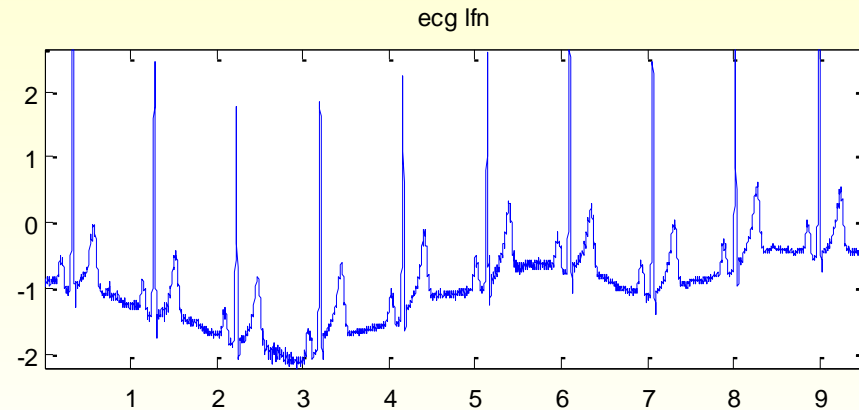
## Nelineární filtr

```
xd=decimate(ecg,round(fs/20),'fir');
```

```
lbx=medfilt1(xd,10);
```

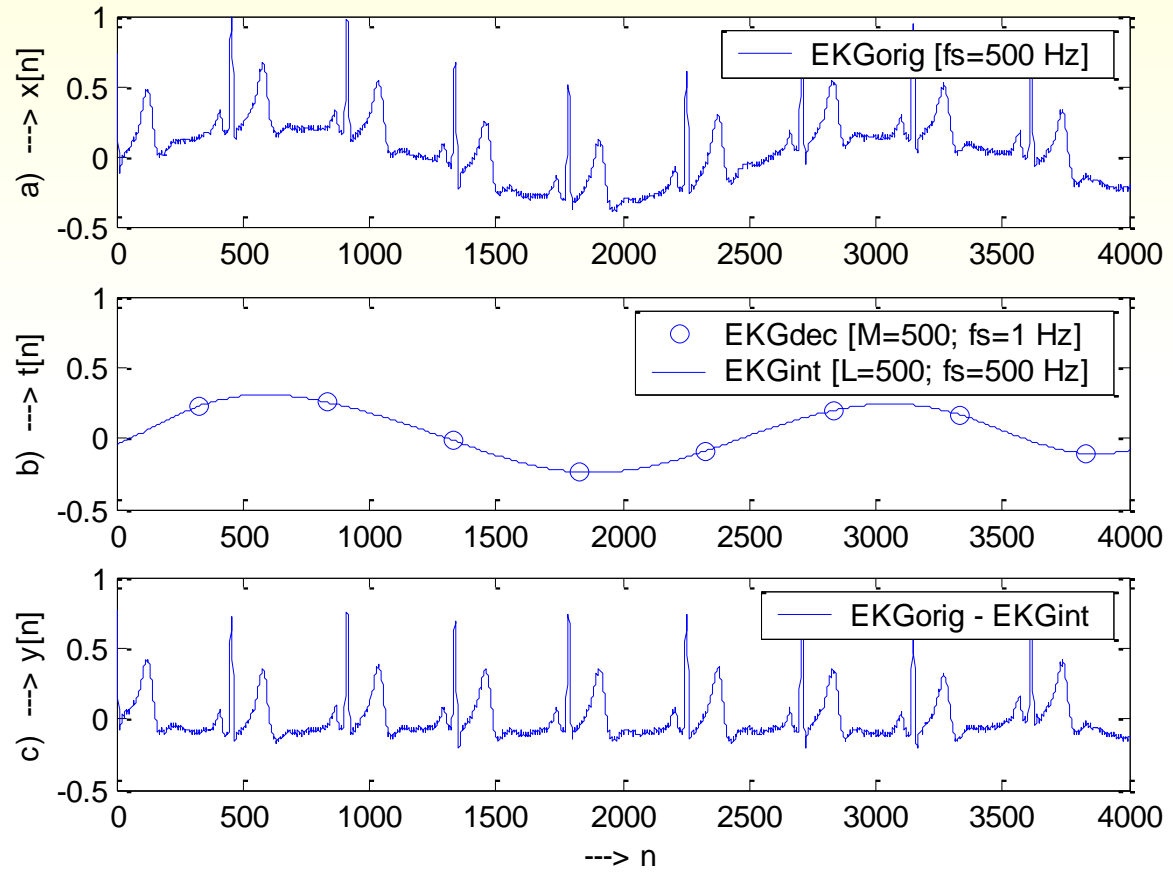
```
lb=interp(lbx,round(fs/20));
```

```
z=ecg-lb(1:length(ecg));
```



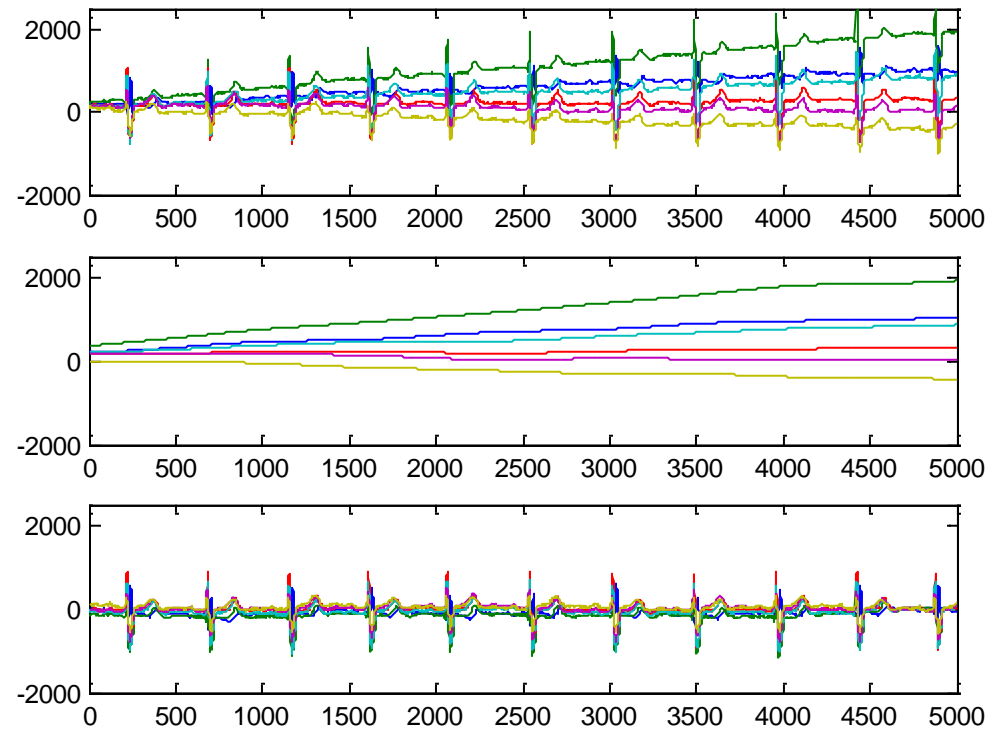


# drift



# drift

$f_s=500$  Hz,  $M=500$

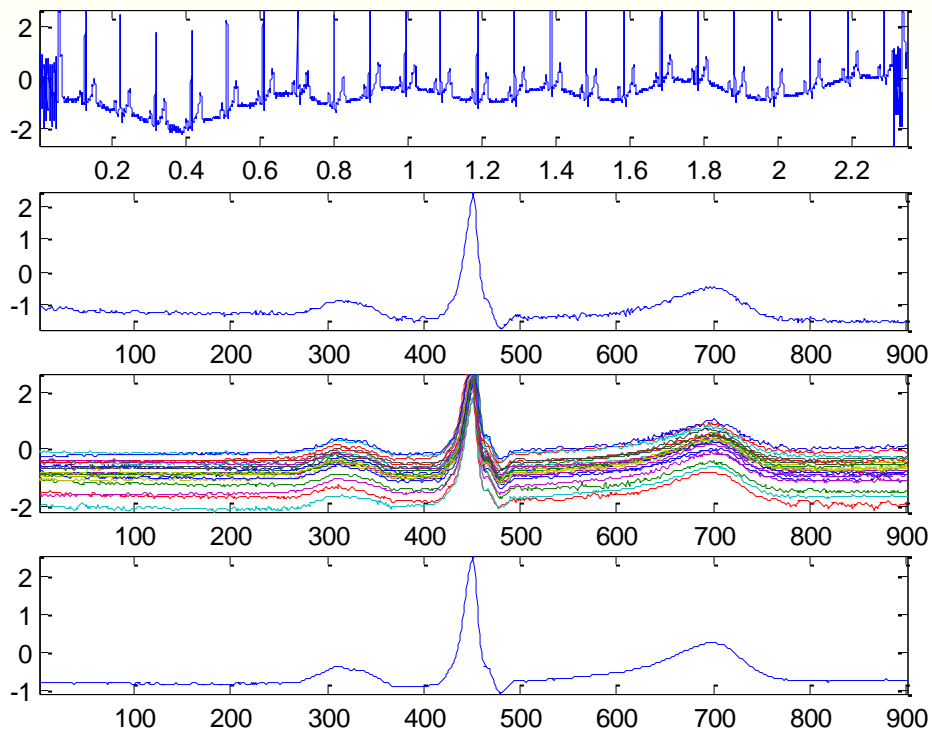


myo

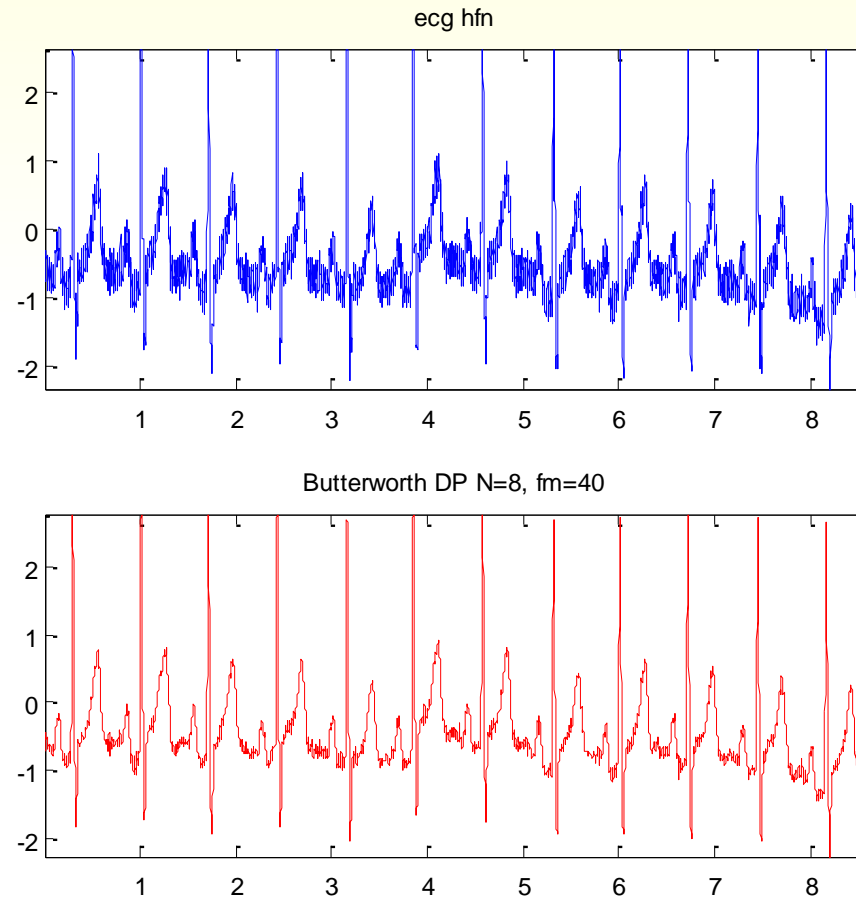
# Potlačení rušení

## Filtrace myopotenciálu

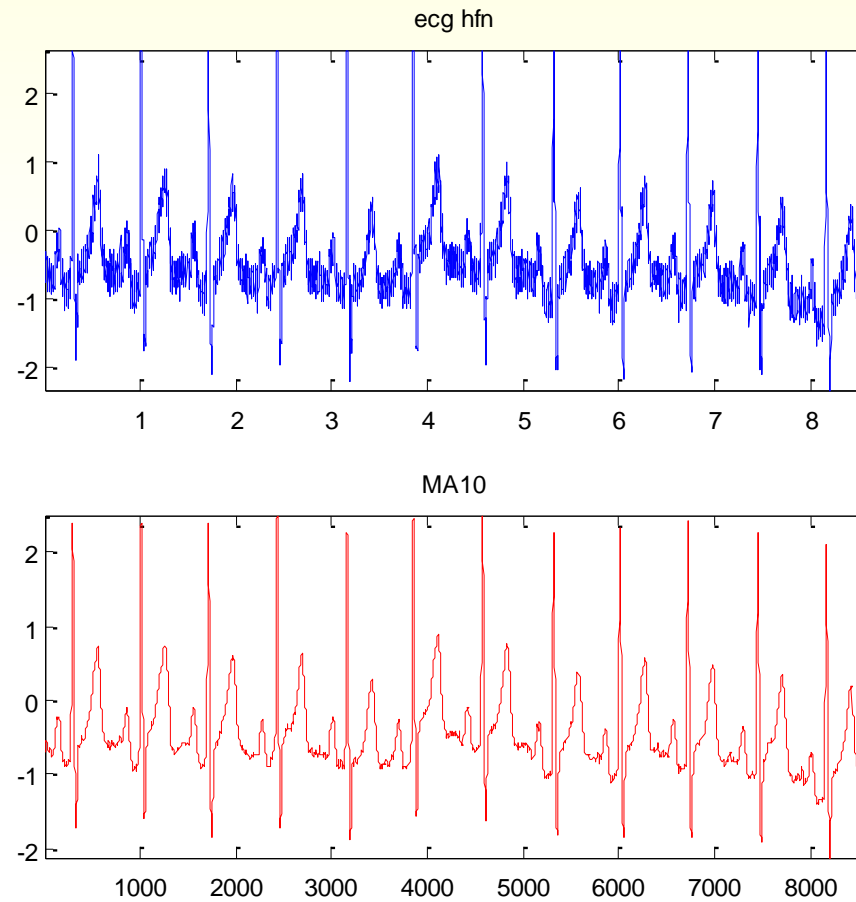
- synchronní průměrování
- wavelety
- dekompoziční techniky



# Dolnoproputný filtr



# Klouzavé průměry

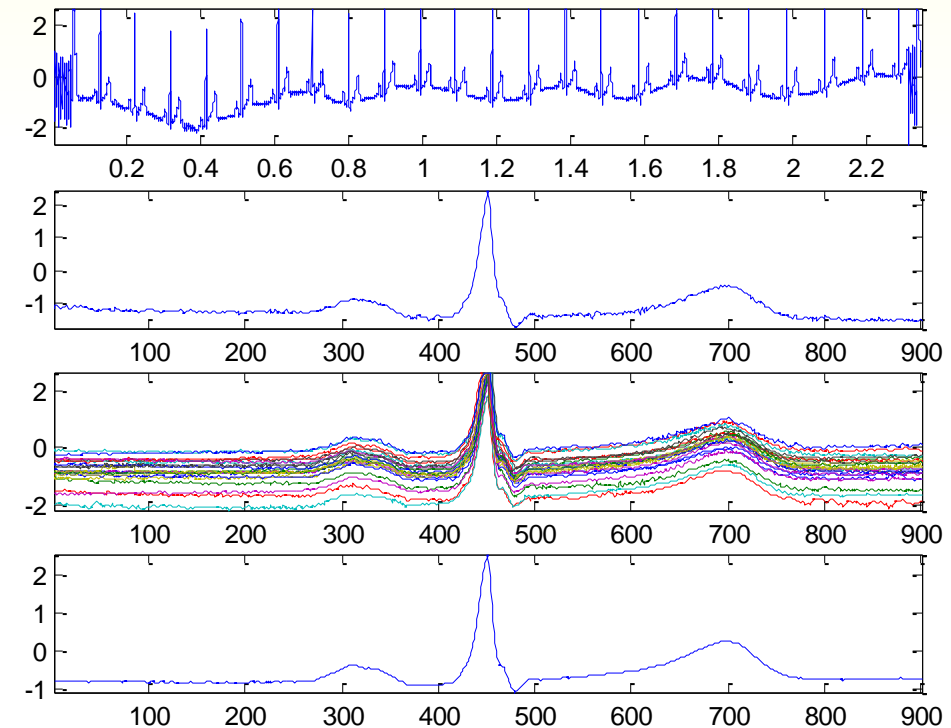




# myo

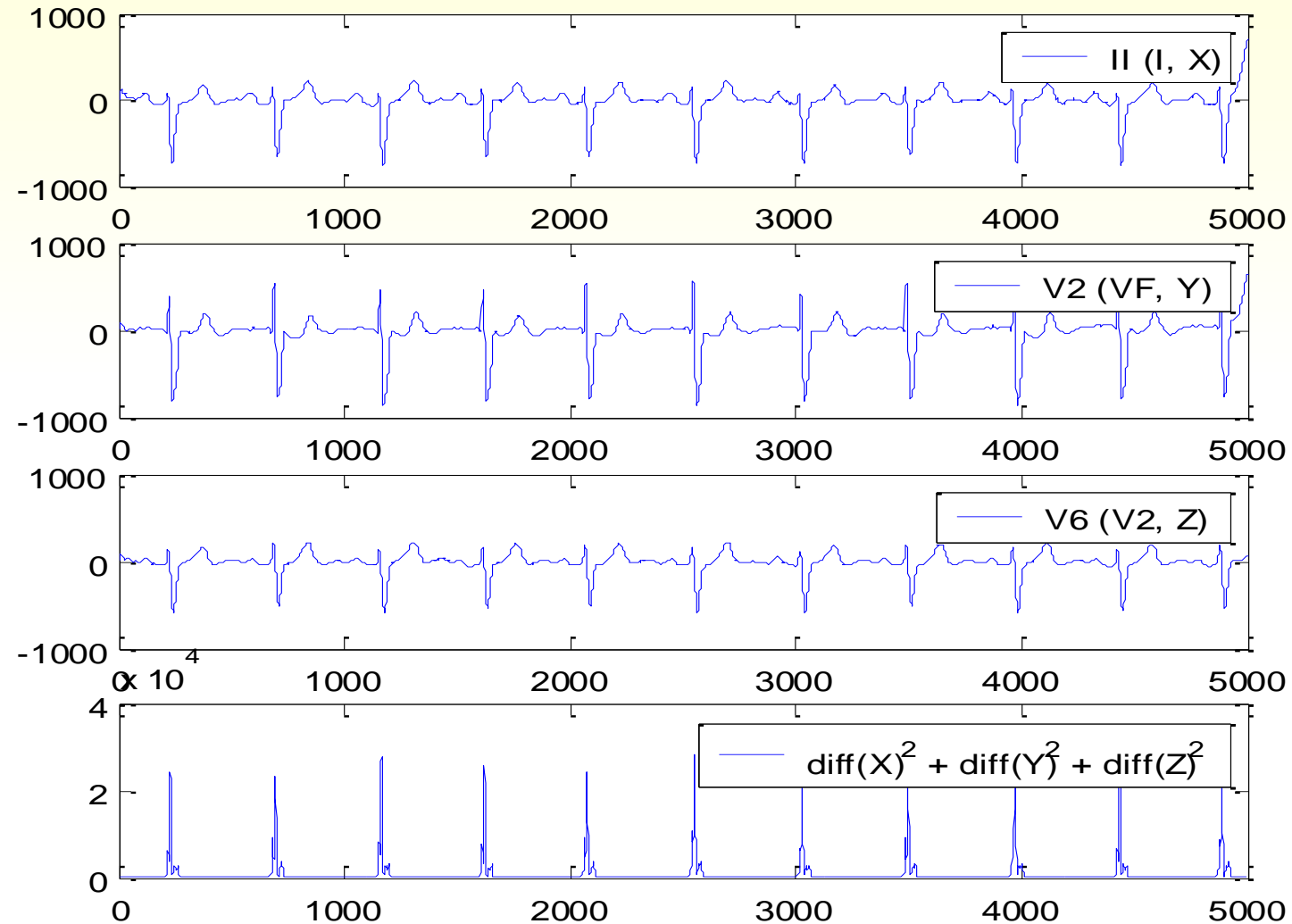
překrývání spekter rušení a užitečného signálu  $\Rightarrow$  **průměrování**

$$y(t + kT) = x(t + kT) + n(t + kT)$$



- signál  $x(t)$  je časově invariantní;
- $n(t)$  je aditivní a nekorelovaný s  $x(t)$ ;
- $n(t)$  je stacionární;
- $n(t)$  má normální rozložení s nulovým průměrem;

# Zpracování vícesvodového záznamu



# Detekce signálů v EKG

## Obecný postup:

- Pan Tompkinsův algoritmus detekce R špičky
- Rozměření QRS komplexu
- Detekce T-vlny
- Určení konce T vlny
- Detekce atriálního signálu
- Analýza S-T segmentu

# Detekce komplexu QRS

## QRS komplex

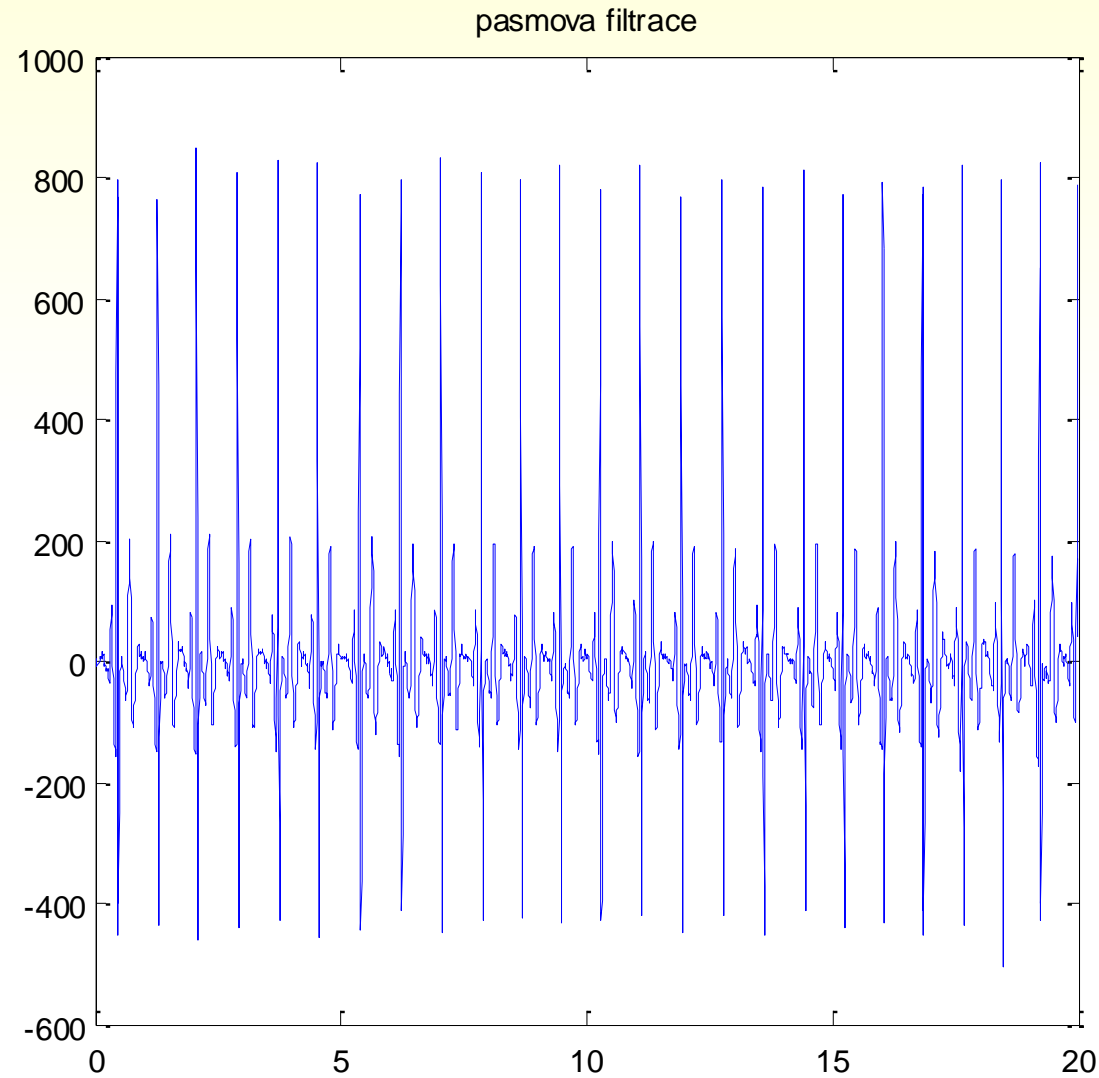
- nejvýraznější grafoelement v EKG signálu
- základní procedura všech počítačových analýz
- na spolehlivosti, přesnosti a rychlosti QRS detekce závisí celá EKG analýza

# Pan-Tompkinsonův algoritmus nalezení QRS

1. PP
2.  $\text{diff}(x)$
3.  $x^2$
4. MA
5. práh

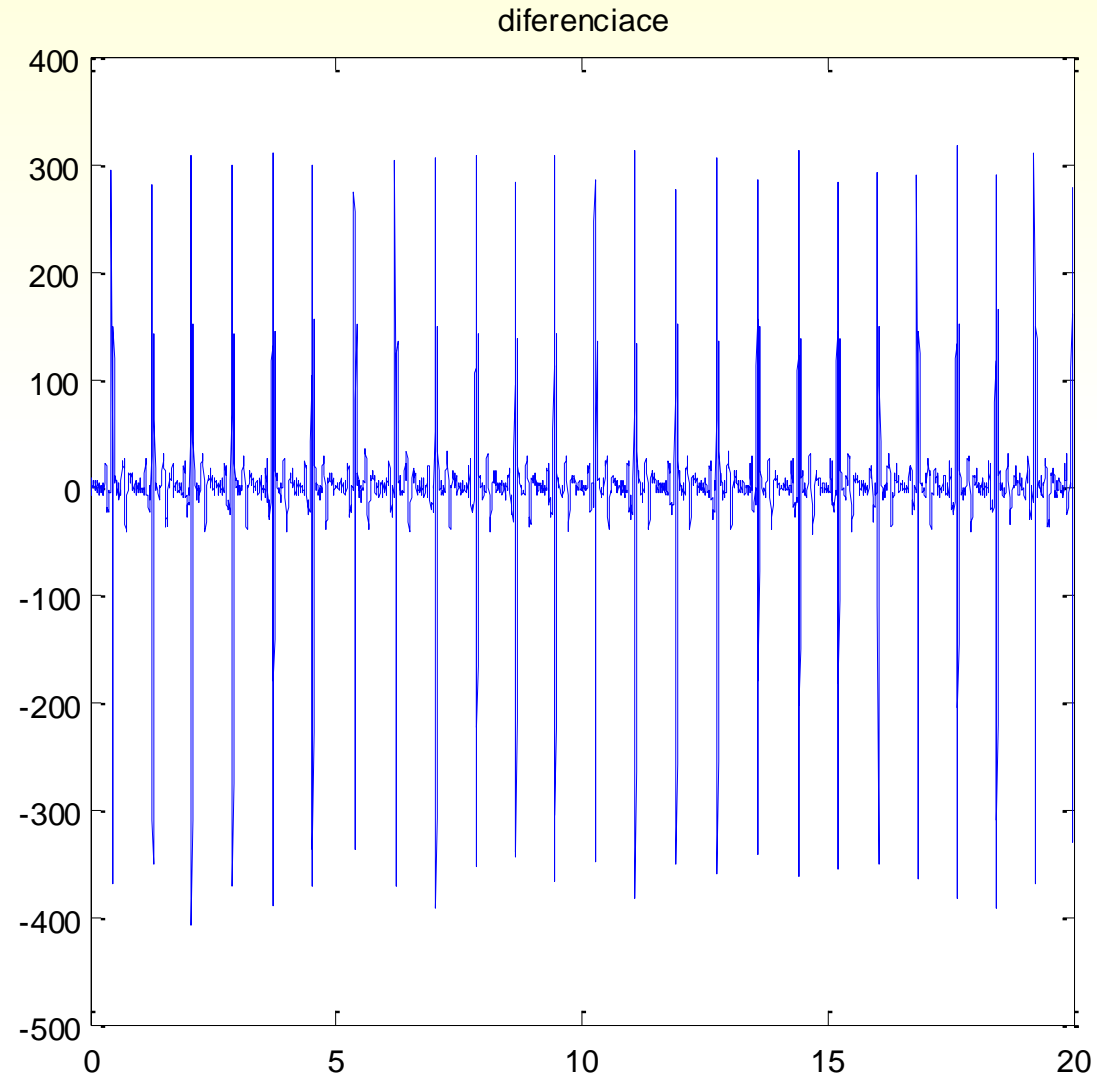


# 1. filtrace



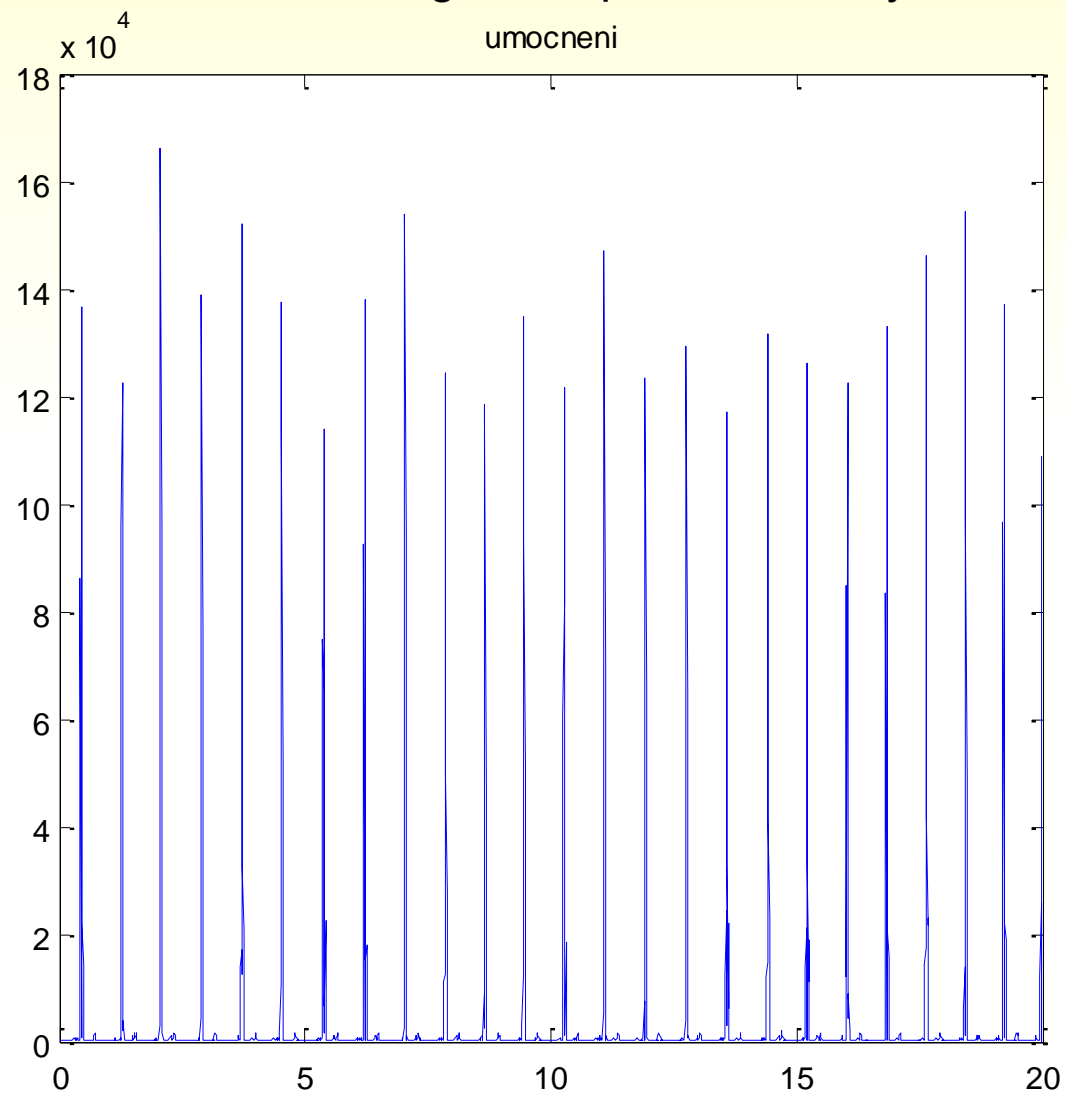
```
[b,a] = butter(2, [4 30]/(fs/2)); % filtrace mezi 4 a 30 Hz
```

# 2. differenziace

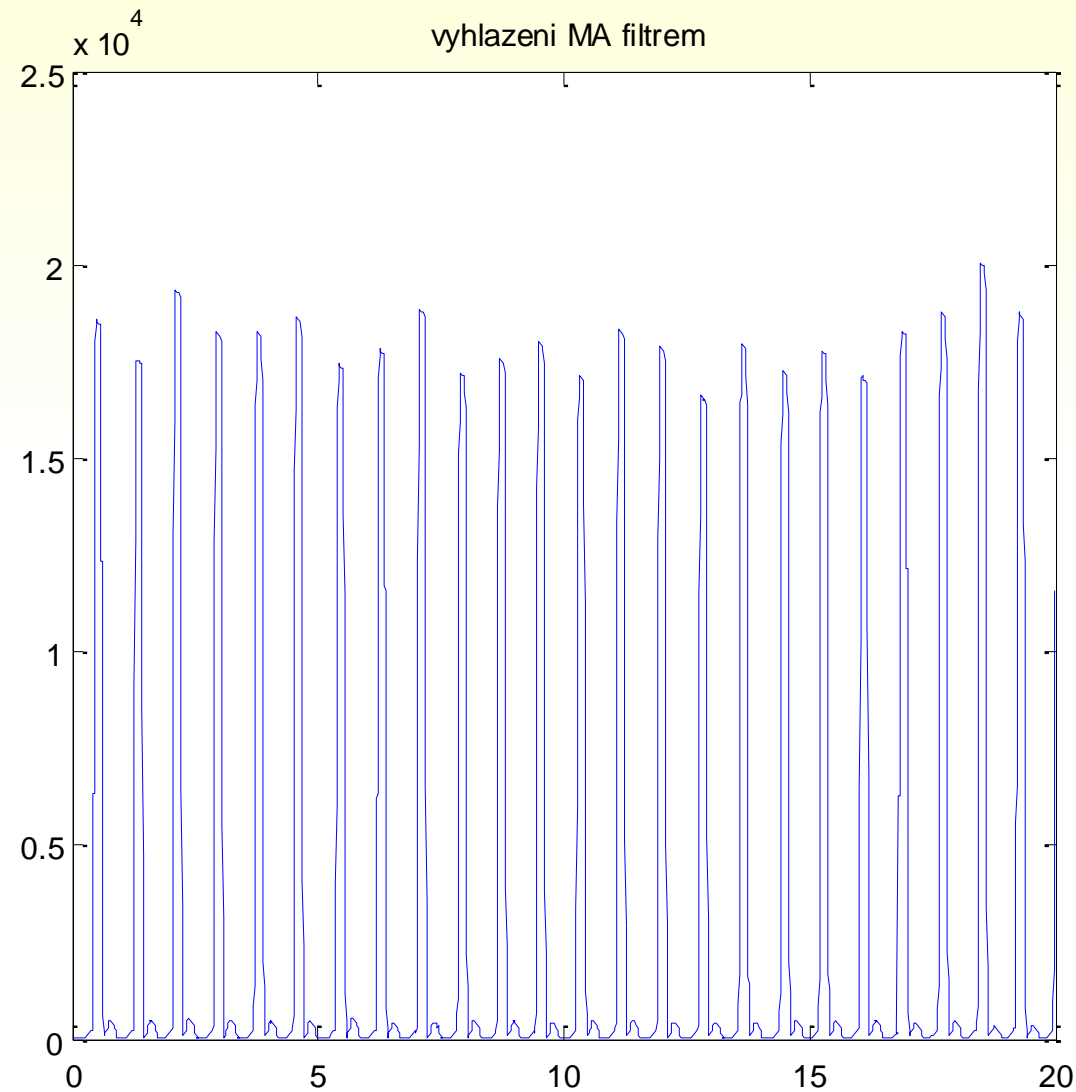


# 3. umocnění

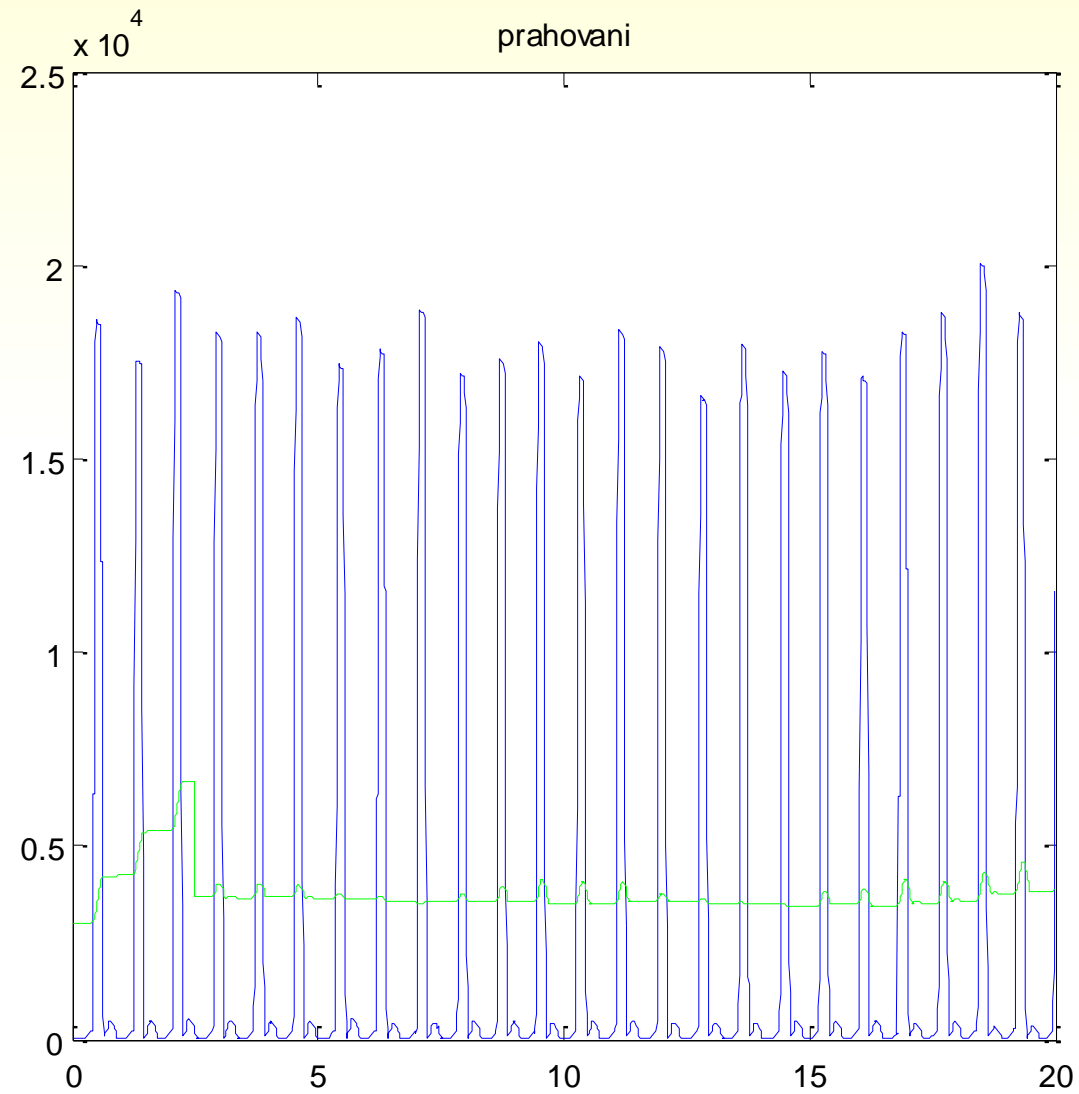
zvýraznění větších hodnot signálu a potlačení malých hodnot signálu



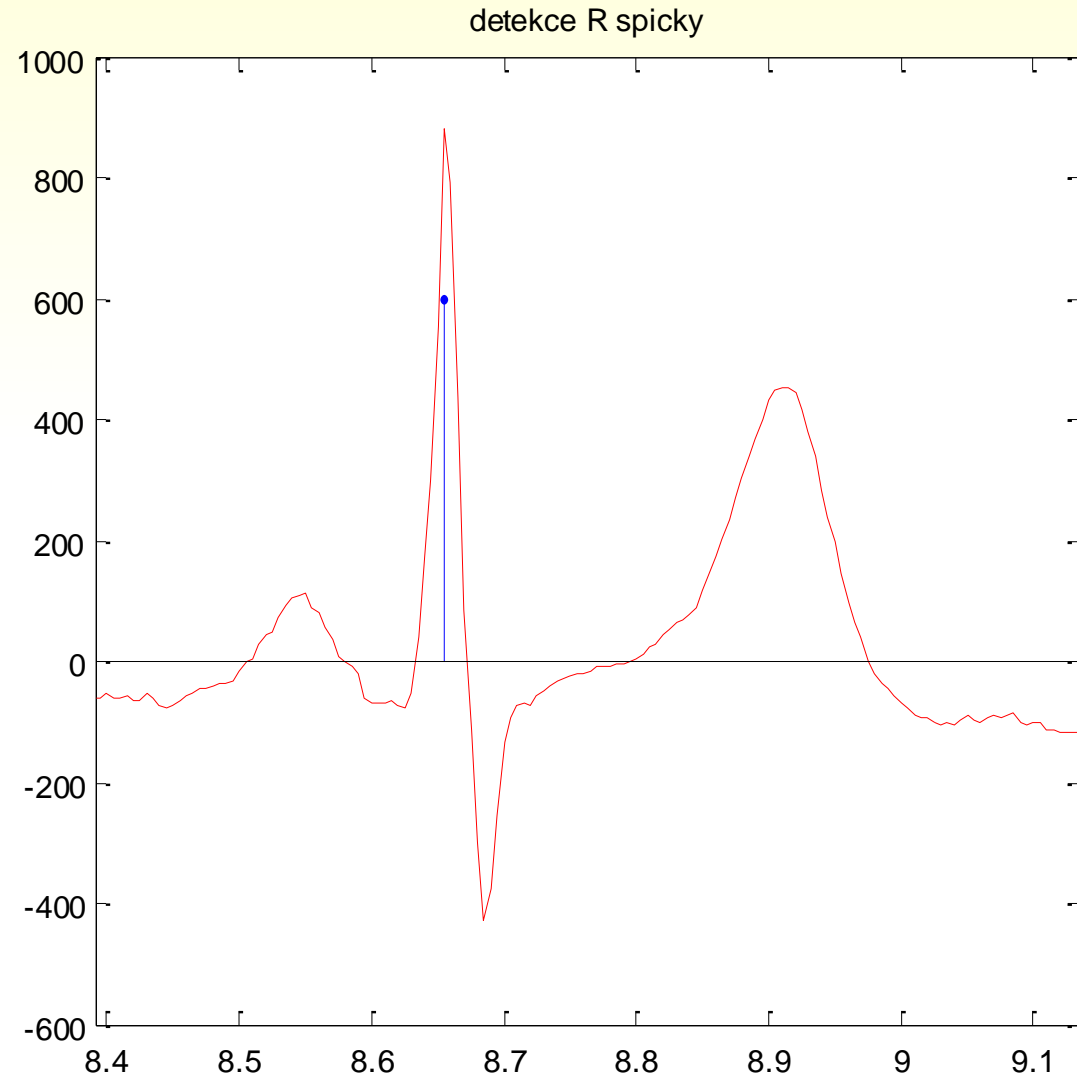
# 4. vyhlazení MA filtrem



# 5. prahování



# 6. detekce R špiček





```

function r=spicky(signal,fs)
% Implementace algoritmu pro detekce QRS komplexu v EKG signalu
% fs vzorkovaci kmitocet
signal= signal-mean(signal);           % odstraneni ss slozky
N      = length(signal);                % delka signalu
x_osa  = [1:length(signal)]./fs;        % horizontalni osa
[b,a]  = butter(2, [4 30]/(fs/2));      % pasmova filtrace
signalf = (filtfilt(b,a,signal));       % filtrace s nulovym f.p.
sig_dif=[diff(signalf);0];              % diferenciaci EKG
sig_2   = (sig_dif).^2;                  % umocneni signalu
sig_ma  = filtfilt([ones(1,160/160)],1,sig_2); % klouzavy prumer
prah    = mean(sig_ma);
kpp=find(diff(sig_ma>prah)==1);
kpn=find(diff(sig_ma>prah)==-1);
if kpn(1) > kpp(1)
for i=1:length(kpn)
    [m,nr(i)]=max(signal(kpn(i):kpn(i))); % vypocet presne pozice
end ;
else
for i=1:length(kpp)
    [m,nr(i)]=max(signal(kpn(i):kpp(i))); % vypocet presne pozice
end;
end;
r=kpp+nr'-1;

```

# Filtrace IIR filtry off-line

- **filtry s IIR**

nelineární fázová charakteristika – kompenzace pomocí doplňkové filtrace v inverzním čase

$$G(e^{j\omega T}) = H(e^{j\omega T}) \cdot H(e^{-j\omega T})$$

$$|G(e^{j\omega T})| = |H(e^{j\omega T})|^2$$

$$\arg(G(e^{j\omega T})) \equiv 0$$

```
fs = 100;
```

# Filter IIR filtry off-line

```
t = 0:1/fs:1;
```

```
x = sin(2*pi*t*3)+.25*sin(2*pi*t*40);
```

```
b = ones(1,10)/10;
```

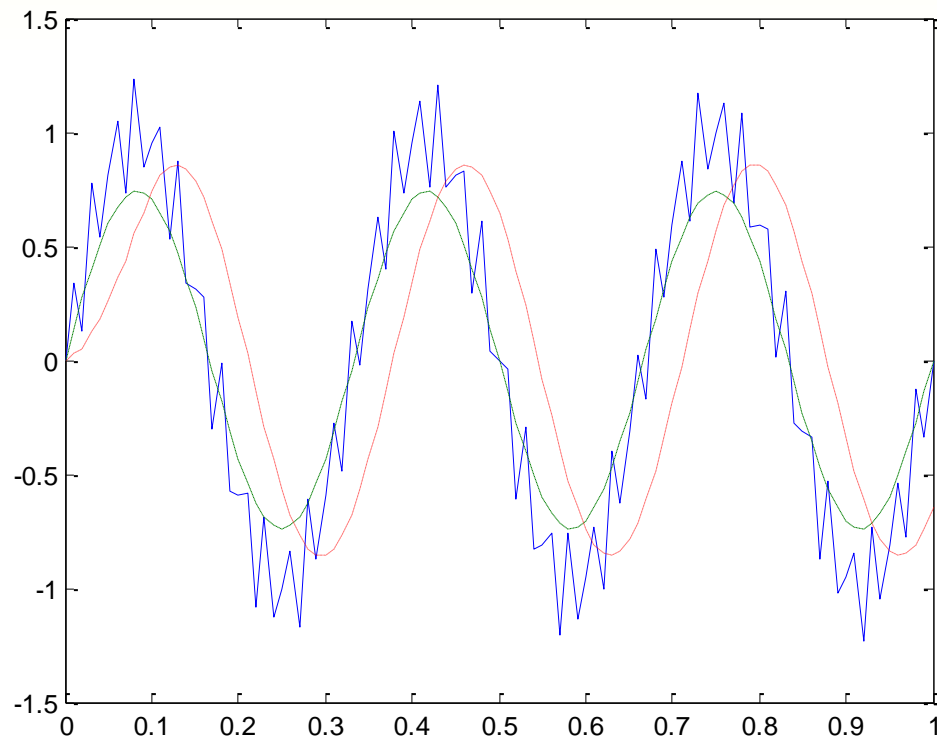
```
y = filtfilt(b,1,x);
```

% Nekauzalni filtrace

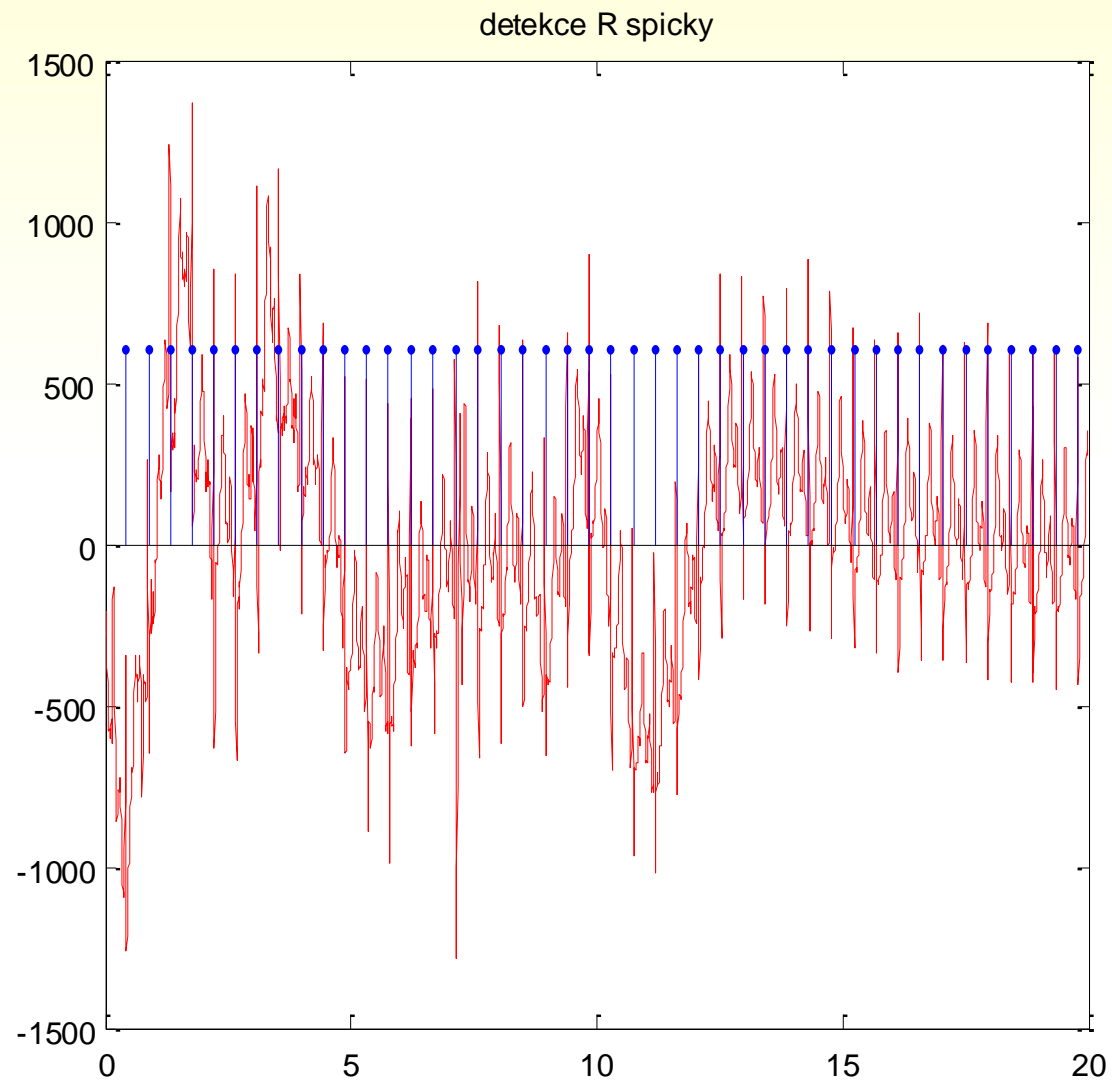
```
yy = filter(b,1,x);
```

% Normalni filtrace

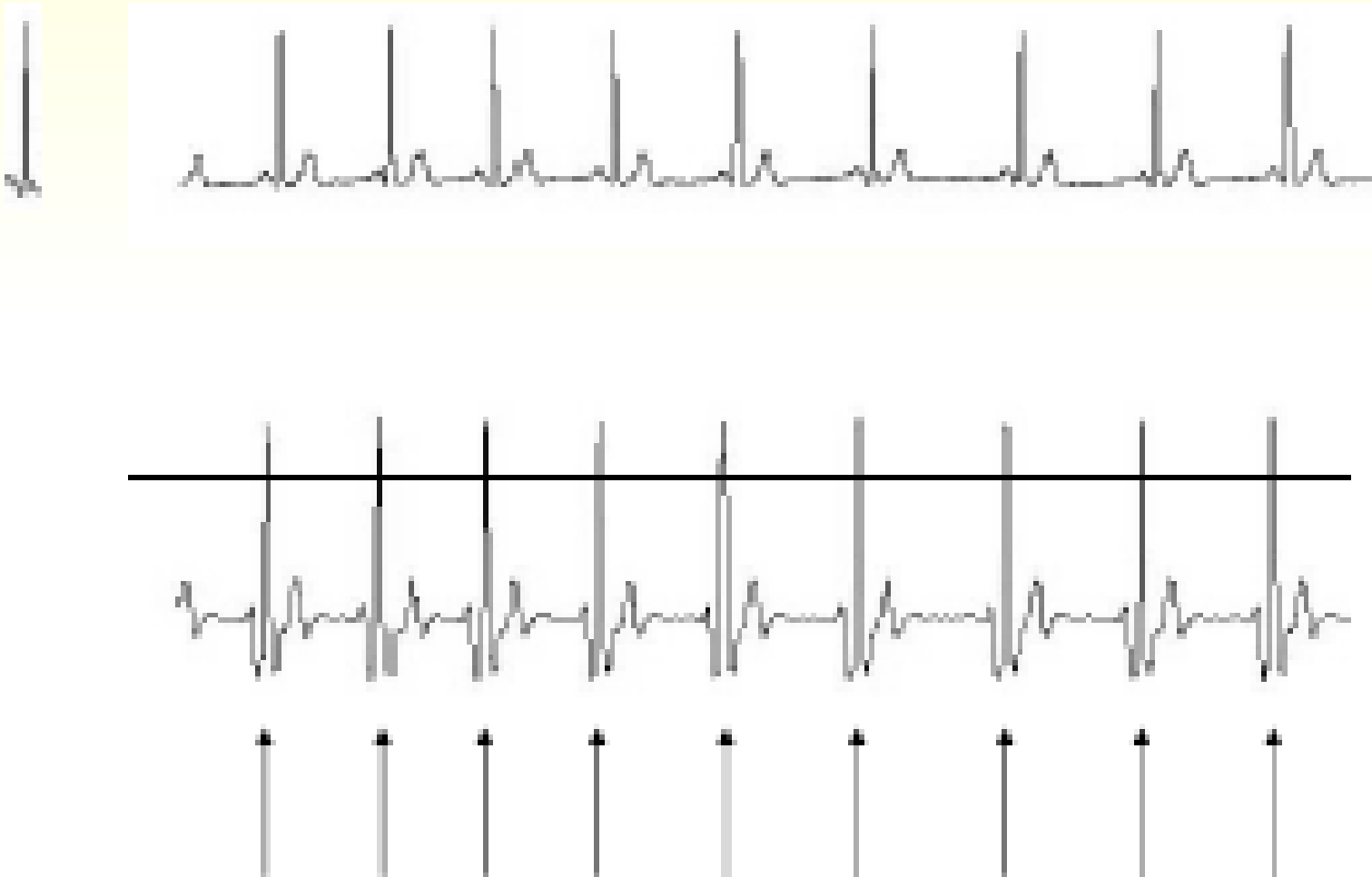
```
plot(t,x,t,y,'--',t,yy,':')
```



# Analýza EKG signálu

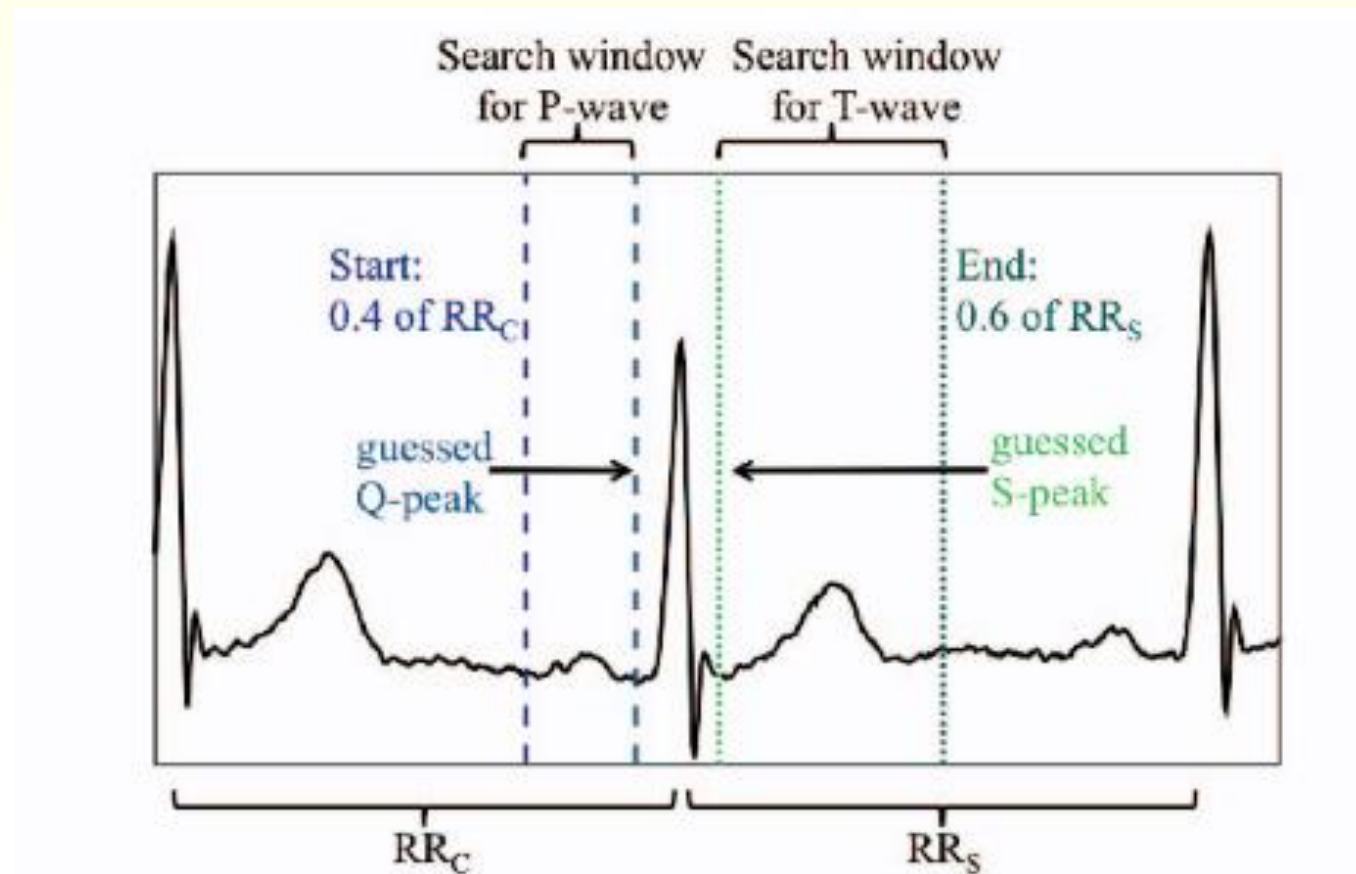


# Hledání R špiček pomocí vzájemné korelace



# Detekce signálů v EKG

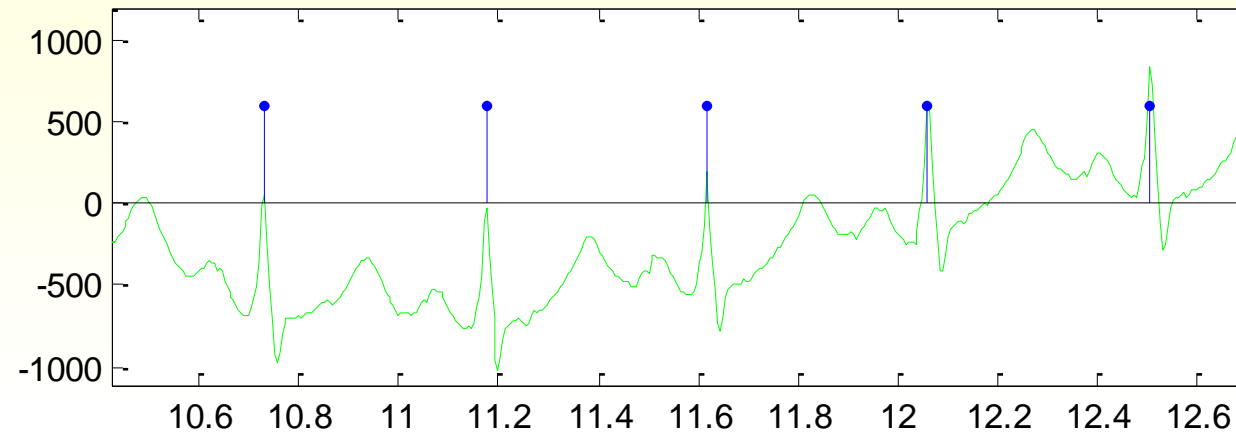
## detekce T vlny



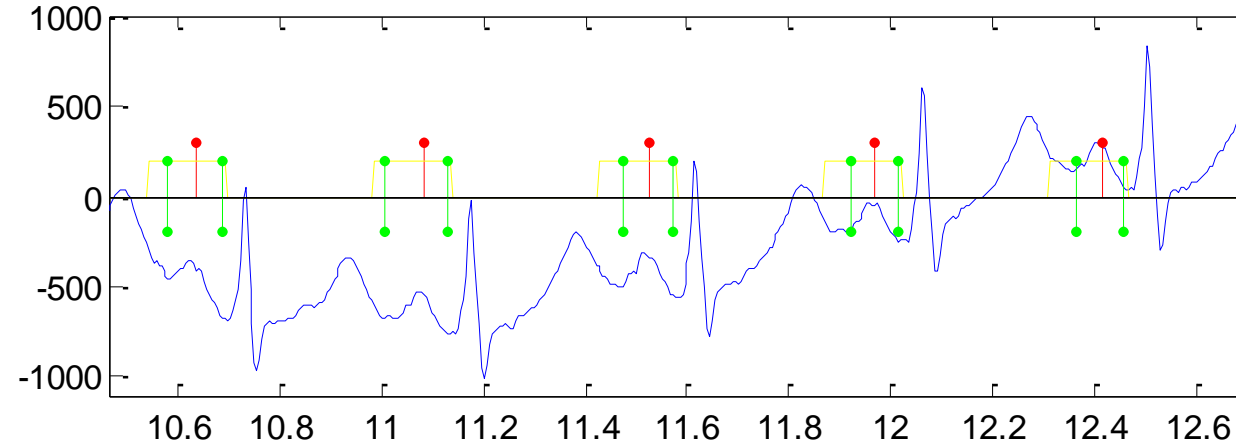


# Detekce P vlny

detekce QRS komplexu



detekce P vlny



# Určení začátků a konců vln

