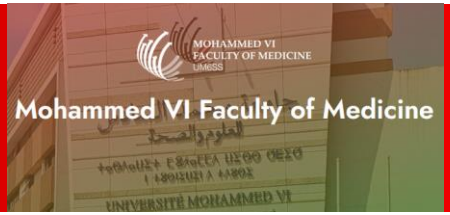


Electrocardiography

Prof Stéphane Carlier

Department of Cardiology, UMons (B)

Acromegalic Syndrome

Table 1 Main cardiovascular comorbidities observed in acromegalic patients, and the most useful methods and procedures for their diagnosis and follow-up

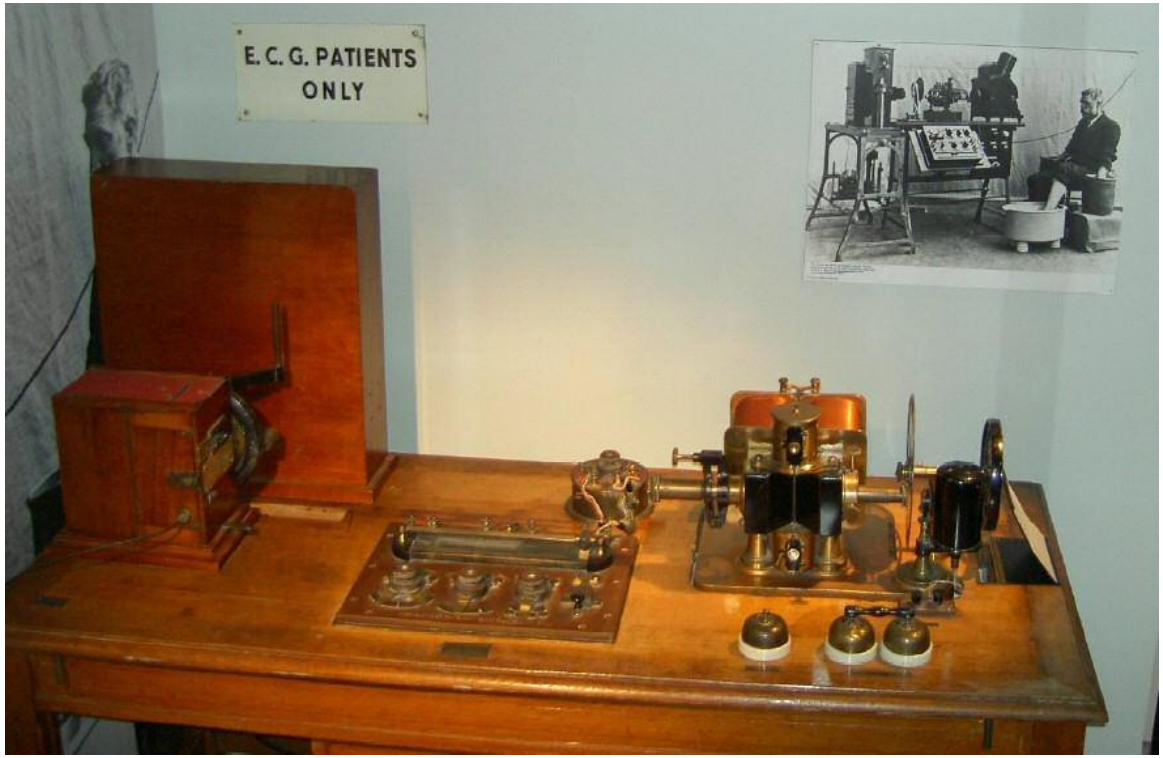
Hypertension	•Office manual blood pressure measurement. •Repeated home blood pressure measurement. •24 h ABPM. •AOBP measurement.
Cardiomyopathy	•Single clinic 12-lead ECG. •24 h Holter ECG monitoring. •Exercise, tredmill or stress tolerance test. •Echocardiography. •Cardiac magnetic resonance imaging.
Heart valve disease	•Exercise or stress tolerance test. •Echocardiography. •Cardiac magnetic resonance imaging.
Arrhythmias	•Single clinic ECG. •24 h Holter ECG monitoring. •Exercise, treadmill or stress tolerance test.
Atherosclerosis and coronary artery disease	•Exercise, treadmill or stress tolerance test.•Ultrasound and duplex study of carotid and supraaortic trunk. •Intima-media thickness measurement. •Quantification of internal carotid stenosis. •Number, morphology and surface characteristics of carotid plaques. •Other specific baseline and dynamic tests (computed tomography angiography, coronary catheterization, positron-emitted tomography).

Diagnostic Tools in Cardiology

1. ECG
2. Stress test
3. Holter ECG or BP
4. Tilt test
5. Chest X-ray
6. Echocardiography
7. Myocardial scintigraphy
8. Coronary CT scan
9. Cardiac magnetic resonance
10. Coronary angiography & Catheterization

The first ECG

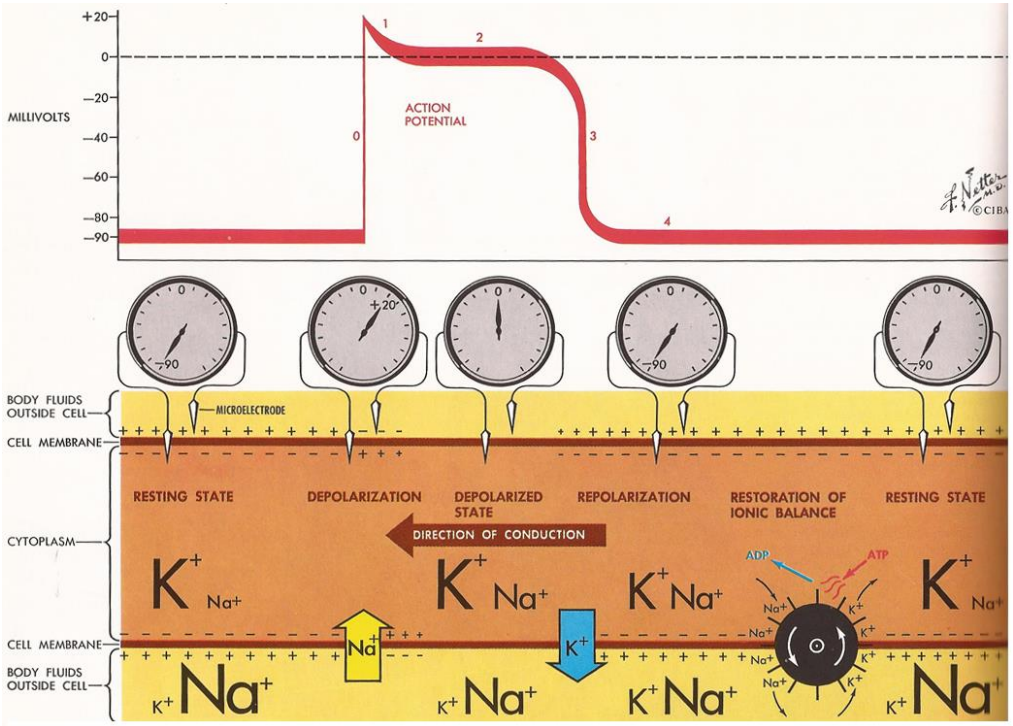
1897
A French electrical engineer, Clement Ader, developed an amplification system called a galvanometer for underwater telegraph lines.
1901
Einthoven modifies this recorder to produce ECGs with a 300 kg device

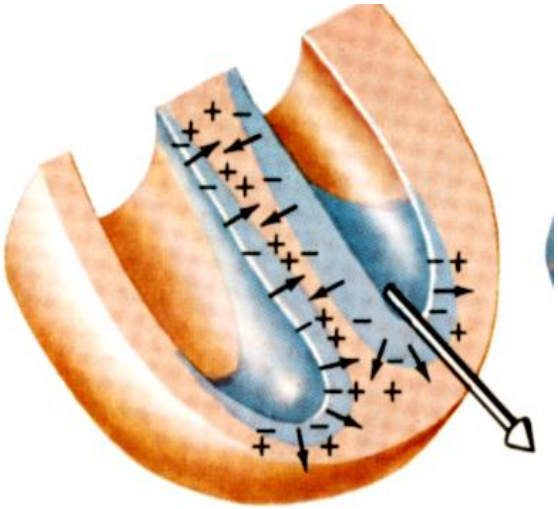


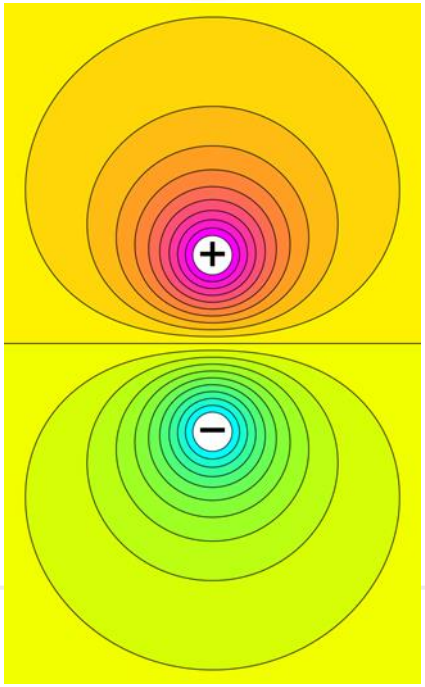
Willem Einthoven
Nobel Prize of Medicine 1924

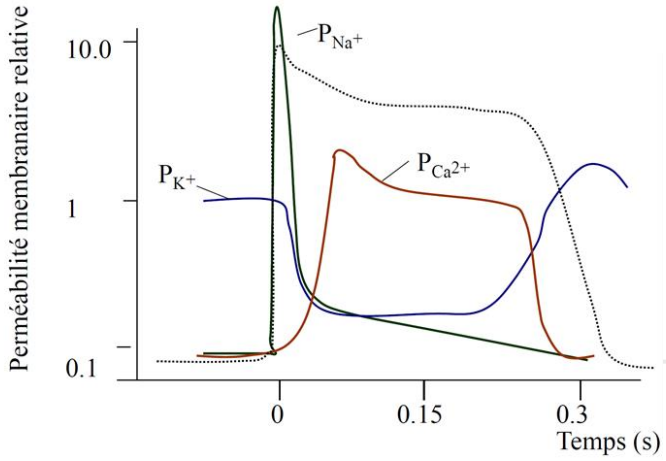
There have been tremendous progress

Genesis of the ECG

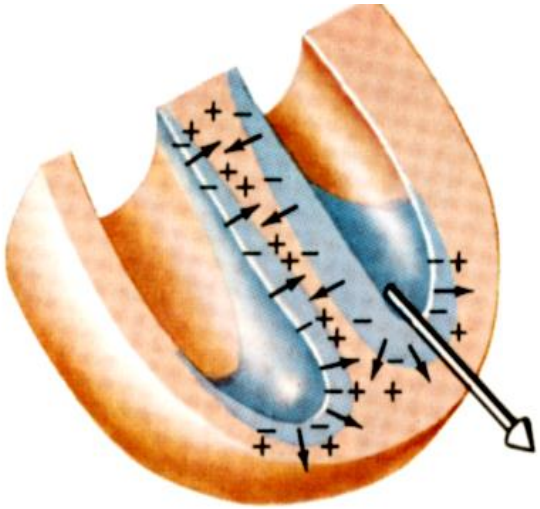


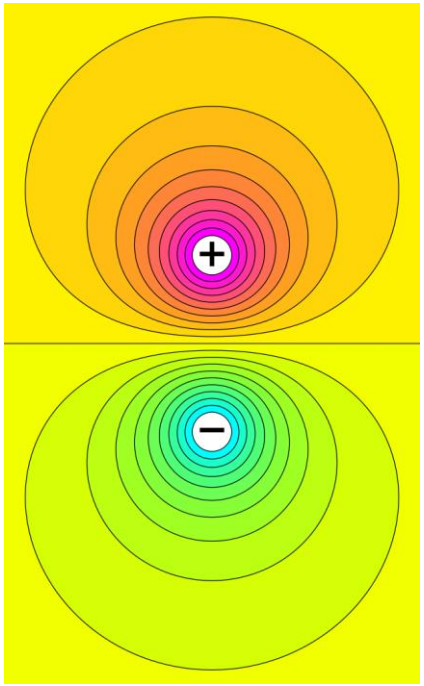


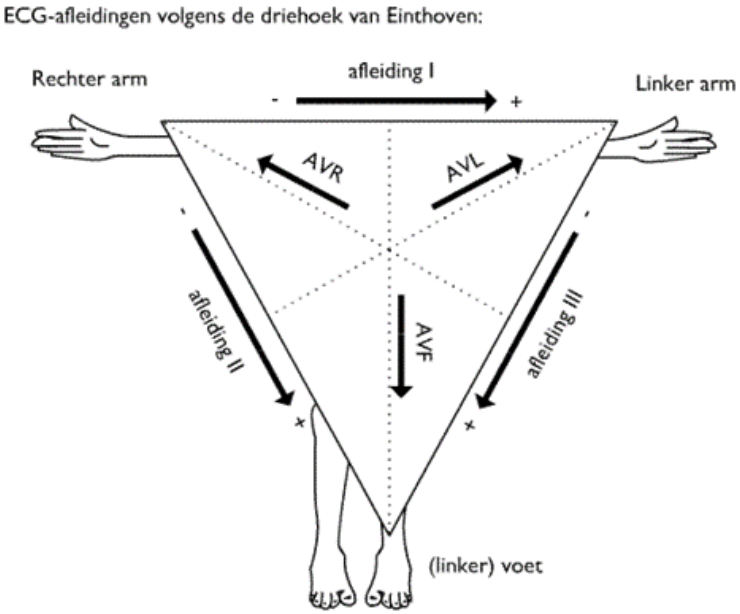




Einthoven's Triangle

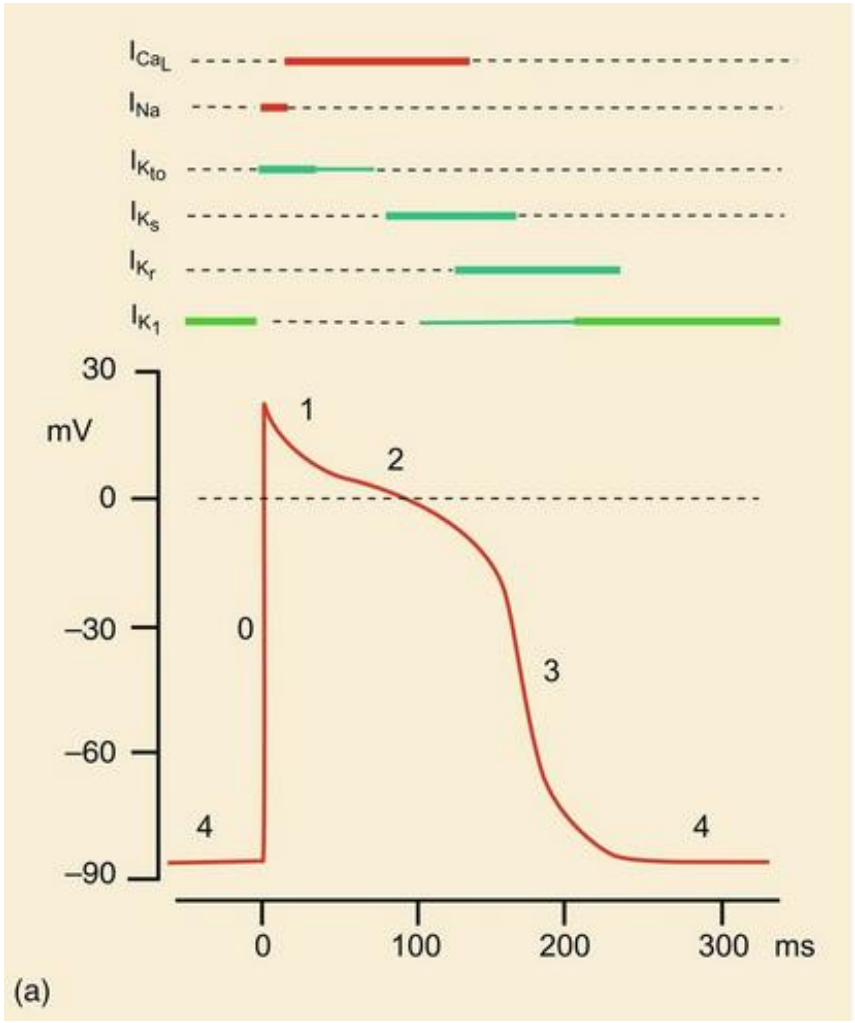


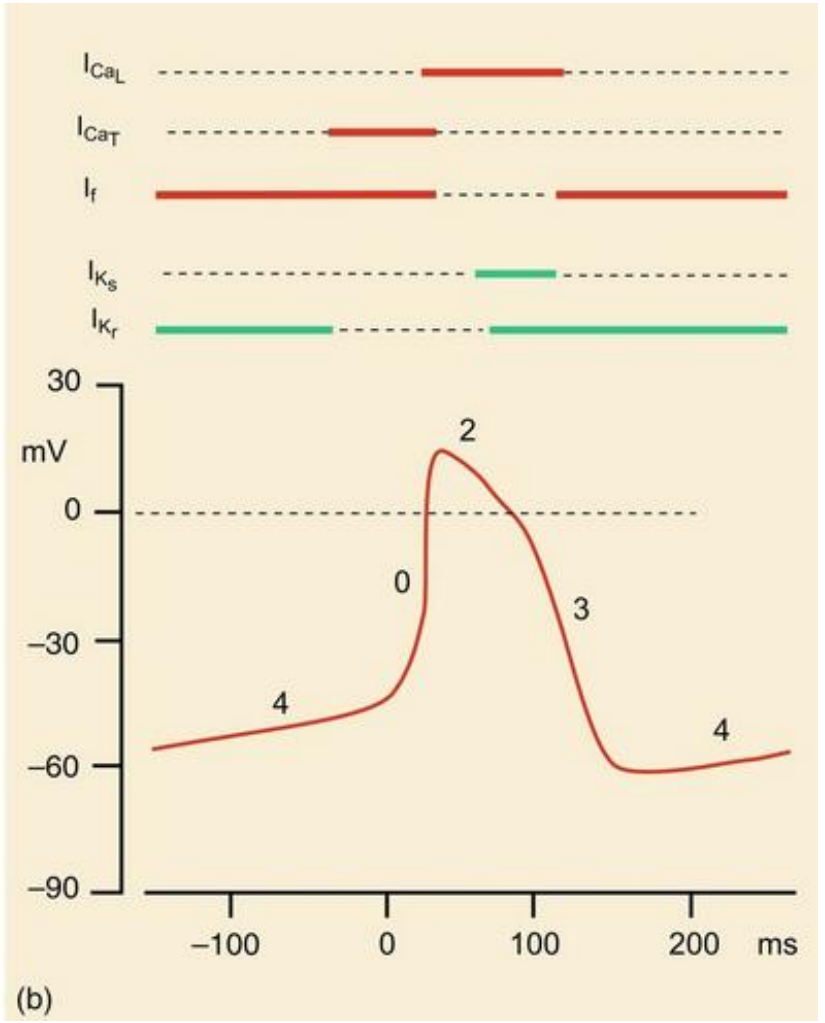




$$V(M) = \frac{qa\cos\theta}{4\pi\varepsilon_0 r^2} = \frac{\vec{P}\cdot\vec{e}_r}{4\pi\varepsilon_0 r^2}$$

Differential Ionic Currents

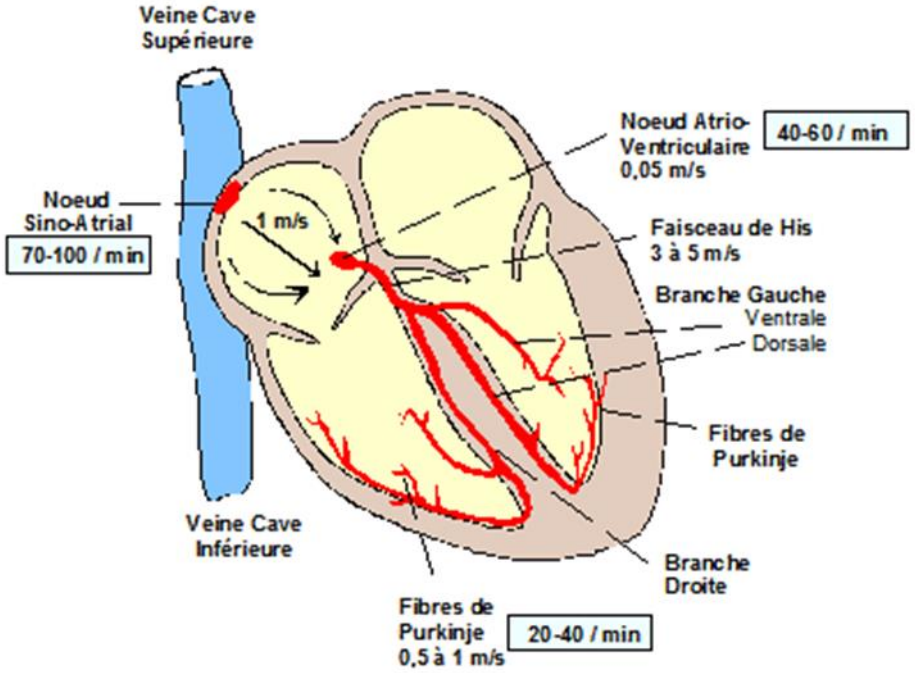


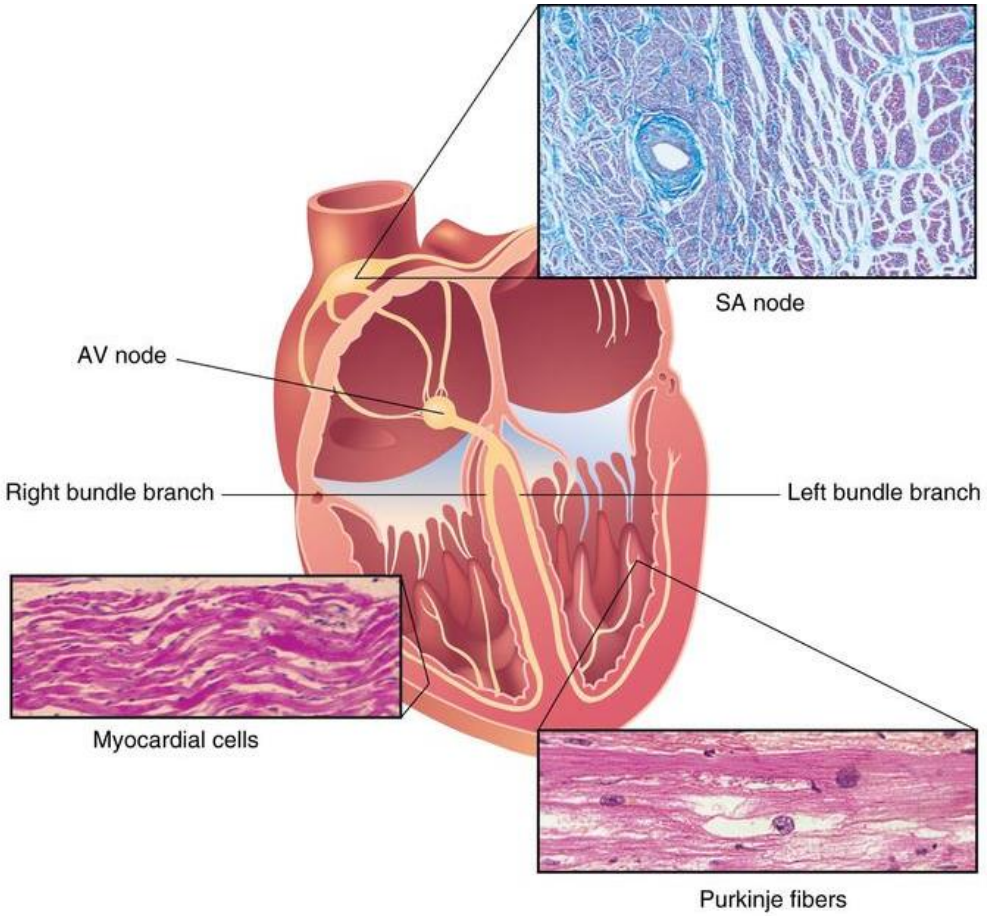


Cardiomyocytes

Sinoatrial node: PM

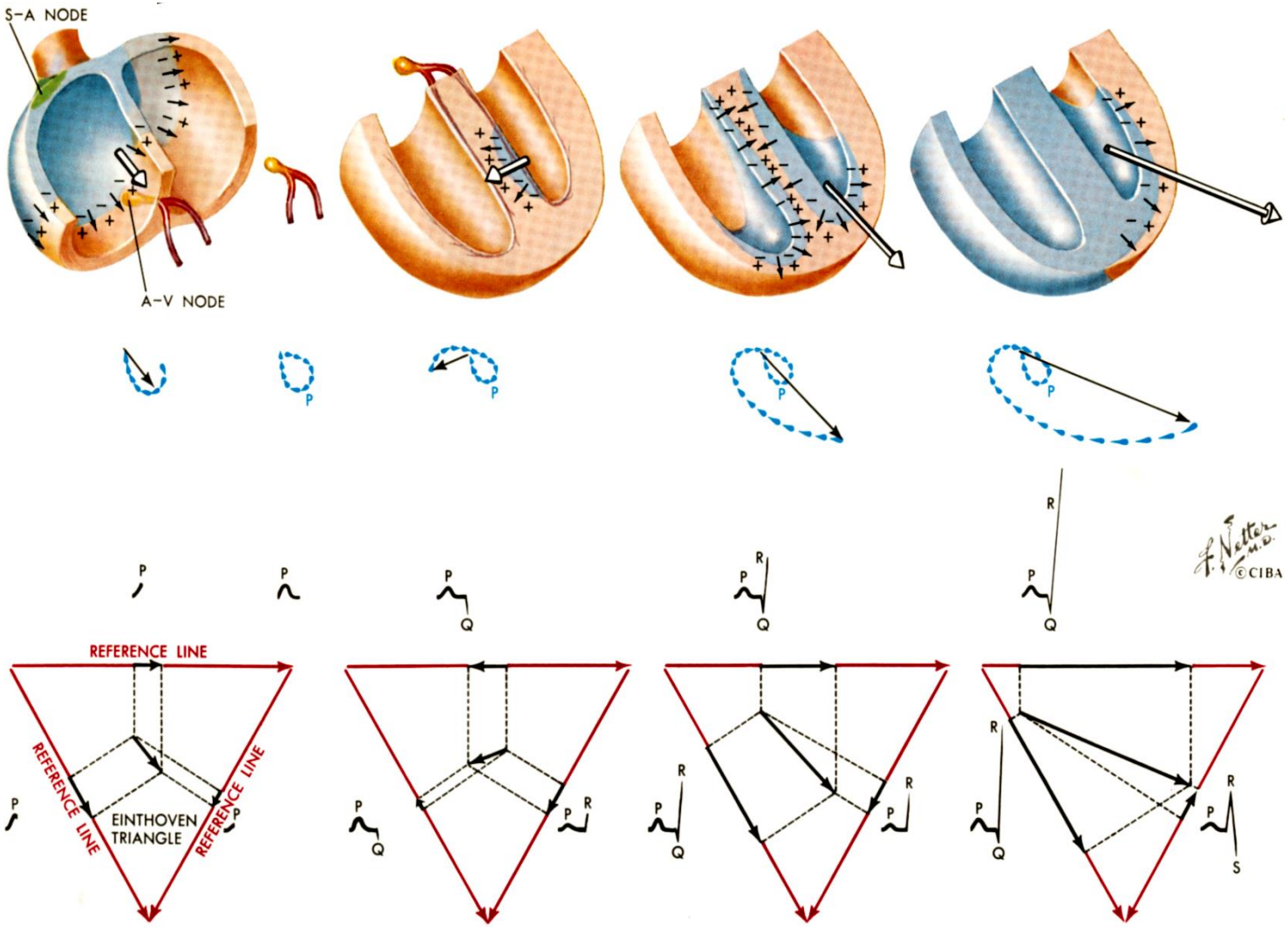
The Cardiac Pacemaker: SA Node





Sinus node made up of non-contractile cells: few unorganised myofibrils within collagen-rich connective tissue and vessels with numerous nerve fibres in the periphery which modulate activity.

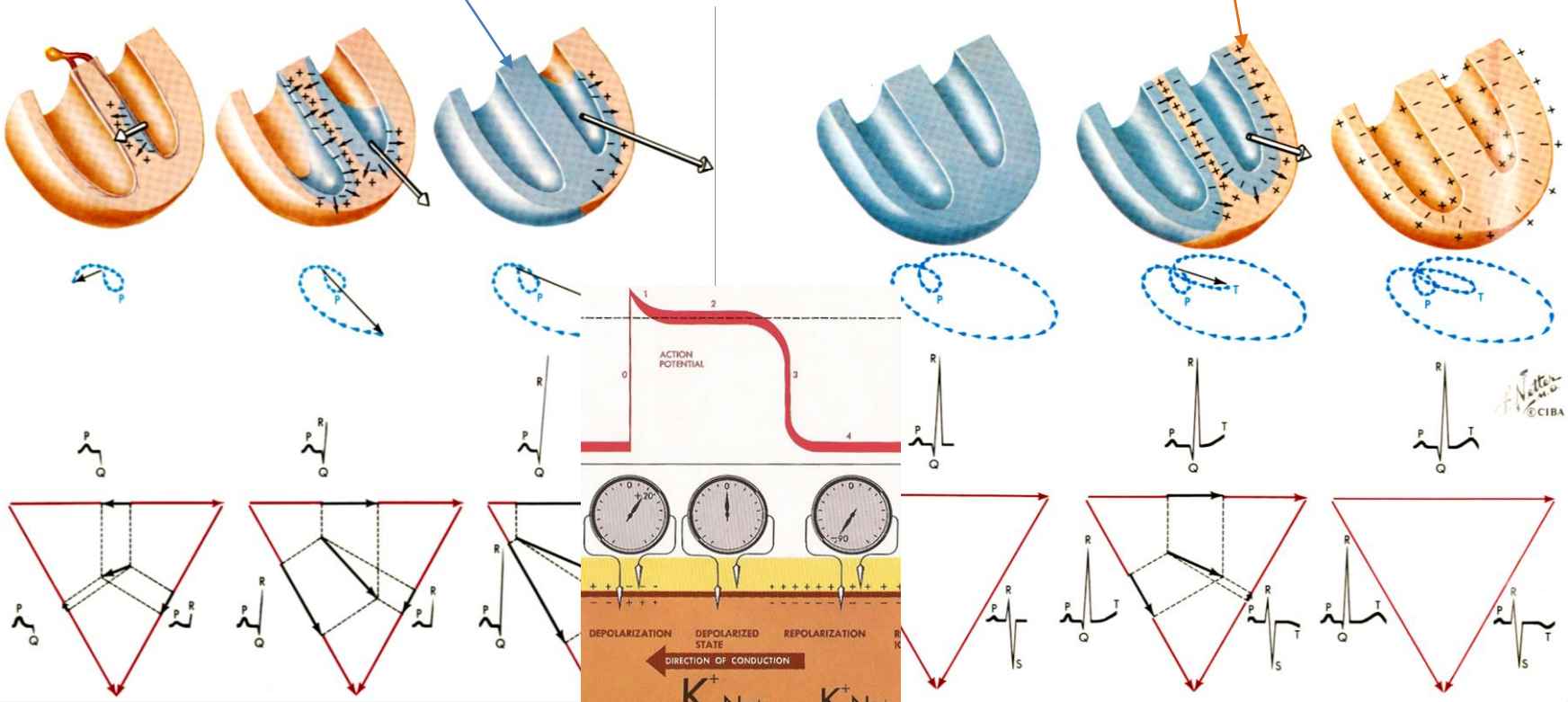
Cardiac Wave Front



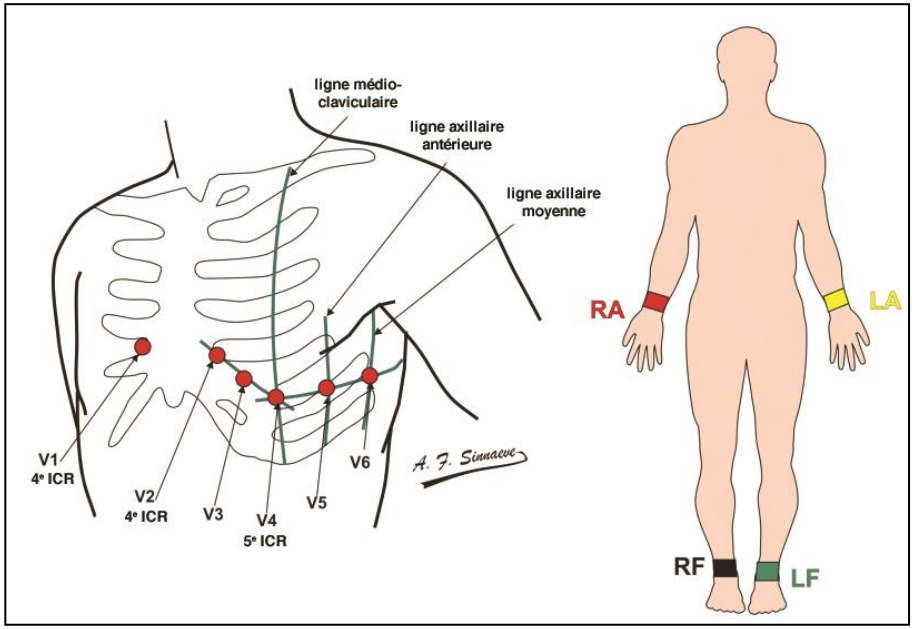
Normal QRS - T

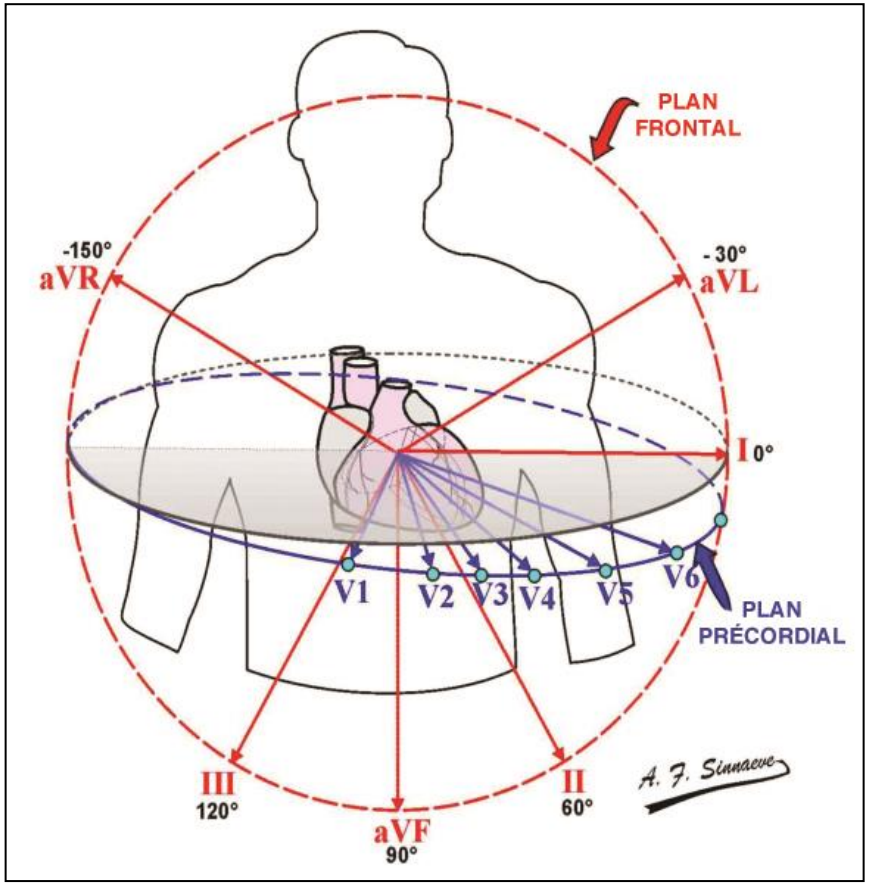
- QRS < DEPOLARISATION
- Myocardium depolarises from the endocardium to the epicardium

- T < REPOLARISATION
- Myocardium redepolarises from the epicardium to the endocardium



Placement of electrodes

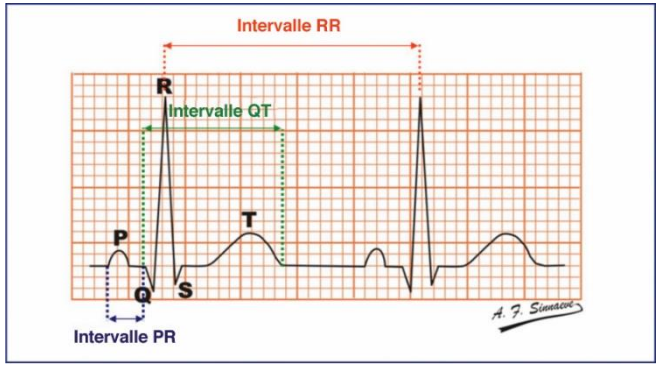


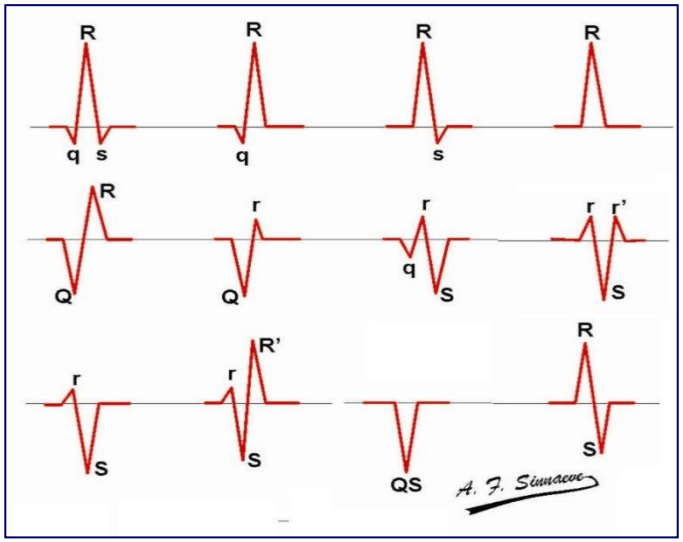


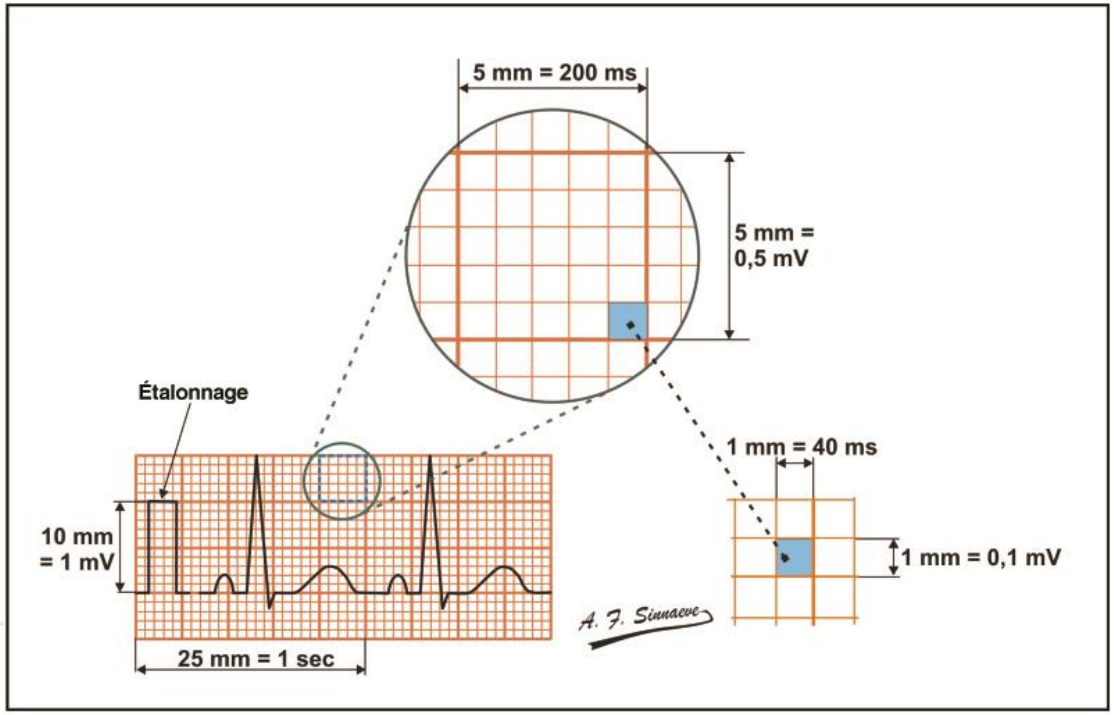
I SuperoLateral	aVR	V1 Anteroseptal	V4 Anterior
II Inferior	aVL SuperoLateral	V2 Anteroseptal	V5 Lateral
III Inferior	aVF Inferior	V3 Anterior	V6 Lateral

Amplitudes & timing of ECG

- Speed of ECG “paper” = 25 mm/s
- Amplitude of a large square (5 mm) = 0.5 mV
- Duration of a large square (5 mm) = 200 ms
- Amplitude of a small square (1 mm) = 0.1 mV
- Duration of a small square (1 mm) = 40 ms
- Calibration signal = 10 mm or 1 mV

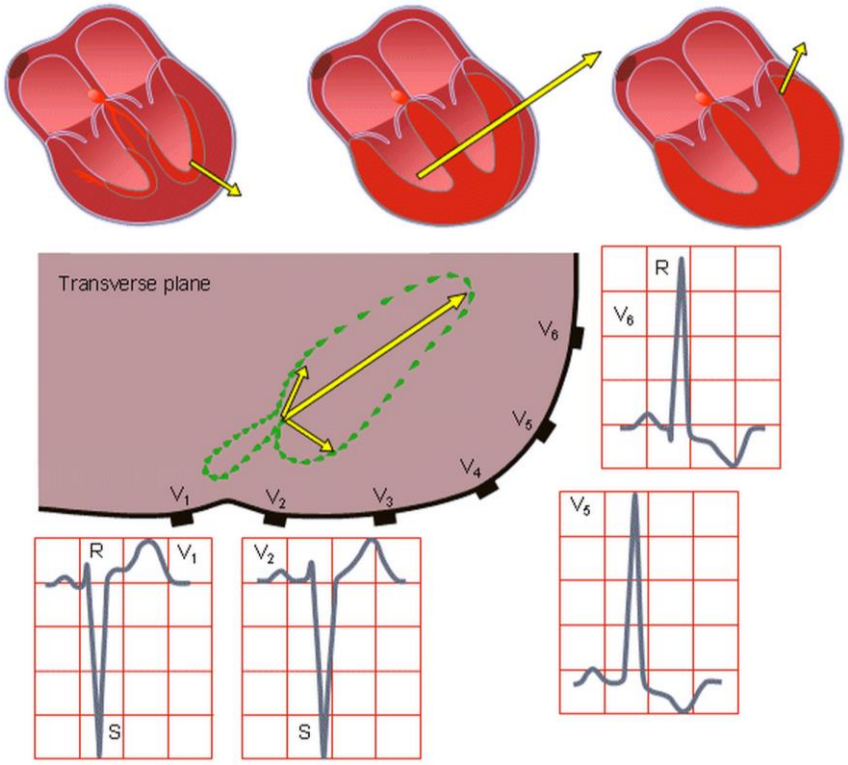




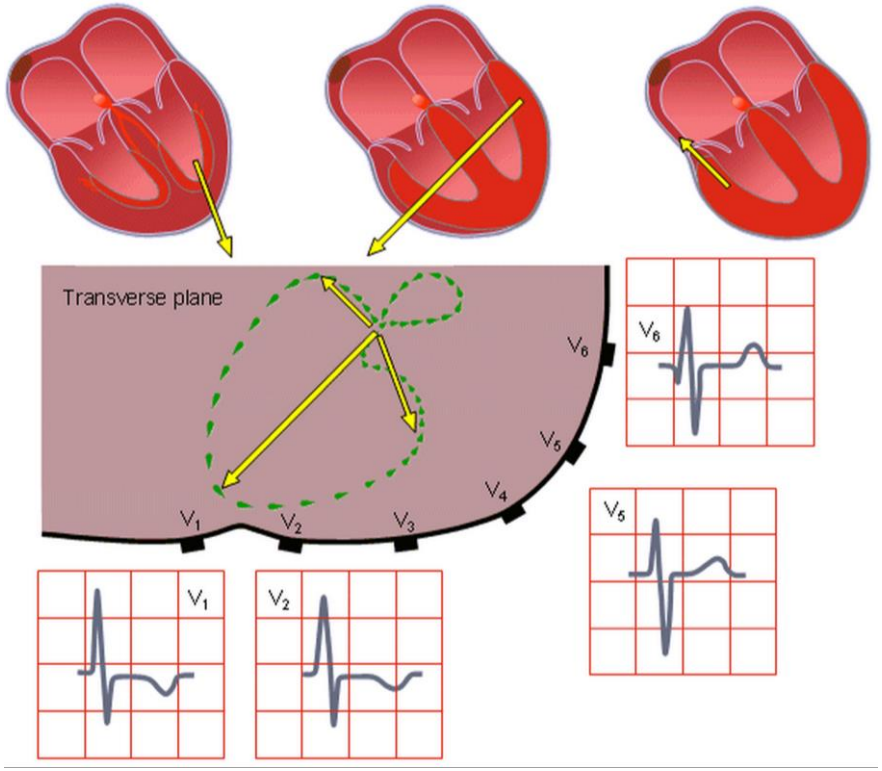


High Amplitudes: Left/Right Ventricular HYpertrophy

LVH



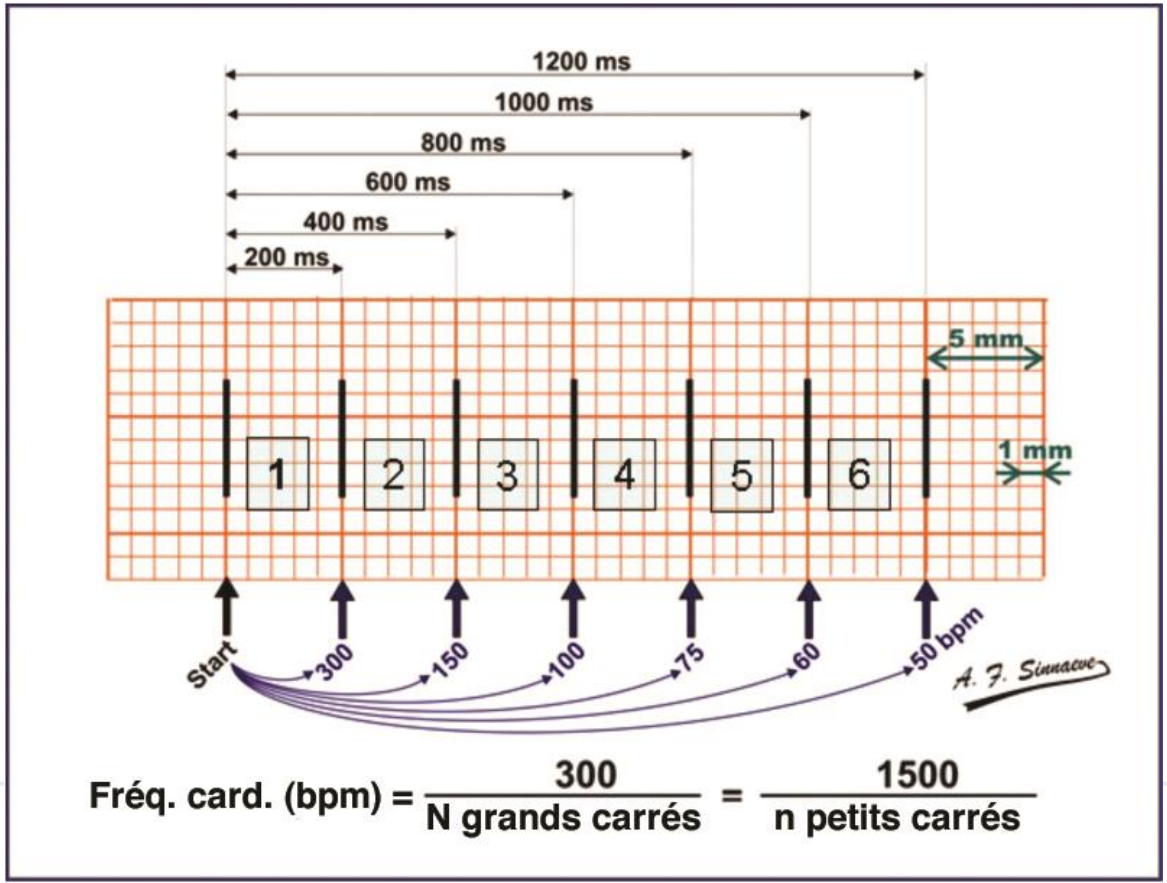
RVH



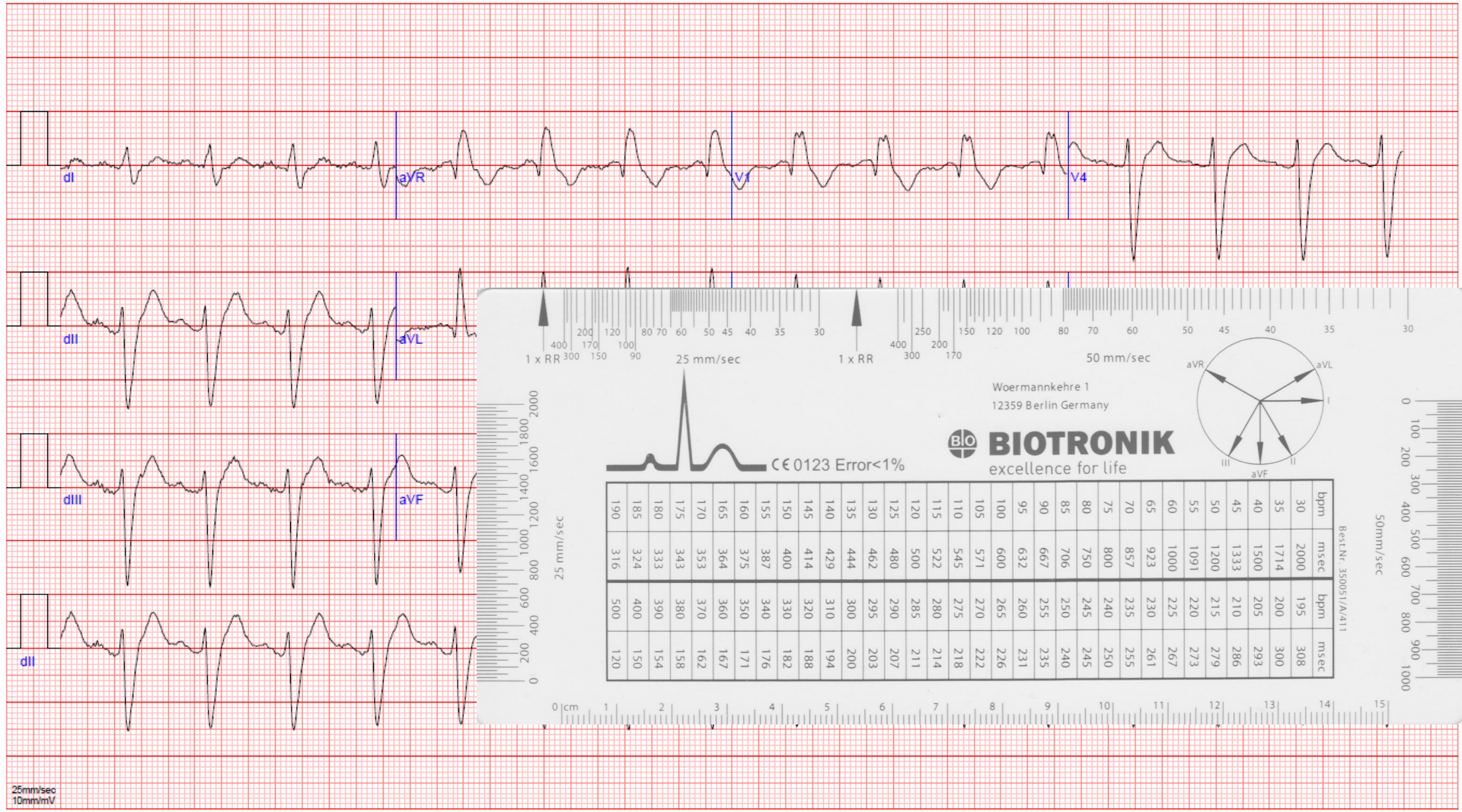
Heart Rate

- Heart rate (HR) beats/min.
  1 min = 60 x 1000 ms = 60 000 ms

  soit : HR (bpm) = $\frac{60\,000}{\text{RR interval (in ms)}}$



Example

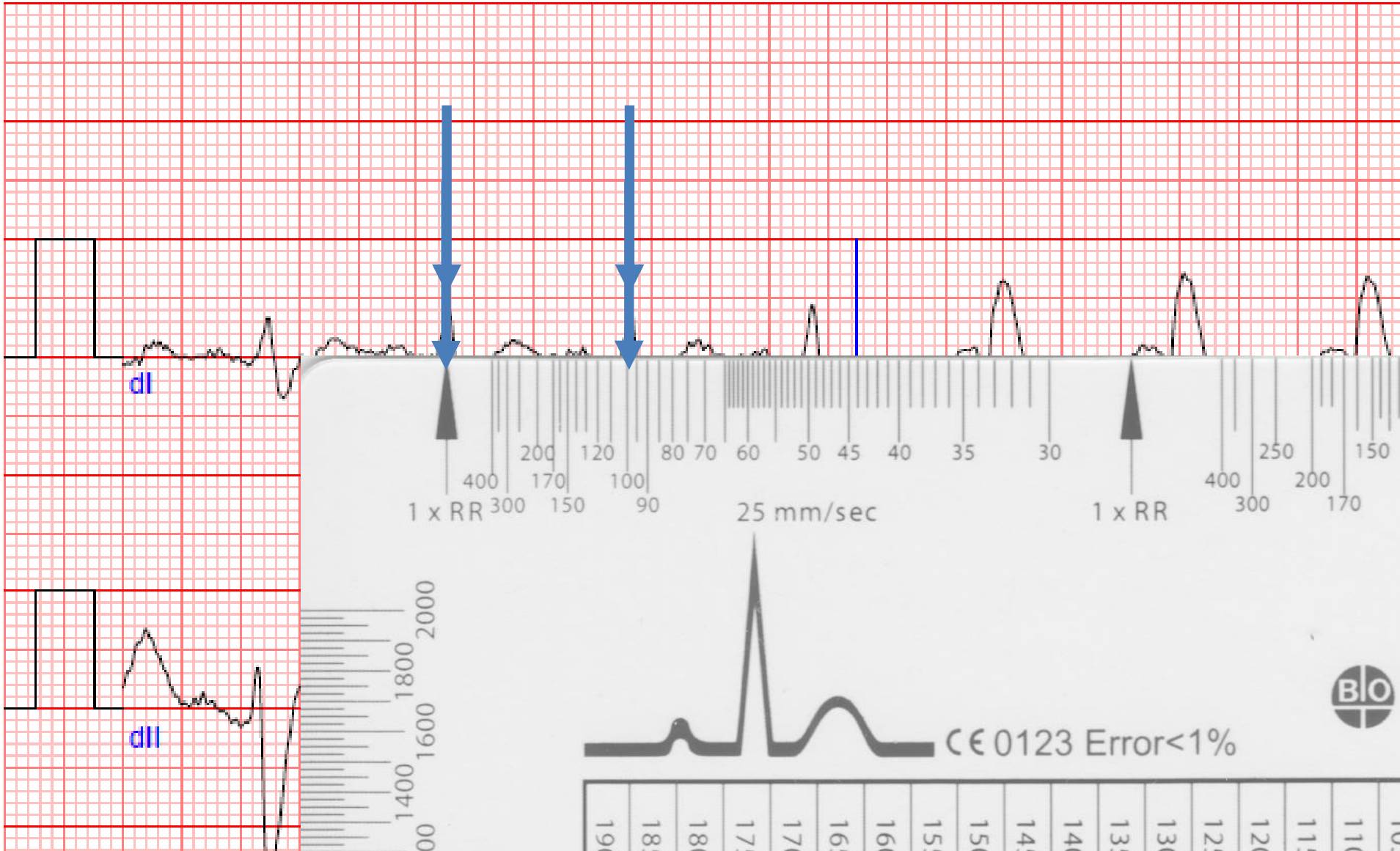


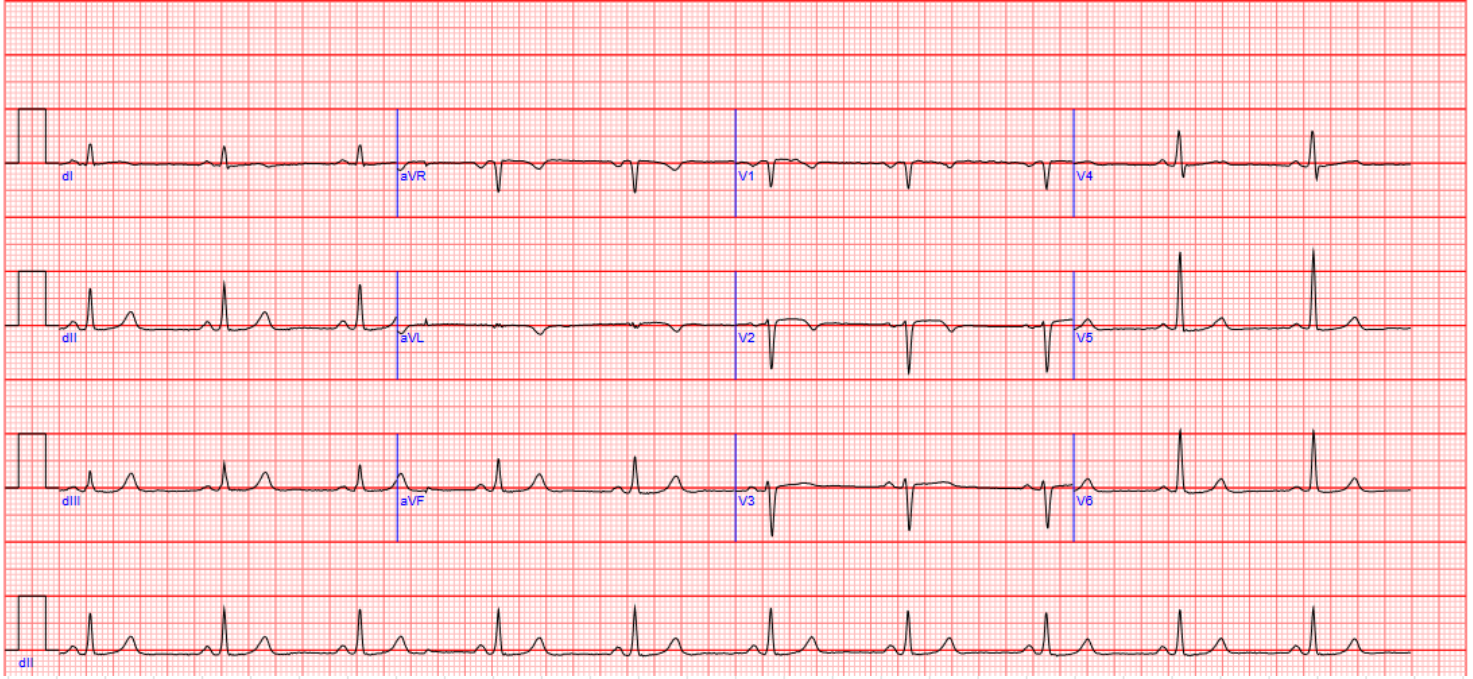
bpm	msec	bpm	msec
190	316	500	120
185	324	400	150
180	333	390	154
175	343	380	158
170	353	370	162
165	364	360	167
160	375	350	171
155	387	340	176
150	400	330	182
145	414	320	188
140	429	310	194
135	444	300	200
130	462	295	203
125	480	290	207
120	500	285	211
115	522	280	214
110	545	275	218
105	571	270	222
100	600	265	226
95	632	260	231
90	667	255	235
85	706	250	240
80	750	245	245
75	800	240	250
70	857	235	255
65	923	230	261
60	1000	225	267
55	1091	220	273
50	1200	215	279
45	1333	210	286
40	1500	205	293
35	1714	200	300
30	2000	195	308

ECG from 05/02/2019 at 18:33:28

PDF Export V1.0.0

65 y-old, sub acute coronary syndrome



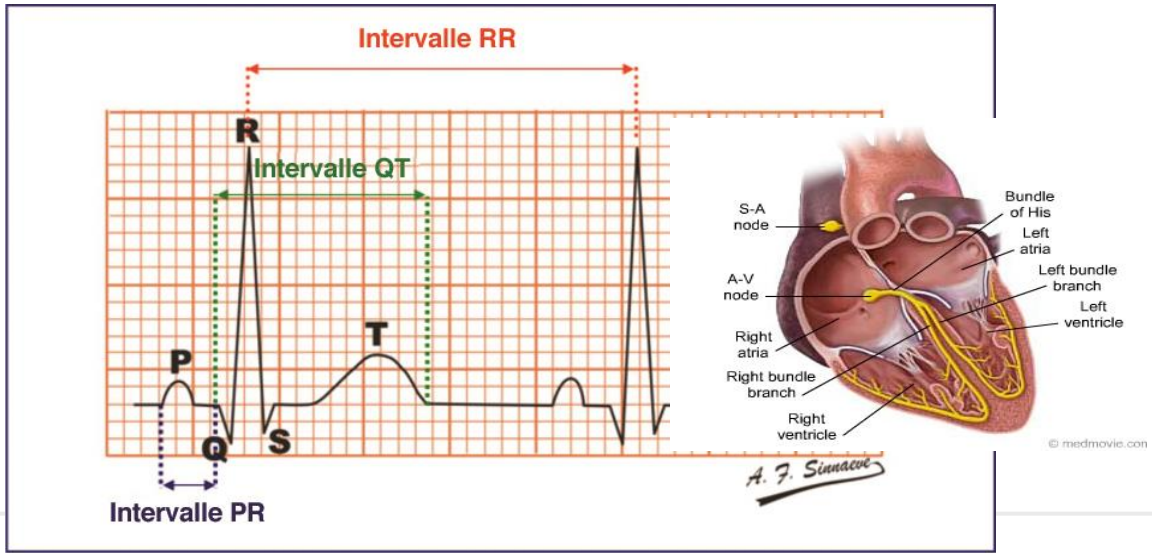


	A	B	C	D	E		
Rythme	◯ Sinusal	◯ FA	◯ Flutter atrial	◯ AVNRT	◯ TV	70	0 0 0 0 ● 0
Fréquence	◯ <45	◯ 45-100	◯ 101-160	◯ >160		71	1 1 1 ● 1 1
Morpho onde P	◯ Normale	◯ HyperT Or Dr	◯ HyperT Or G	◯ P non-sinusale	◯ Pas d'onde P	72	● 2 2 2 2 2
Conduction AV	◯ Normale	◯ BAV1	◯ BAV2	◯ BAV3	◯ Pas d'onde P	73	3 3 3 3 3 3
QRS	◯ Normal	◯ Onde Delta	◯ BBD mineur	◯ BBD majeur	◯ BBG	74	4 ● 4 4 4 4
Axe	◯ Normal	◯ Dév. Droite	◯ Gauche < -30°	◯ Gauche > -30°	◯ indéterminé	75	5 5 5 5 5 5
Repolarisation	◯ Normale	◯ Wellens	◯ ST sus-décallé	◯ ST sous-décallé	◯ indéterminé	76	6 6 6 6 6 ●
QT	◯ Normal	◯ Court	◯ Allongé	◯		77	7 7 7 7 7 7
Onde T	◯ Normale	◯ Inversée	◯ Hyperkaliémie	◯ Hypokaliémie	◯ biphasique	78	8 8 8 8 8 8
Complexe QRS	◯ Normal	◯ Microvoltage	◯ HVD	◯ HVG	◯ HVD+G	79	9 9 ● 9 9 9
DIAGNOSTIC	◯ Normal	◯ Péricardite/ épanchement	◯ IC G aiguë / OPH	◯ IC Droite / HTAP	◯ Autre (ci-dessous...)	80	
autre Diagnostic	◯ nonSTEMI	◯ STEMI	◯ Amyloïdose	◯ Embolie Po	◯ N/A	81	

Votre matricule

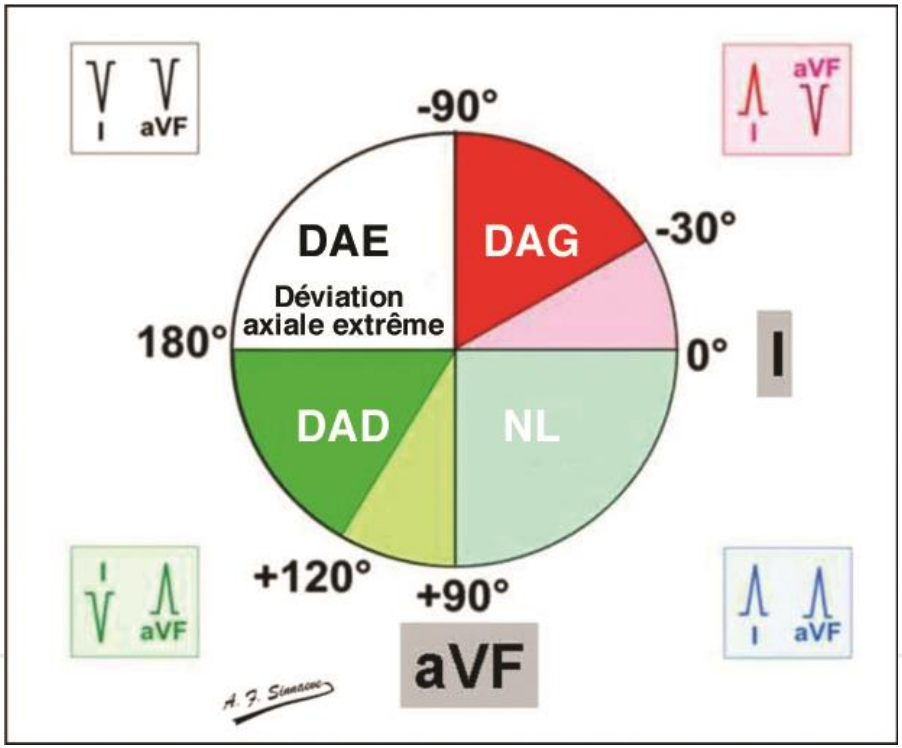
Normal intervals of ECG

- **PR**: [**120 ms à 200 ms]**
  from the beginning of P up to start of QRS
  QRS = Q of R
- **QRS**: **< 100 ms**
  from the beginning of QRS up to the end of QRS
- **QT**: **< 440 ms** avec une fréq. de 60/min.
  from the beginning of QRS up to the end of T
- **RR**: interval between 2 QRS



QRS axis

- Average direction and sense of electrical forces during ventricular depolarization
- Normal axis between - 30°and + 120°
- LAD (left axial deviation) between - 30°and - 90°
- RAD (right axial deviation) between 120° and + 180
- DAE (extreme axial deviation) between -90°and ± 180°.



Le complexe QRS : axe

Quadrant method :

determines the polarity (pos. or neg.) of the QRS complex in deriv. I & aVF

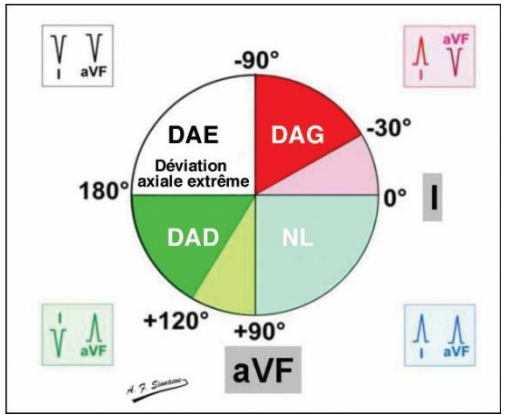
e.g. the axis is normal (bottom right of the quadrant) if the QRS complex is positive in deriv. I & aVF leads

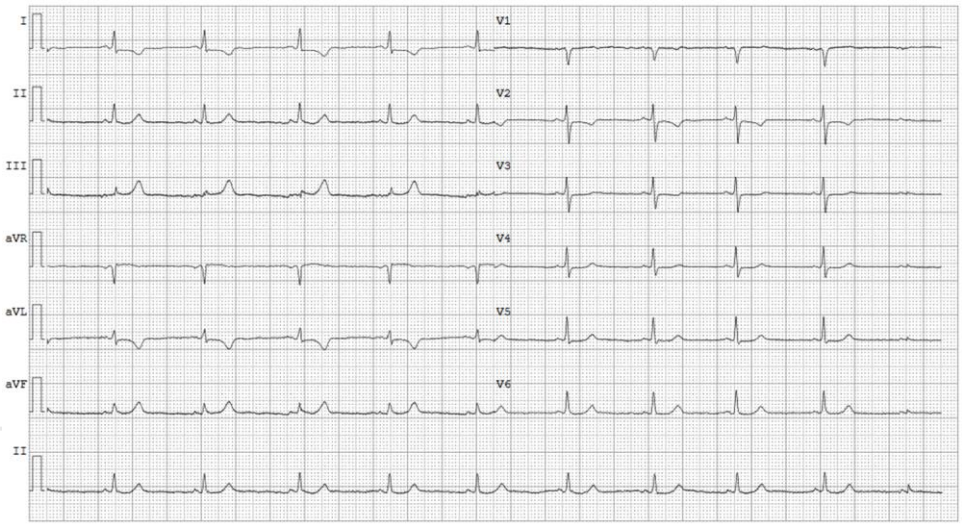
2. Perpendicular method: looks for an equiphasic complex

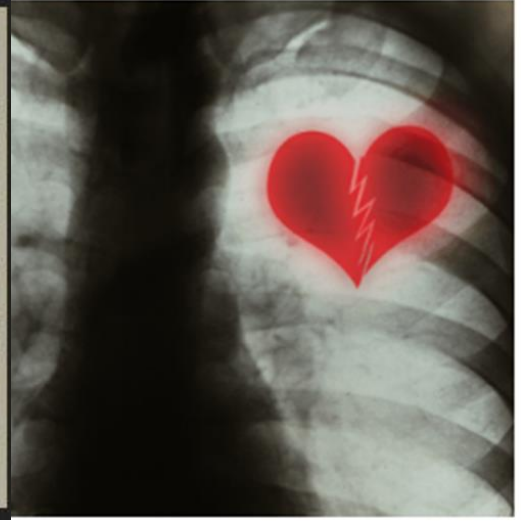
the electrical axis is perpendicular to the lead, with the sum of the positive and negative deflections approximately zero

3. Highest R or lowest S method:

the axis runs parallel to the positive side of the lead with the highest QRS complex







- ~86.400 heart beats / day

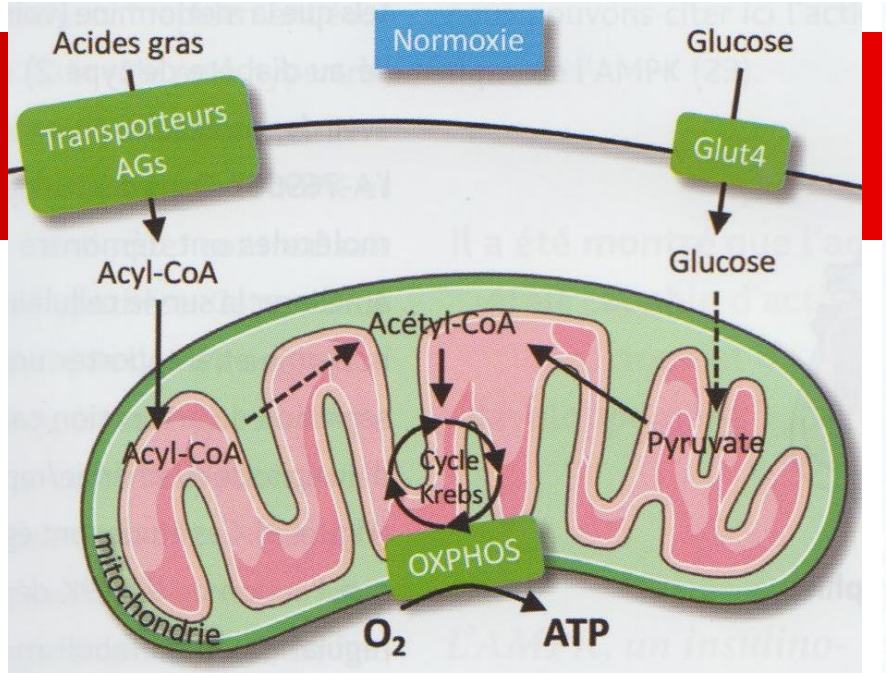
  ~31.536.000 x / 1 year

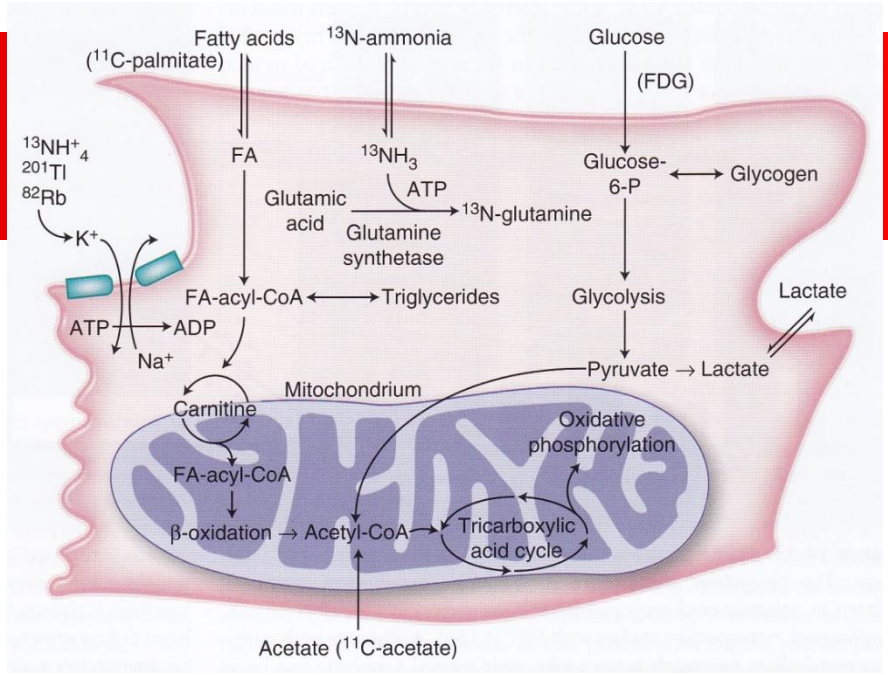
  1 billion in ~32 years
- Stroke volume: 80 ml
- 60 times / minute → 4800 ml ~ 5 liters

  x60 x24 → 1440 x 5 kg ~ 7 tons /day

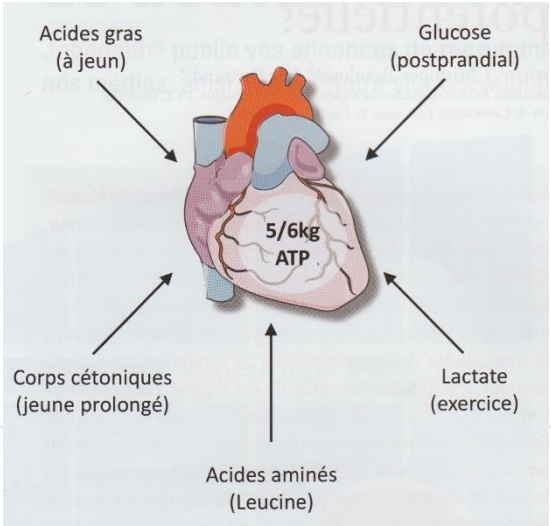
Needs ~6 kg of ATP and weight only 300 gr

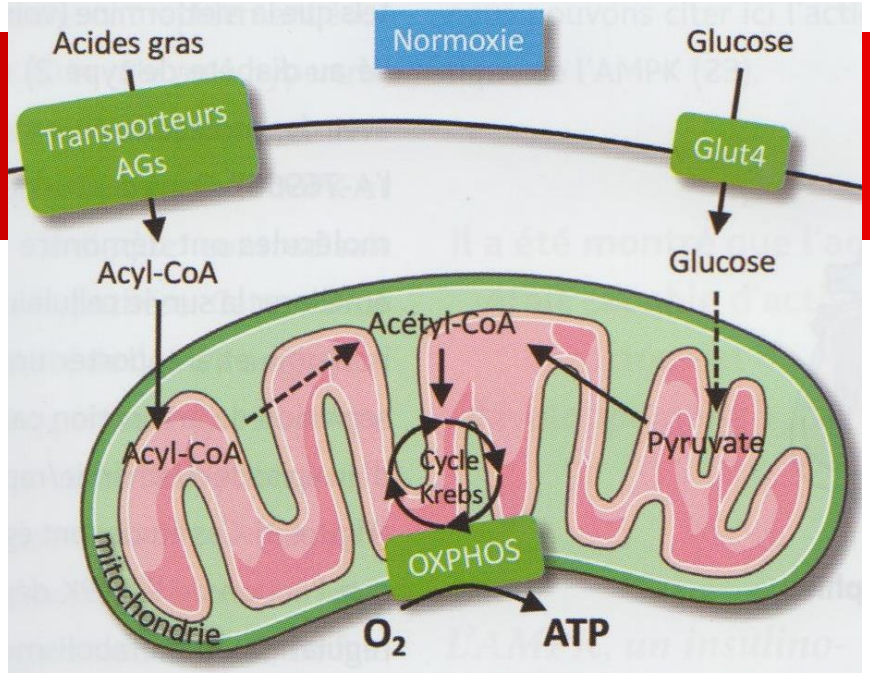
→ metabolic challenge

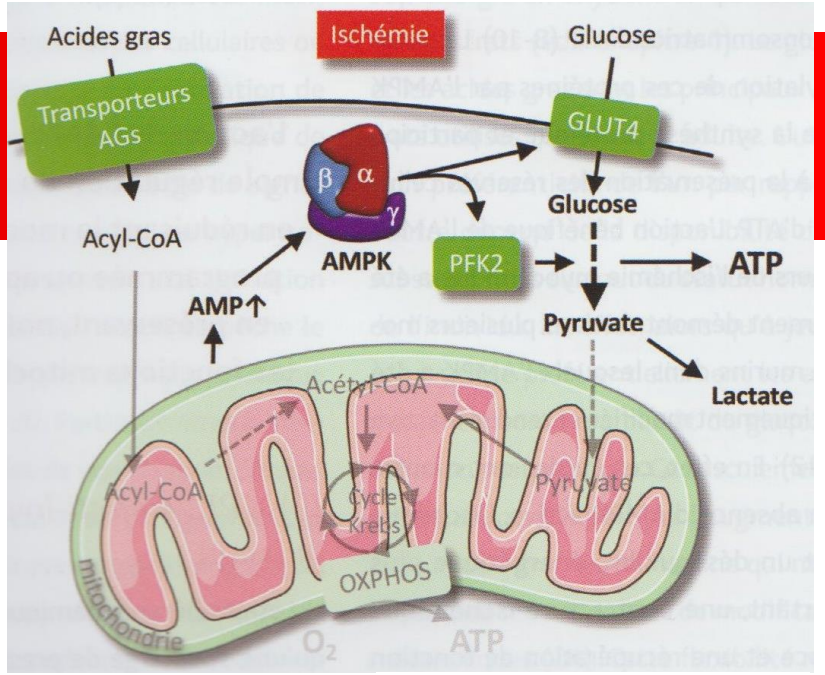




Cardiac contraction requires a lot of ATP, produced by mitochondrial oxidative metabolism using fatty acids (60%), lactates (18%), glucose (16%) and certain amino acids and ketone bodies (6%).Oxygen consumption is high.





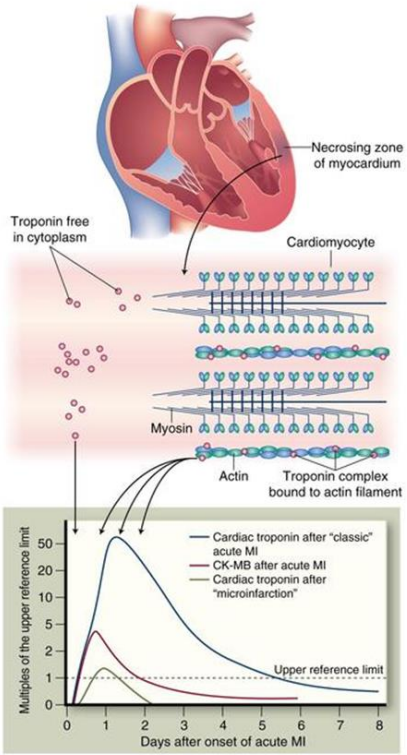


ISCHEMIA = reduction / interruption of oxygen supply

→ mitochondria stop producing ATP

ATP production only by anaerobic glycolysis
→ significantly lower yield (1/18)
→ accumulation of lactate and ↓ ATP and ↑ AMP

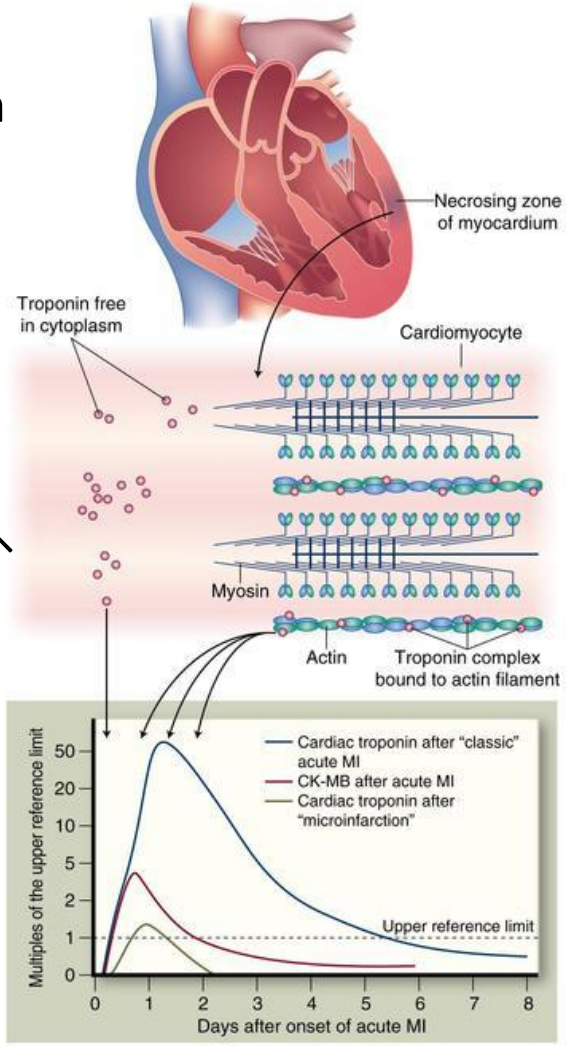
Myocardial necrosis→ release of troponin, CK-MB,...



Consequences of ischemia

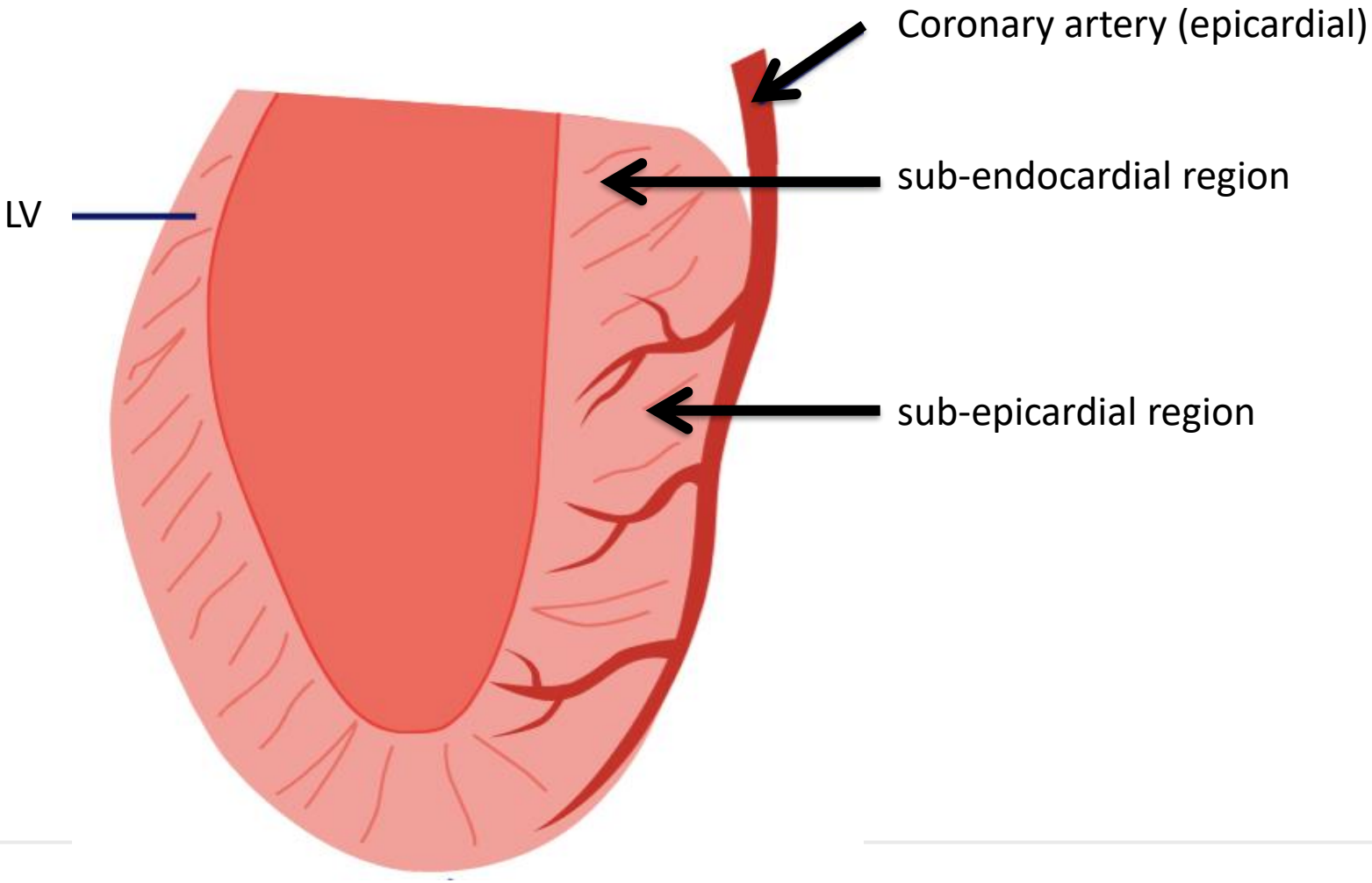
Ischemia = **lack of oxygen et energetic substrates**

- ↓oxidative metabolism and aerobic ATP production with blocking of the Krebs cycle
- anaerobic glycolysis with lactate production
- acidification of the intracellular environment and ↓ ATP synthesis with ↑ membrane permeability
- cytoplasmatic leakage of LDH (lactate dehydrogenase), CK (creatine kinase), troponin
- ELECTRIC PERTURBATIONS with ↑ extracellular K, ↑ lactate, ↑ CO2 and H+
- → PERMANENT DEPOLARISATION
- → electrical current between the injured area (subendocardial) and the normal area (subepicardial)



Ischemia and lesion

Subendocardial regions are more sensitive to ischaemia than subepicardial regions



Ischemia and lesion

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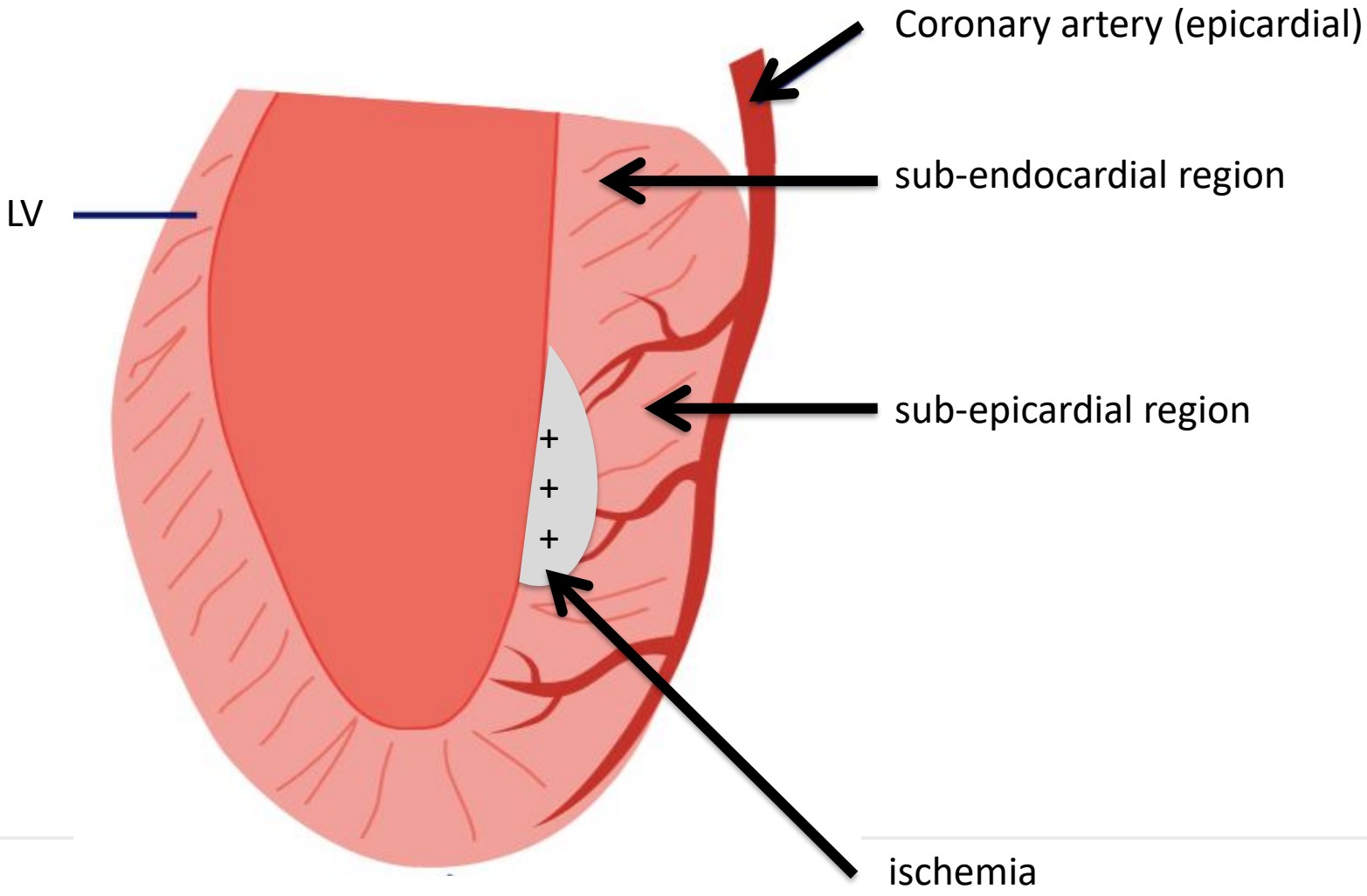
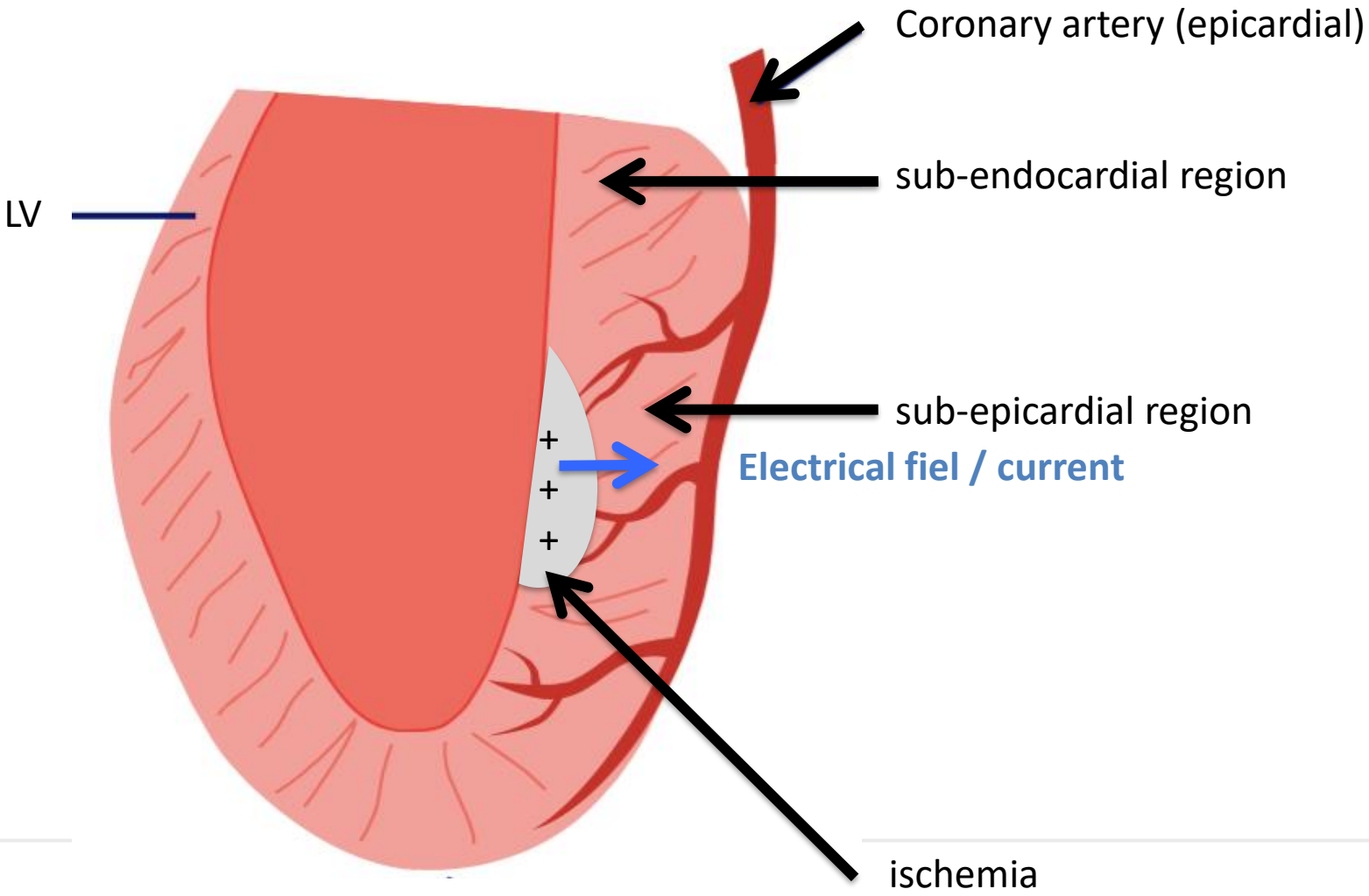
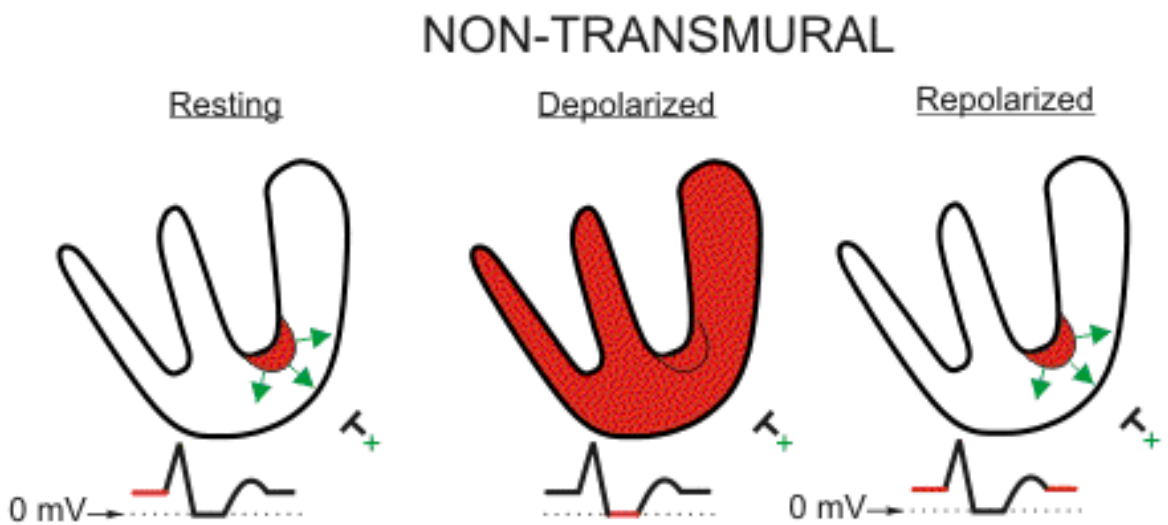


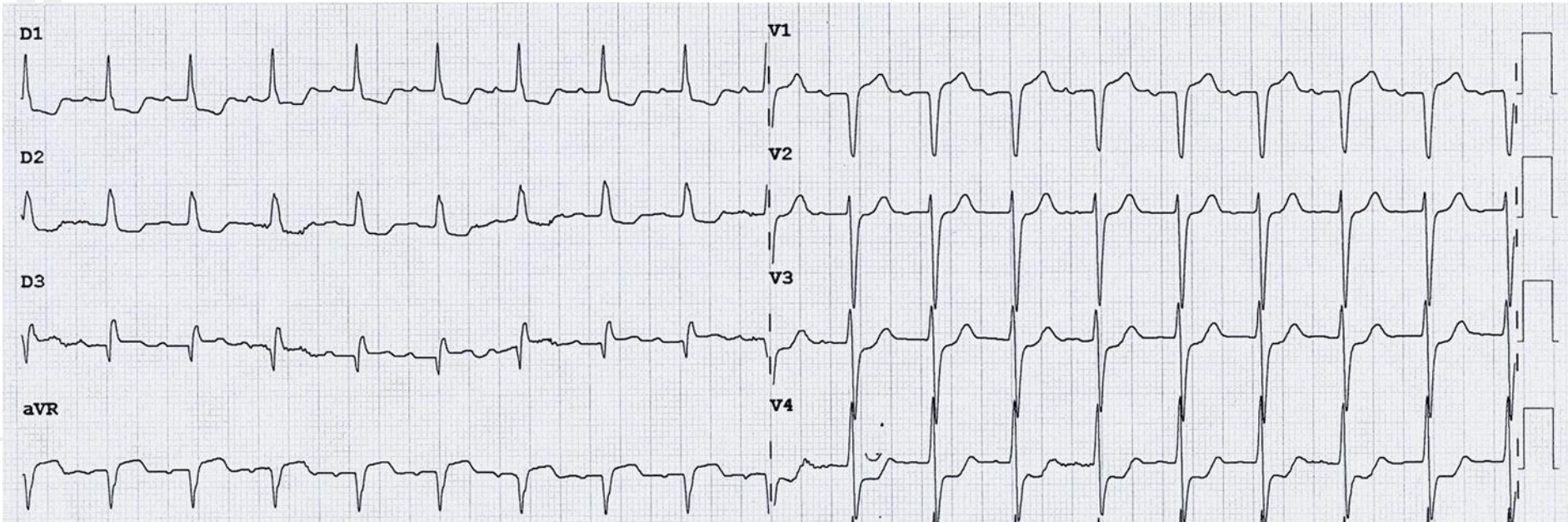
Ischemia and lesion

Subendocardial regions are more sensitive to ischaemia than subepicardial regions

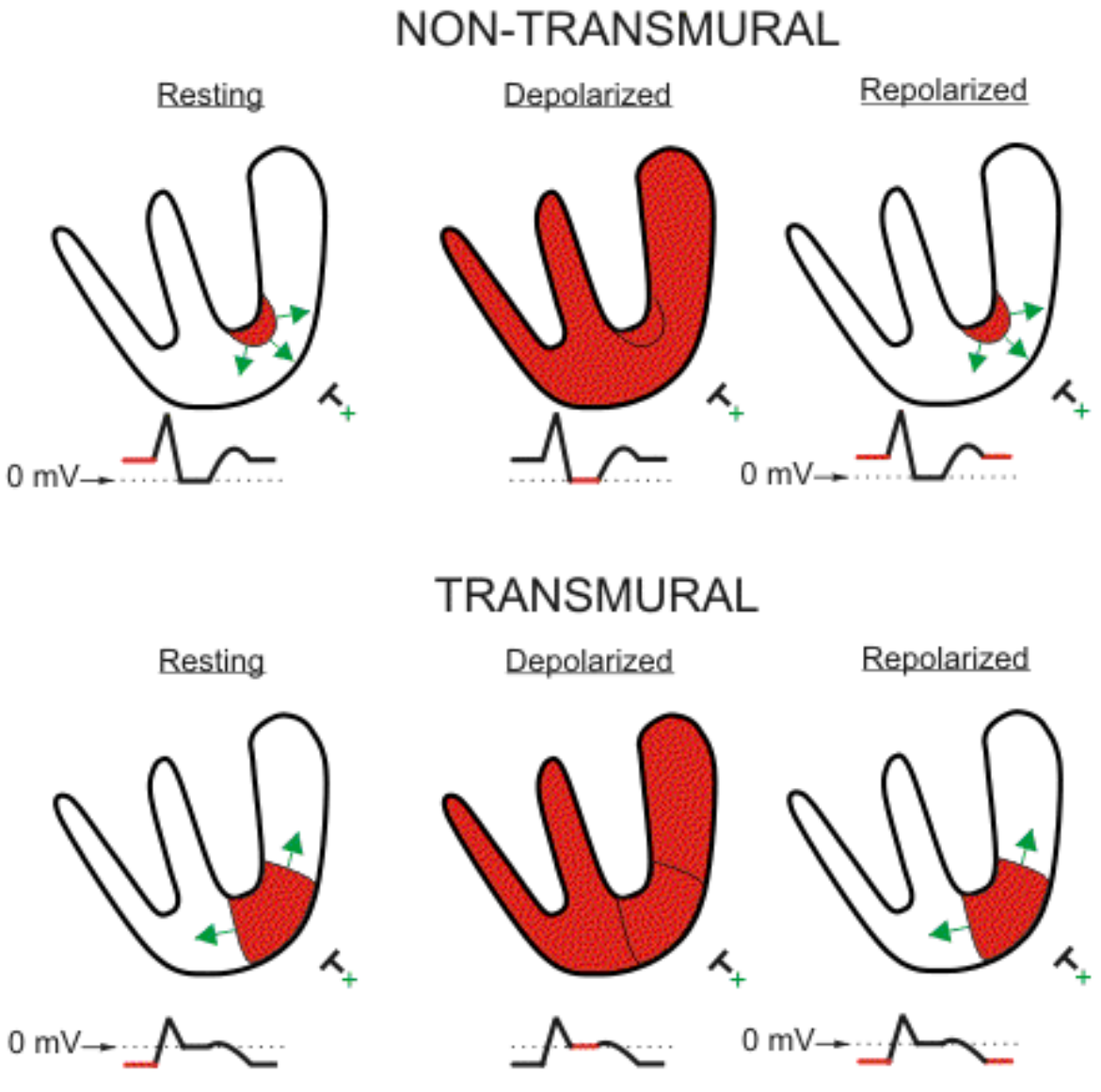


Ischemia-lesion and ST segment

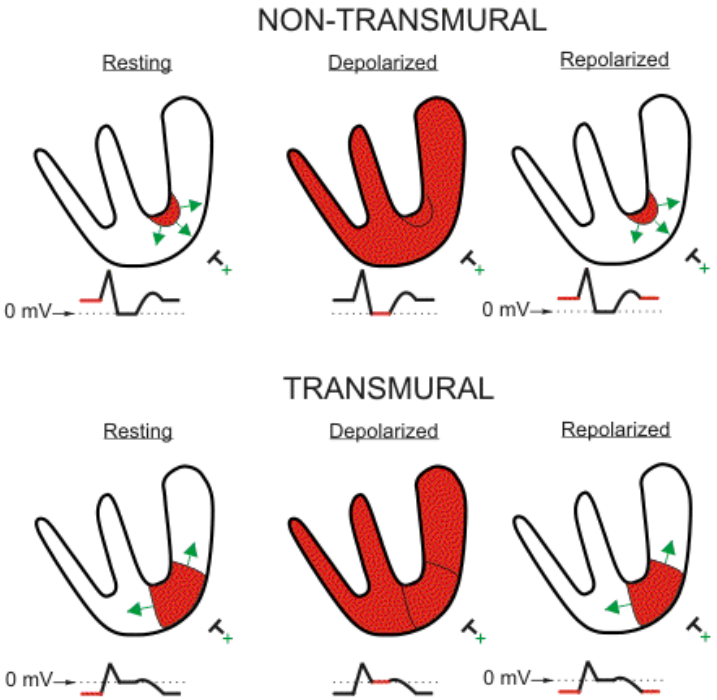


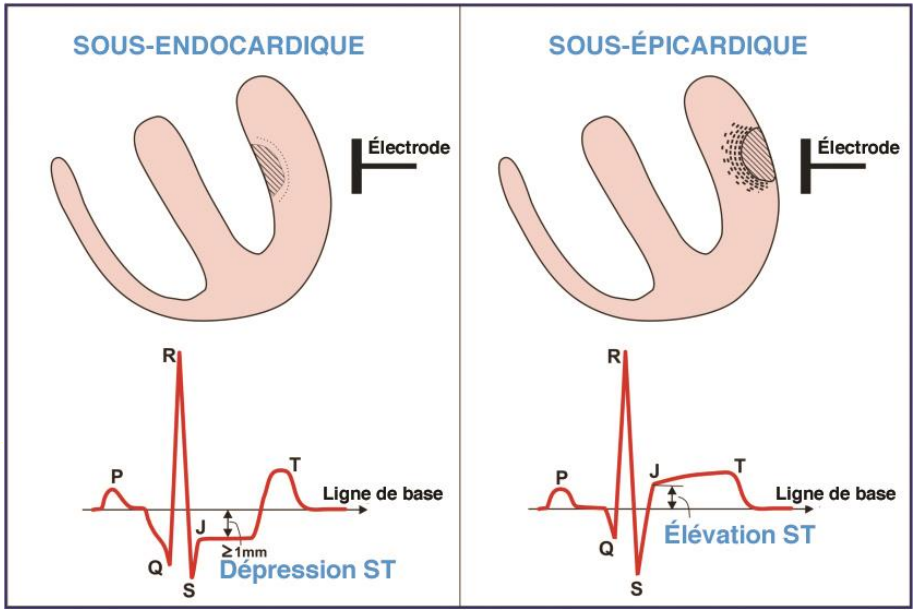


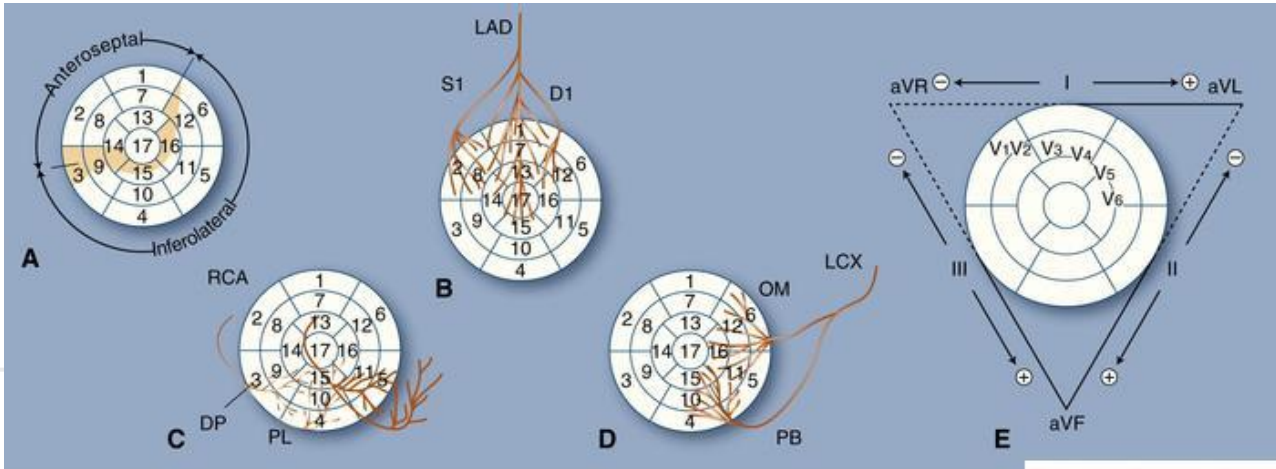
Ischemia-lesion and ST segment



Ischemia-lesion and ST segment







Diagnostic Tools in Cardiology

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2. **Stress test**
3. Holter ECG or BP
4. Tilt test
5. Chest X-ray
6. Echocardiography
7. Myocardial scintigraphy
8. Coronary CT scan
9. Cardiac magnetic resonance
10. Coronary angiography & Catheterization

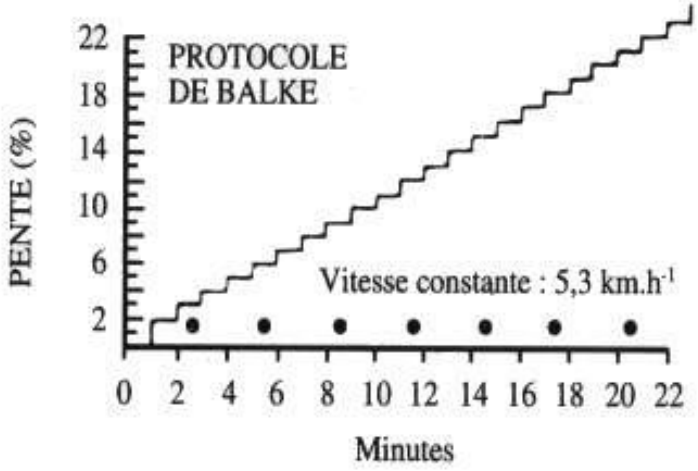
Exercise test

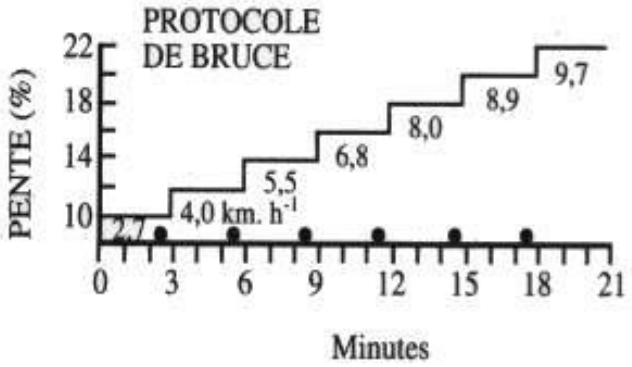
Exercise test

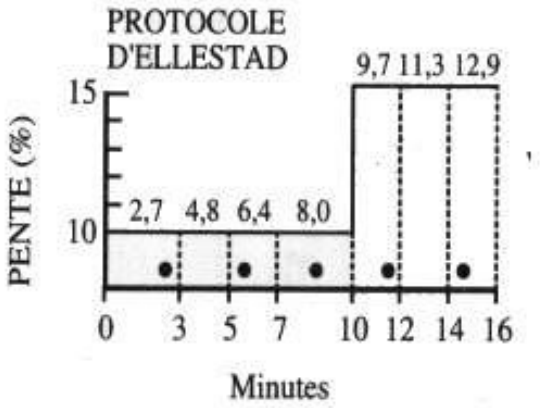
✓ ***Modality***

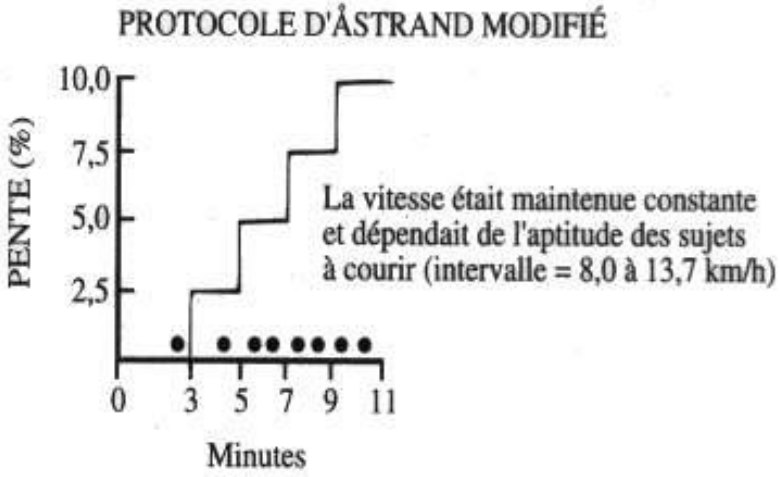
- *On treadmill or cycle ergometer*
- *ECG and BP at rest*
- *Increasing effort by increasing speed and gradient in stages every 3 minutes (BRUCE protocol)*
- *Continuous monitoring of clinical data: chest pain, dyspnea, fatigue, etc.*
- *BP measurement at each level*
- *ECG monitoring: ST changes, rhythm disorders*

Exercise test









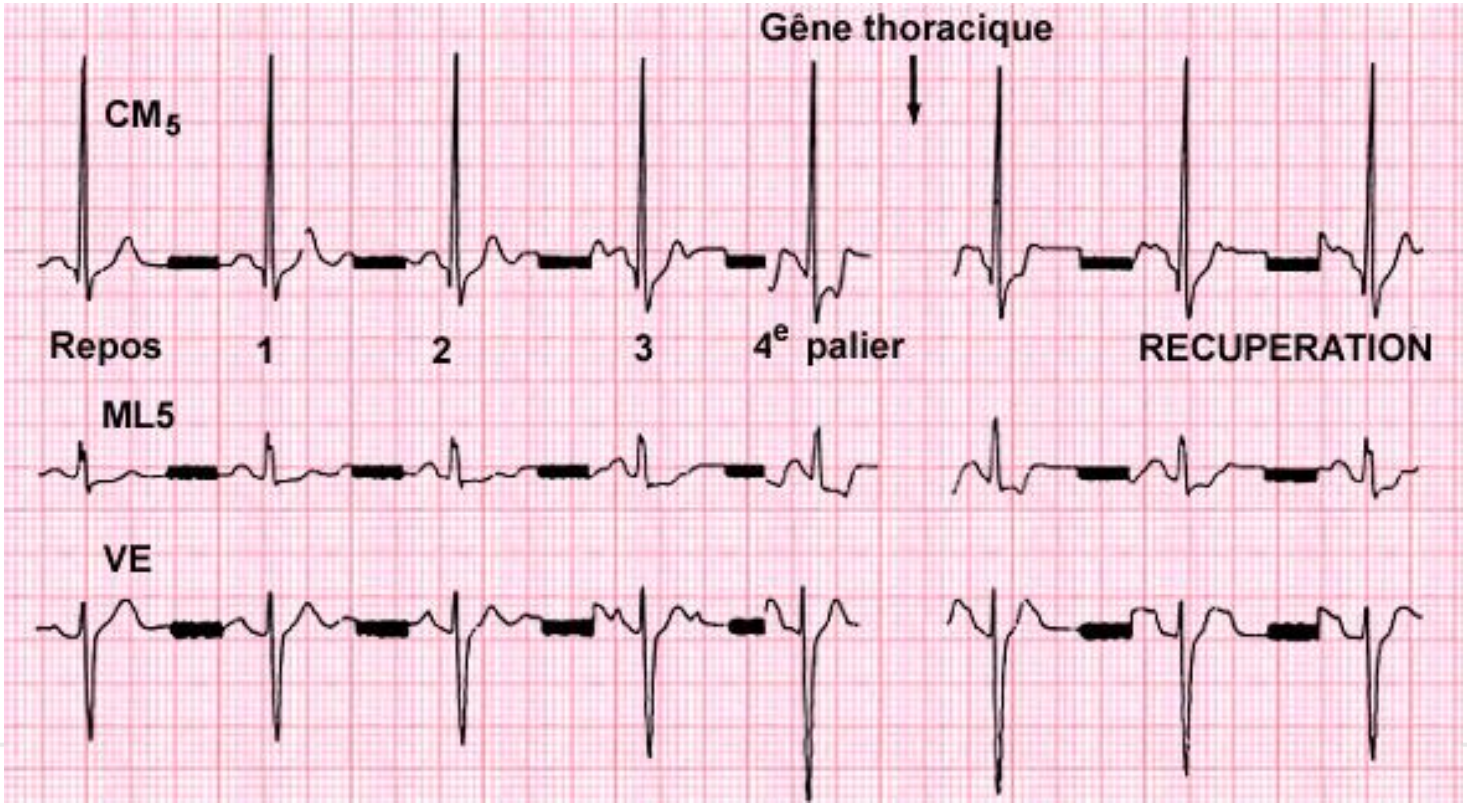
Epreuves d'effort

Exercise test

✓ *Criteria:*

- ***Electrical criteria for positivity:***

Horizontal or descending ST offset > 1mm and > 0.08 s



Exercise test

- ***The maximum frequency reached as a % of the theoretical maximum frequency for the age (FMT=220-age)***
- ***The maximum load and duration of the test***
- ***Clinical signs: angina, fatigue, dyspnea***
- ***Blood pressure profile during exercise***
- ***Presence or absence of rhythmic or conductive disorders.***

J point & ST segment

J point

Located at the end of the QRS complex

(i.e. at the end of S or R)

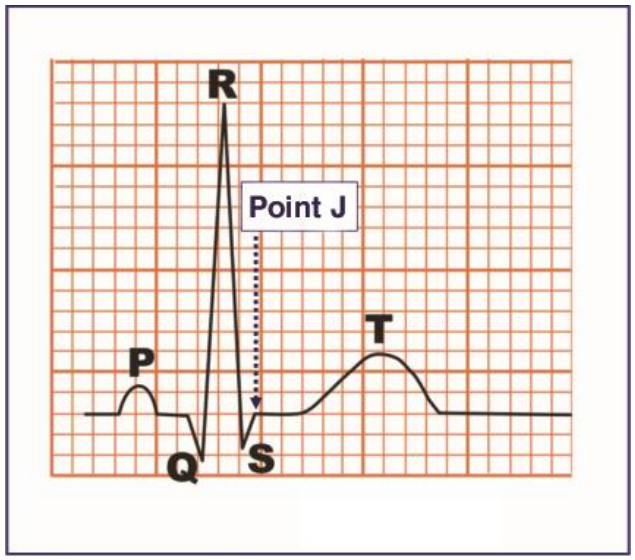
Normally located on the isoelectric line

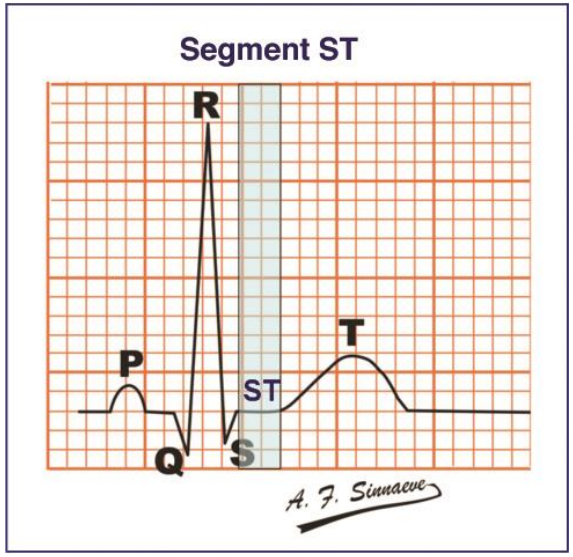
Starting point of the ST segment

ST segment

From point J to the start of the T wave

Normally isoelectric

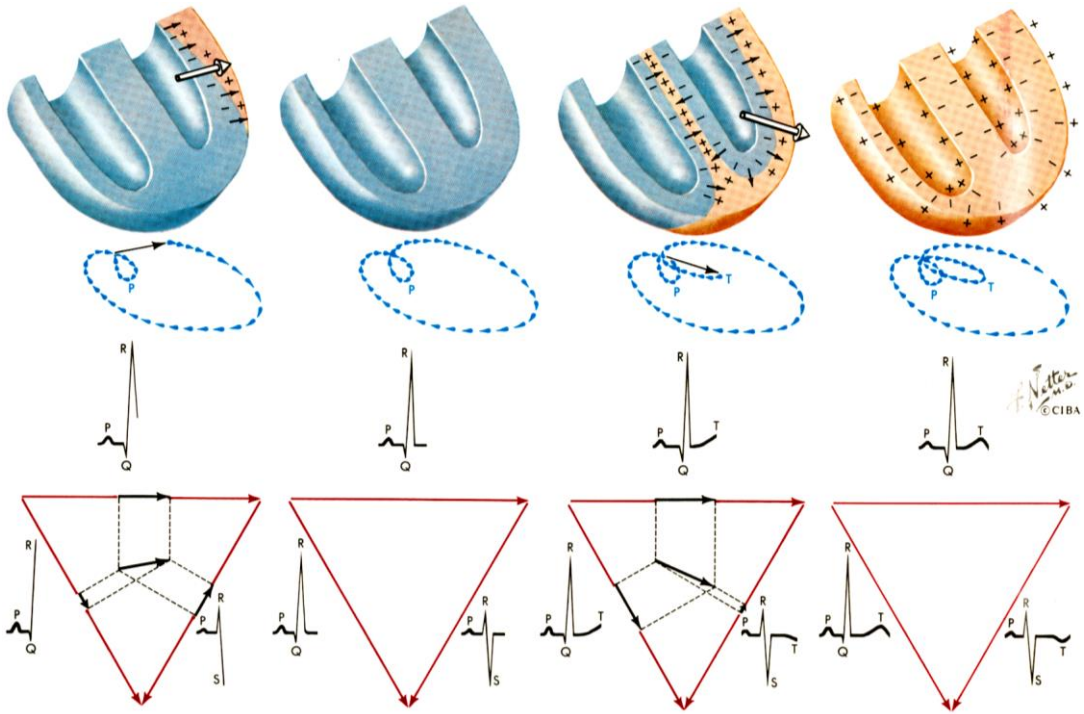




Normal T wave

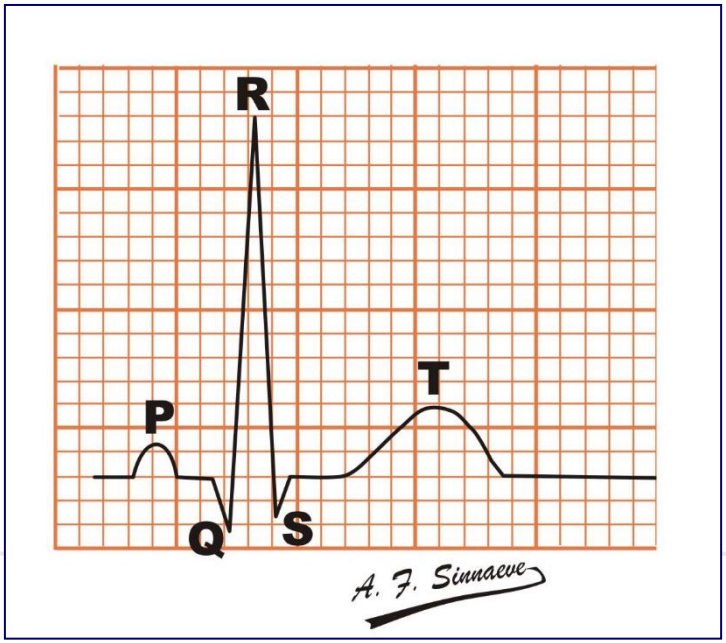
- The T wave has the same axis as the QRS because repolarisation begins in the epicardium and progresses towards the endocardium

→ same electrical vector



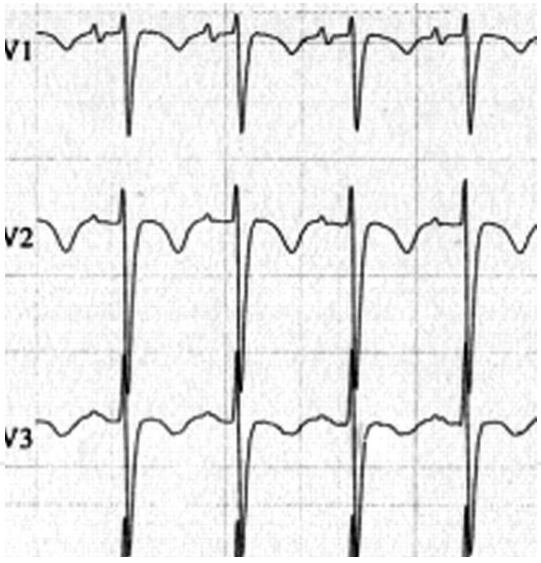
Abnormal T waves

- L'onde T : correspond à la repolarisation des ventricules
- Est une déflexion pos., nég. ou biphasique
- A généralement une polarité identique à celle du complexe QRS, sauf dans les dériv. V1-V2 & III
- Est asymétrique et présente une portion ascendante lente et une portion descendante rapide
- Amplitude : max. 5 mm dans les dériv. périphériques
- Amplitude : max. 10 mm dans les dériv. précordiales

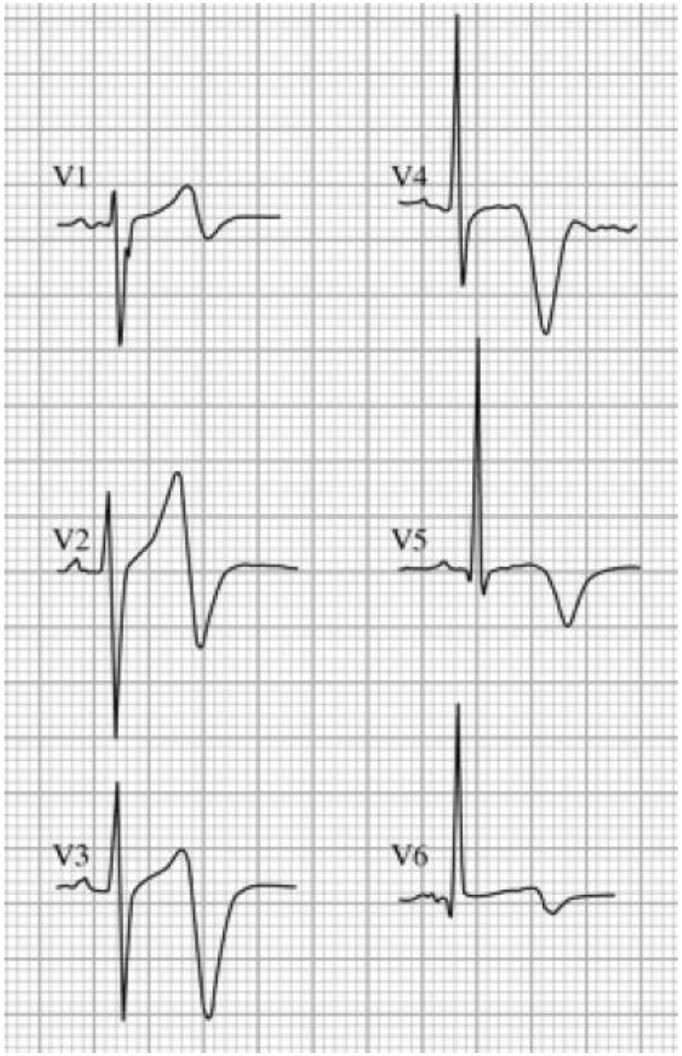


Negative T waves

- Variant of normal (young people, women)
- During or after BB, WPW, pacing, ectopic rhythm (escape, tachycardia,...)
- Left ventricular hypertrophy (especially if apical hypertrophy)
- Subendocardial ischaemia (during pain)
- Wellens syndrome type" ischaemia (critical stenosis of the proximal LAD)
- After subepicardial ischaemia
- Aspecific repolarisation disorders (sequelae of infarction)
- Acute pulmonary embolism
- Arrhythmogenic right ventricular cardiomyopathy (ARVC)
- Increased intracranial pressure



Ischemic T waves

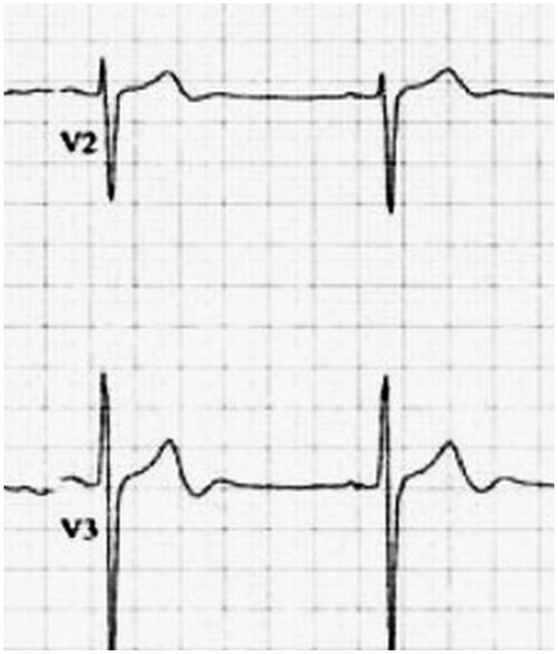


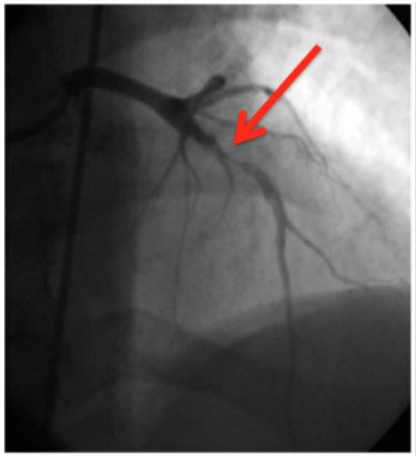
Biphasic T waves in V2 V3 V4 V5

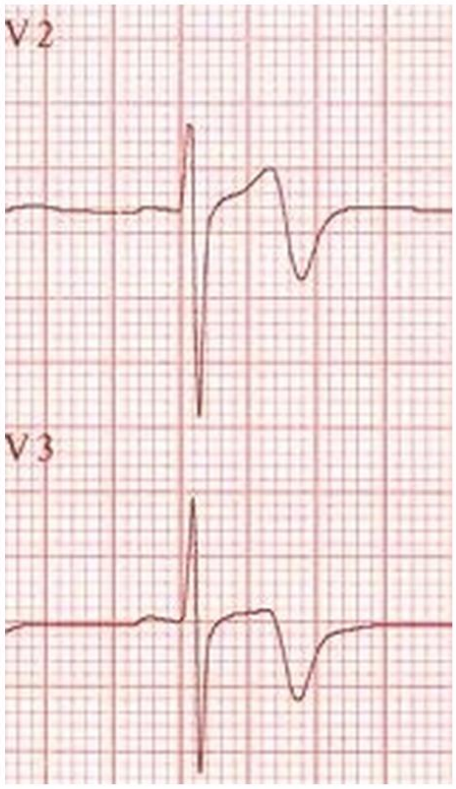
Anterior Ischemia < critical proximal stenosis

= **Wellens Syndrome**

Wellens Syndrome







Type II (25%): biphasic T, - at the end

Exercise test

✓ *Indications*

The main indications are:

screening for or monitoring coronary pathology

monitoring the functional capacity of chronic heart failure

Patients investigation of rhythmic disorders during exercise

Assessment of severe asymptomatic valvular heart disease

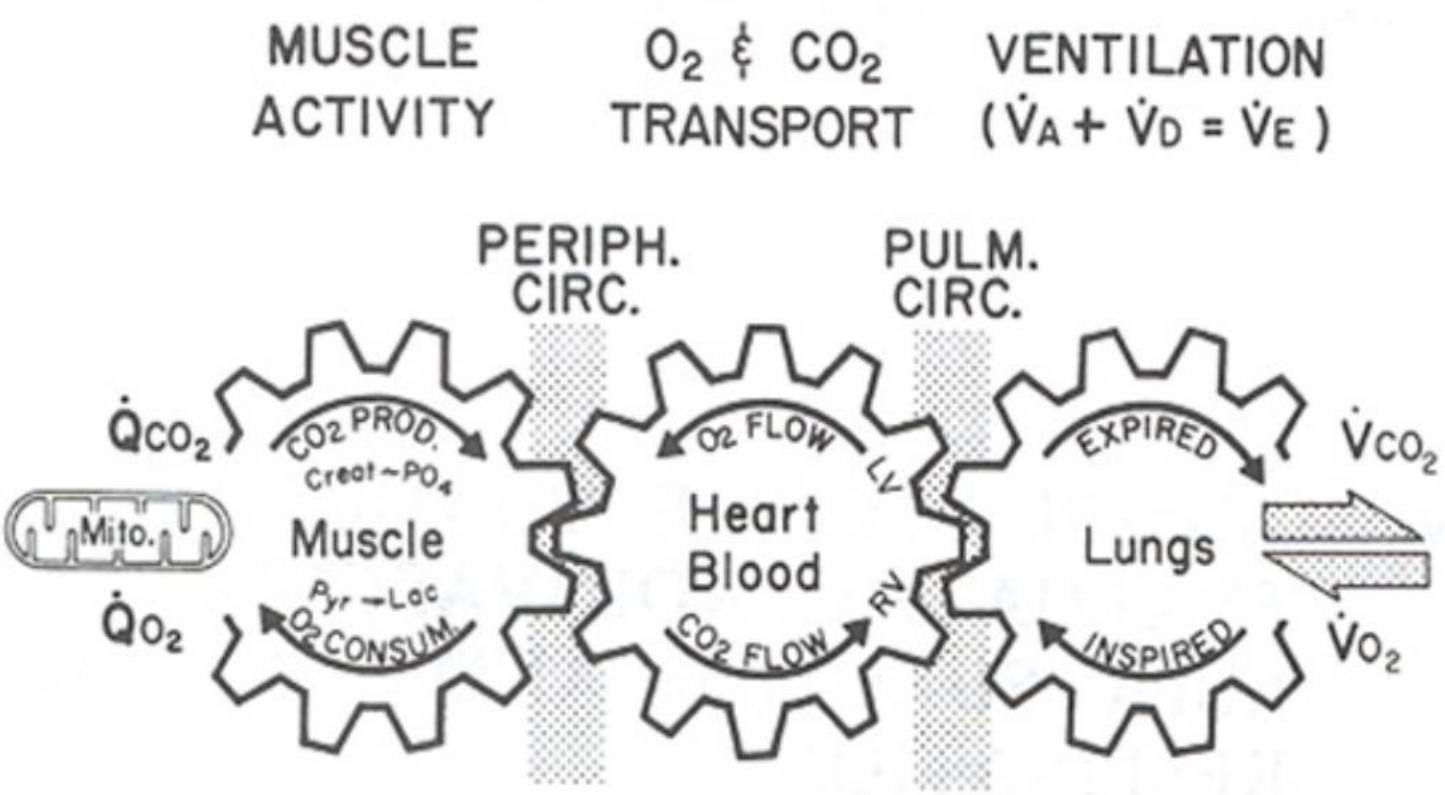
Assessment before and after cardiovascular rehabilitation

Exercise test

✓ *Contra-indications*

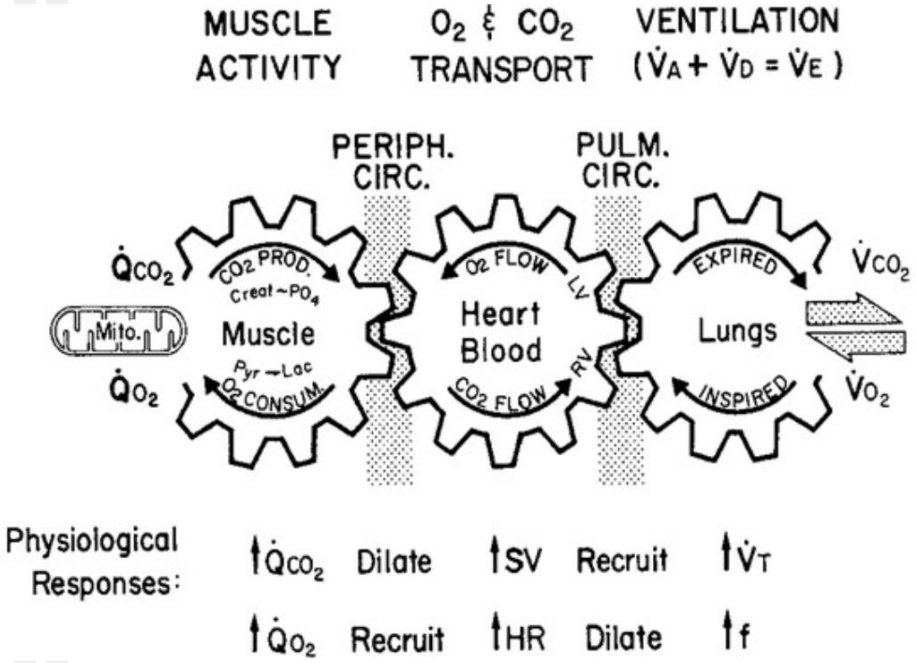
- *Acute phase of myocardial infarction*
- *Unstable angina*
- *Severe uncontrolled rhythm disorders*
- *Symptomatic aortic stenosis*
- *Uncontrolled heart failure*
- *Pulmonary embolism*
- *Ongoing phlebitis*
- *Ongoing pericarditis, myocarditis, endocarditis*
- *Aortic dissection*
- *Patient refusal*

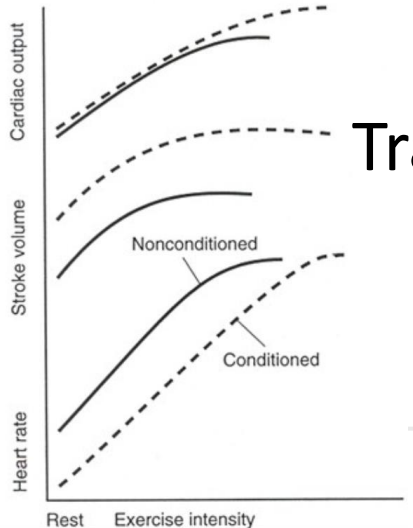
ERGOSPIROMETRY



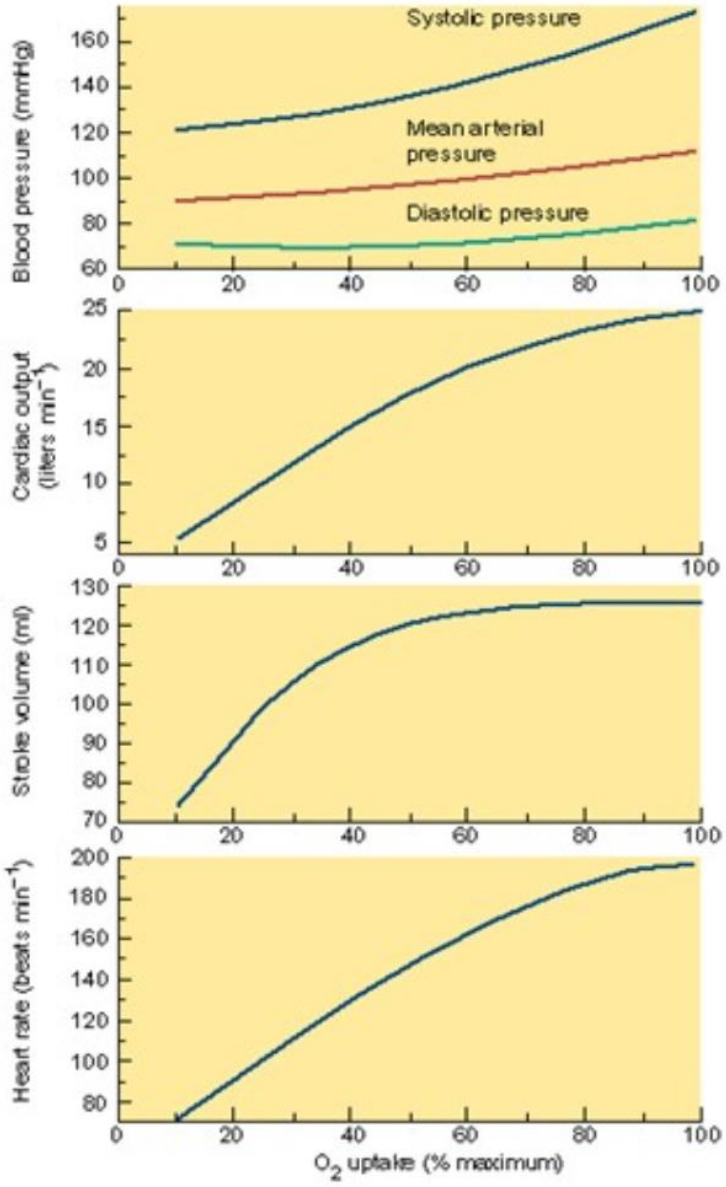
V_{CO^2} et V_{O^2} measured during exercise

ERGOSPIROMETRY

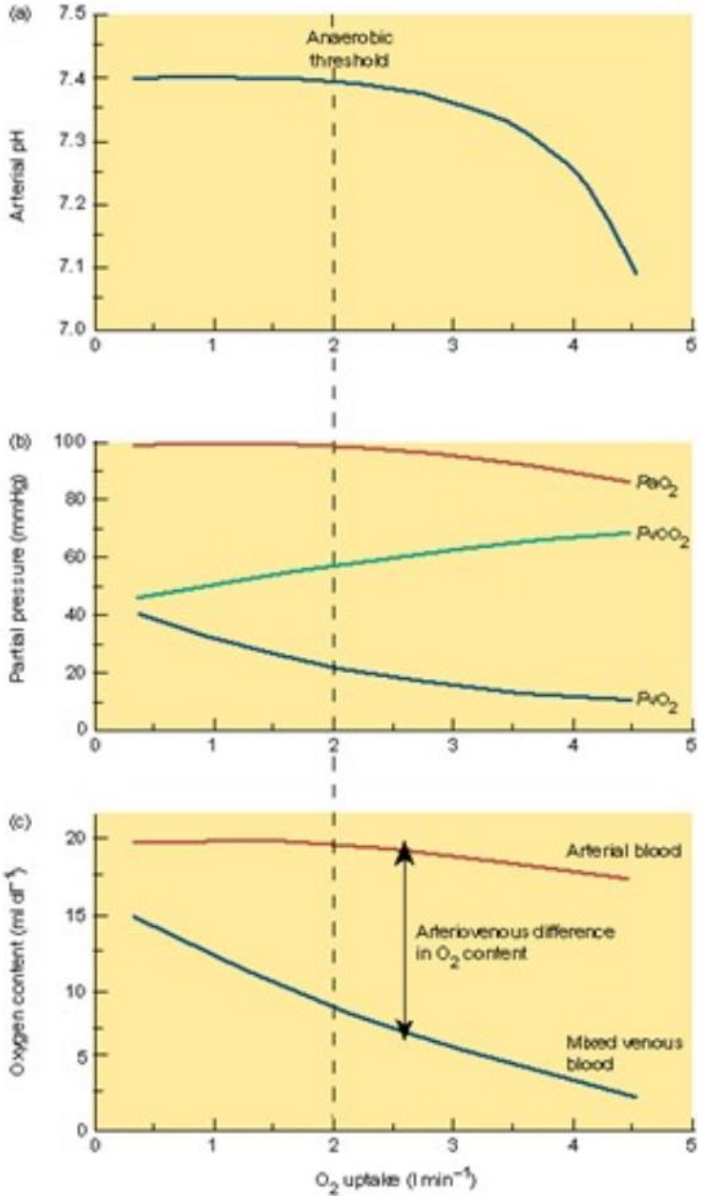


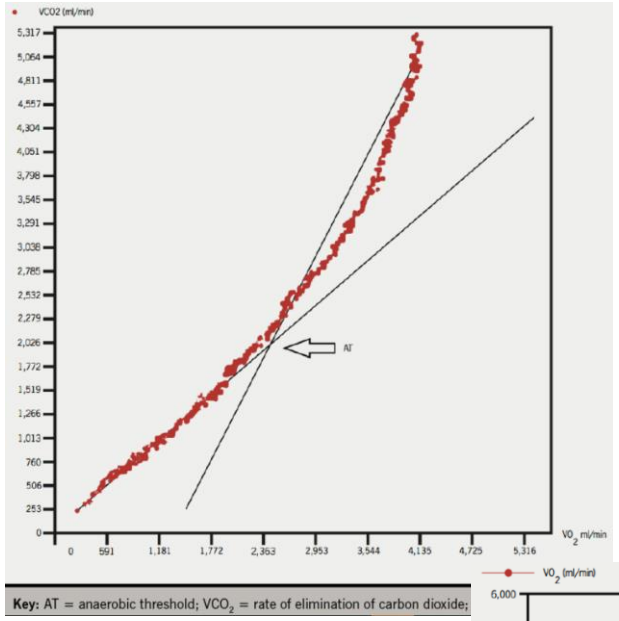


Training effect



ERGOSPIROMETRY
anaerobic threshold

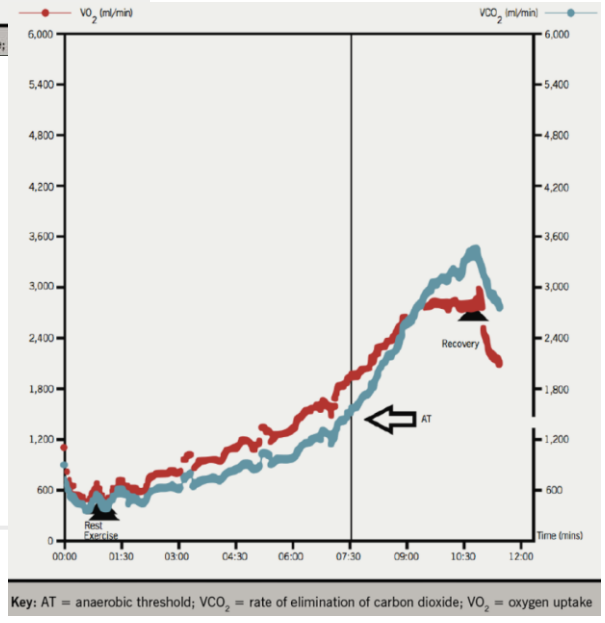




normal:

47-64% VO² max

> 60% sportman



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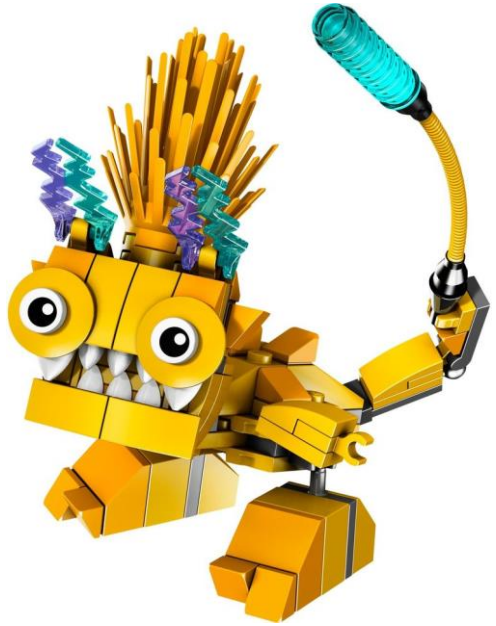


Holter: 24 hour recordings

RESULTATS (Tous)

FREQUENCE CARDIAQUE : (Nombre total de QRS : 87918) (Temps Heure : 22:8)

Moyenne : 66 bpm
Jour (08:00 - 21:00) : 74 bpm
Nuit (23:00 - 06:00) : 54 bpm

FC Max : 125 bpm à (1)17:58:29
FC Min : 33 bpm à (1)00:28:06

RR Max : 1940 ms à (1)00:28:06
RR Min : 470 ms à (1)18:11:44

BRADYCARDIE : 117
Durée totale : (1)00:39:30 (2.7%)
1/ à (1)06:26:42 : 35bpm (1)00:00:51
2/ à (1)05:45:33 : 35bpm (1)00:01:37
3/ à (1)05:00:55 : 35bpm (1)00:00:33

PAUSES : 0

PERIODES LONGUES : 27
1/ à (1)00:28:06 RR = 1940ms
2/ à (1)01:16:01 RR = 1845ms
3/ à (1)00:56:00 RR = 1775ms

EVENEMENTS VENTRICULAIRES :

EXTRASYSTOLES :
Isolées : 1365 1.6 %
Doublets : 9 0.0 %
Salves : 0 0.0 %
Total : 1383

BI & TRIGEMIN. : 0 & 2
Durée totale : (1)00:00:14
1/ à (1)17:52:39 : Durée : (1)00:00:08
2/ à (1)18:20:23 : Durée : (1)00:00:06

TACHYCARDIE : 0

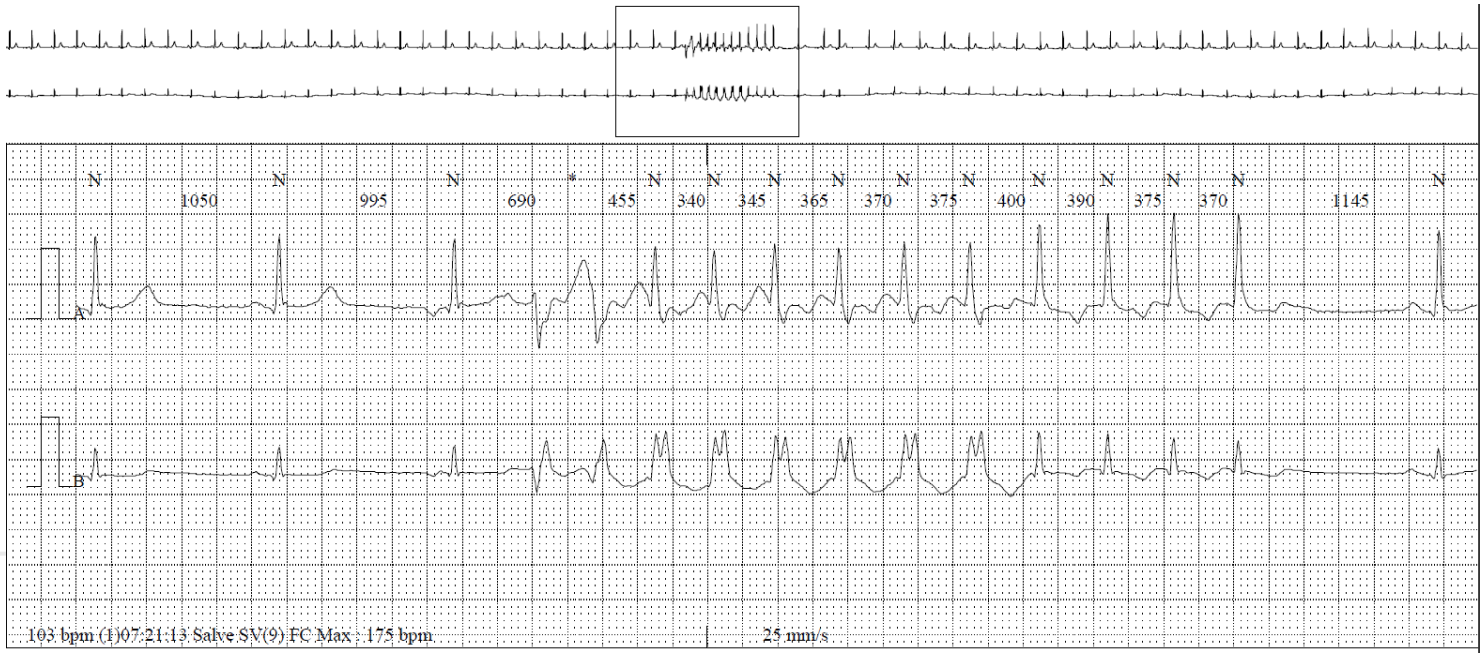
EVENEMENTS SUPRAVENTRICULAIRES :

EXTRASYSTOLES :
Isolées : 1394 1.6 %
Doublets : 0 0.0 %
Salves : 0 0.0 %
Total : 1394

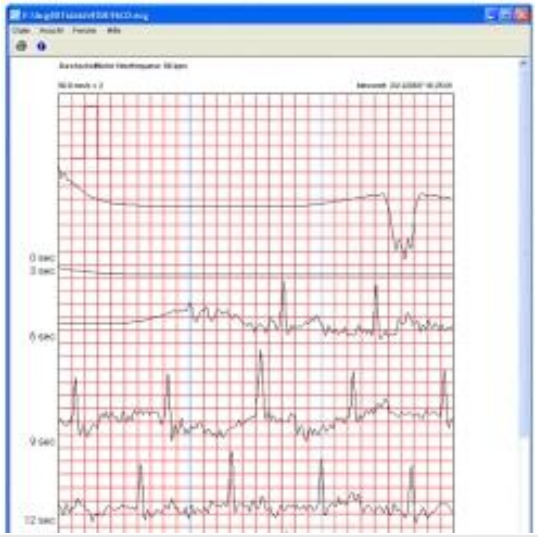
BI & TRIGEMIN. : 2 & 0
Durée totale : (1)00:00:11
1/ à (1)08:34:16 : Durée : (1)00:00:07
2/ à (1)08:34:29 : Durée : (1)00:00:04

Holter Monitor

Holter: Counting and Detecting Arrythmias



Alternative tools



Implantable Holters

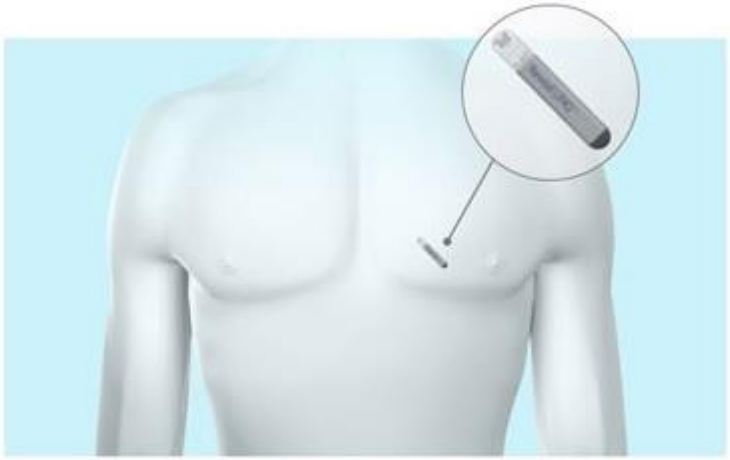
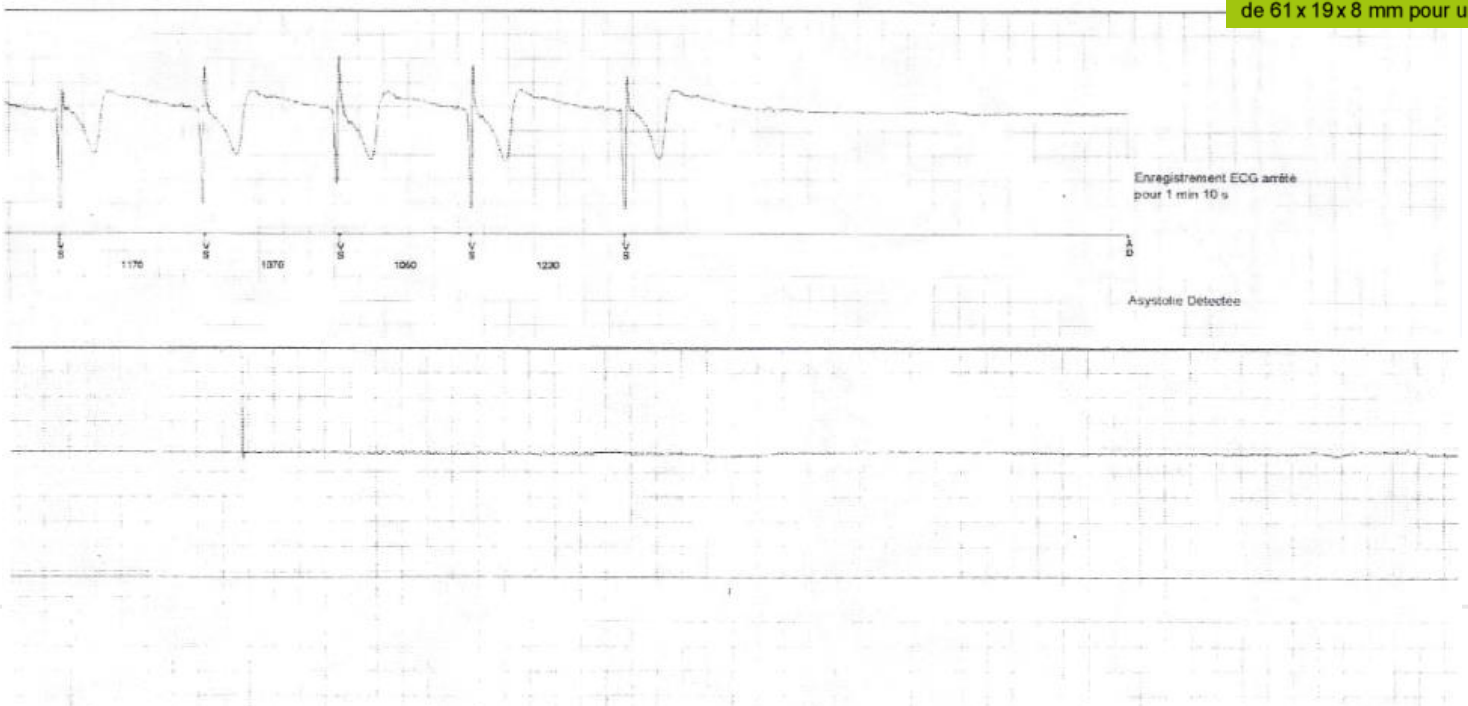
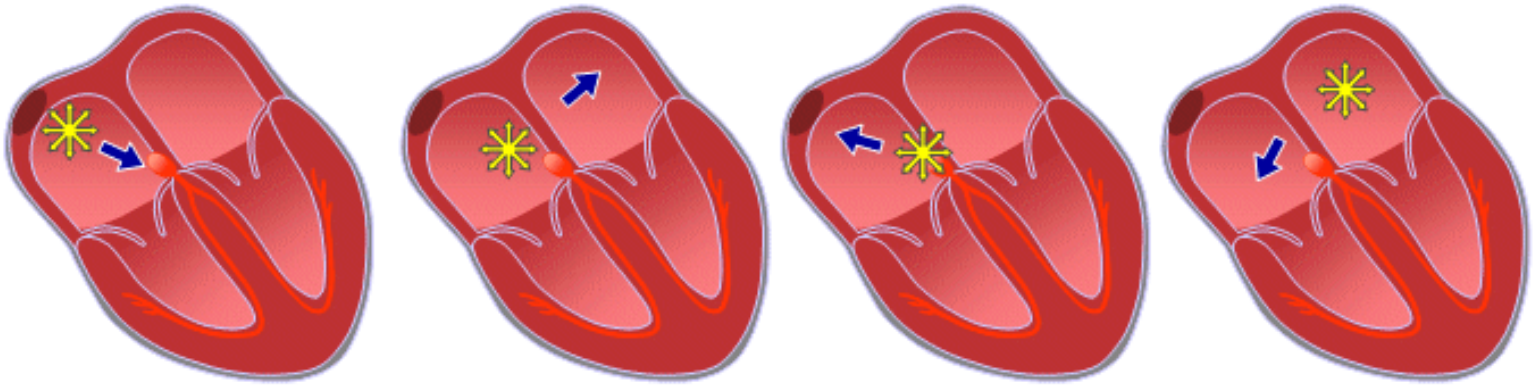


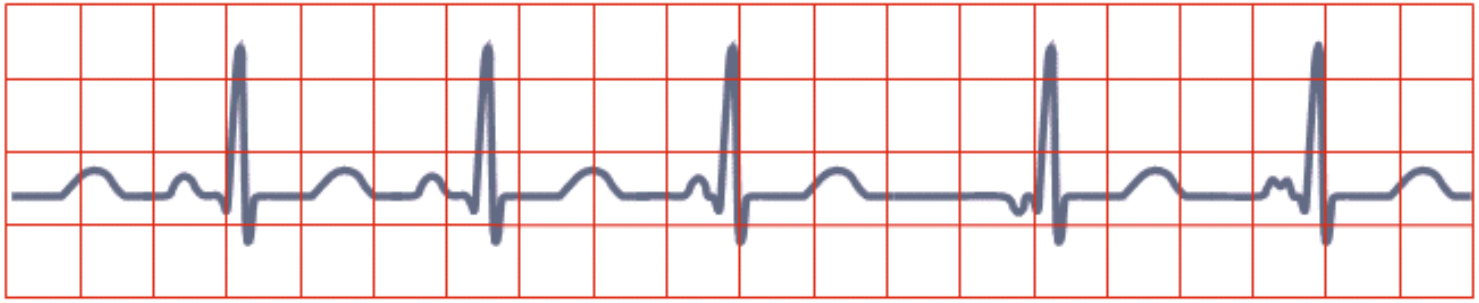
Figure 1. Photo représentant un moniteur ECG implantable (Reveal Plus, Medtronic) d'une dimension de 61 x 19 x 8 mm pour un poids de 17 g



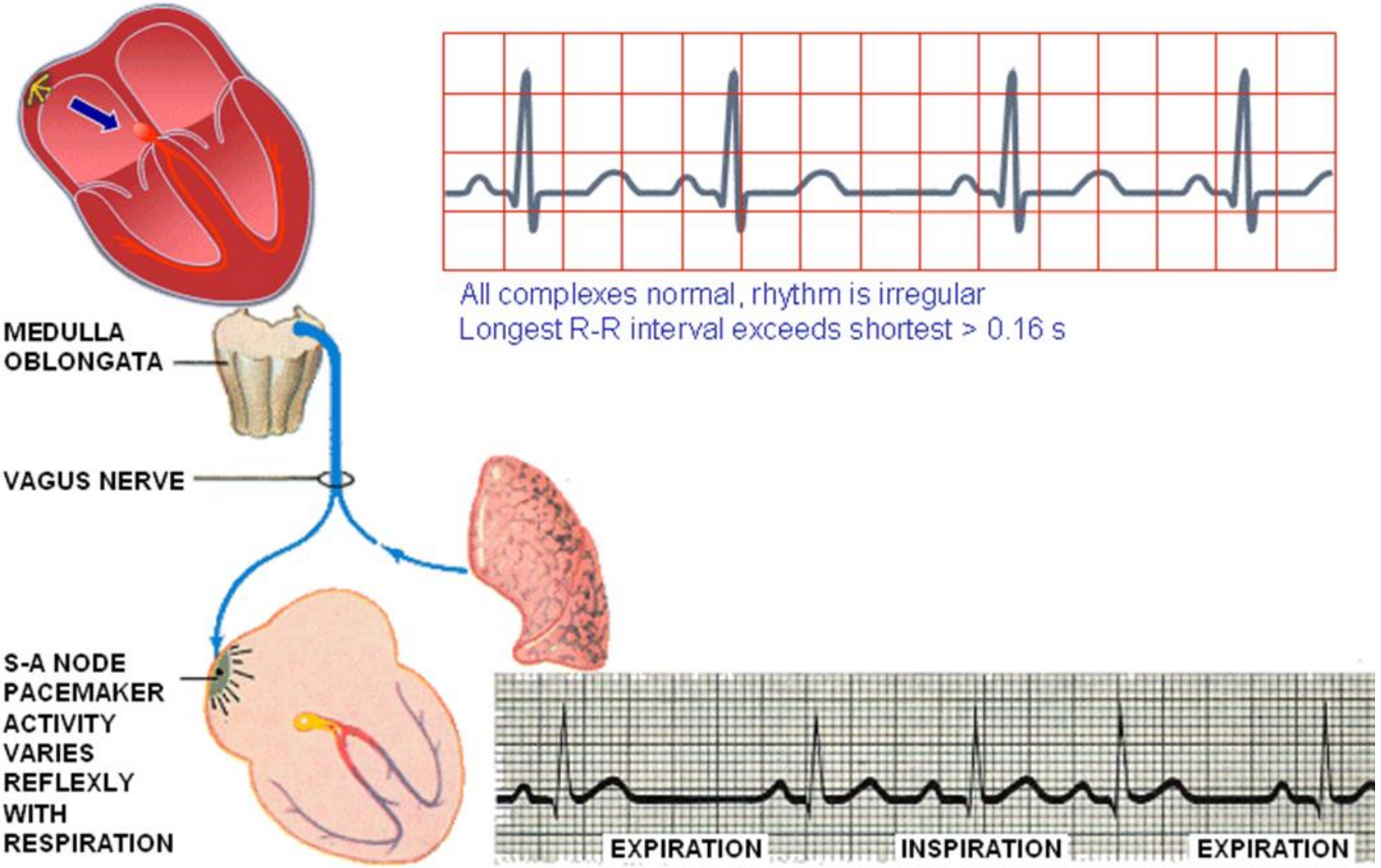
Abnormal P waves

SVES: Supra Ventricular ExtraSystole

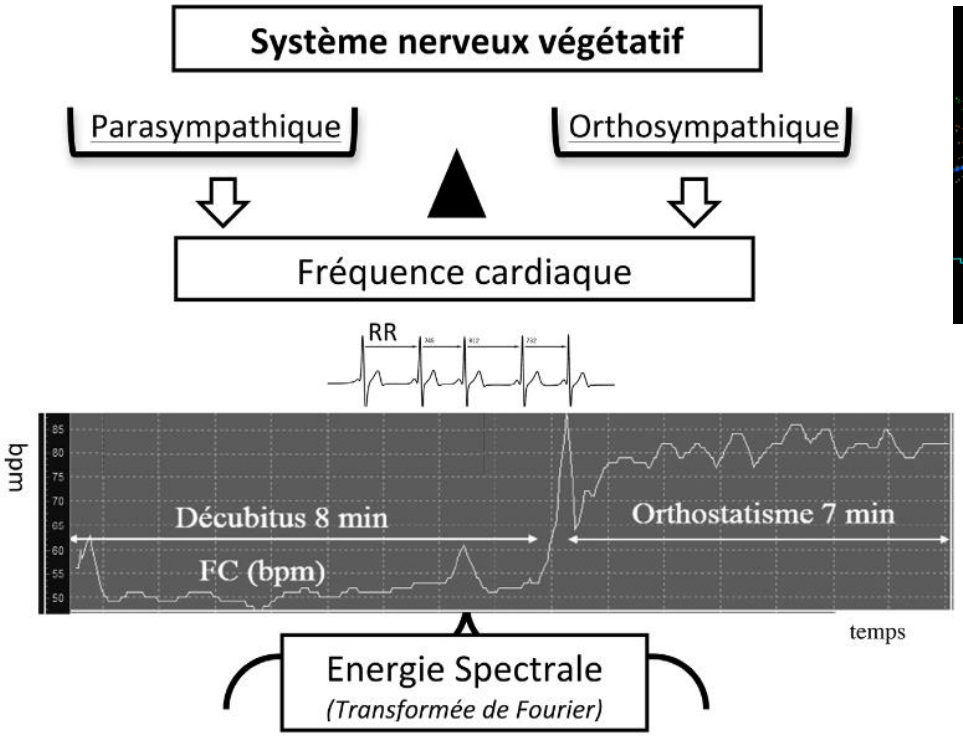


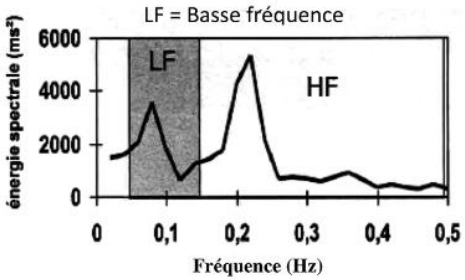


Sinus arrhytmia

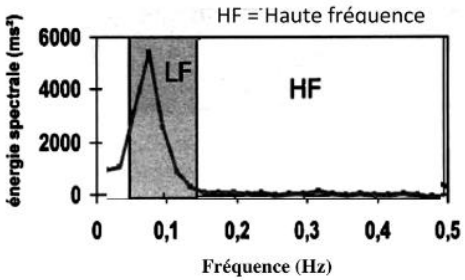


Heart Rate Variability Assessment

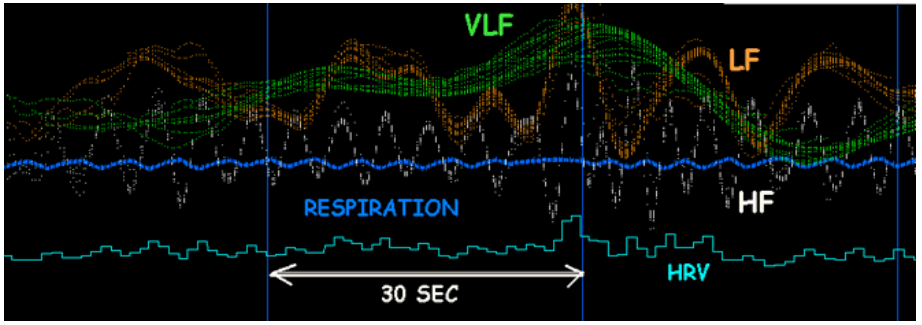




Activité parasympathique prédominante
(HF : Haute Fréquence)



Activité orthosympathique prédominante
(LF : Basse Fréquence)



Spectral Components :

High frequencies (HF) between 0,15 and 0,4 Hz. Reflecting parasympathetic activity.

Low frequencies (LF) between 0,04 and 0,15 Hz. Reflecting orthosympathetic activity, e.g. baroreflex.

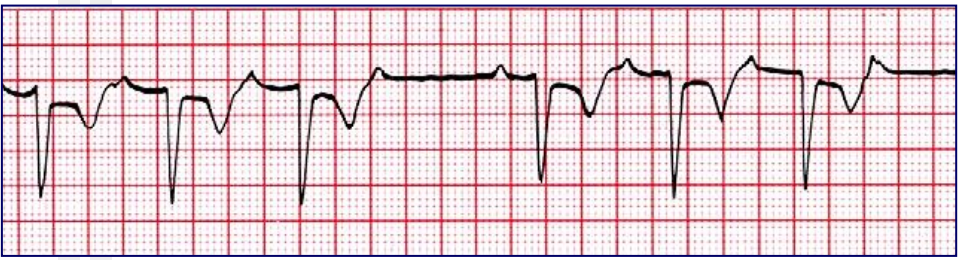
Very low frequencies (VLF) <0,04 Hz. Long term regulation such as thermoregulation, renin-angiotensin system,…

Bull. Acad. Natle Méd., 2013, *197*, nº 1, 175-186, séance du 22 janvier 2013

AV blocks

- First-degree atrioventricular block : PR > 200 ms

- Second-degree atrioventricular block : number of QRS < number of P



Mobitz I:

↑ PR then 1 QRS is missing

Mobitz II:

- number P > number R
- No ↑ in PR
- (3:2, 4:3, 5:4, variable)

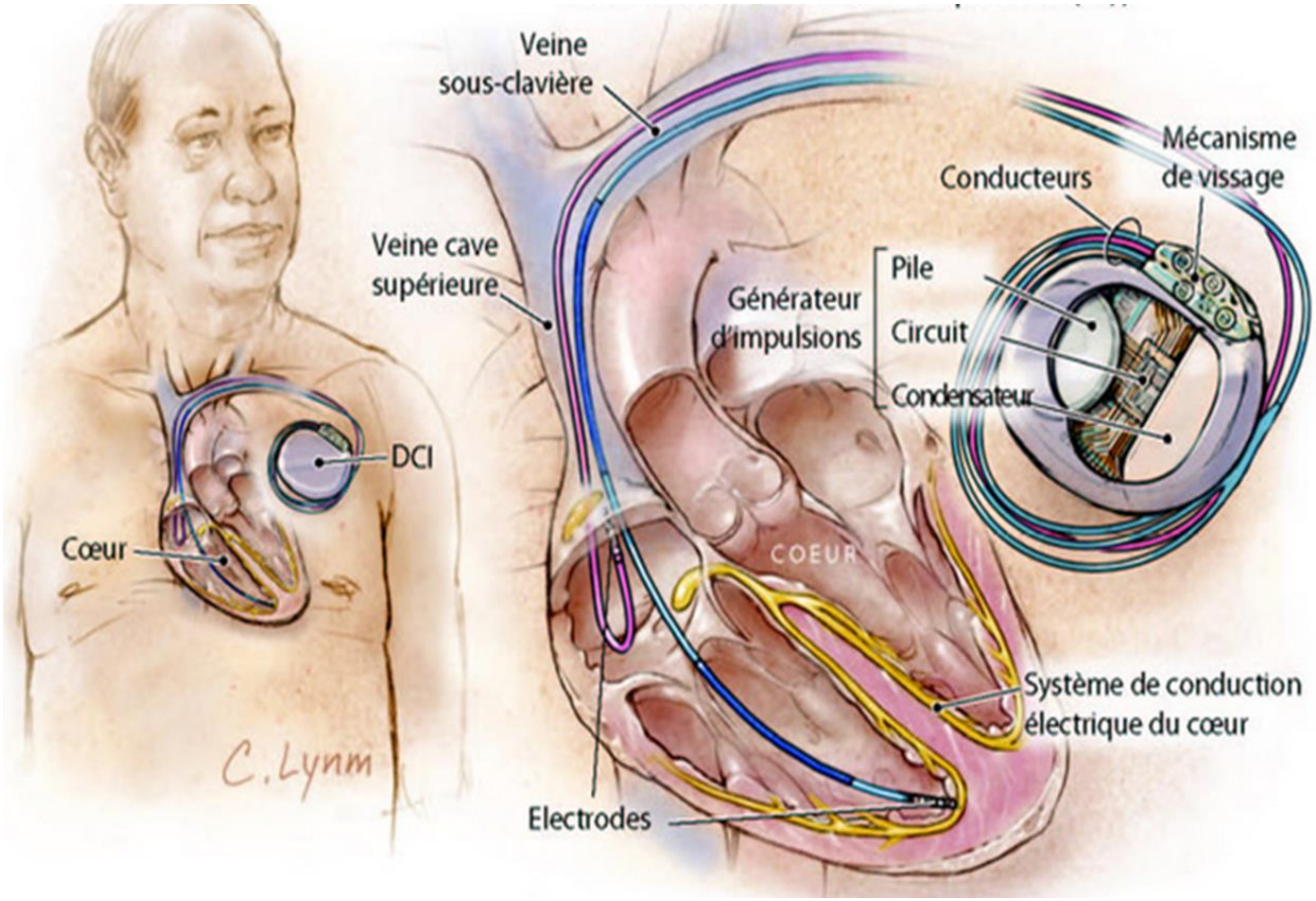
High grade AV block

- Third degree atrioventricular block (complete):
- PP interval is constant and RR interval is constant
- Complete dissociation of P waves and QRS complexes: RR interval is not a multiple of PP interval → variable PR

3rd degree AV block
with ventricular escape rhythm

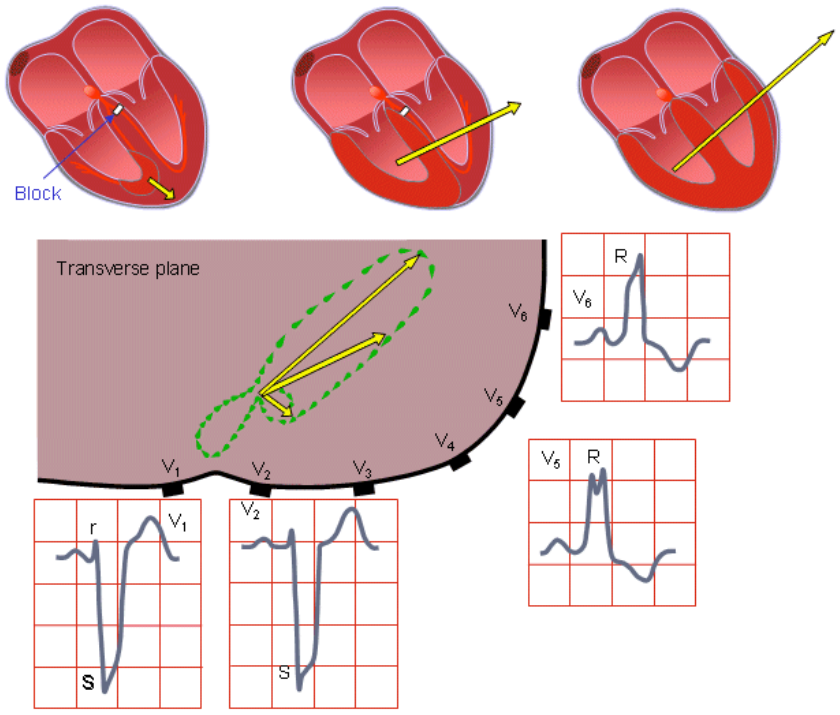
Treatments : PM

- Suppress bradycardia drugs (beta-blockers, digoxin)
- Pacemaker

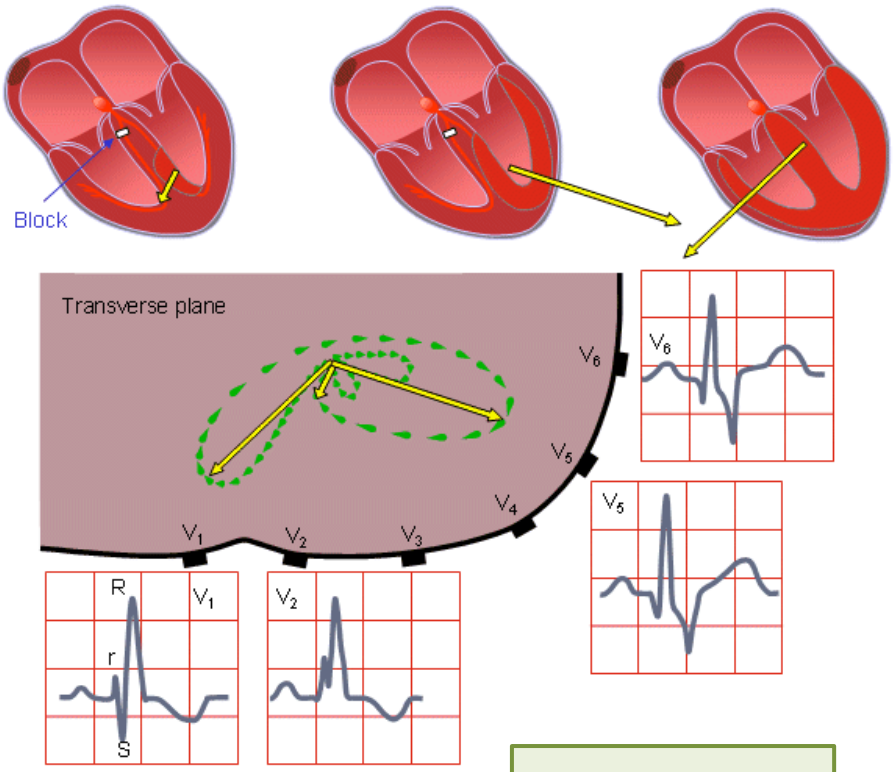


Bundle branch block

- **QRS: > 120 ms**



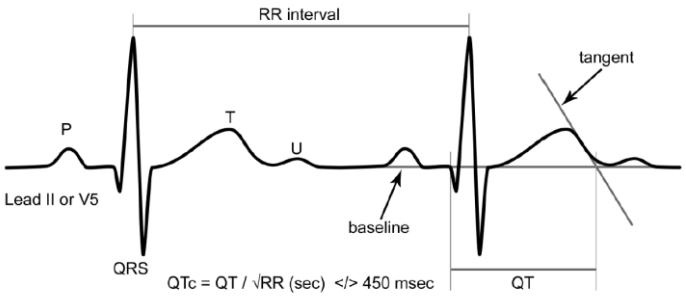
Left Bundle Branch Block



Right Bundle Branch Block

QT

- The QT interval must be corrected for heart rate
- QTc > 480-500 ms: risk of torsade de pointes
- Many drugs lengthen the QT



$$QTc = \frac{QT}{\sqrt{RR\,interval\,(sec)}}$$

Generic Name	Brand Names (Partial List)	Drug Class	Therapeutic Use
Amiodarone	Cordarone®, Pacerone®, Nexterone®	Anti-arrhythmic	Abnormal heart rhythm
Anagrelide	Agrylin®, Xagrid®	Phosphodiesterase 3 inhibitor	Thrombocythemia
Arsenic trioxide	Trisenox®	Anti-cancer	Leukemia
Astemizole (Removed from US Market)	Hismanal®	Antihistamine	Allergic rhinitis
Azithromycin	Zithromax®, Zmax®	Antibiotic	Bacterial infection
Bepridil (Removed from US Market)	Vascor®	Anti-anginal	Angina Pectoris (heart pain)
Chloroquine	Aralen®	Anti-malarial	Malaria infection
Chlorpromazine	Thorazine®, Largactil®, Megaphen®	Anti-psychotic / Anti-emetic	Schizophrenia/ nausea
Cisapride (Removed from US Market)	Propulsid®	GI stimulant	Heartburn
Citalopram	Celexa®, Cipramil®	Anti-depressant, SSRI	Depression

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