Fondamenti di bioingegneria

Laurea in

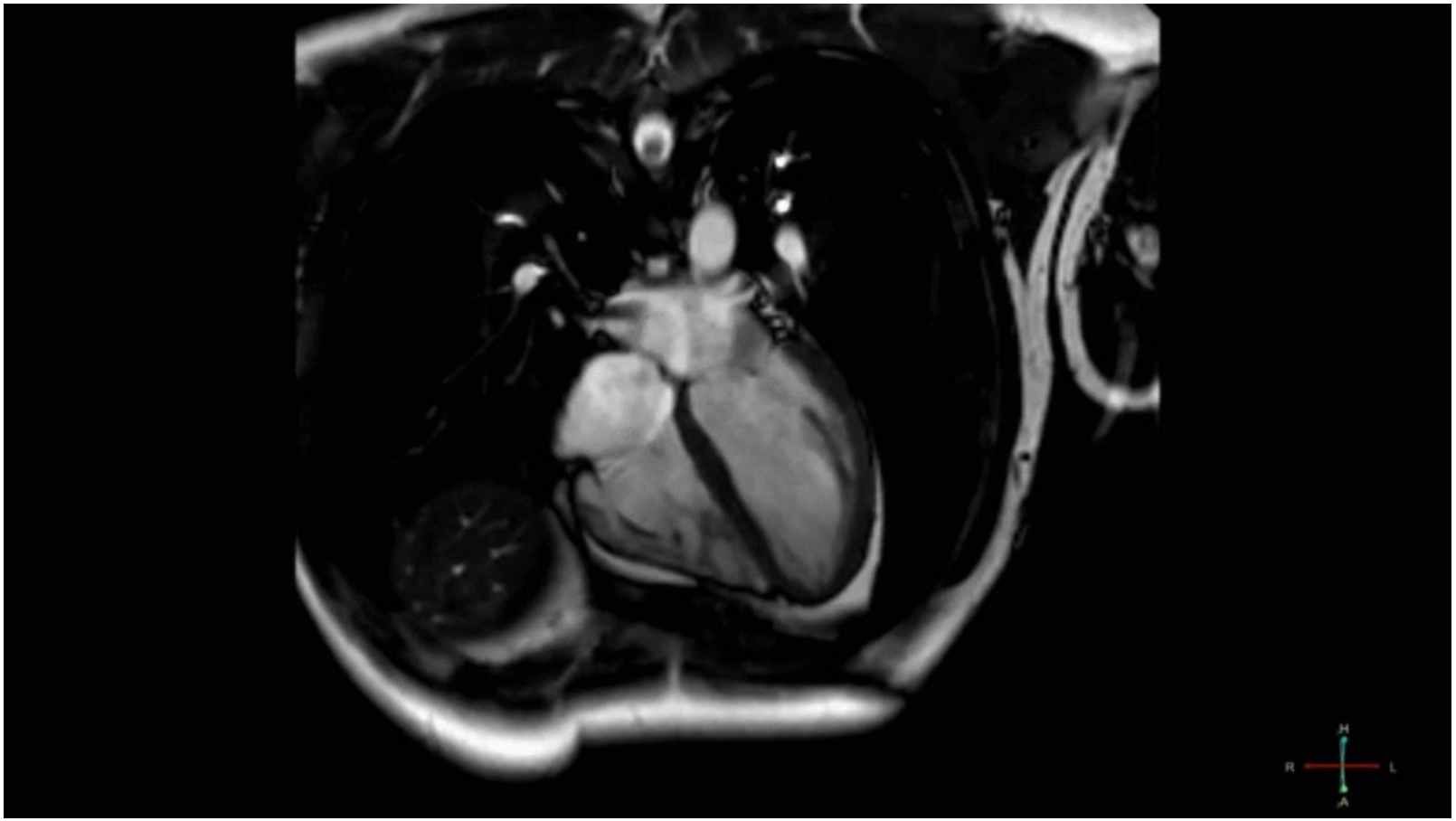
Ingegneria Informatica, Biomedica e delle Telecomunicazioni

Fabio Baselice

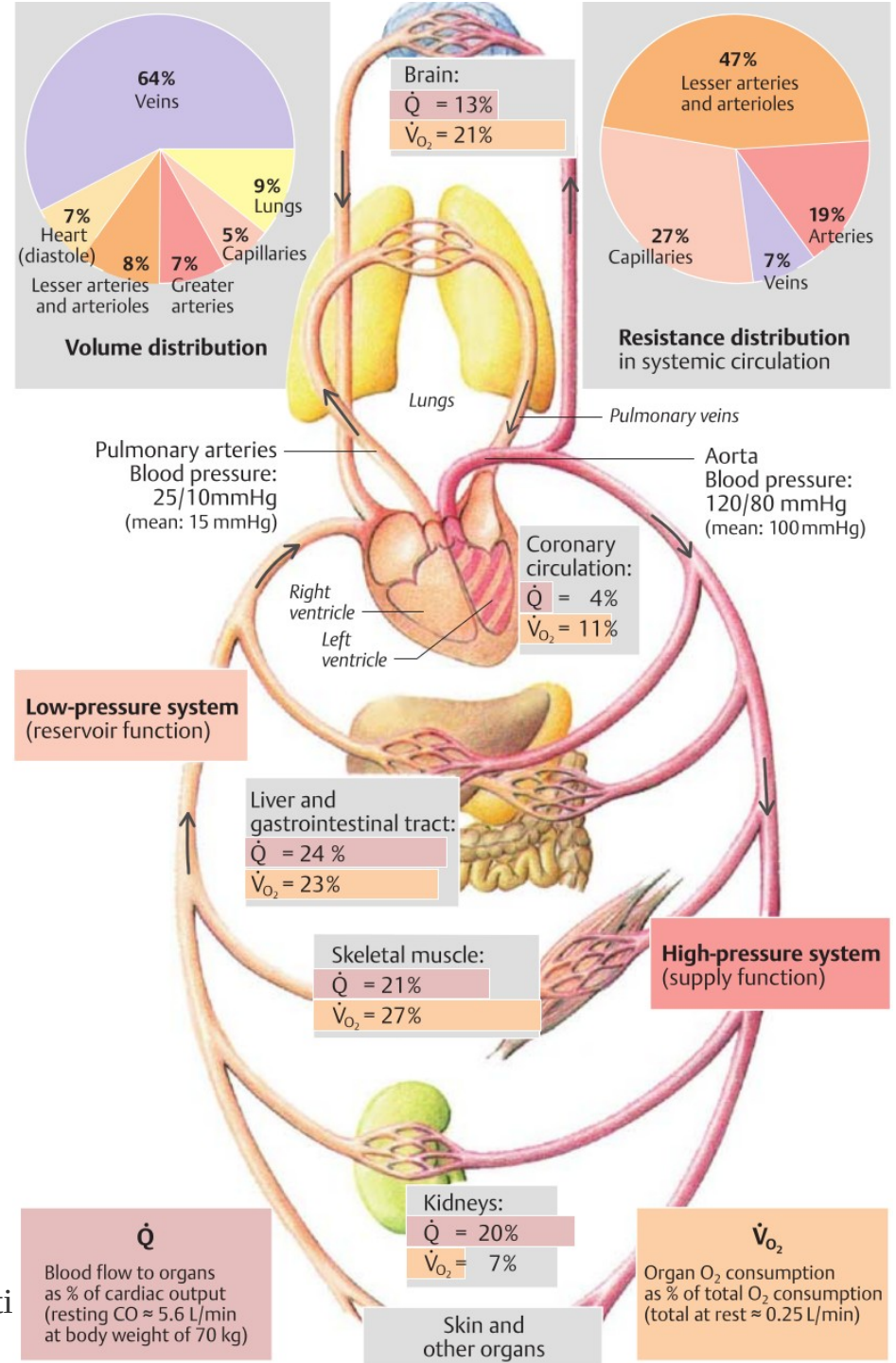
Argomenti

- Elettrocardiogramma (ECG)

L’attività cardiaca



L’attività cardiaca



Il sistema cardiovascolare.

L'attività cardiaca

I vasi sanguigni.

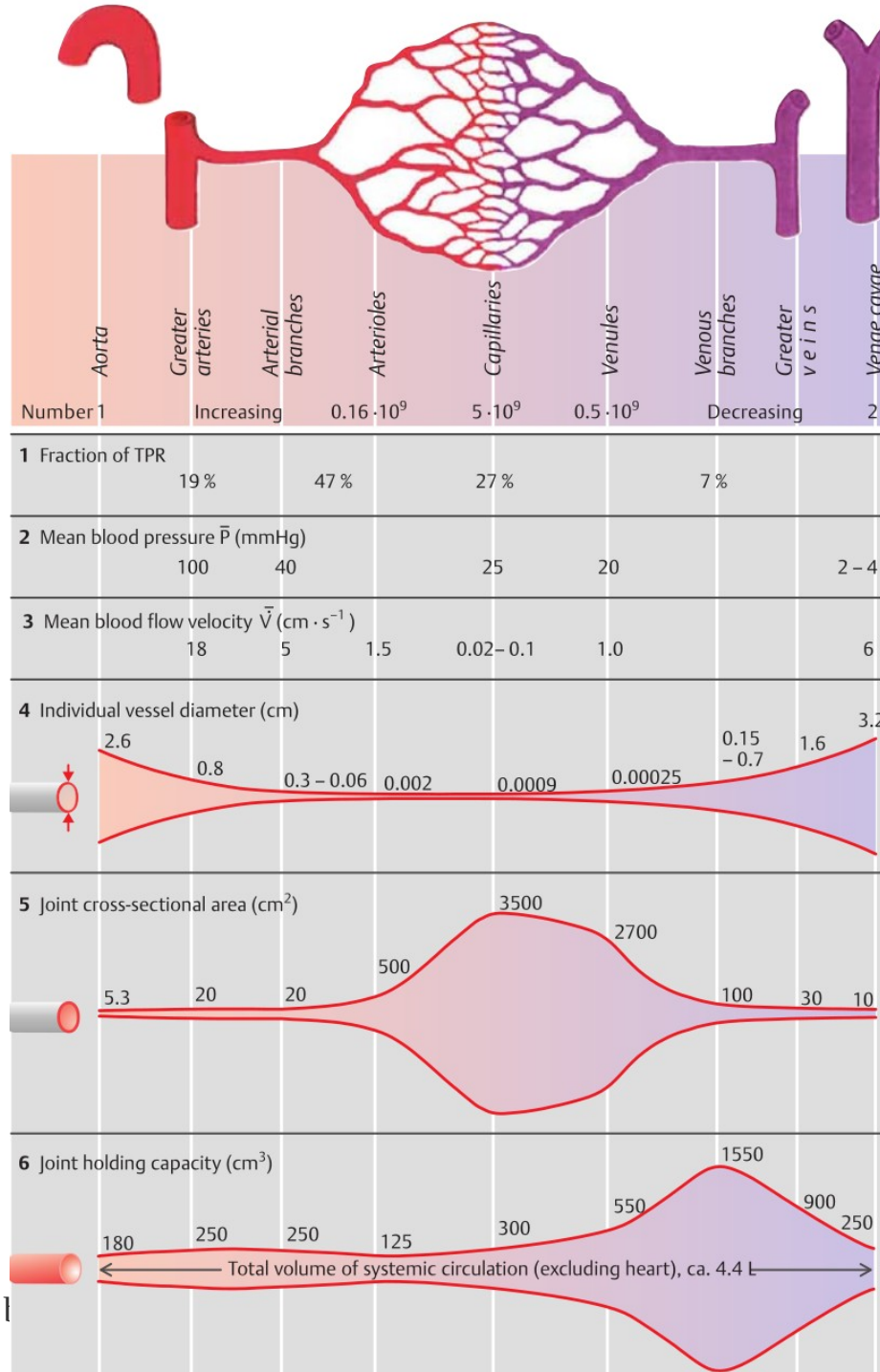
Vale la legge di Ohm:

$$\Delta P = \dot{Q} \cdot R$$

ΔP differenza di pressione

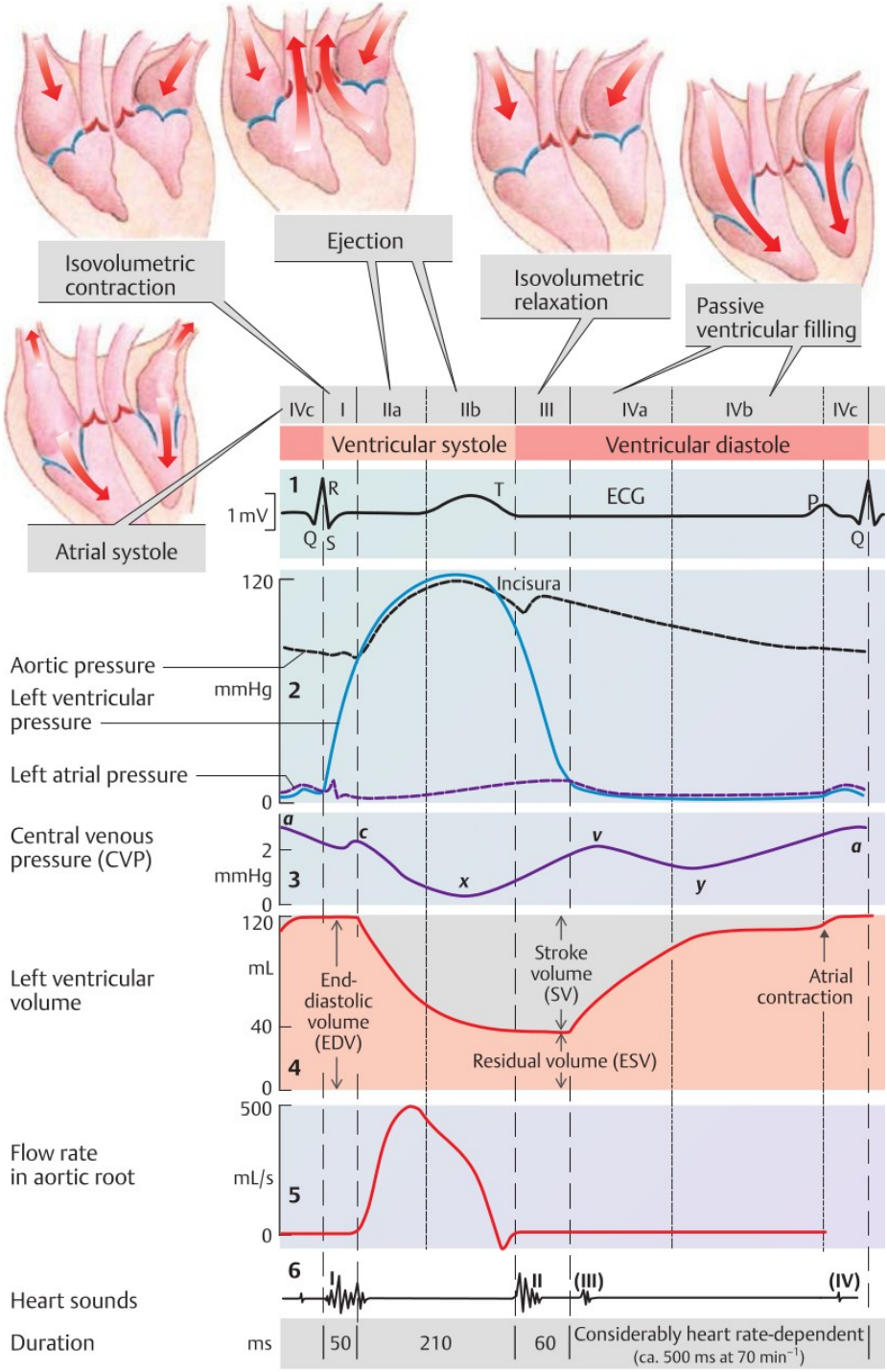
$\dot{Q}$ flusso sanguigno

R resistenza al flusso

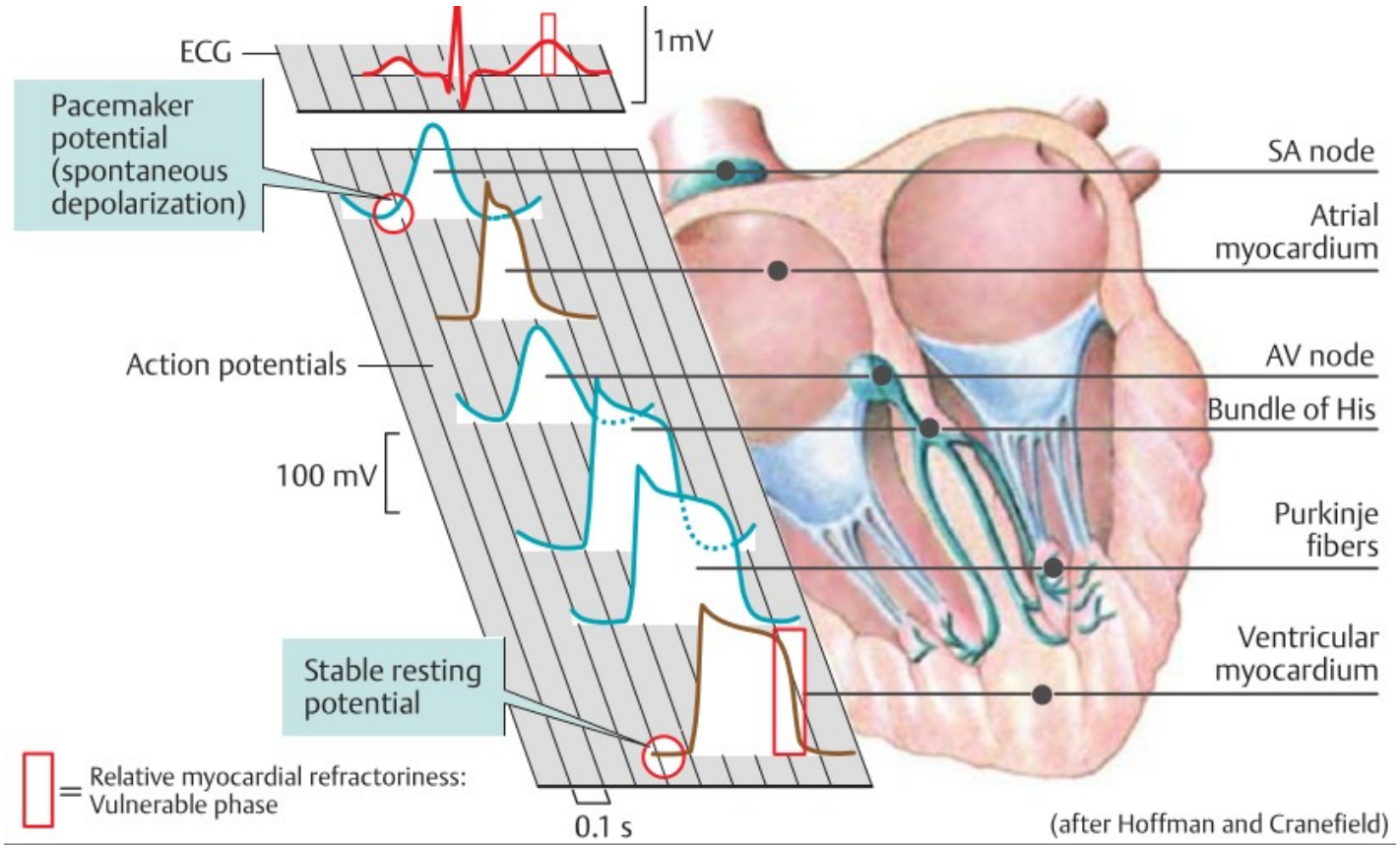


L’attività cardiaca

Il ciclo cardiaco.

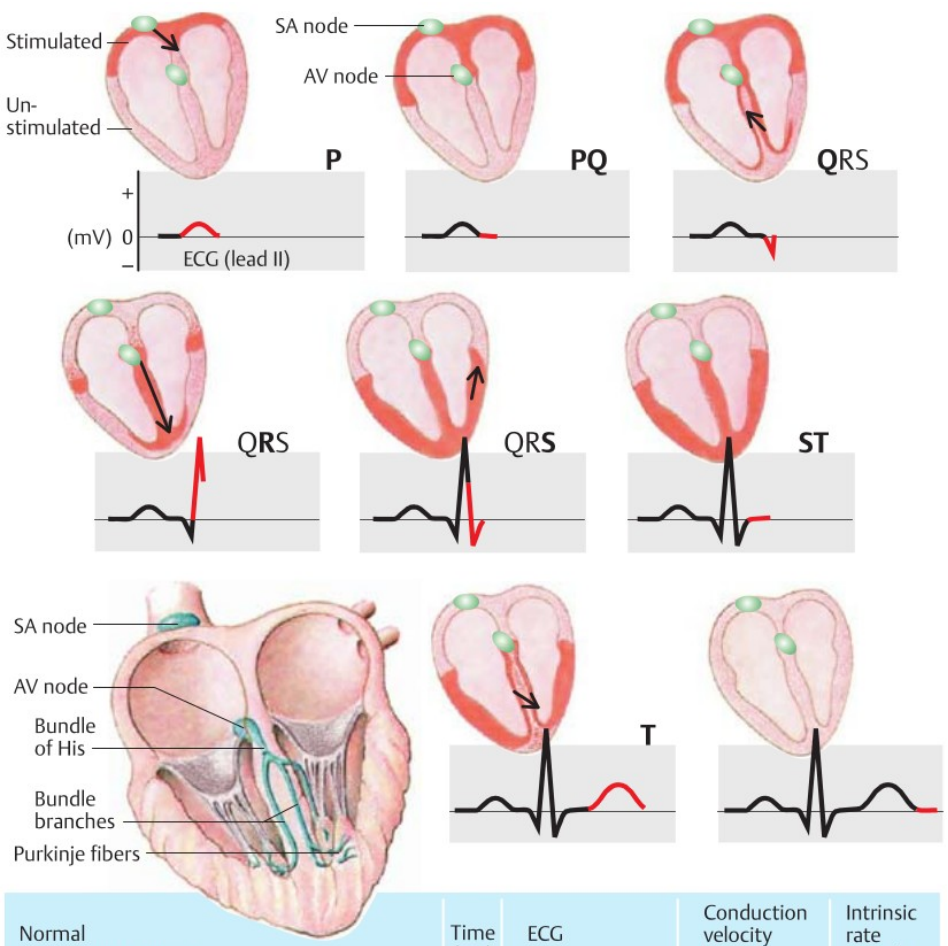


L'attività cardiaca



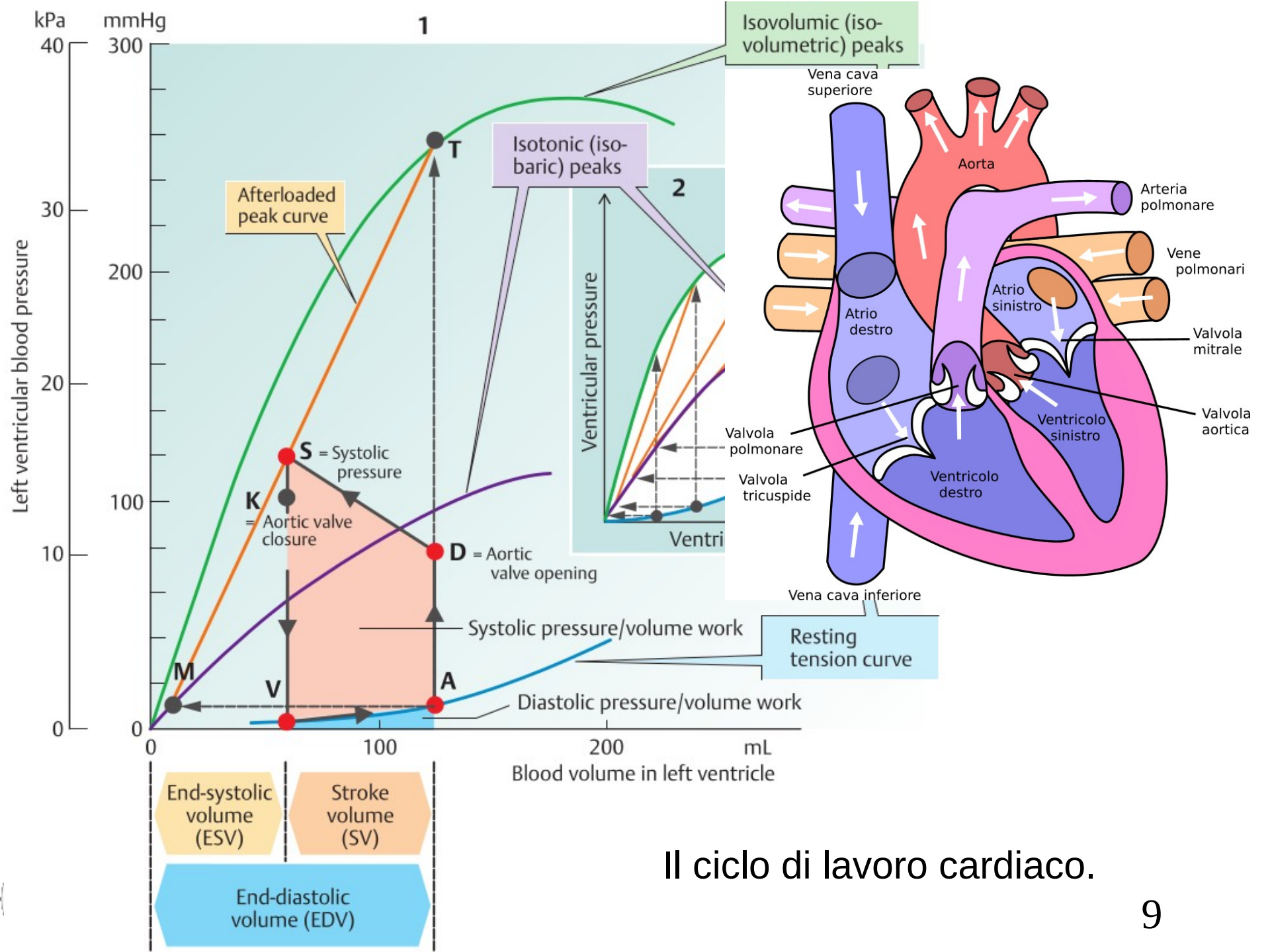
Eccitazione cardiaca: nodo seno-atriale → nodo atrio-ventricolare → fascio di His → fibre del Purkinje

L’attività cardiaca

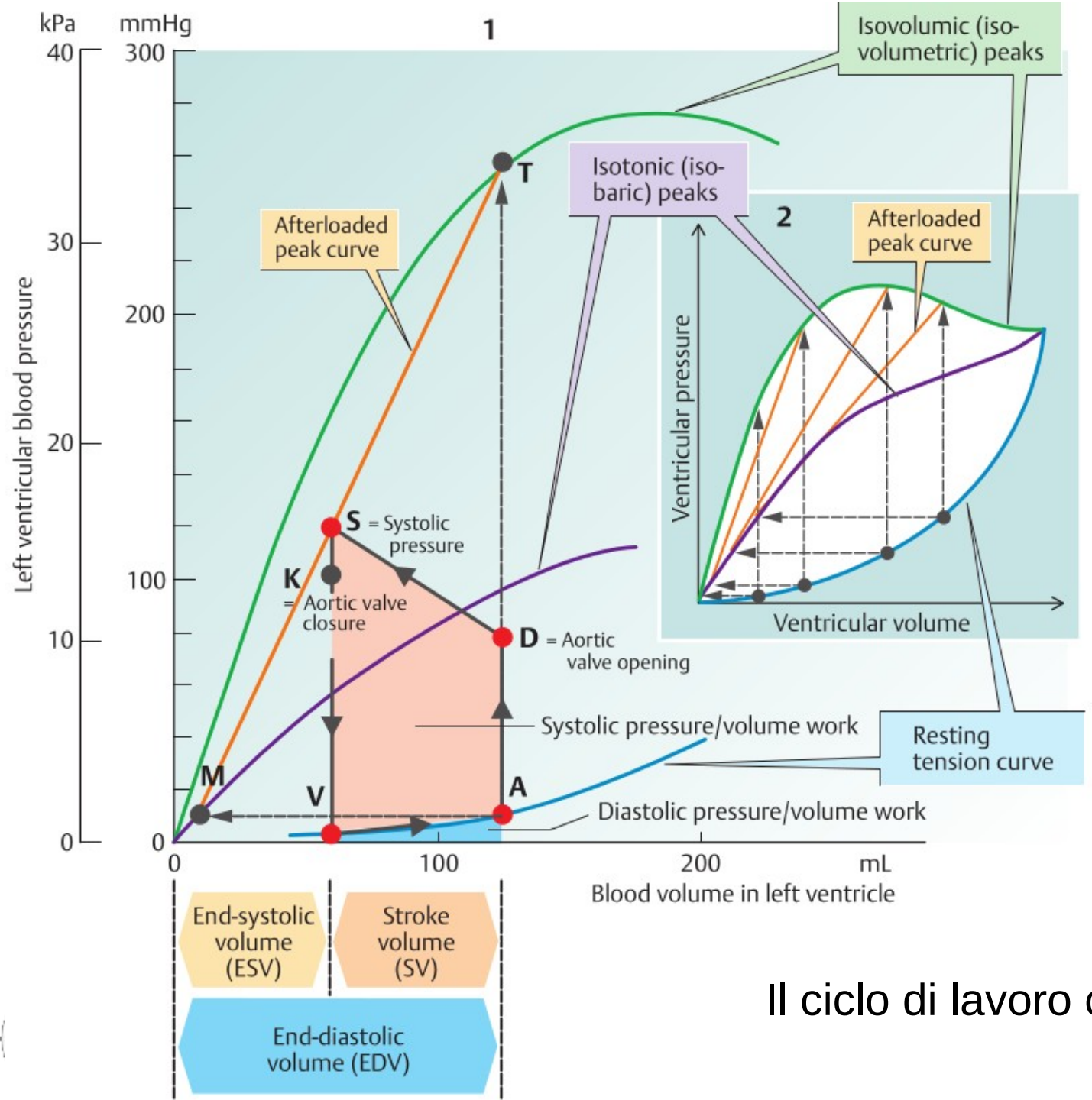


Normal activation sequence		Time (ms)	ECG	Conduction velocity ($m \cdot s^{-1}$)	Intrinsic rate (min^{-1})
SA node					60–100
Impulse generation		0	P wave	0.05	
Arrival of impulse in distal parts of atrium	Right atrium	50		0.8–1.0 in atrium	
	Left atrium	85			
AV node			P-Q segment (delayed conduction)		40–55
Arrival of impulse		50		0.05	
Relaying of impulse		125			
His bundle activated		130		1.0–1.5	25–40
End of bundle branches activated		145		1.0–1.5	
Purkinje fibers activated		150		3.0–3.5	
Inner myocardium completely activated	Right ventricle	175	QRS complex	1.0 in myocardium	None
	Left ventricle	190			
Outer myocardium completely activated	Right ventricle	205			
	Left ventricle	225			

Propagazione
dell’impulso cardiaco.



Il ciclo di lavoro cardiaco.



Il ciclo di lavoro cardiaco.

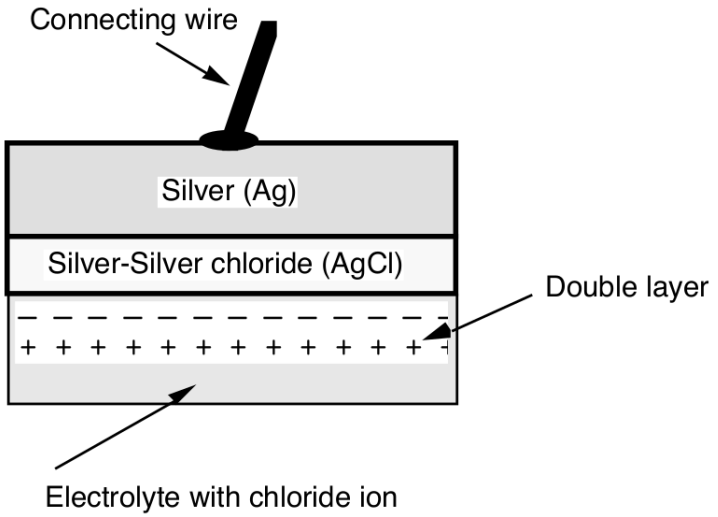
Elettrocardiogramma

L’elettrocardiogramma consente di dedurre difetti elettrici o meccanici del cuore tramite l’analisi di potenziali elettrici misurati sulla superficie del corpo.

Vi sono 3 tecniche di base usate in elettrocardiografia clinica:

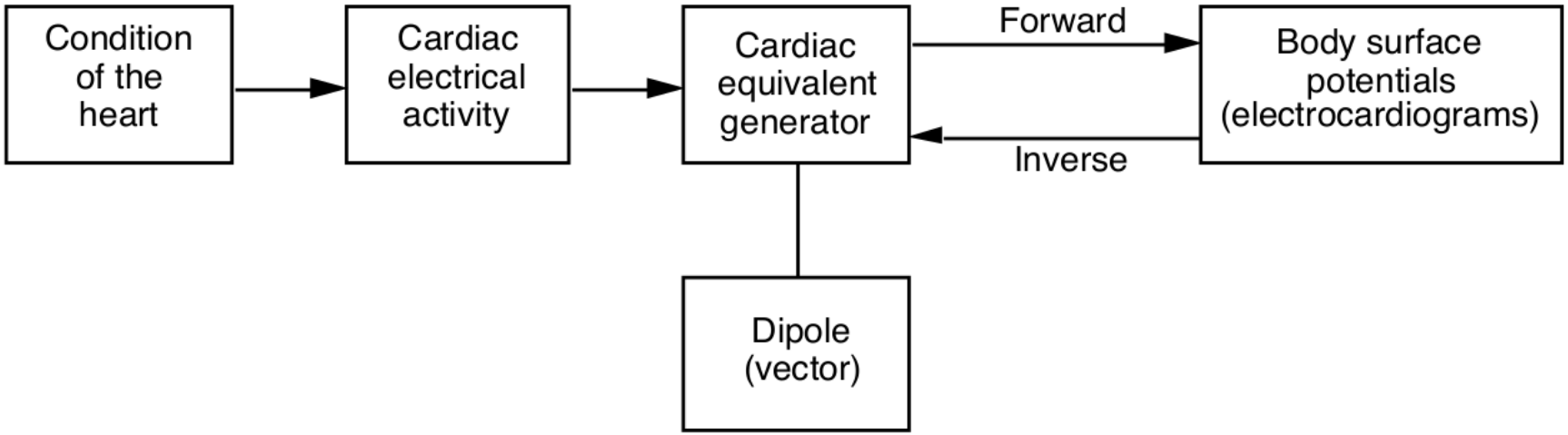
- ECG clinico standard - 12 leads
- Vettocardiogramma (VCG) - 3 leads ortogonali
- Monitoraggio ECG - 1 o 2 leads

Elettrocardiogramma

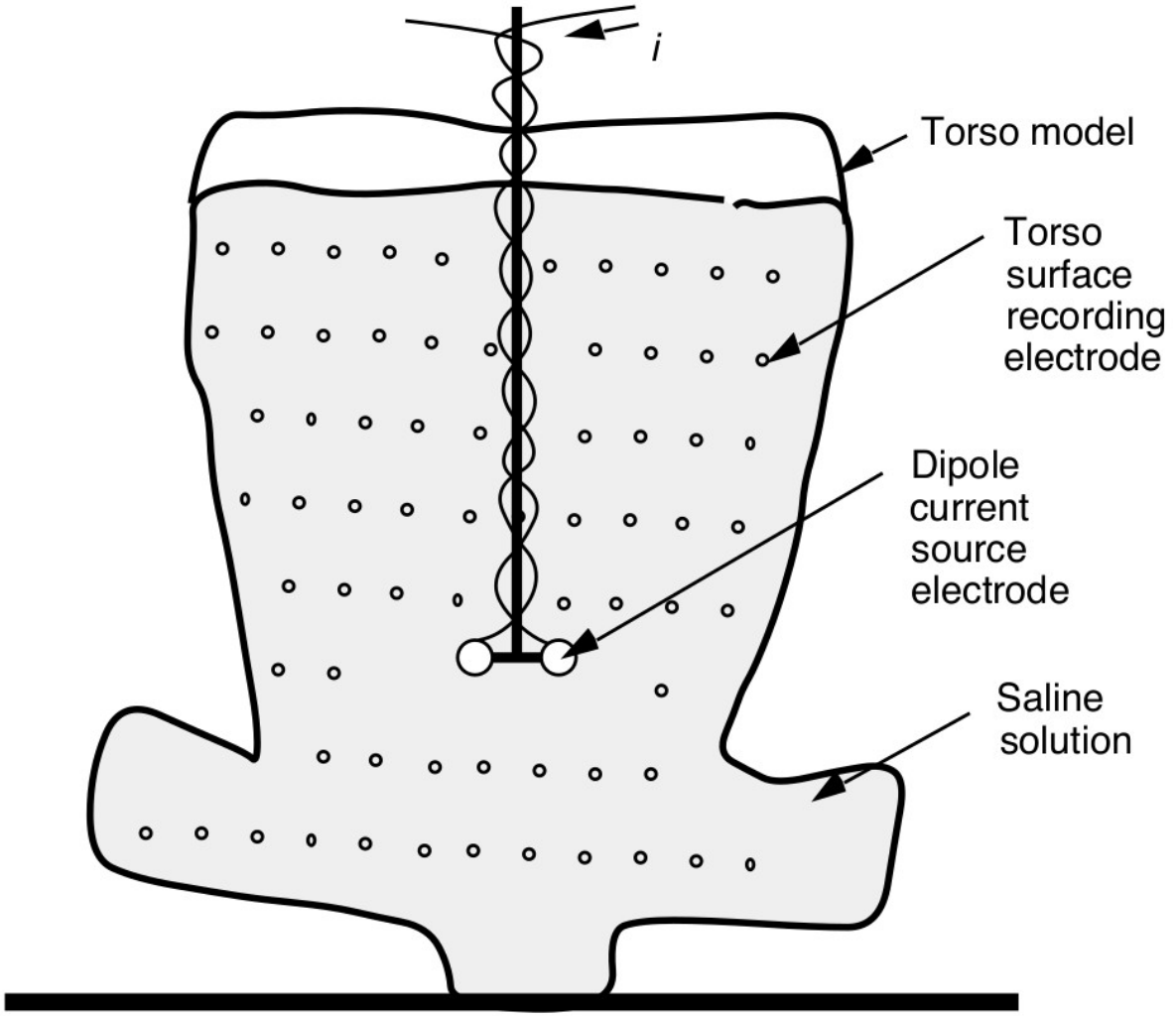


Elettrodi

Generatore Equivalente Cardiaco



Modello elettrico del torace di Frank



Modello del torace di Frank

Il potenziale misurato in ciascun punto n sulla superficie del corpo è dato dalla somma del prodotto di un insieme di coefficienti di trasferimento per le componenti dei vettori dei dipoli corrispondenti, ovvero:

$$v_n(t) = t_{nx}\, p_x(t) + t_{ny}\, p_y(t) + t_{nz}\, p_z(t)$$

Considerando k *leads* perveniamo alla formulazione vettoriale:

$$\boldsymbol{V}_{k\times 1} = \boldsymbol{T}_{k\times 3} \times \boldsymbol{P}_{3\times 1}$$

dove $\boldsymbol{V}$ contiene le misure e $\boldsymbol{P}$ descrive il vettore cardiaco.

Modello del torace di Frank

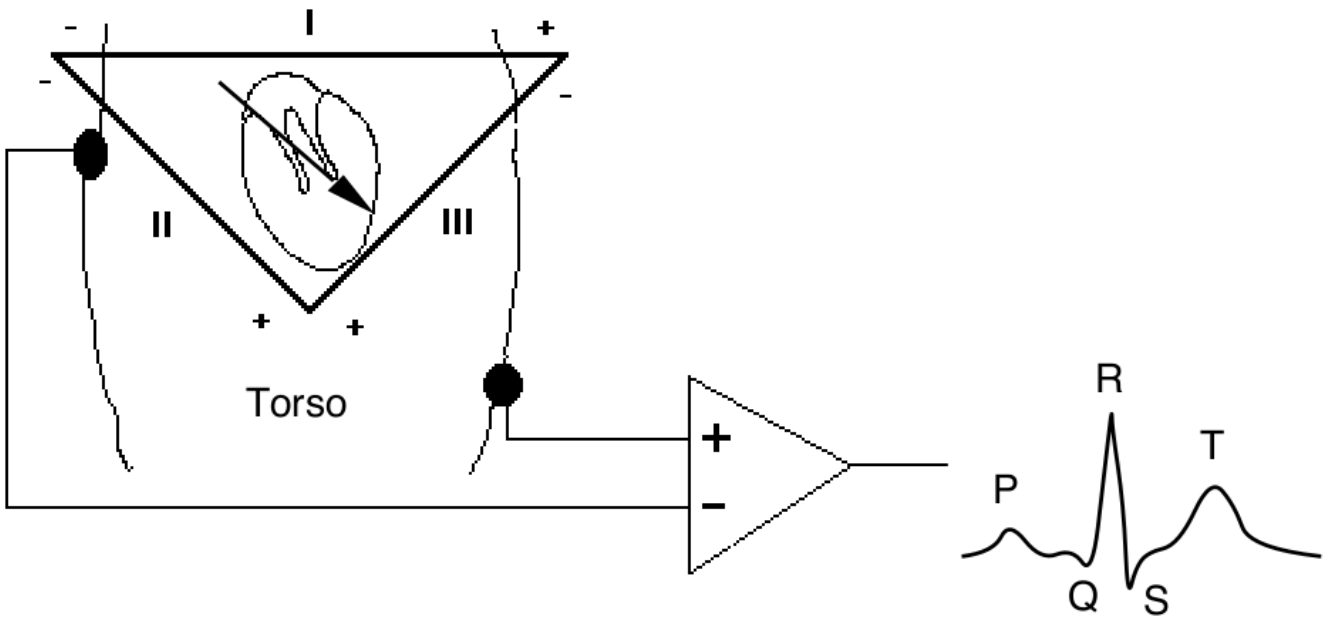
La matrice di trasformazione $\boldsymbol{T}$ varia da persona a persona, ma può essere standardizzata tramite un modello fisico del torso. A questo punto a partire dalle misure possiamo calcolare il vettore di dipolo cardiaco:

$$\boldsymbol{P} = \boldsymbol{B} \times \boldsymbol{V}$$

dove $\boldsymbol{B}$ è una matrice $3 \times k$ ottenuta dall'inversione di $\boldsymbol{T}$. Pertanto le componenti di $\boldsymbol{P}$ sono calcolate come:

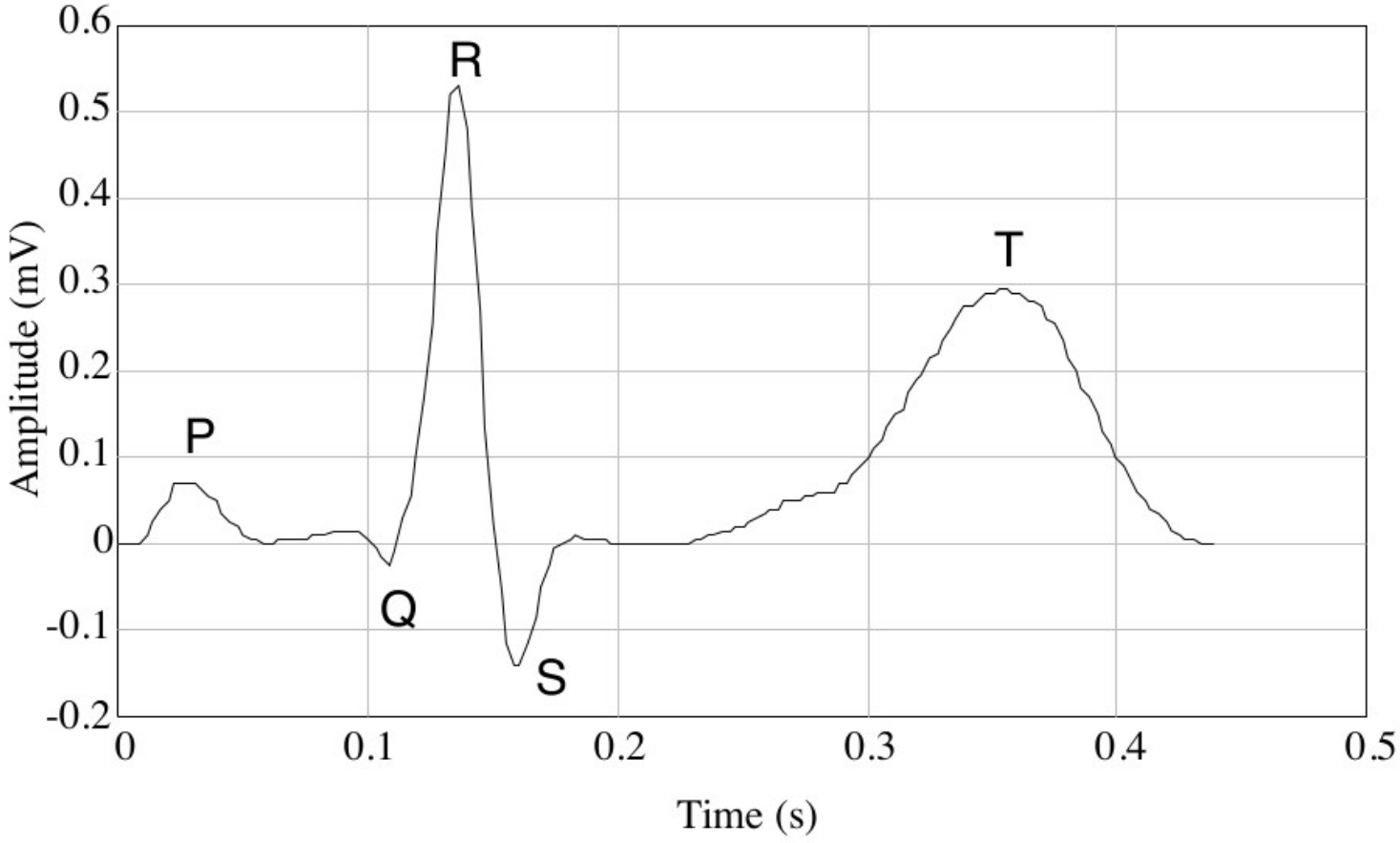
$$\begin{aligned} p_x(t) &= b_{x1} v_1(t) + b_{x2} v_2(t) + \ldots + b_{xk} v_k(t) \\ p_y(t) &= b_{y1} v_1(t) + b_{y2} v_2(t) + \ldots + b_{yk} v_k(t) \\ p_z(t) &= b_{z1} v_1(t) + b_{z2} v_2(t) + \ldots + b_{zk} v_k(t) \end{aligned}$$

ECG

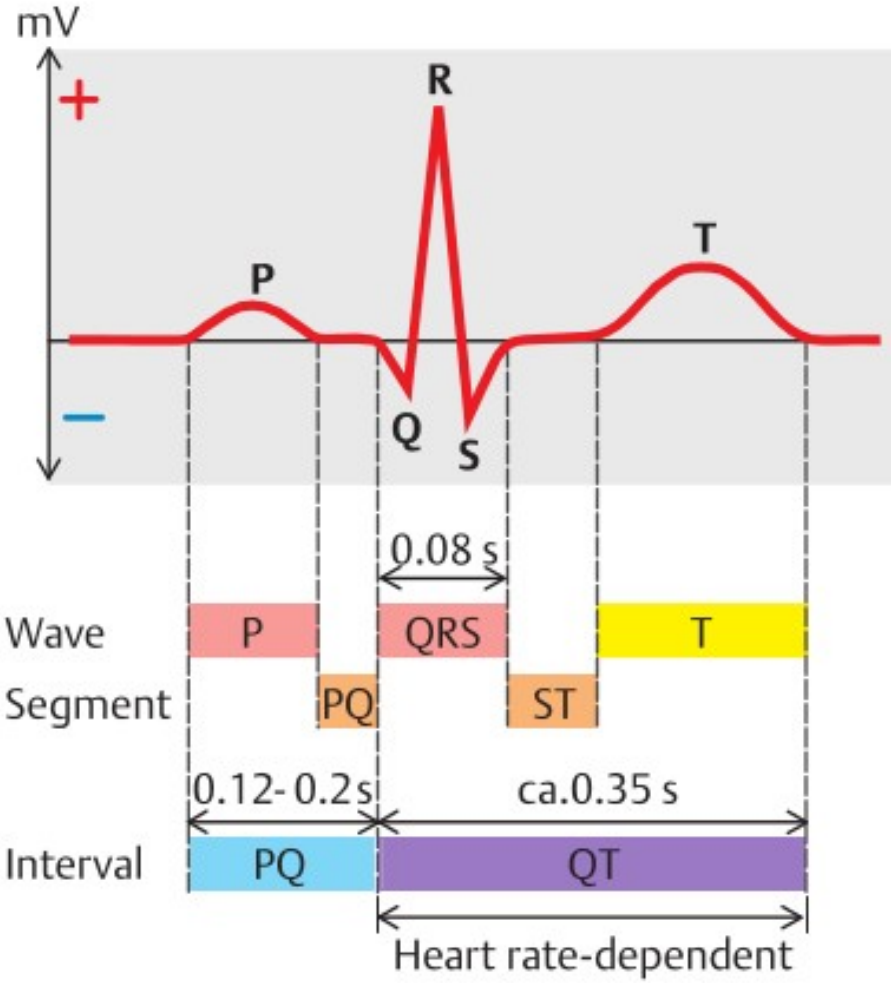


Esempio di un ECG. In base ai terminali dell'amplificatore cambia il segno del segnale registrato. Un tipico segnale ECG relativo ad un battito viene decomposto in 5 onde: P, Q, R, S, T.

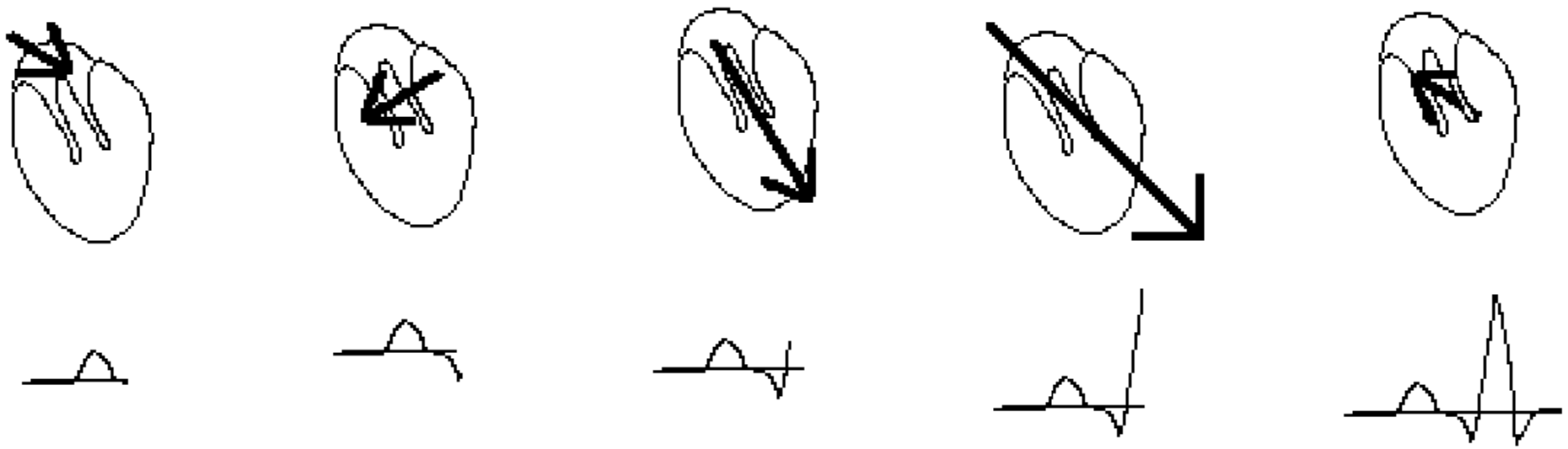
ECG



ECG


mV
+
−
R
P
T
Q
S
0.08 s
Wave
P
QRS
T
Segment
PQ
ST
0.12- 0.2 s
ca.0.35 s
Interval
PQ
QT
Heart rate-dependent

ECG



Dep. atriale

Onda P

Stimolo ventricoli

Onda Q

Dep. ventricoli

Onda R

Max dep. ventricoli

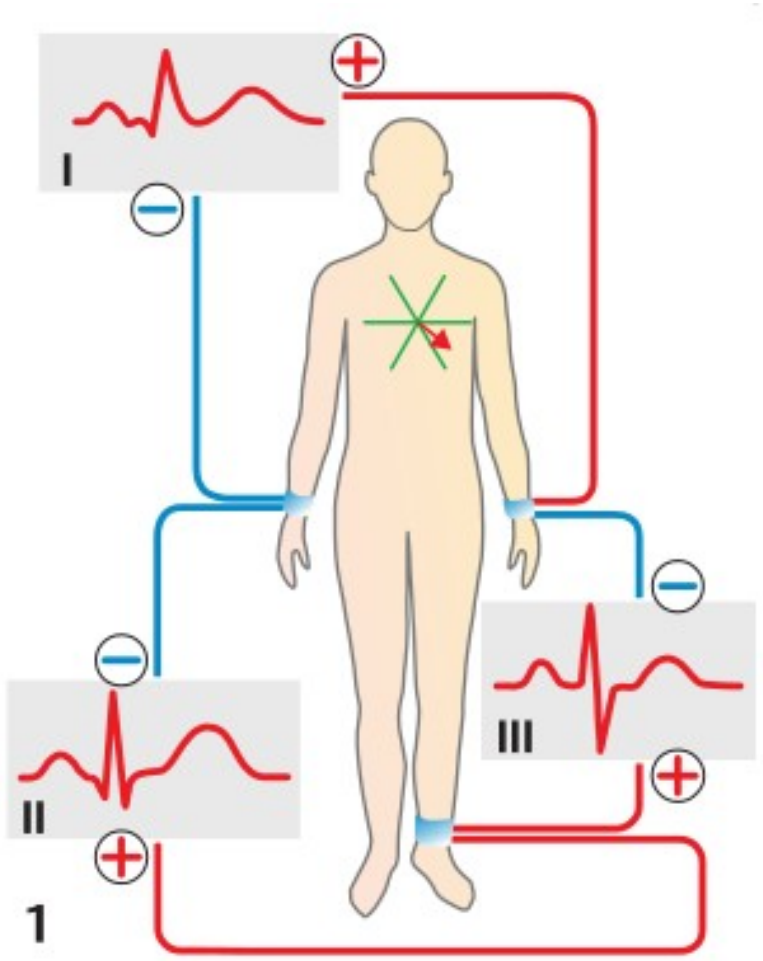
Picco onda R

Fine dep. ventricoli

Onda S

Vettore di eccitazione cardiaca e complesso PQRS.

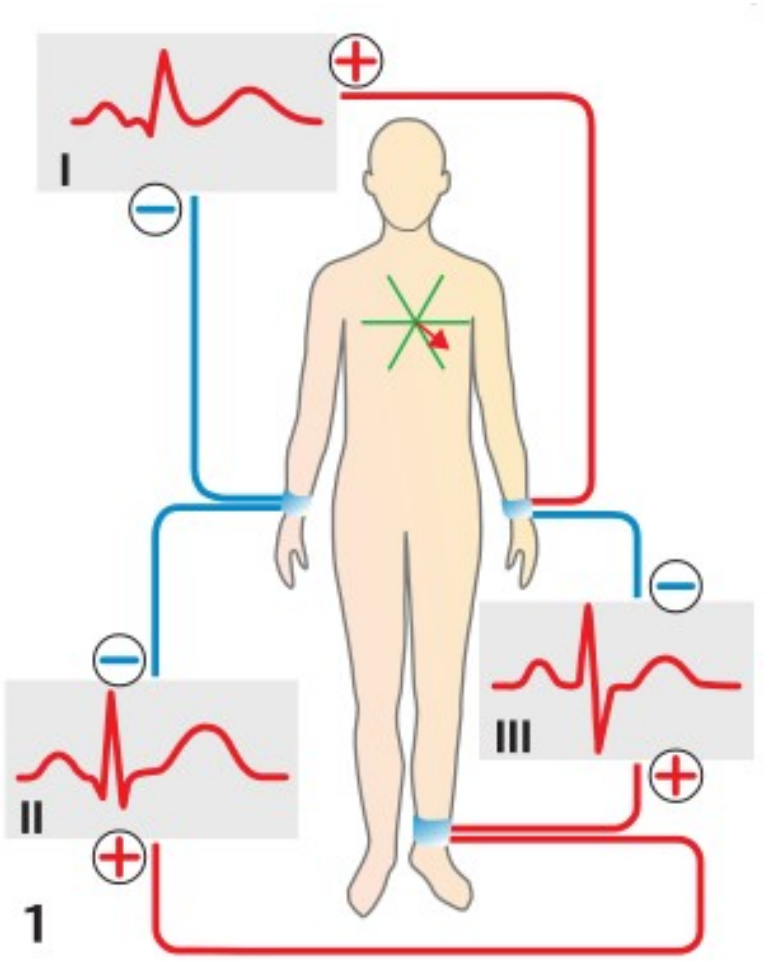
Triangolo equilatero di Einthoven



Triangolo equilatero di Einthoven

Einthoven ha postulato che l'eccitazione elettrica cardiaca può essere descritta da un vettore.

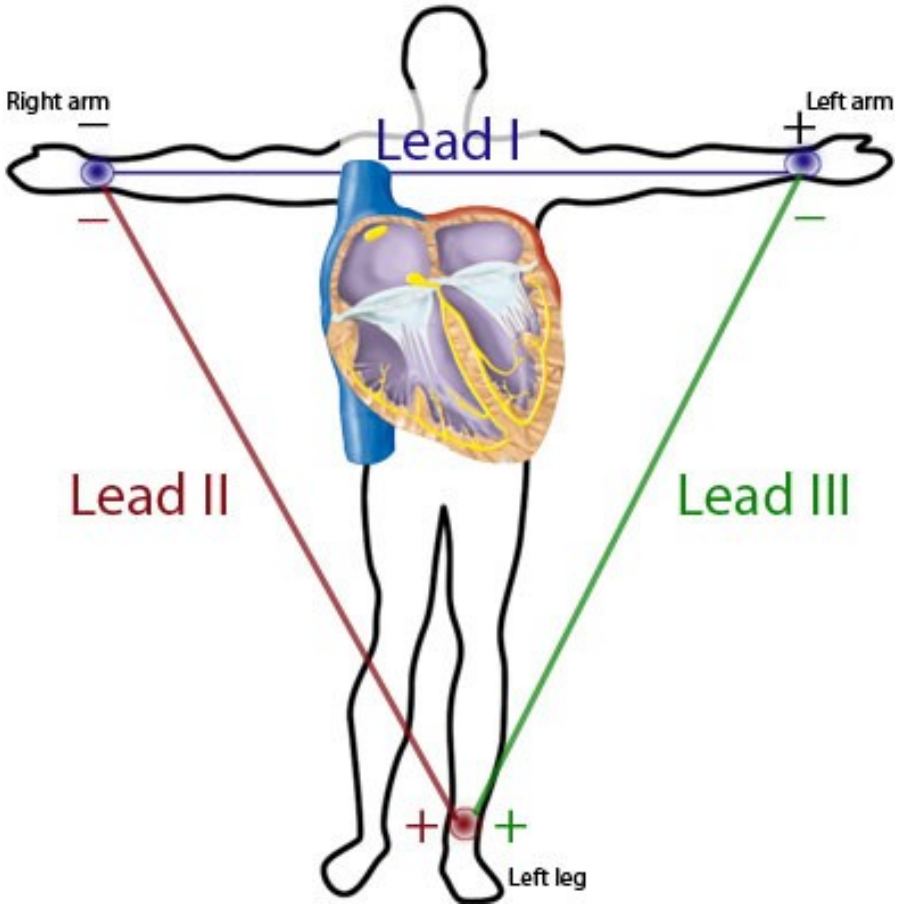
Ciascun lato del suo triangolo descrive una componente del vettore cardiaco, ed è registrato come differenza di potenziale fra una coppia di arti.



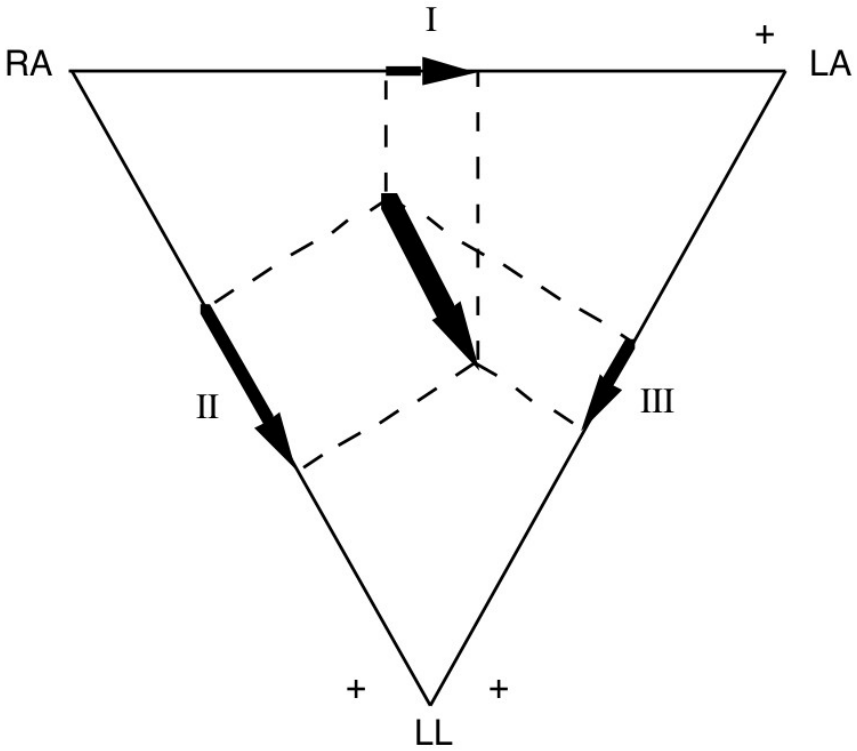
Triangolo equilatero di Einthoven

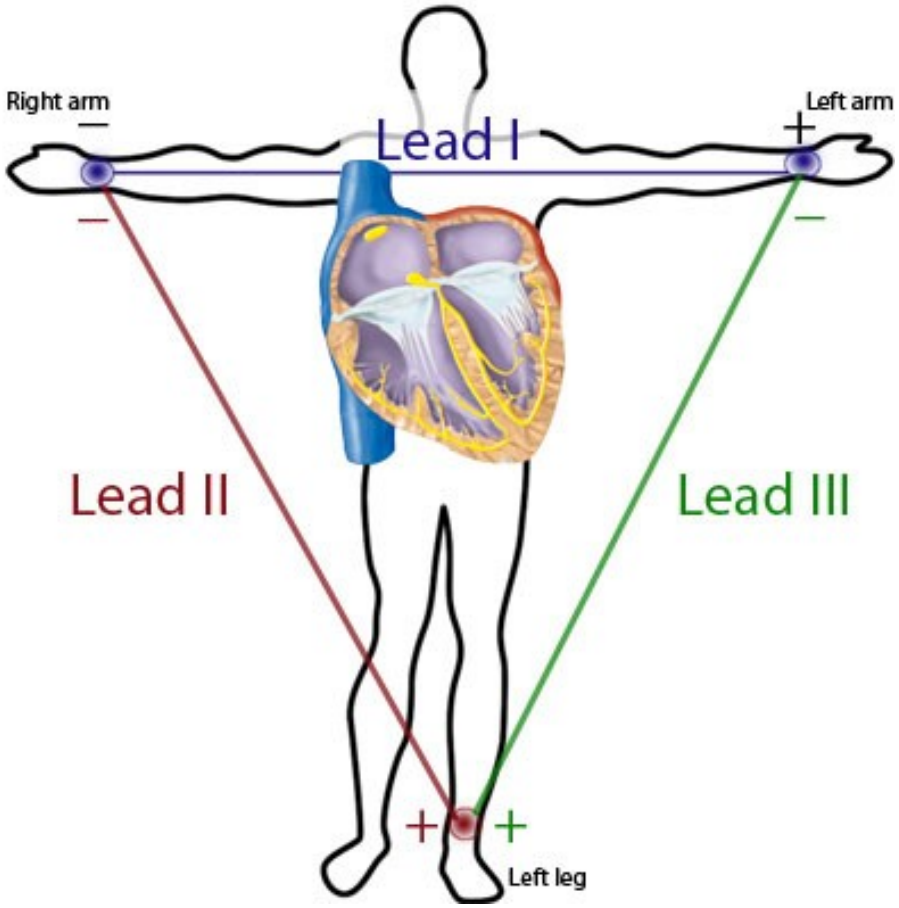
Einthoven ha postulato che l'eccitazione elettrica cardiaca può essere descritta da un vettore.

Ciascun lato del suo triangolo descrive una componente del vettore cardiaco, ed è registrato come differenza di potenziale fra una coppia di arti.

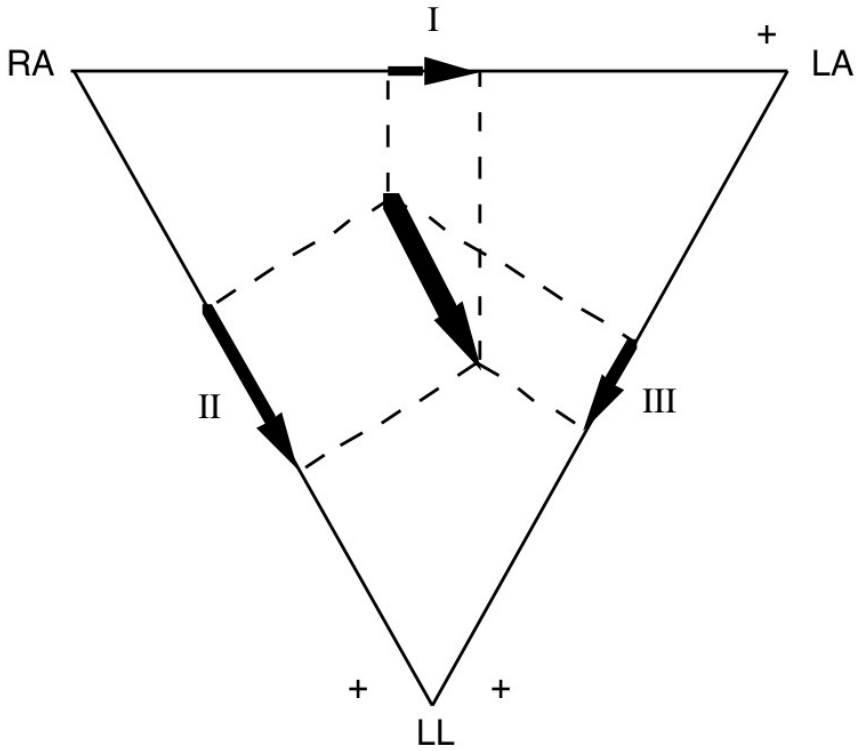


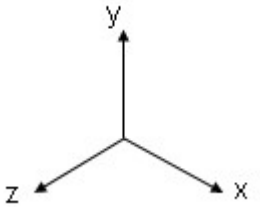
Triangolo equilatero di Einthoven





Triangolo equilatero di Einthoven

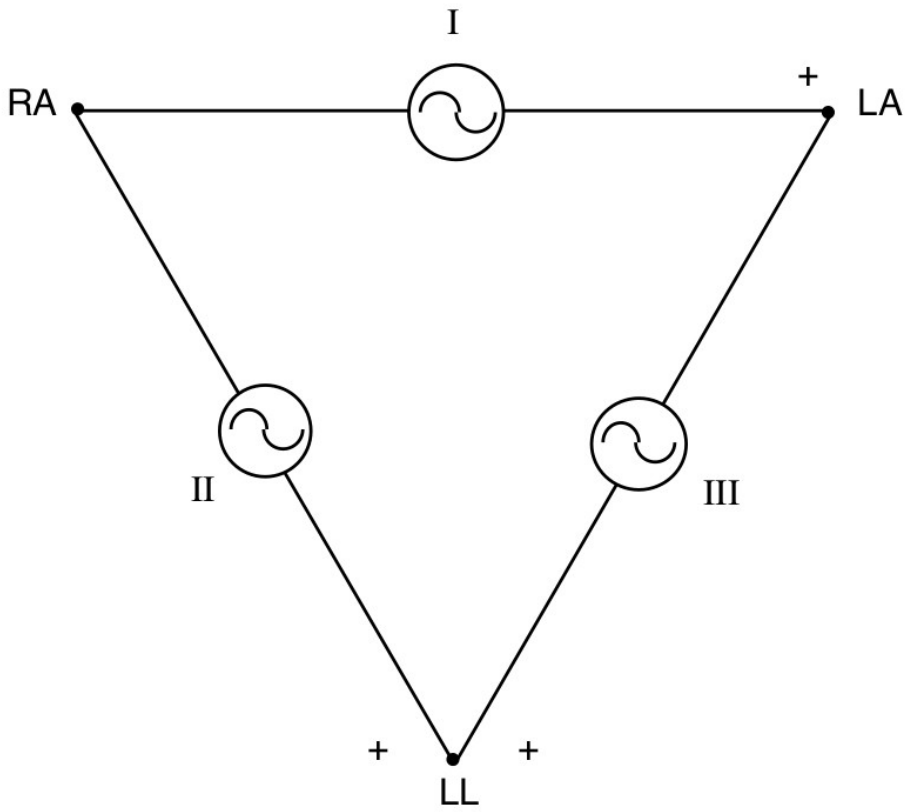




$$\boldsymbol{p}(t) = p_x(t)\,\hat{\boldsymbol{x}} + p_y(t)\,\hat{\boldsymbol{y}} + p_z(t)\,\hat{\boldsymbol{z}}$$

Il vettore cardiaco (tempo variante) può essere decomposto in componenti ortogonali.

Standard limb leads



Per la legge di Kirchoff:

$$II - I - III = 0$$

da cui:

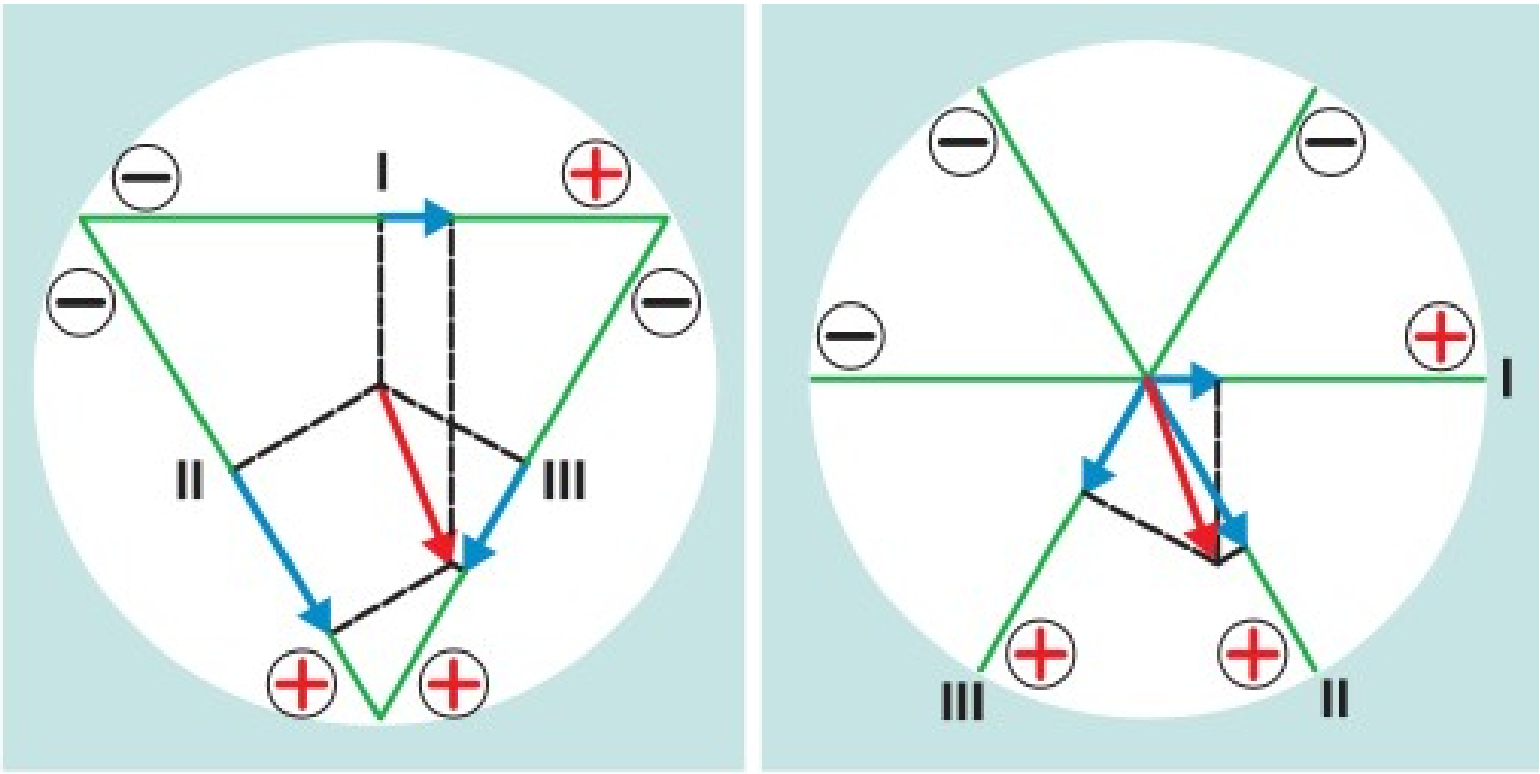
$$II = I + III$$

$$I = II - III$$

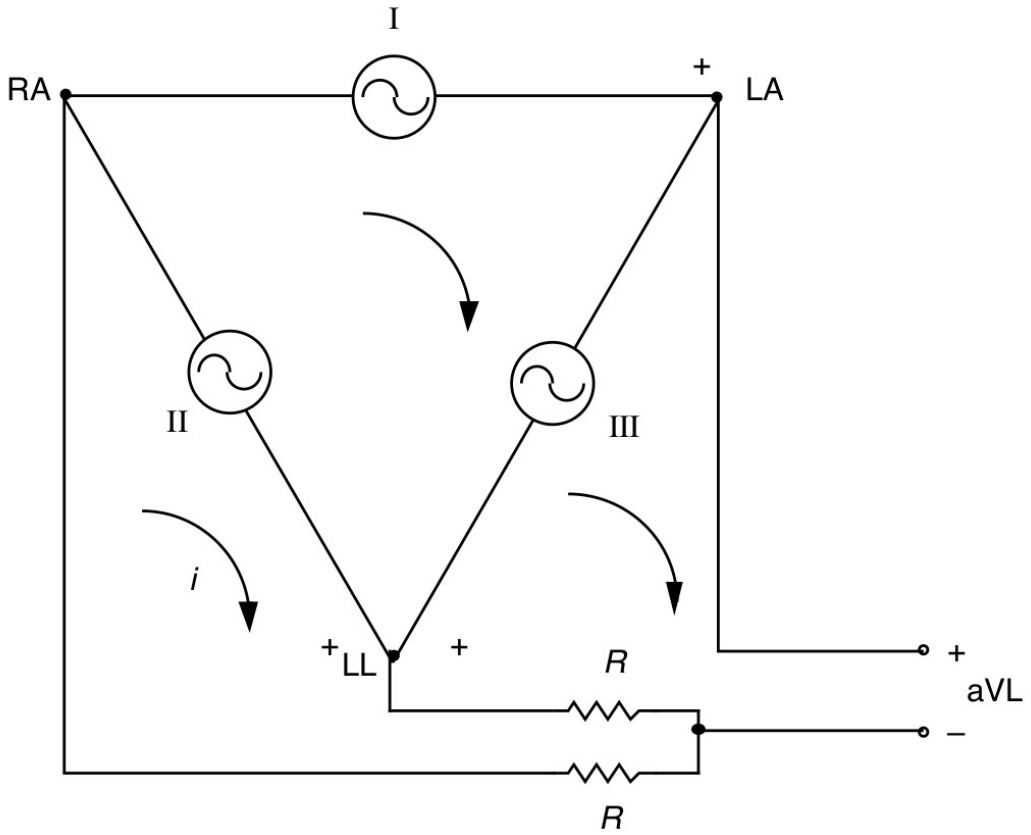
$$III = II - I$$

Non è necessario registrare tutti i leads, uno è ridondante.

Triangolo equilatero di Einthoven



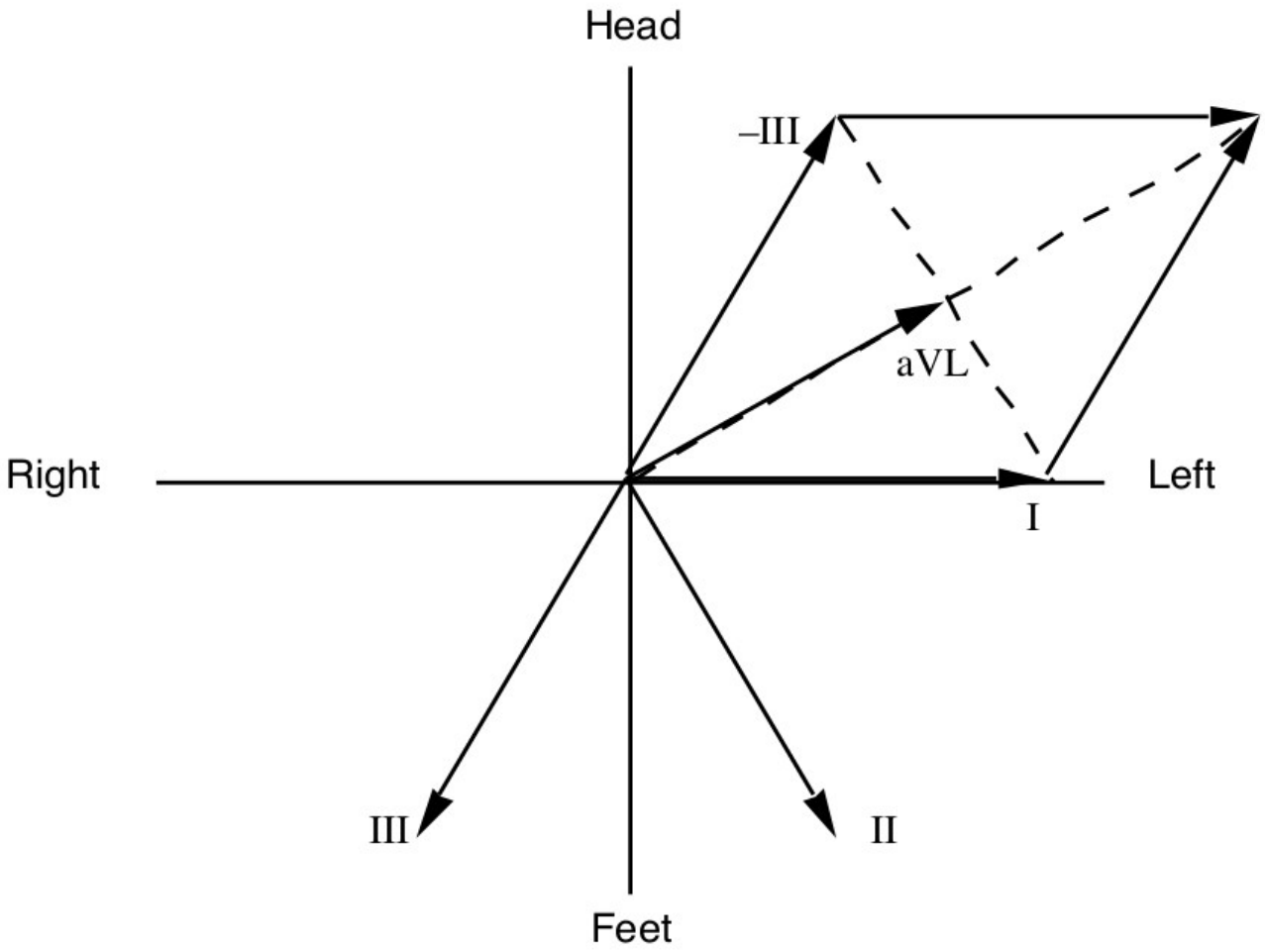
Augmented limb leads



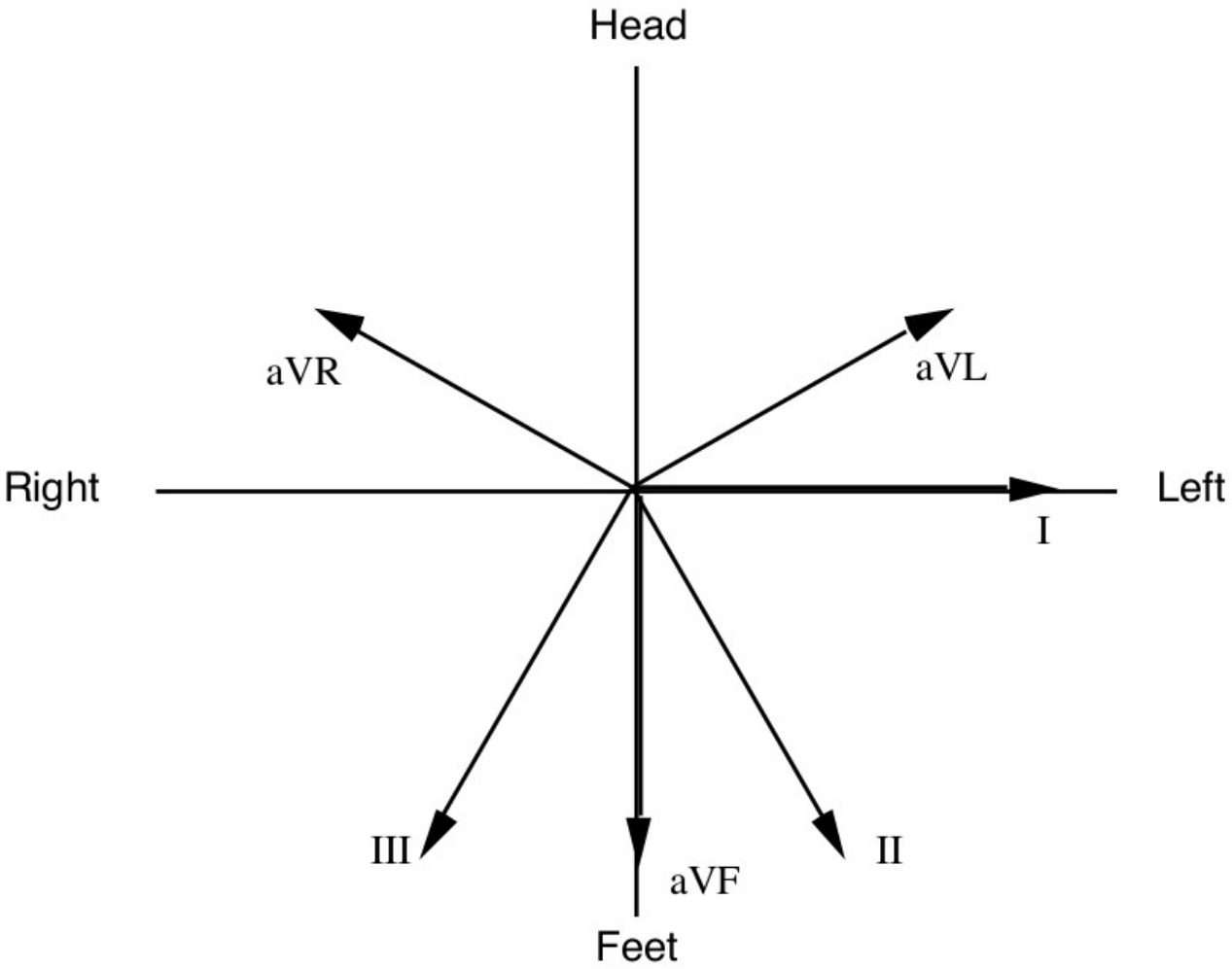
I limb lead classici producono un segnale di modesta ampiezza, non ottimale per amplificatori di modesto guadano.

Lo schema in figura garantisce un segnale più intenso.

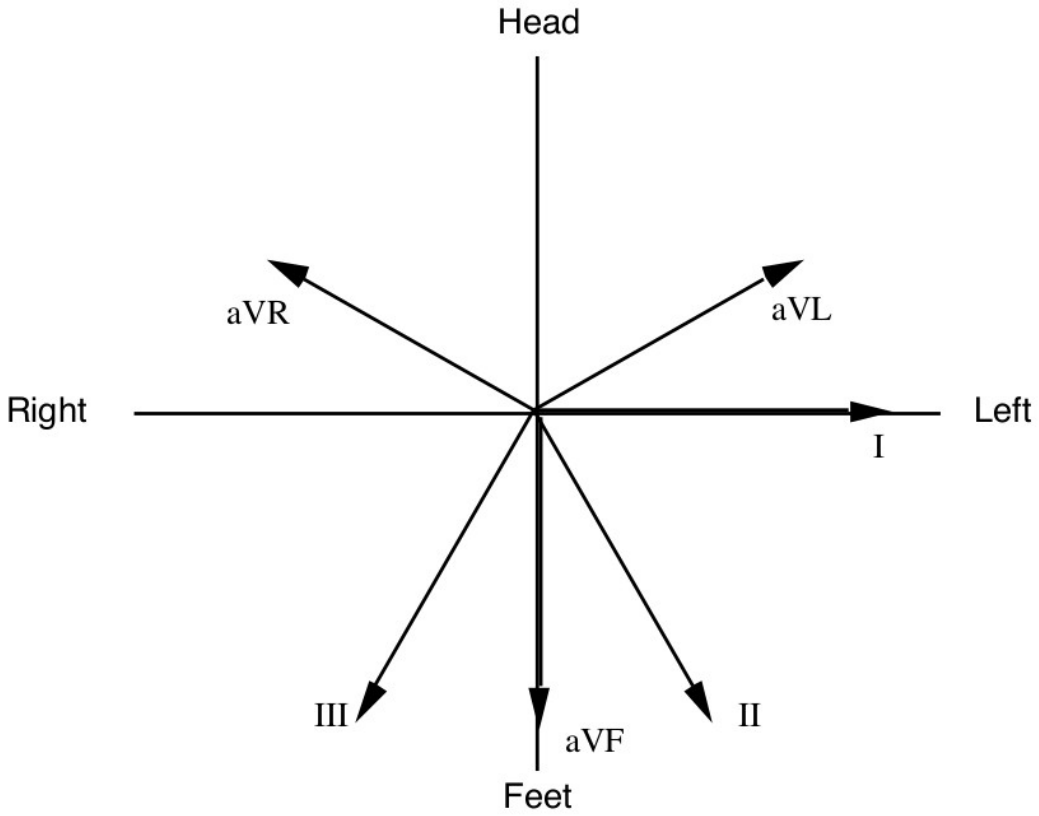
Augmented limb leads

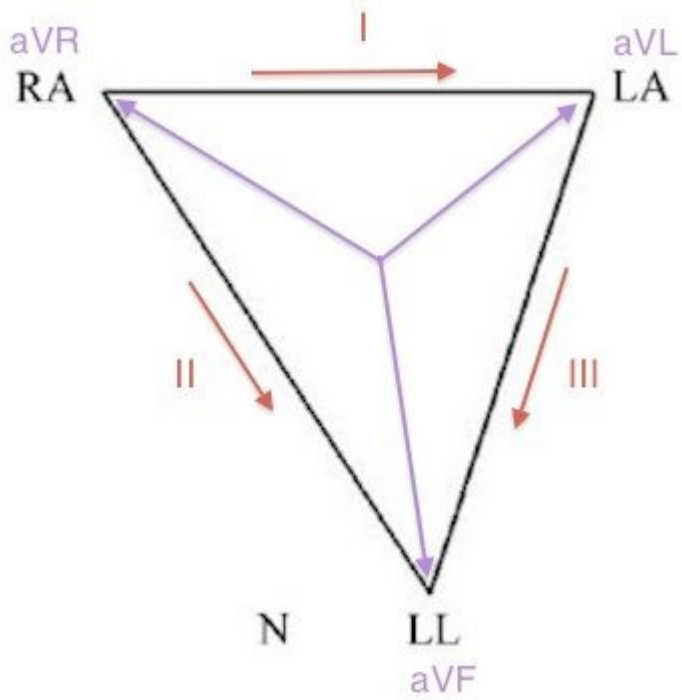


Augmented limb leads

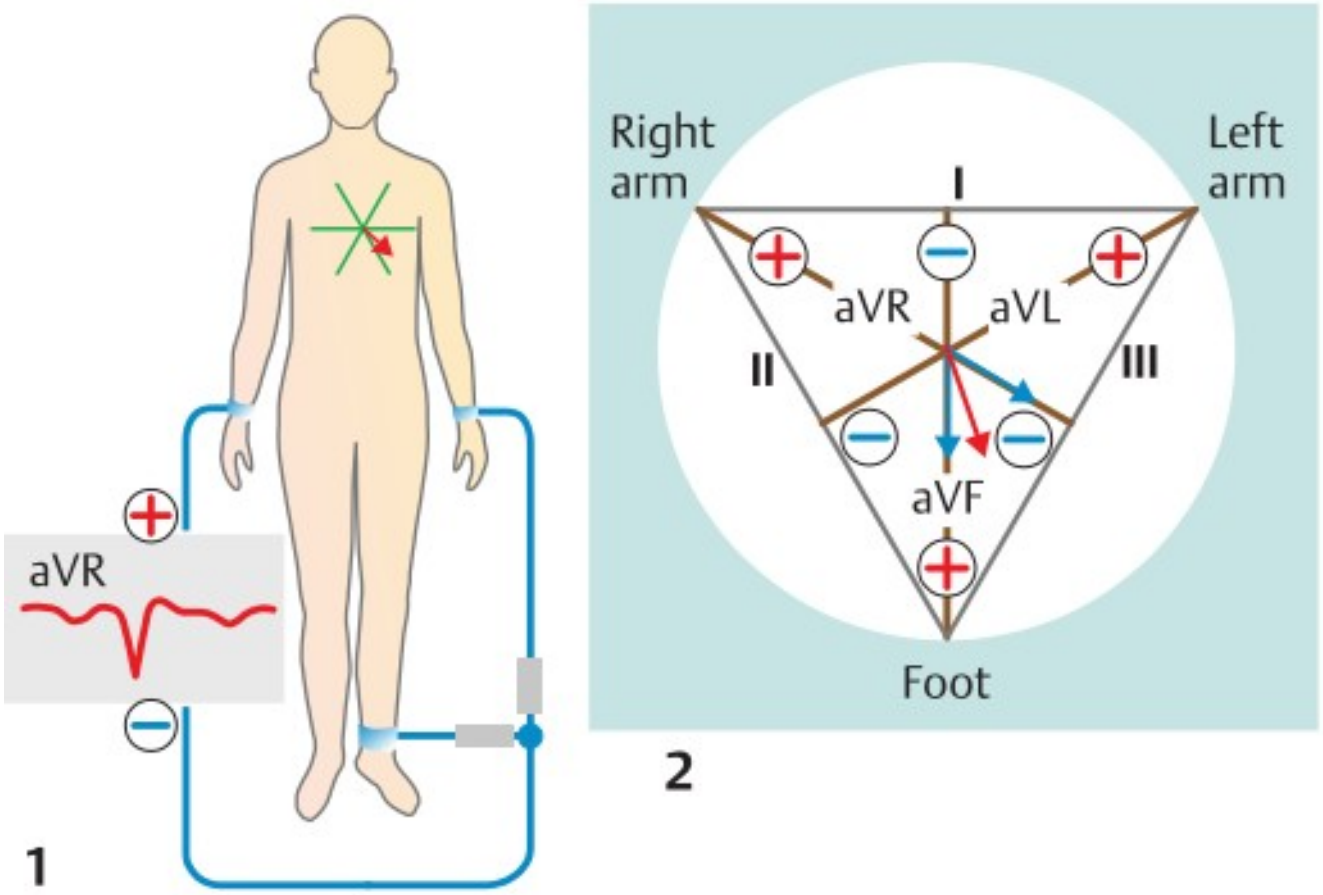


Augmented limb leads

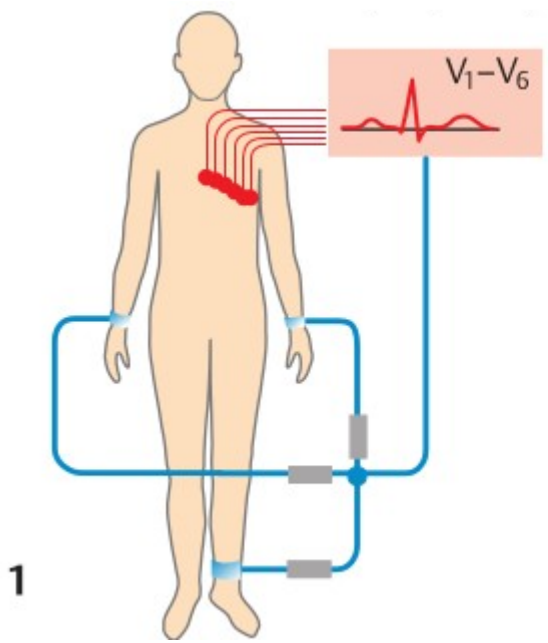


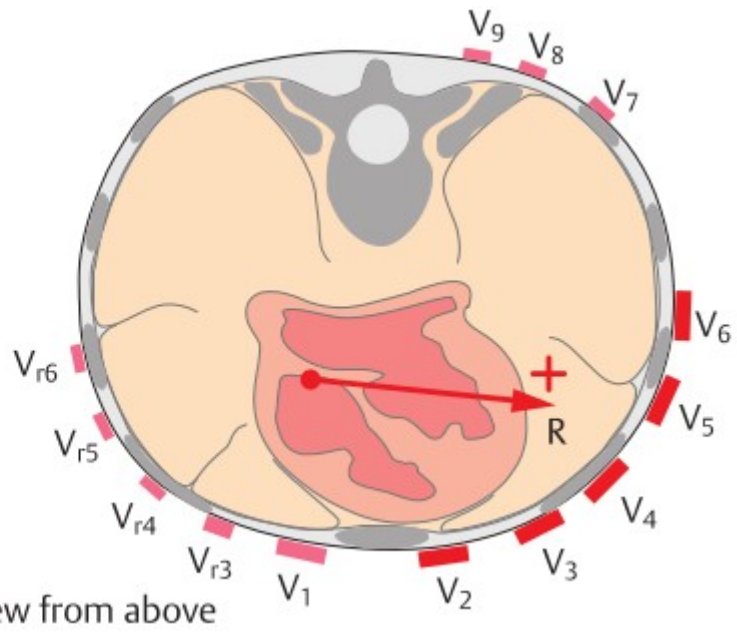


Schema Goldberger

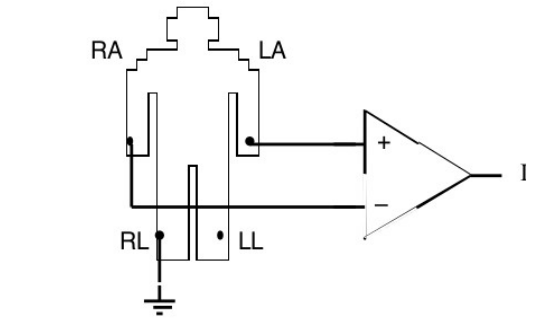


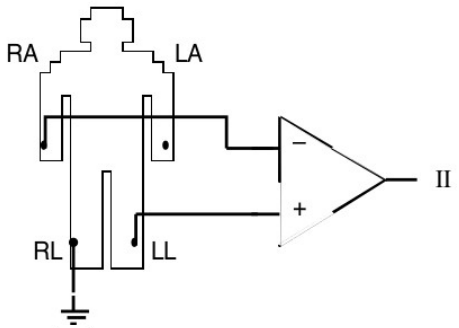
Schema Wilson

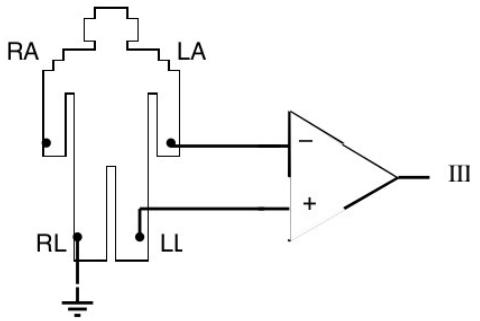


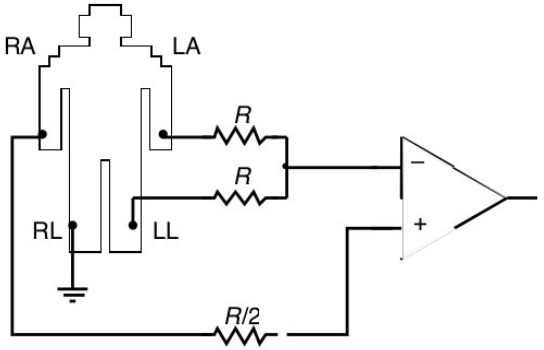


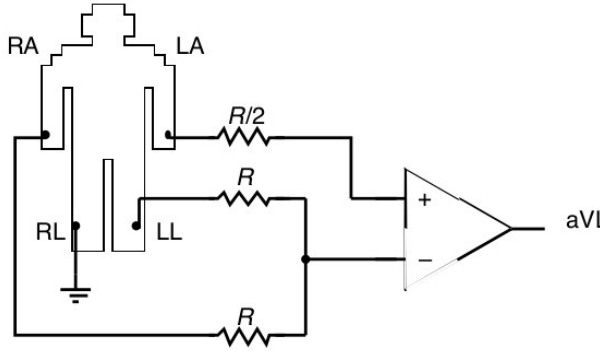
Augmented limb leads

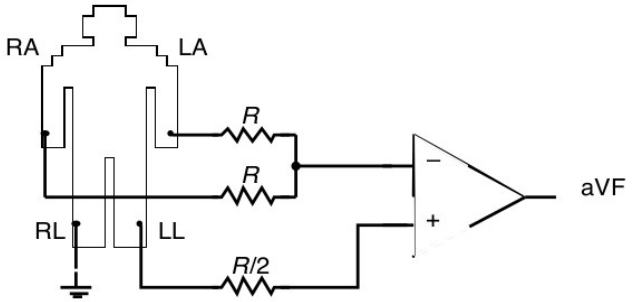


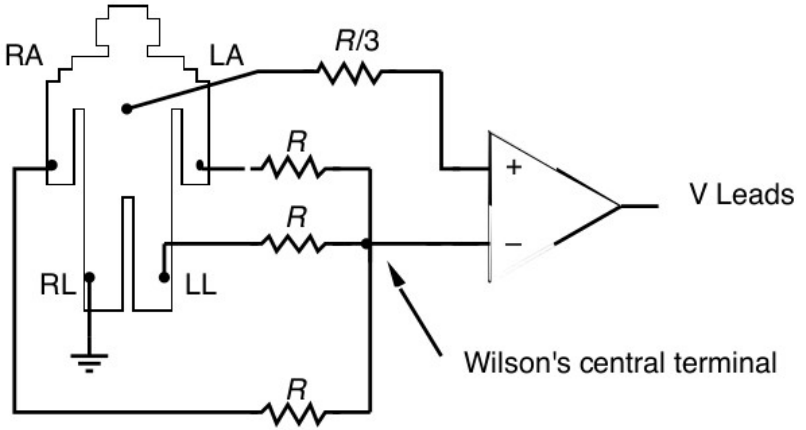






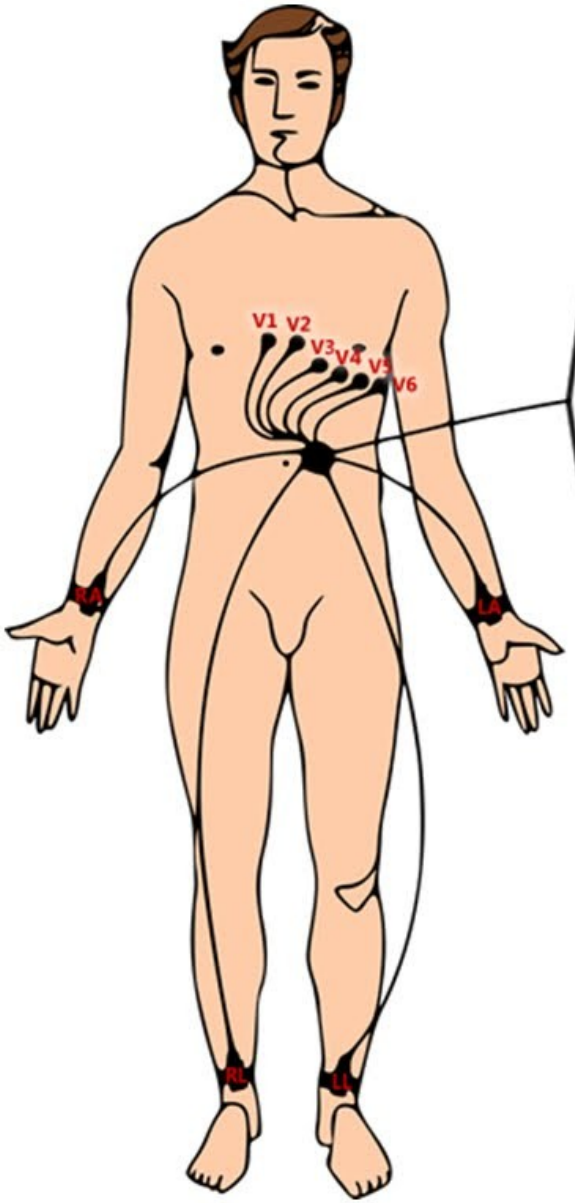


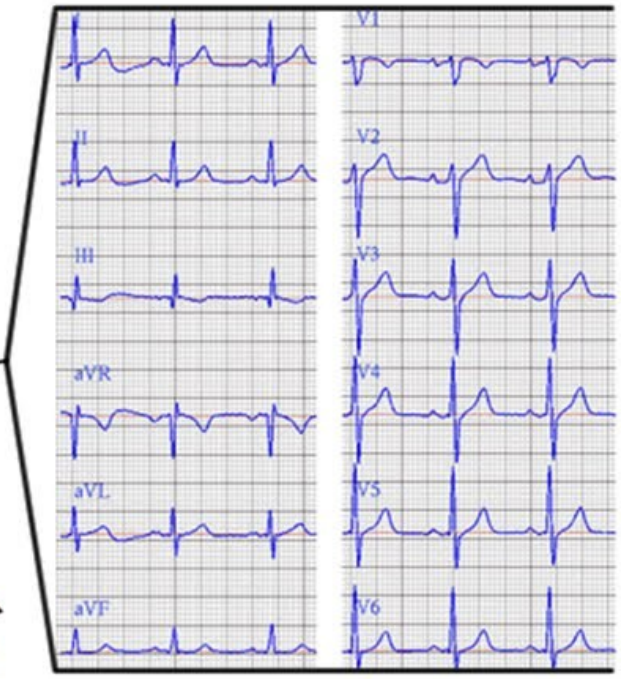


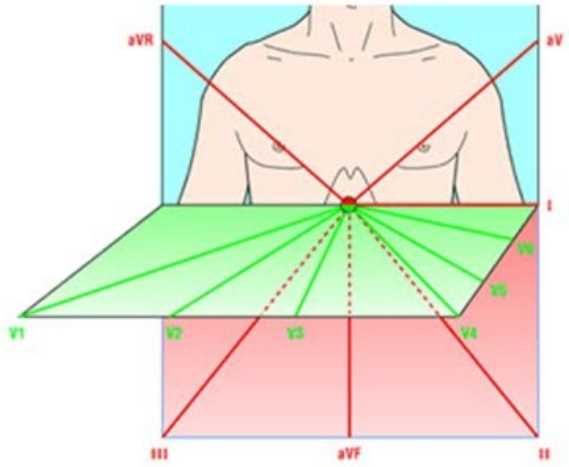


Vi sono 6 “V leads”, relative a posizioni diverse sul torace

12 leads ECG







V1 - 4th intercostal space
R sternal border

V2 - 4th intercostal space
L sternal border

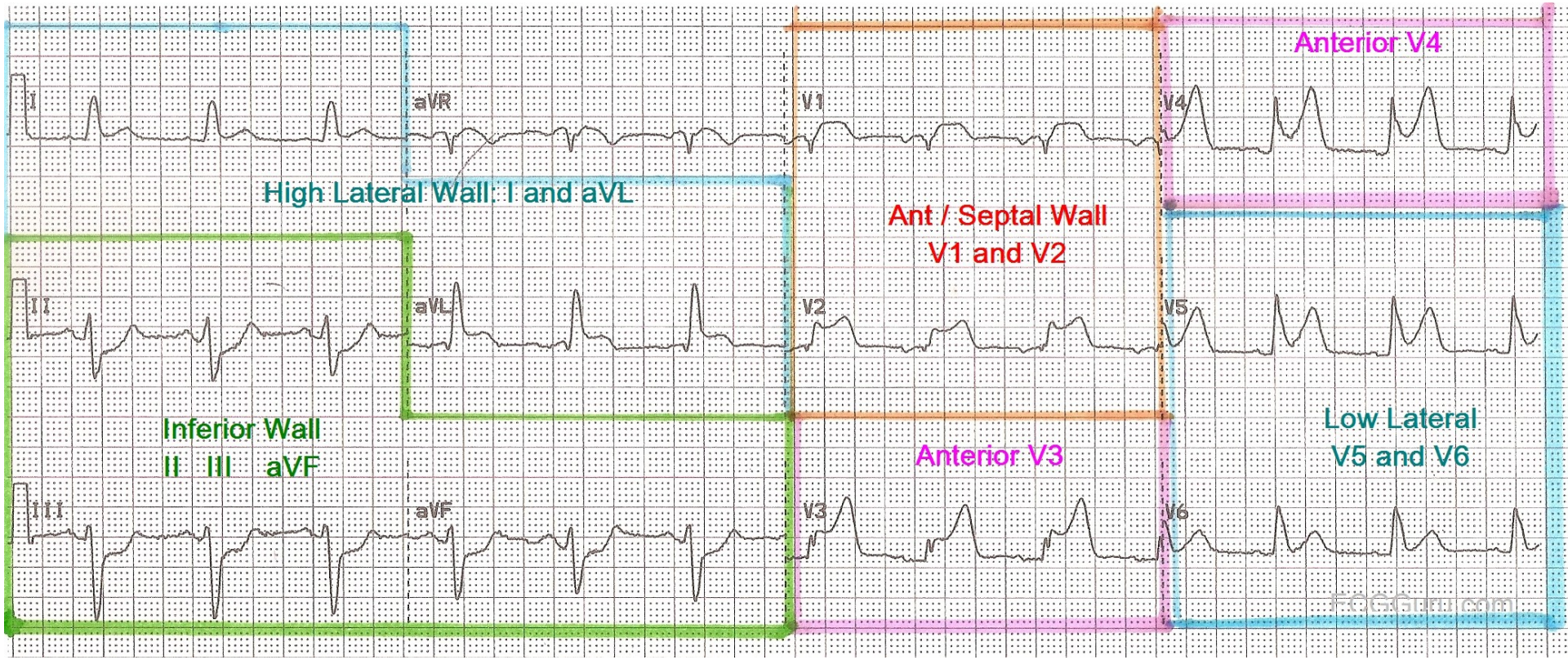
V3 - Between leads V2 and V4.

V4 - 5th L intercostal space in midclavicular line

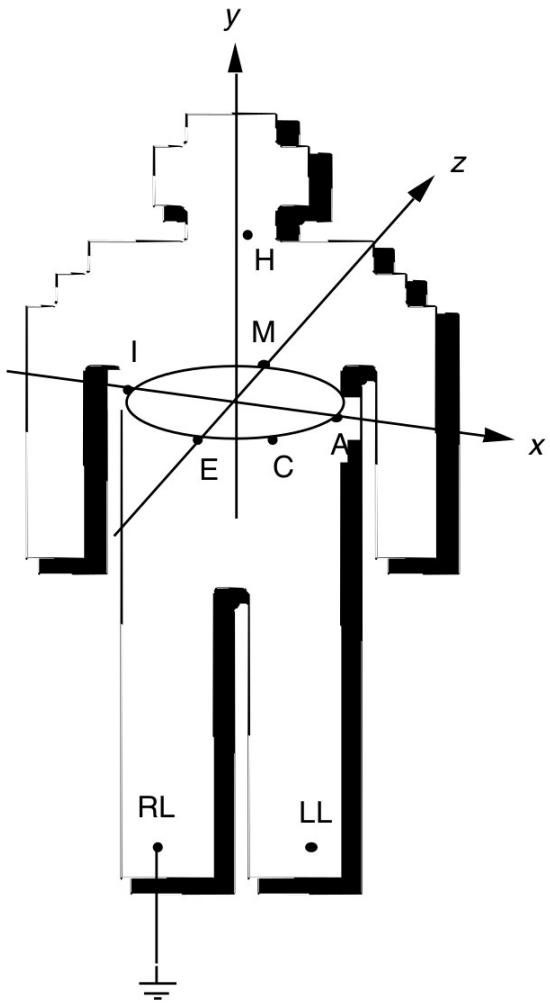
V5 - Horizontally even with V4, but in the anterior axillary line.

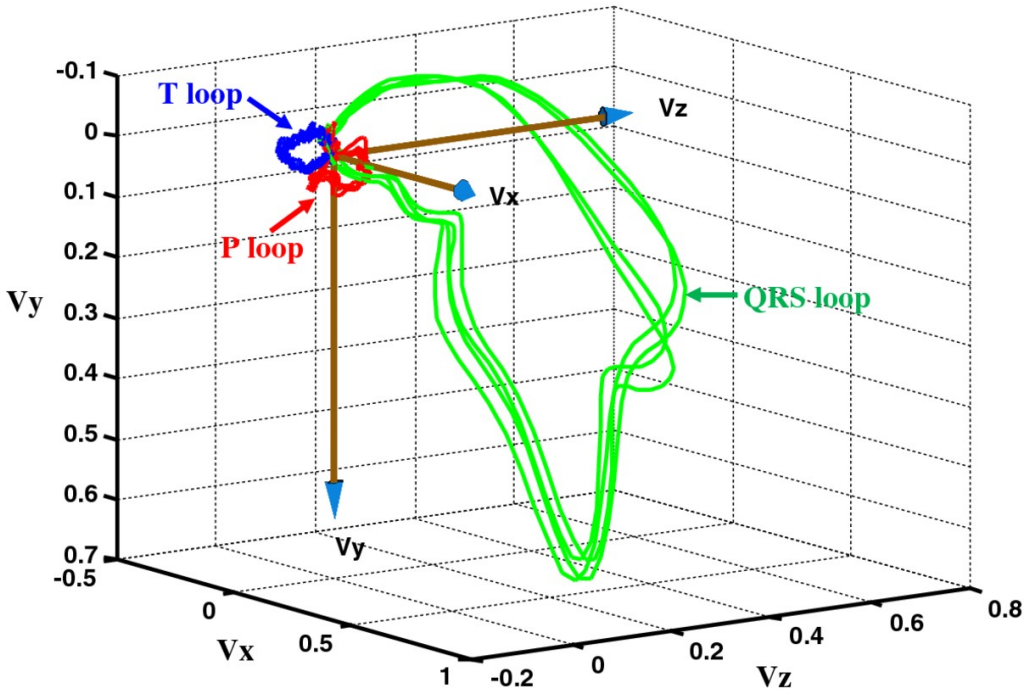
V6 - Horizontally even with V4 and V5 in the midaxillary line. (The midaxillary line is the imaginary line that extends down from the middle of the patient's armpit.)

12 leads ECG

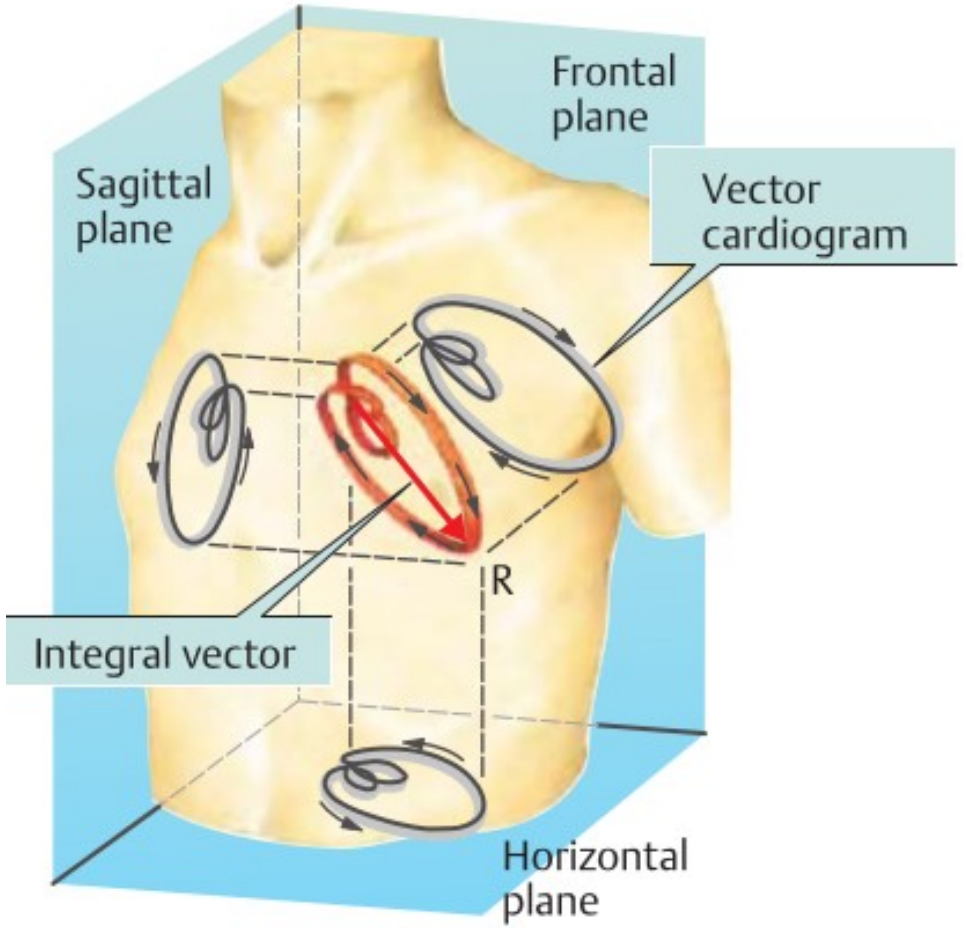

I
aVR
V1
V4
High Lateral Wall: I and aVL
Anterior V4
Ant / Septal Wall
V1 and V2
II
aVL
V2
V5
Inferior Wall
II III aVF
Anterior V3
Low Lateral
V5 and V6
III
aVF
V3
V6

Vectorcardiogram

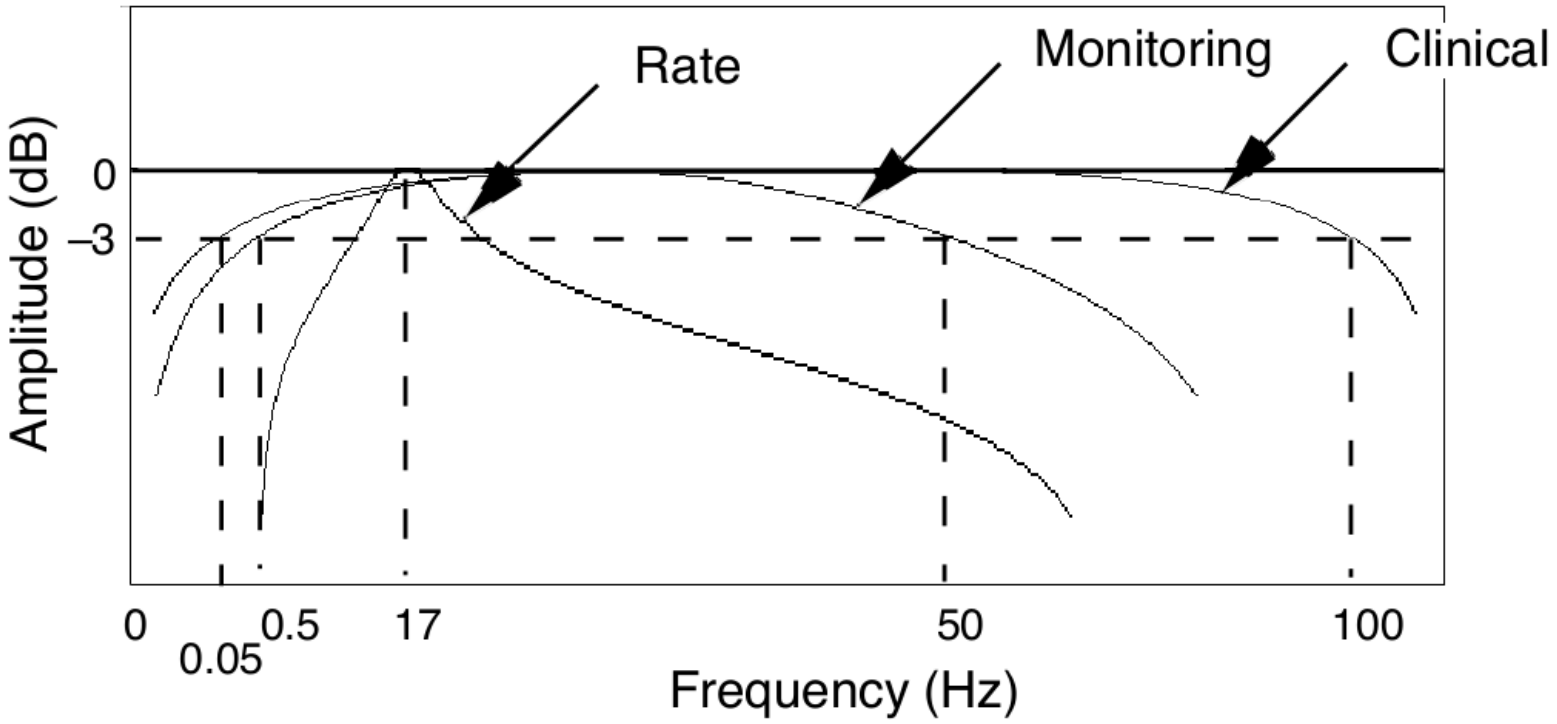




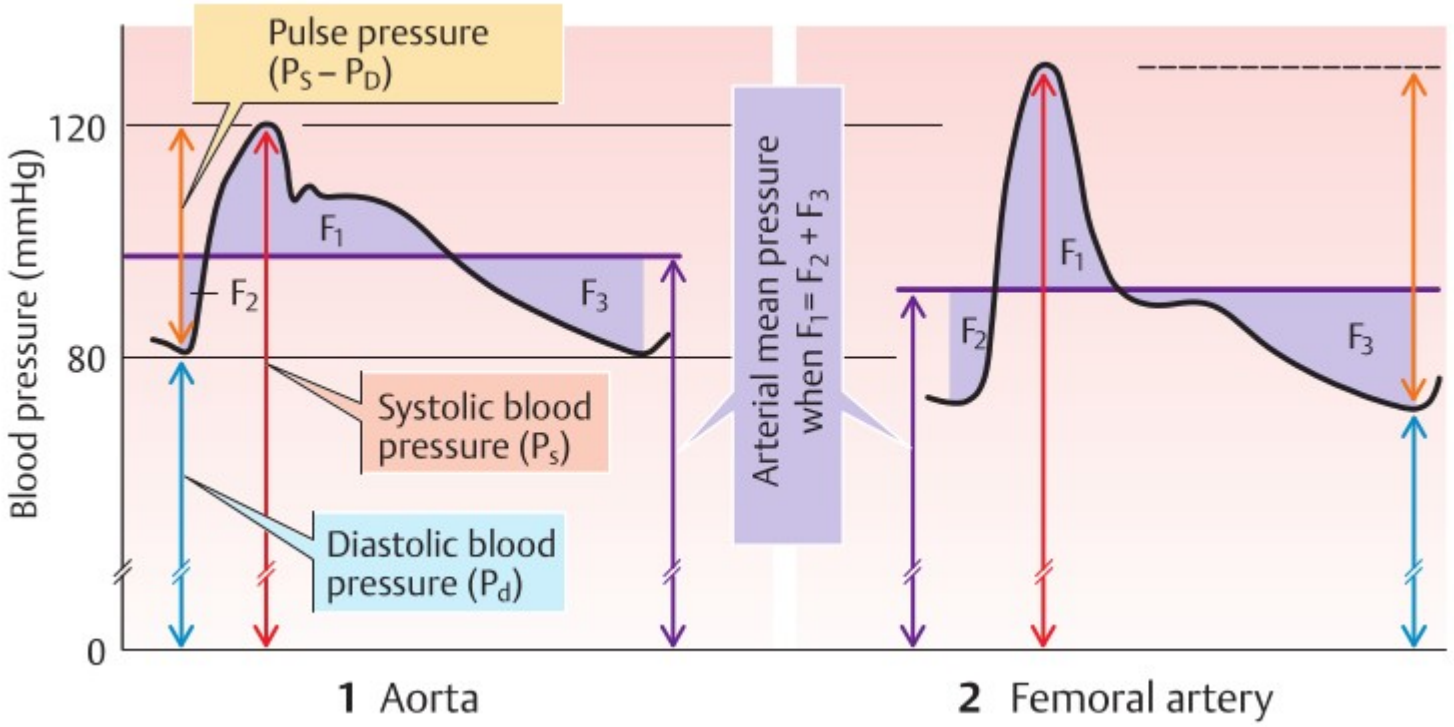
Vectorcardiogram



Bande di interesse

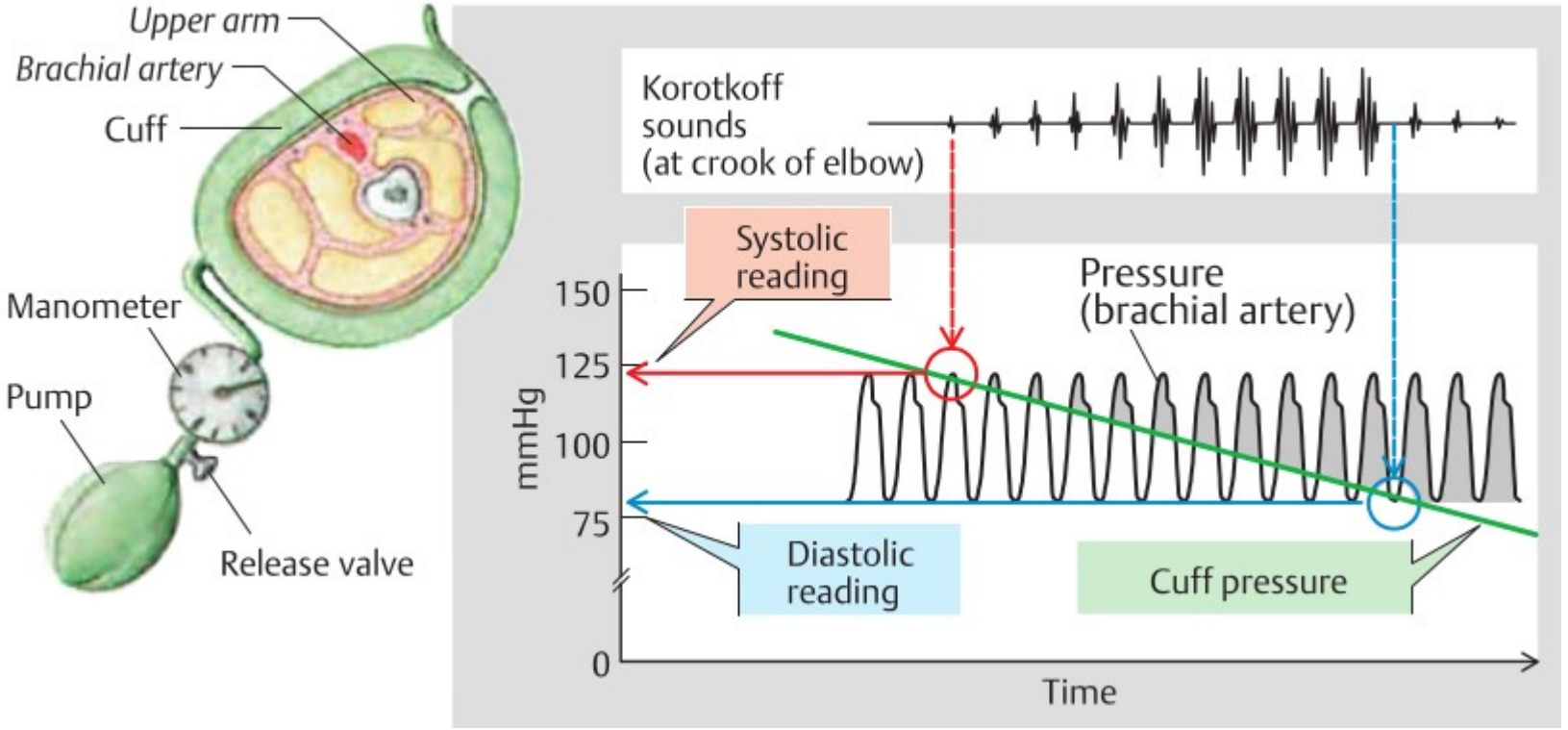


Pressione sanguigna



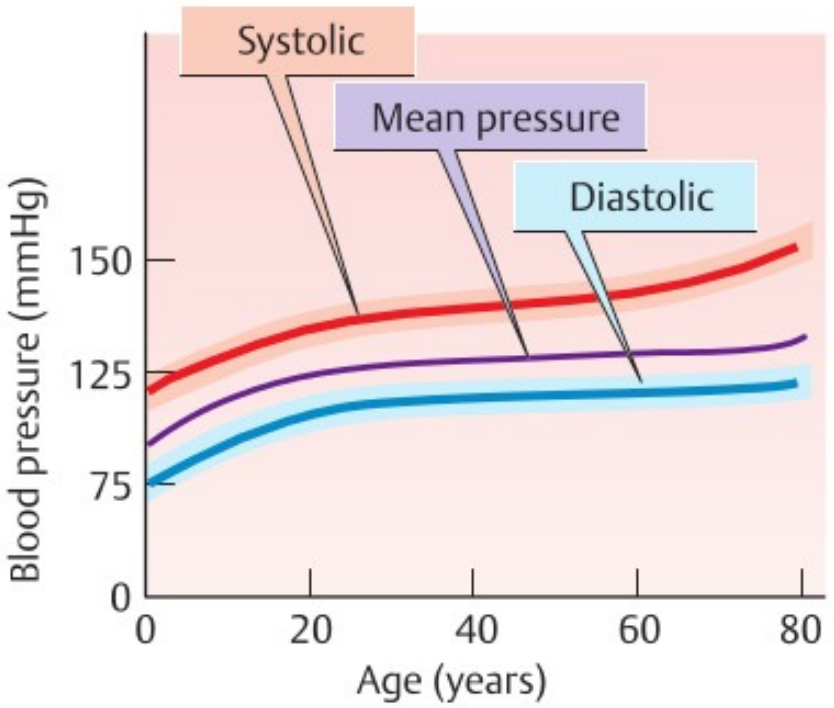
Andamento della pressione arteriosa.

Pressione sanguigna



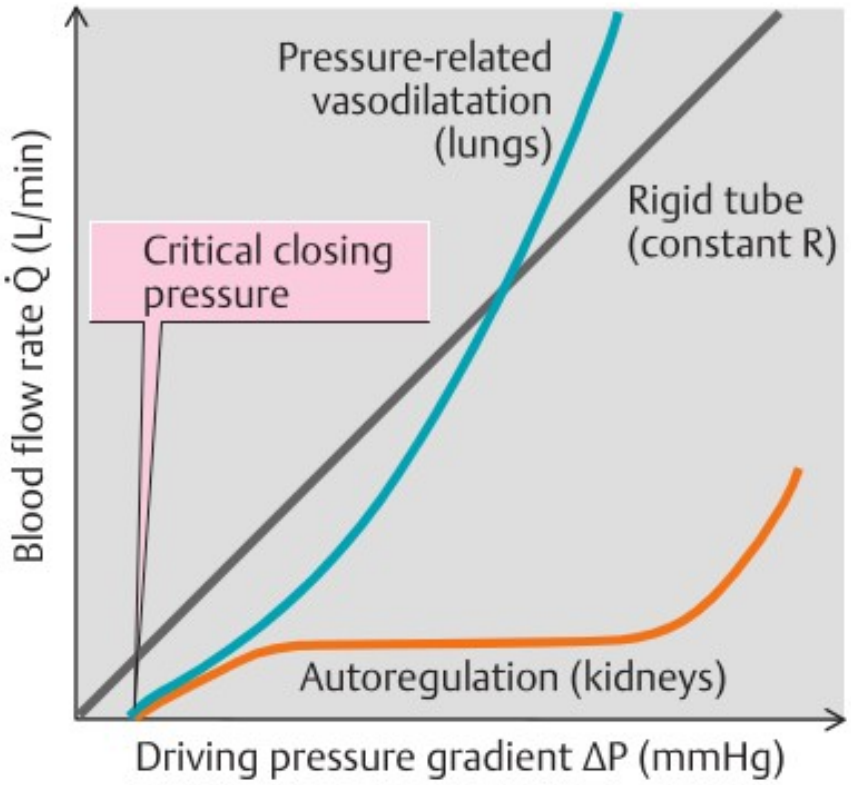
Misurazione della pressione tramite sfigmomanometro.

Pressione sanguigna



Dipendenza della pressione dall'età.

Pressione sanguigna



Pressione e flusso sanguigno.