ECG

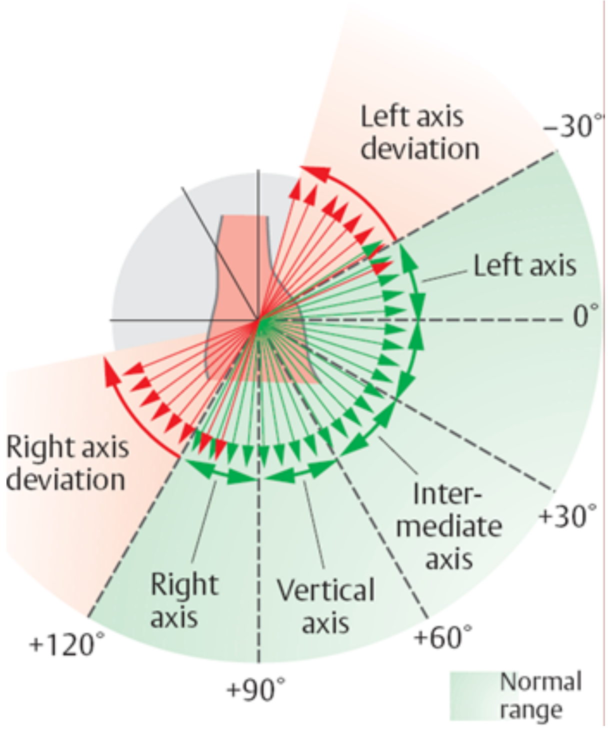
Any of the following calculations may be asked in the midterms/exam.

1. The average R–R distance of an ECG-curve is 19 mm, the paper speed is 25 mm/s. Find the pulse rate of the patient.

2. What is the average R–R distance on an ECG-curve, if the paper speed is 25 mm/s and the heart rate of the patient is 75/min?

3. The amplitude of the R-peak in Einthoven's I lead is 4 mm while in Einthoven's II lead it is 12 mm. Find the amplitude of the R-peak ...
   a) ... in Einthoven's III lead.
   b) ... in Goldberger's aVR lead.
   c) ... in Goldberger's aVL lead.
   d) ... in Goldberger's aVF lead.

New information for the following calculations: the electric axis of the heart is the frontal projection of the integral vector in the time of the R-peak. It can be constructed using Einthoven's triangle. The angle of the axis of the heart is measured relative to the horizontal plane. Basically, there are three possible axis states: normal, left, and right deviation as shown in the figure.



4. Determine the direction of the axis of the heart (its angle and whether it is normal or it deviates from normal) if Einthoven's II lead is R_{II} = 1.4 mV while Einthoven's III lead is R_{III} = 0.1 mV.

5. Determine the direction of the axis of the heart (its angle and whether it is normal or it deviates from normal) if Einthoven's II lead is R_{I} = 1.2 mV while Einthoven's III lead is R_{III} = −0.8 mV.

Formulæ

$U = \Delta\phi = \dfrac{\Delta E}{\Delta q}$ (voltage = electric potential difference)

$U_{TM} = \phi_{\text{intracell}} - \phi_{\text{extracell}}$ (transmembrane potential difference)

$U_I = \phi_L - \phi_R = U_{frontal} \cdot \cos(0° - \alpha) = U_{frontal} \cdot \cos(\alpha)$ (Einthoven's I lead)

$U_{II} = \phi_F - \phi_R = U_{frontal} \cdot \cos(60° - \alpha)$ (Einthoven's II lead)

$U_{III} = \phi_F - \phi_L = U_{frontal} \cdot \cos(120° - \alpha) = U_{frontal} \cdot \sin(\alpha - 30°)$ (Einthoven's III lead)

$U_{II} = U_I + U_{III}$ (relationship between Einthoven's leads)

$\phi_{CT} = \dfrac{(\phi_R + \phi_L + \phi_F)}{3}$ (Wilson Central Terminal [CT])

$U_V = \phi_C - \phi_{CT} = \phi_C - \dfrac{(\phi_R + \phi_L + \phi_F)}{3}$ (Wilson's precordial leads)

$U_{aVR} = \phi_R - \dfrac{(\phi_L + \phi_F)}{2}$ (Goldberger's aVR lead)

$U_{aVL} = \phi_L - \dfrac{(\phi_R + \phi_F)}{2}$ (Goldberger's aVL lead)

$U_{aVF} = \phi_F - \dfrac{(\phi_R + \phi_L)}{2}$ (Goldberger's aVF lead)

$\sin(\alpha \pm \beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$ (sine of a sum [trigonometric identity])

$\cos(\alpha \pm \beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$ (cosine of a sum [trigonometric identity])

Solutions

1. $$T=\frac{19mm}{25\frac{mm}{s}}=0.76s$$

$$f=\frac{1}{T}=\frac{1}{0.76s}=1.31/s=\underline{\underline{79/\min}}$$

2. $$f=75/\min=1.25/s$$

$$T=\frac{1}{f}=\frac{1}{1.25/s}=0.8s$$

$$d_{R-R}=0.8s\cdot 25\frac{mm}{s}=\underline{\underline{20mm}}$$

3. a) $U_{II}=U_{I}+U_{III}$

$$U_{III}=U_{II}-U_{I}=12mm-4mm=\underline{\underline{8mm}}$$

b) $U_{aVR}=\phi_R-\frac{(\phi_L+\phi_F)}{2}=\frac{2\phi_R-\phi_L-\phi_F}{2}=\frac{(\phi_R-\phi_L)+(\phi_R-\phi_F)}{2}=\frac{(-U_I)+(-U_{II})}{2}$

$$U_{aVR}=\frac{(-4mm)+(-12mm)}{2}=\underline{\underline{-8mm}}$$

c) $U_{aVL}=\phi_L-\frac{(\phi_R+\phi_F)}{2}=\frac{2\phi_L-\phi_R-\phi_F}{2}=\frac{(\phi_L-\phi_R)+(\phi_L-\phi_F)}{2}=\frac{(U_I)+(-U_{III})}{2}$

$$U_{aVL}=\frac{(4mm)+(-8mm)}{2}=\underline{\underline{-2mm}}$$

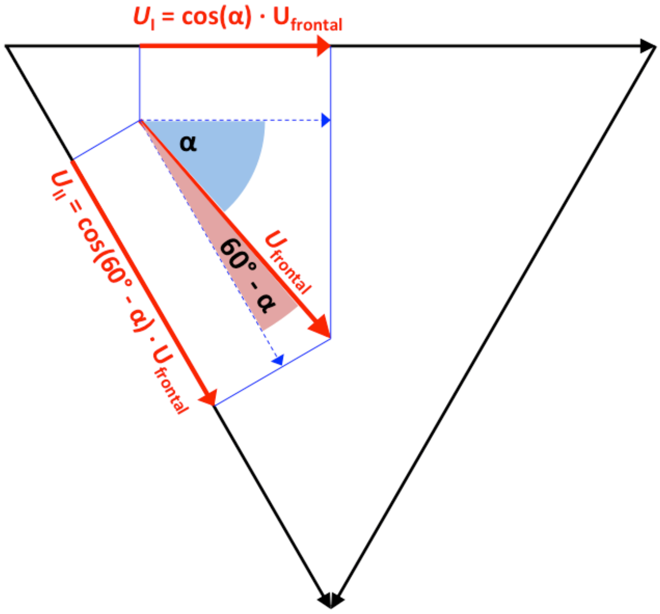
d) $U_{aVF}=\phi_F-\frac{(\phi_R+\phi_L)}{2}=\frac{2\phi_F-\phi_R-\phi_L}{2}=\frac{(\phi_F-\phi_R)+(\phi_F-\phi_L)}{2}=\frac{(U_{II})+(U_{III})}{2}$

$$U_{aVF}=\frac{(12mm)+(8mm)}{2}=\underline{\underline{10mm}}$$

4. First, calculate U_{I} because we will need it later:

$$U_{II}=U_{I}+U_{III}$$

$$U_{I}=U_{II}-U_{III}=1.4mV-0.1mV=1.3mV$$



As can be seen in the figure, the angle of the electric axis of the heart (α) has the following relationship with the frontal projection of the integral vector (U_{frontal}), and the voltage of Einthoven's I and II leads (i.e., U_{I} and U_{II}) (supposing that the angles of Einthoven's triangle are 60°, therefore, the angle between U_{I} and U_{II} is also 60°):

$$\cos\alpha=\frac{U_I}{U_{frontal}}$$, as well as

$$\cos(60°-\alpha)=\frac{U_{II}}{U_{frontal}}$$

transform these to solve the equation system:

$$\left.\begin{aligned} U_{frontal} &= \frac{U_I}{\cos\alpha} \\ U_{frontal} &= \frac{U_{II}}{\cos(60^\circ - \alpha)} \end{aligned}\right\} \frac{U_I}{\cos\alpha} = \frac{U_{II}}{\cos(60^\circ - \alpha)}$$

after cross multiplication:

$$\frac{\cos(60^\circ - \alpha)}{\cos\alpha} = \frac{U_{II}}{U_I}$$

use the trigonometric identity of cosine of a sum:

$$\frac{\cos 60^\circ \cdot \cos\alpha + \sin 60^\circ \cdot \sin\alpha}{\cos\alpha} = \frac{U_{II}}{U_I}$$

$$\frac{\cos 60^\circ \cdot \cos\alpha}{\cos\alpha} + \frac{\sin 60^\circ \cdot \sin\alpha}{\cos\alpha} = \frac{U_{II}}{U_I}$$

simplify and use the following:

$\cos 60^\circ = \frac{1}{2}$ and $\sin 60^\circ = \frac{\sqrt{3}}{2}$, as well as $\frac{\sin\alpha}{\cos\alpha} = \tan\alpha$

$\frac{1}{2} + \frac{\sqrt{3}}{2}\tan\alpha = \frac{U_{II}}{U_I}$, out of this:

$$\tan\alpha = \left(\frac{U_{II}}{U_I} - \frac{1}{2}\right) \cdot \frac{2}{\sqrt{3}} = \left(\frac{1.4mV}{1.3mV} - \frac{1}{2}\right) \cdot \frac{2}{\sqrt{3}} = 0.666$$

$$\alpha = \arctan 0.666 = \underline{\underline{33.67^\circ}}$$

Since the axis angles between –30° and +120° are considered normal, this one is also considered <u>normal</u>.

5. Solution goes as in the previous problem. First calculate U_{II}:

$$U_{II} = U_I + U_{III} = 1.2mV + (-0.8mV) = 0.4mV$$

Then use the formula expressed above to find the angle of the axis of the heart:

$$\tan\alpha = \left(\frac{U_{II}}{U_I} - \frac{1}{2}\right) \cdot \frac{2}{\sqrt{3}} = \left(\frac{0.4mV}{1.2mV} - \frac{1}{2}\right) \cdot \frac{2}{\sqrt{3}} = -0.19245$$

$$\alpha = \arctan(-0.19245) = \underline{\underline{-10.9^\circ}}$$

Since the axis angles between –30° and +120° are considered normal, this one is also considered <u>normal</u>.