# The Origin of P wave

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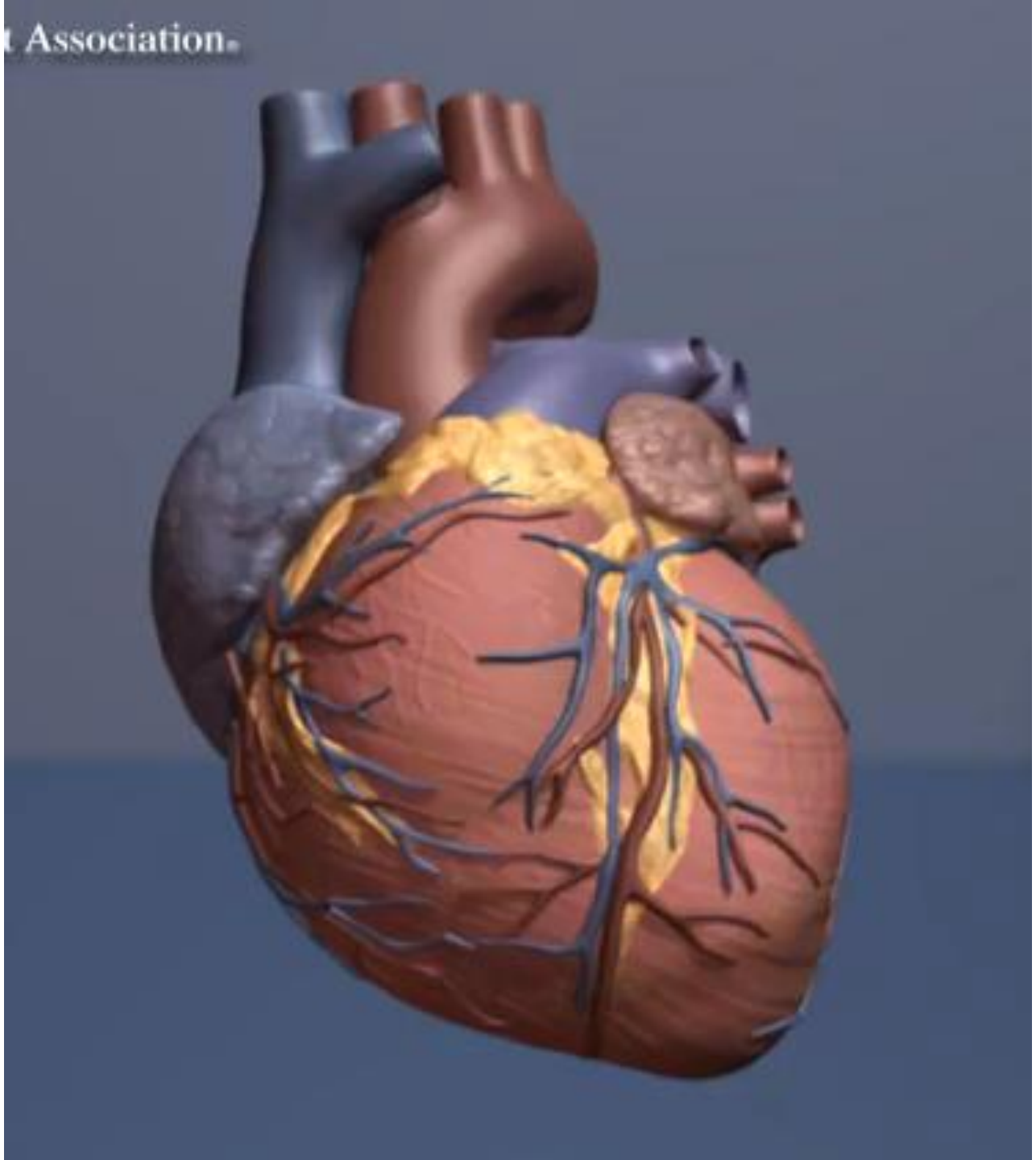
# Outline

- Anatomy of atrium
- Electrical activities in sinus node
- Conduction of system of the heart
- ECG
- The origin of P wave

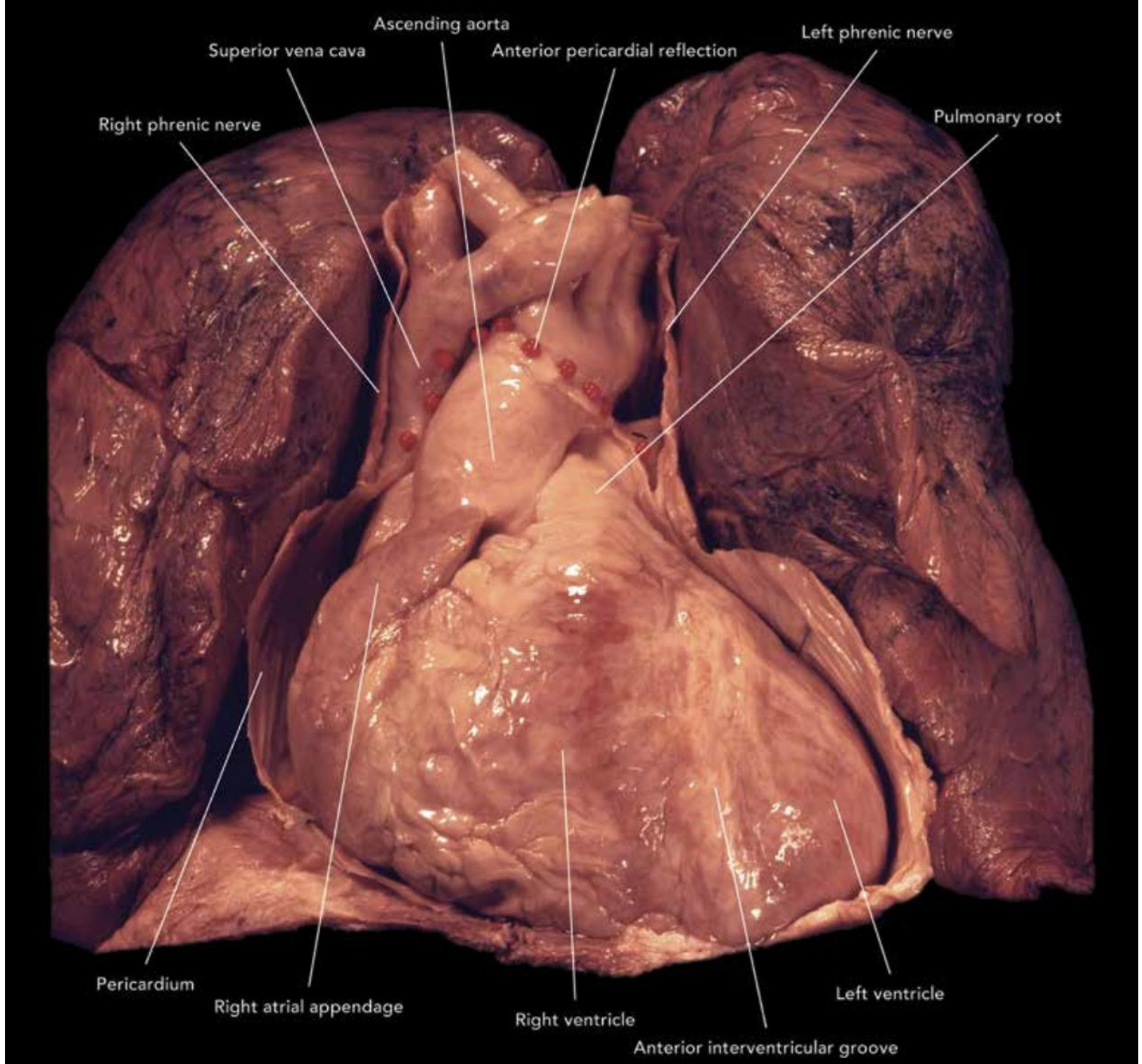
# History

A note on Descartes seems appropriate because although he was born in France in 1596 and died in 1650, he plays a major role in the story that unfolds.[1] He invented analytical geometry. He was the first scientist to state the law of refraction, and he labeled some of the points on the curves he drew P and Q. As discussed later, Einthoven undoubtedly studied the work of Descartes, as did all serious students of geometry and physics.

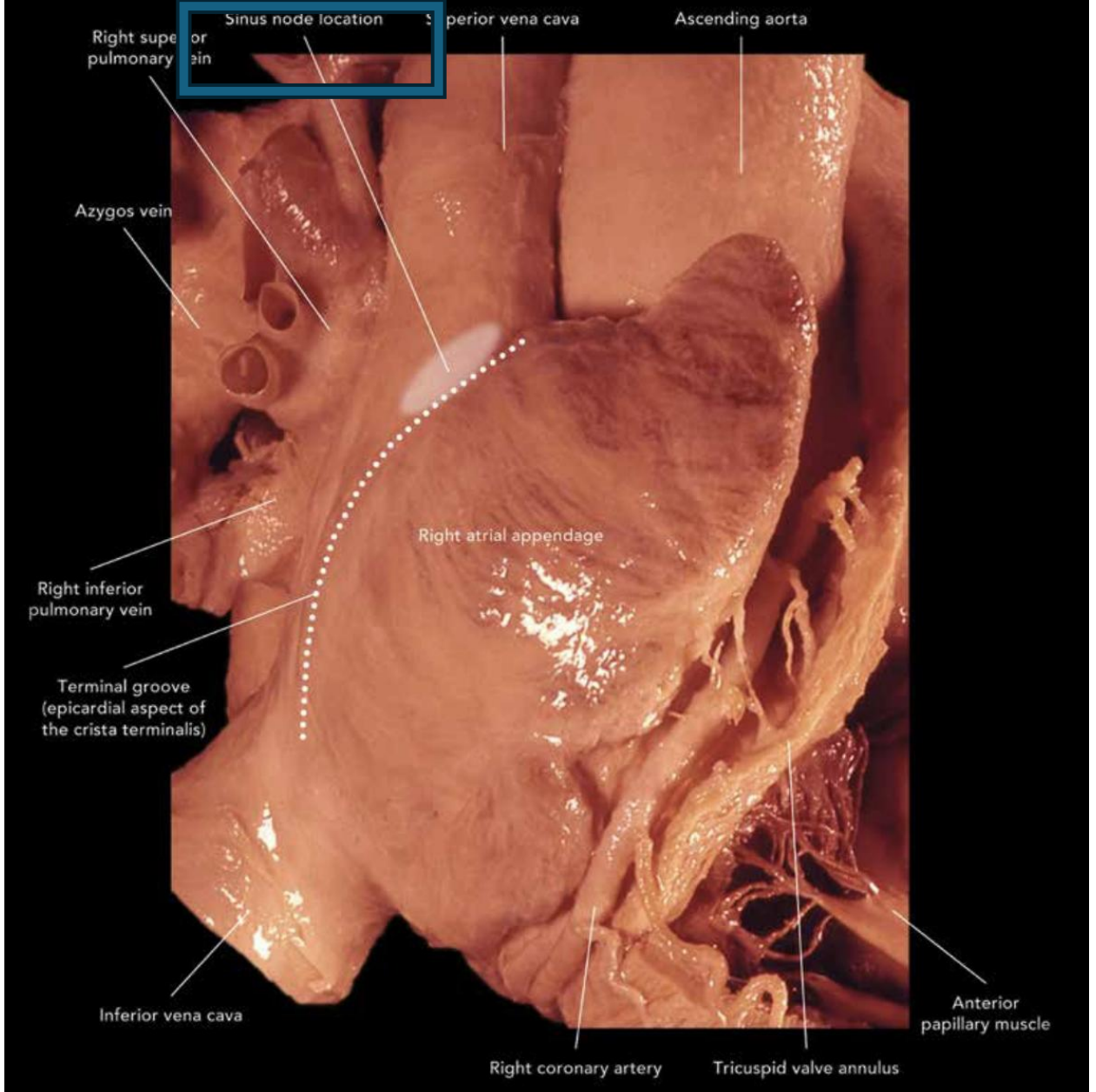
Right Atrial appendage




Left Atrial appendage


Ascending aorta
Superior vena cava
Anterior pericardial reflection
Left phrenic nerve
Right phrenic nerve
Pulmonary root
Pericardium
Right atrial appendage
Right ventricle
Left ventricle
Anterior interventricular groove

# Sinus node




**Figures 2-1 and 2-2 Sinus node.**

The sinus node is a complex that sits at the top of the epicardial and basal side of the terminal groove (crista terminalis) just beneath the level of the right atrial appendage and superior vena cava junction.

# Bachmann Bundle

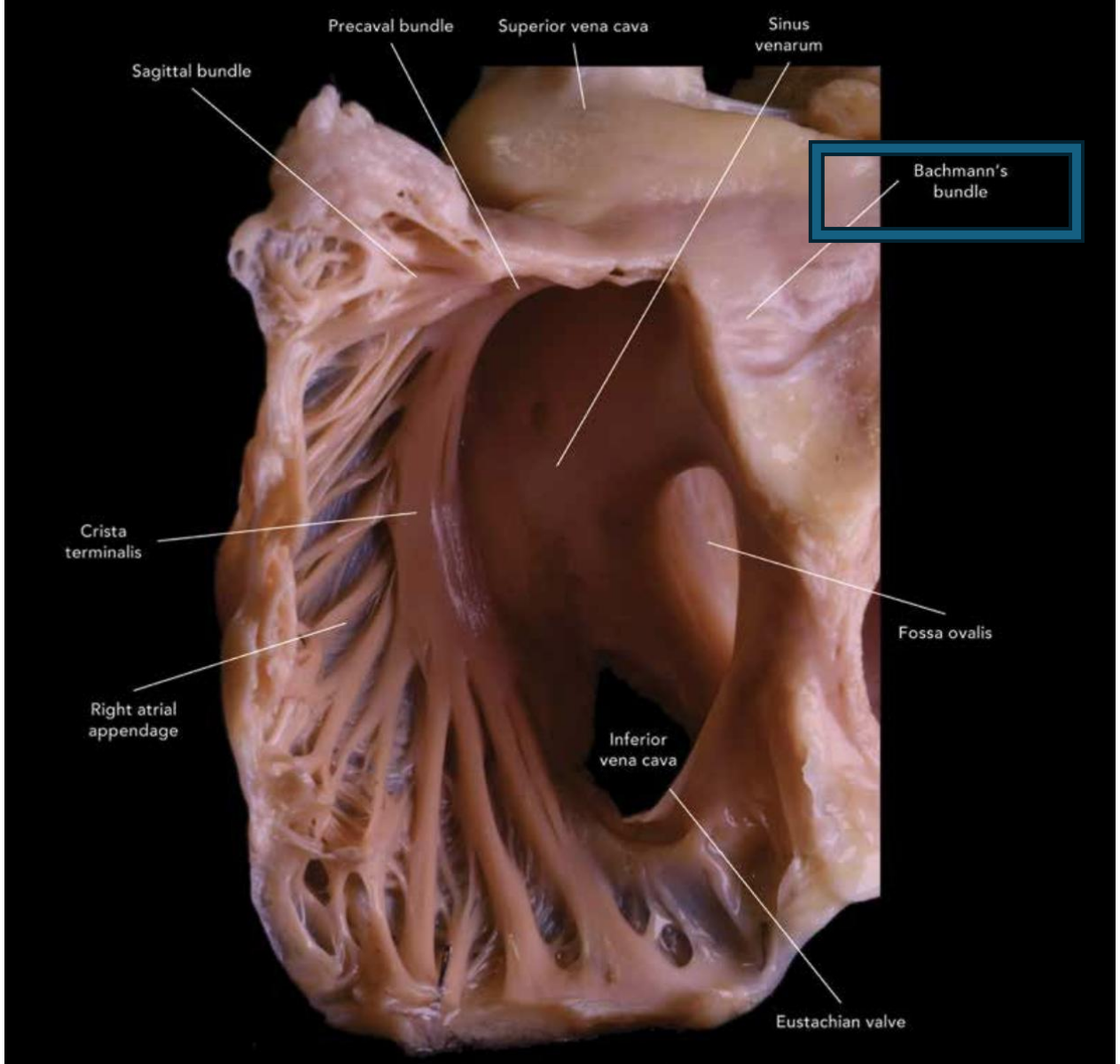
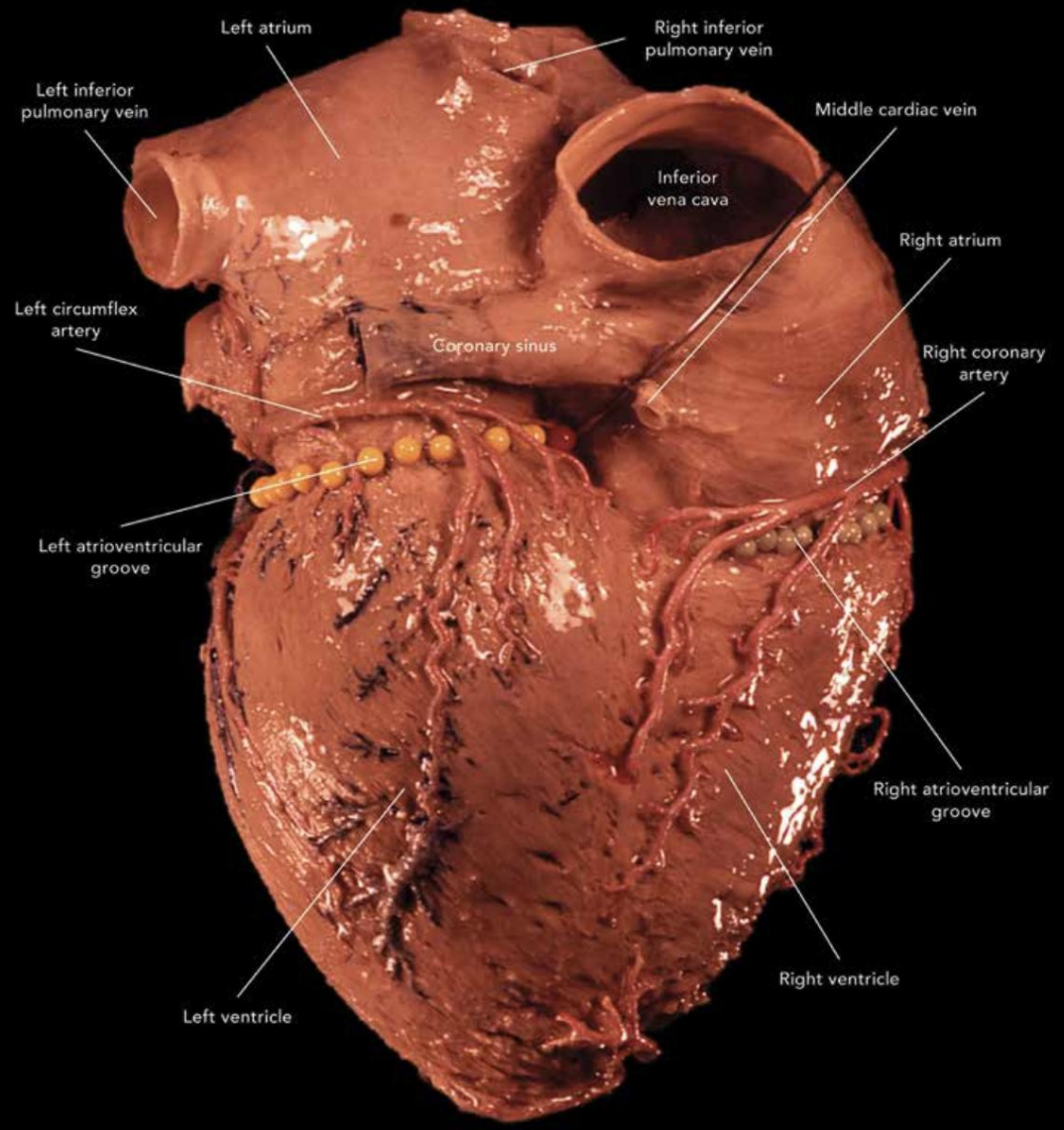
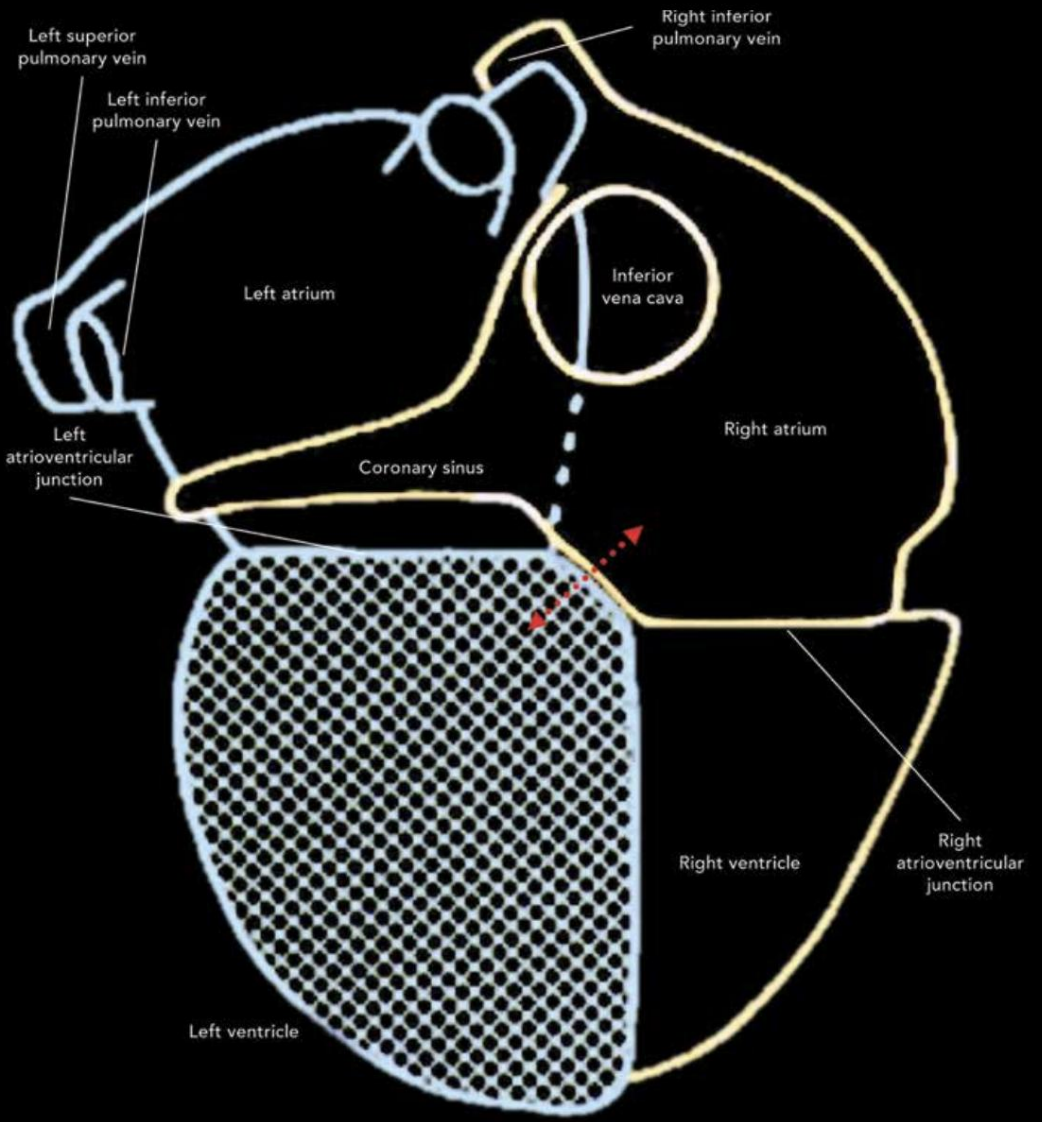



**Figure 2-6** **Internal aspect of the crista terminalis in the frontal view.**

The crista terminalis demarcates the margin between the right atrial appendage, with multiple pectinate muscles, and the sinus venarum, with a smooth endocardial surface. The pectinate muscles extend the superior, lateral, and inferior part of the right atrium, including the cavotricuspid isthmus.




**Figures 2-33 and 2-34** **Inferior crux of the heart.**

The crux of the heart is the center, or meeting point, between all four chambers. However, it is not a typical cross due to the offset of the mitral and tricuspid valve annuli. Furthermore, the epicardial fat carrying the atrioventricular nodal artery, referred to as the inferior pyramidal space,[6] wedges deeply toward the central fibrous body. Thus, the epicardial fat is sandwiched between the right atrium and the left ventricle.

The shared region between the right atrium and left ventricle (red dotted double-headed arrow) is important to understand in the triangle of Koch, inferior pyramidal space, slow pathway modification, ventricular arrhythmias related to the inferoseptal process, and inferior paraseptal accessory pathways.

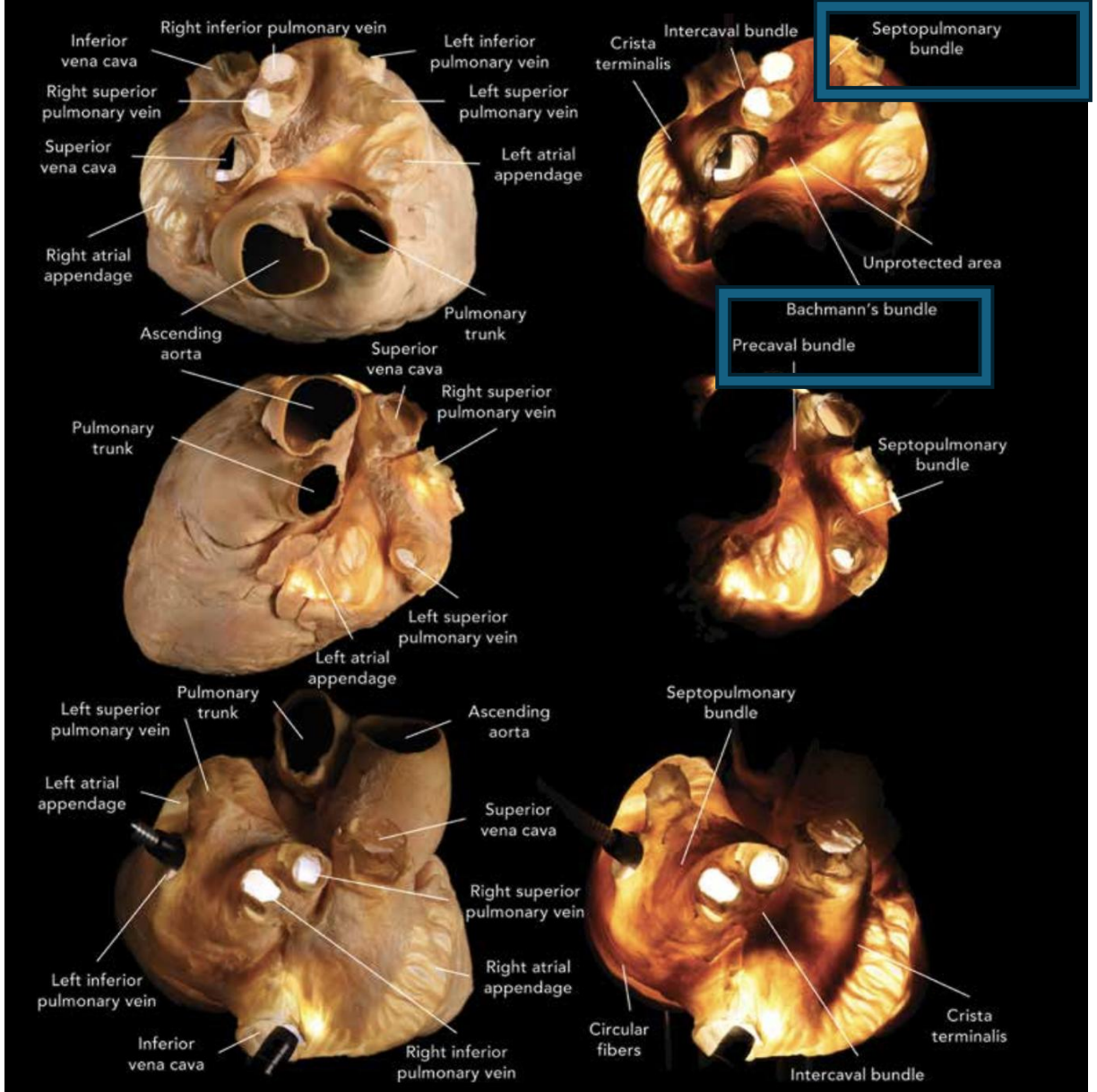
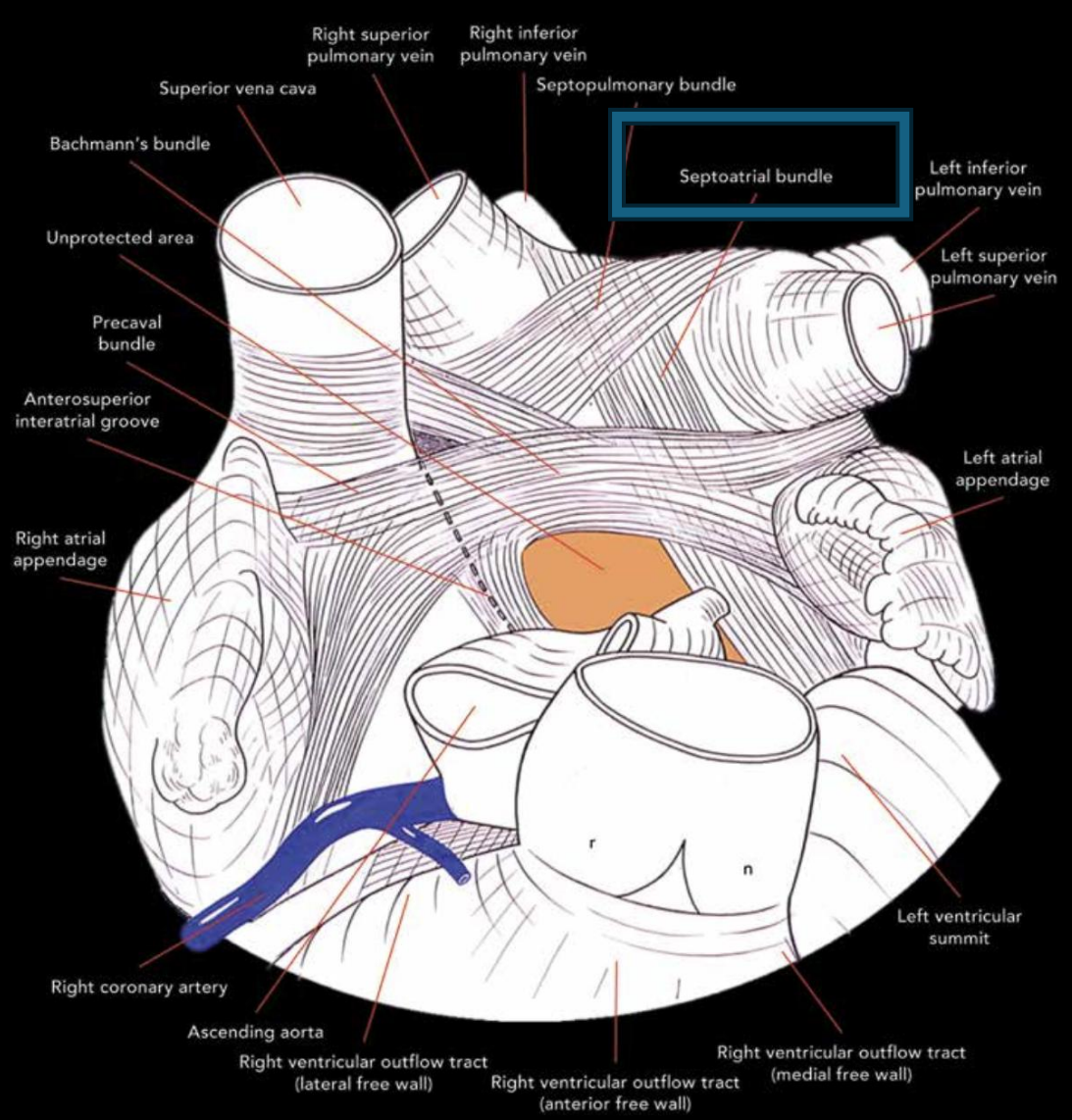



**Figure 4-5 Epicardial fibers and bundles of the left atrium.**

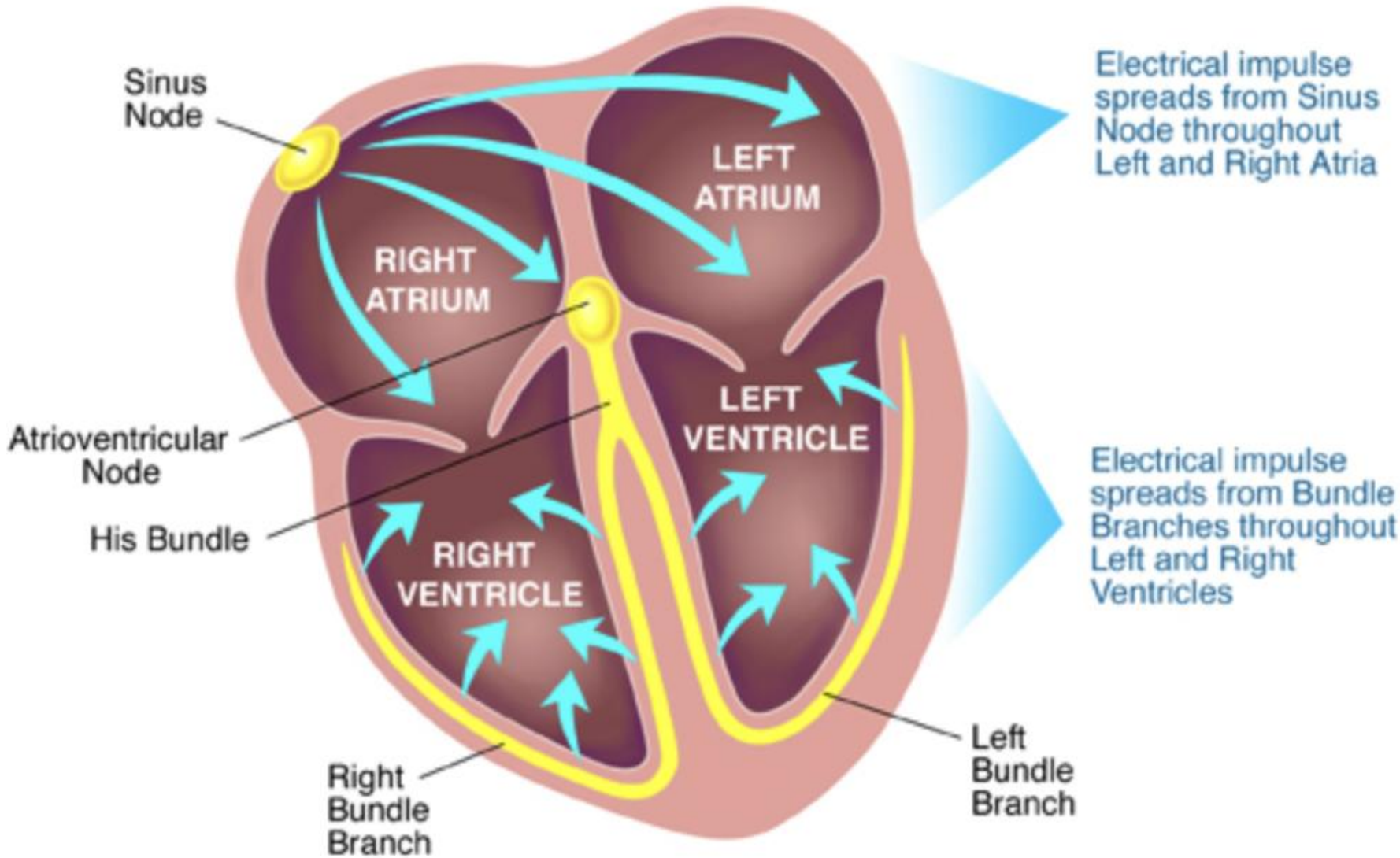
The orientation of the septopulmonary bundle, Bachmann's bundle, intercaval bundle and pectinate muscles within the left atrial appendage, and the fold between the left atrial appendage and the left pulmonary veins (left atrial ridge) are highlighted as the thicker regions compared to the transilluminated area. These structures can render endocardial ablation nontransmural (Figure 4-17).



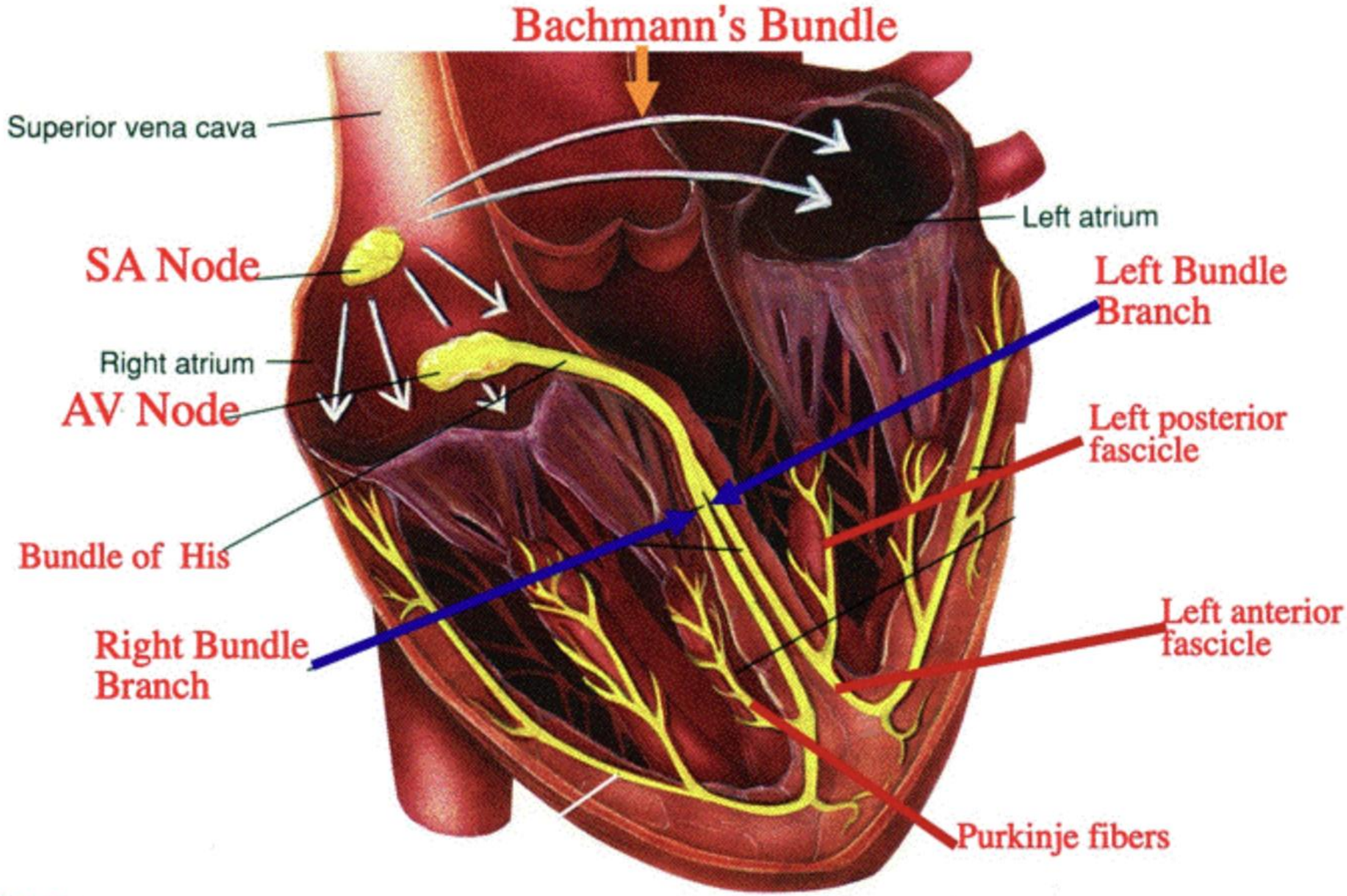

**Figures 4-13 and 4-14 Anterior wall of the left atrium.**

Complex three-dimensional layers of the atrial myofibers are illustrated. The Bachmann's bundle starts from the precaval bundle and runs across the anterosuperior interatrial groove and anterior wall of the left atrium prior to splitting down both sides of the left atrial appendage, into the ridge and toward the mitral valve annulus. The fibers that continue into the ridge is the area of the vein of Marshall. The thinnest region beneath the Bachmann's bundle is immediately posterior to the aortic root, referred to as the unprotected area.

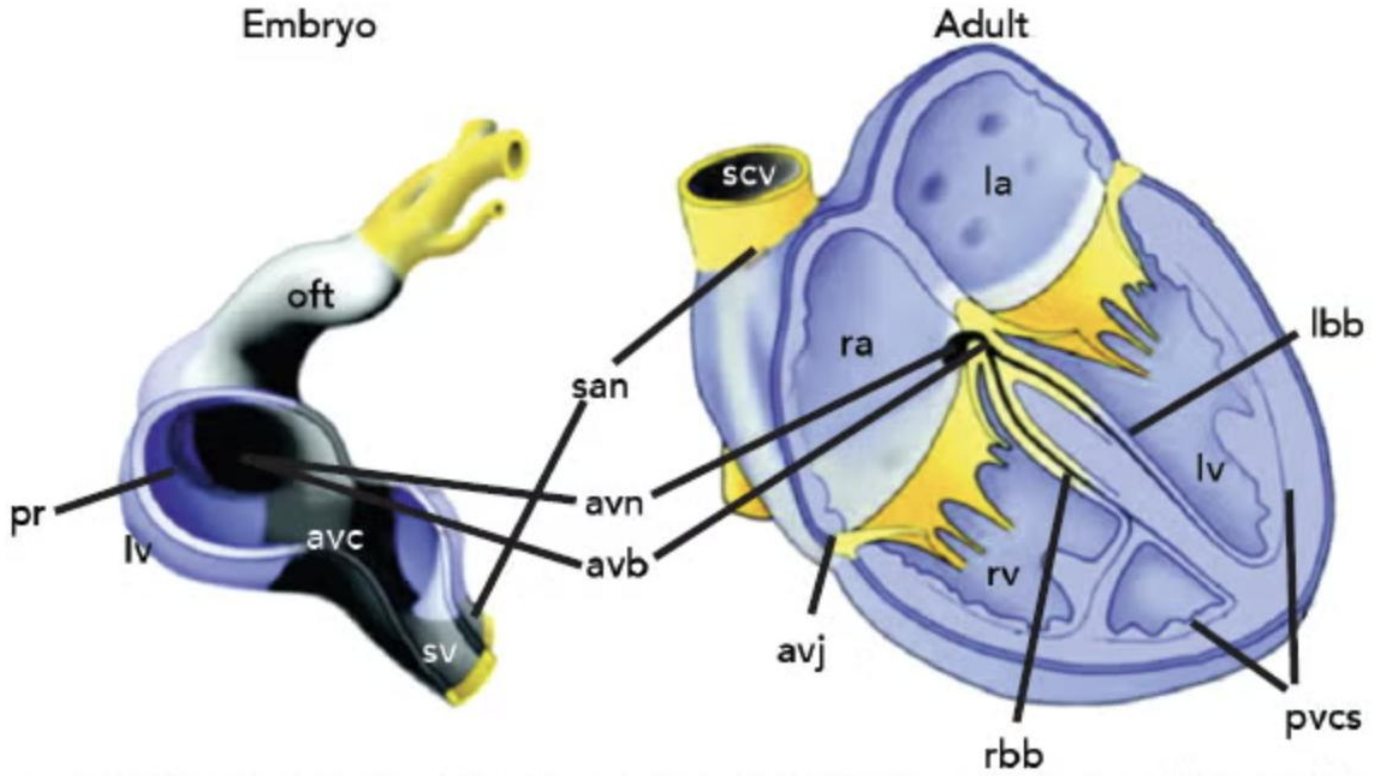
# The conduction system of the heart



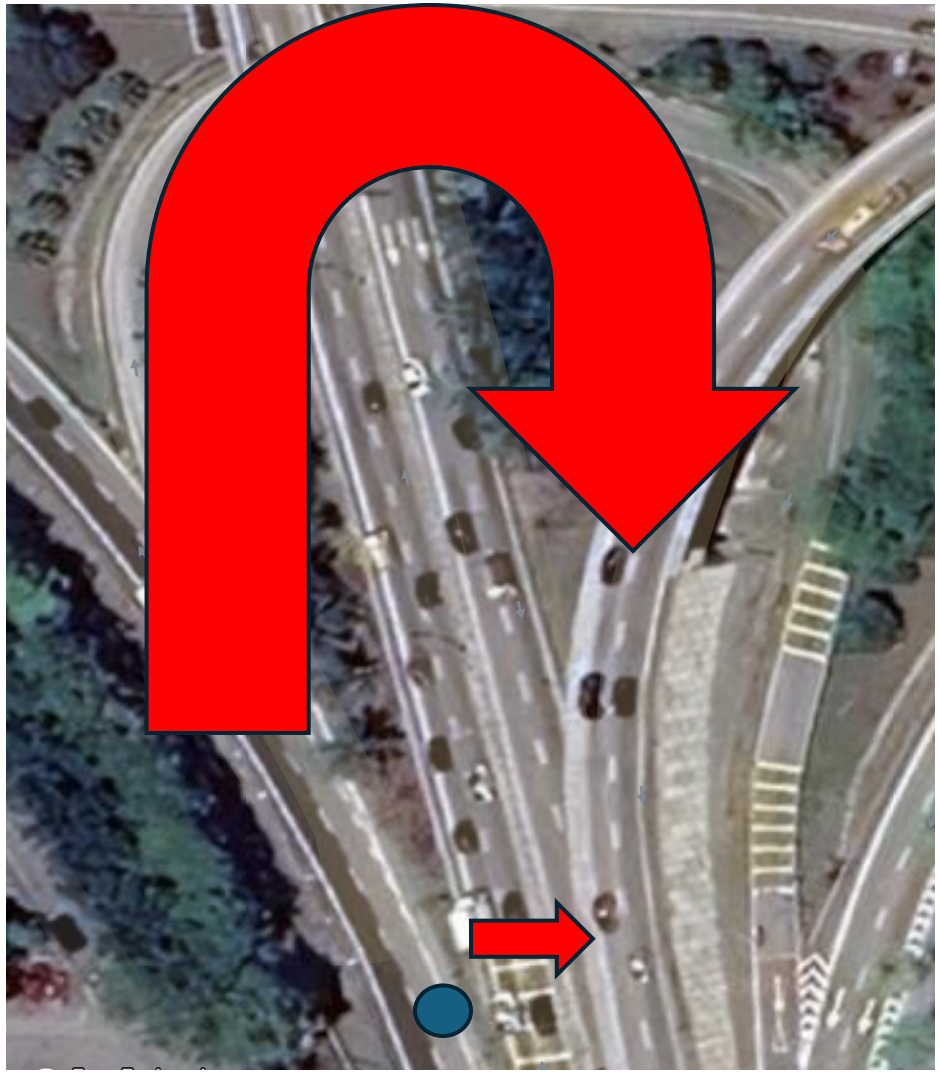
# Electrical Conduction System of Heart



## Figure 1: Embryogenesis of the Sinoatrial Node




*The early heart tube is depicted (left) at day 10.5–12.5 of embryogenesis. The outer curvature of primary myocardium (black) differentiates and expands to form the heart chambers (blue). However, central primary myocardium remains and goes on to form the cardiac conduction system in the adult heart (right). The SAN forms from the sinus venosus (sv). Oft = outflow tract; pr = primary ring; lv = left ventricle; avc = atrioventricular canal; san = sinoatrial node; avn = atrioventricular node; avb = atrioventricular bundle; avj = atrioventricular junction; scv = superior caval vein; ra = right atrium; la = left atrium; rv = right ventricle; lbb = left bundle branch; rbb = right bundle branch; pvcs = peripheral ventricular conduction system. Adapted from Christoffels et al.[7] Reproduced with permission from the American Heart Association, Inc.*



# Electrical ”spark plug”

## Sinus node

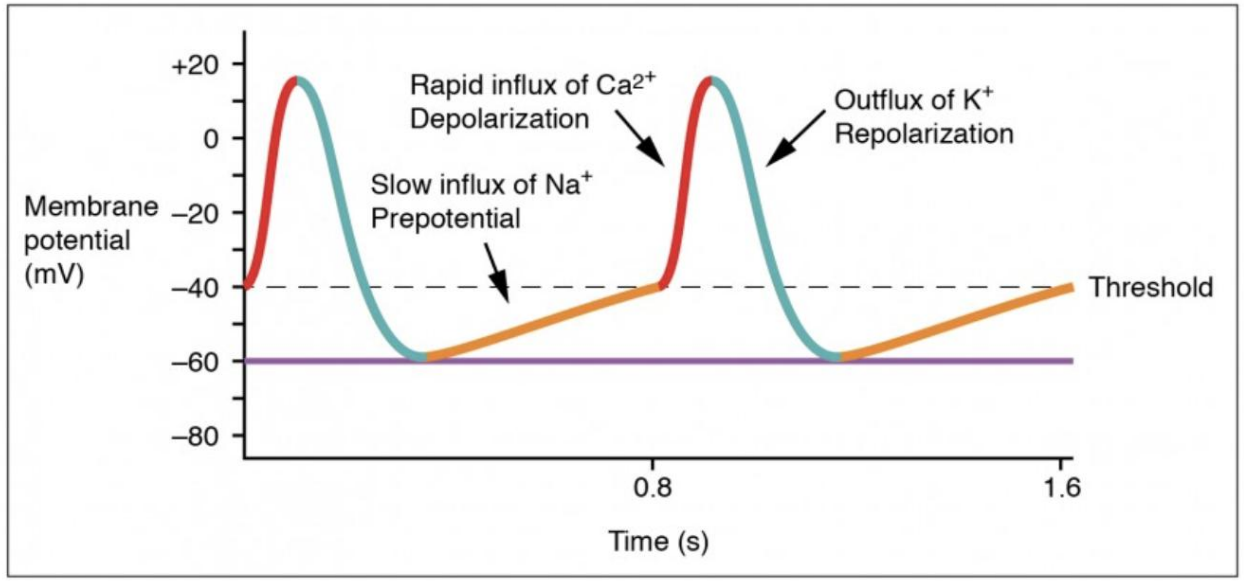
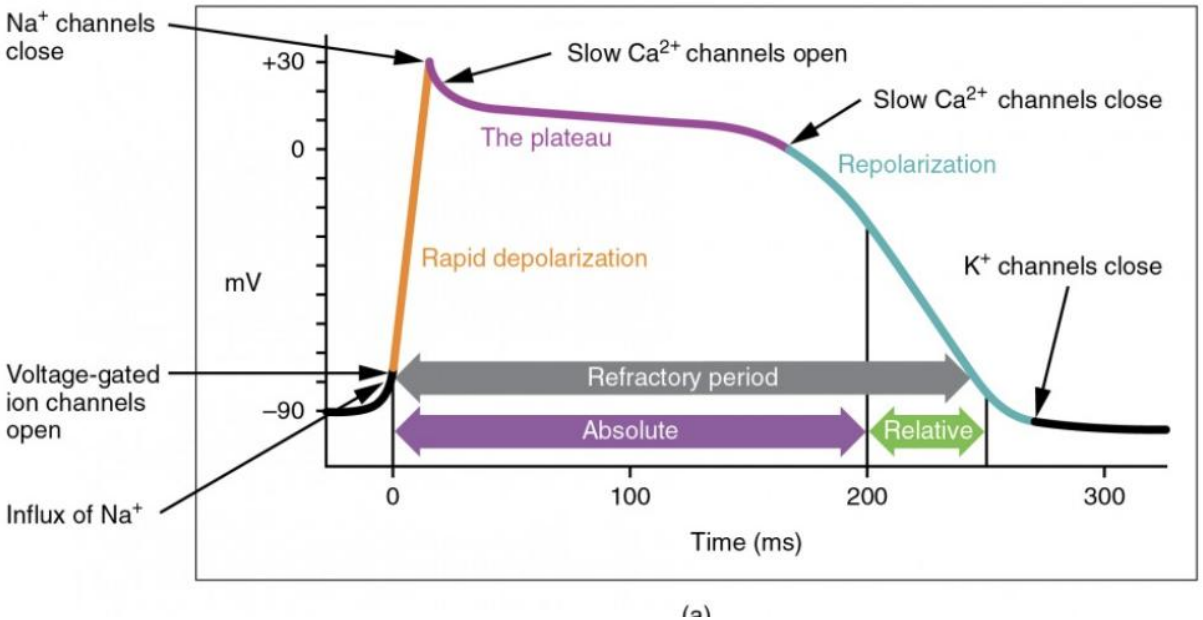
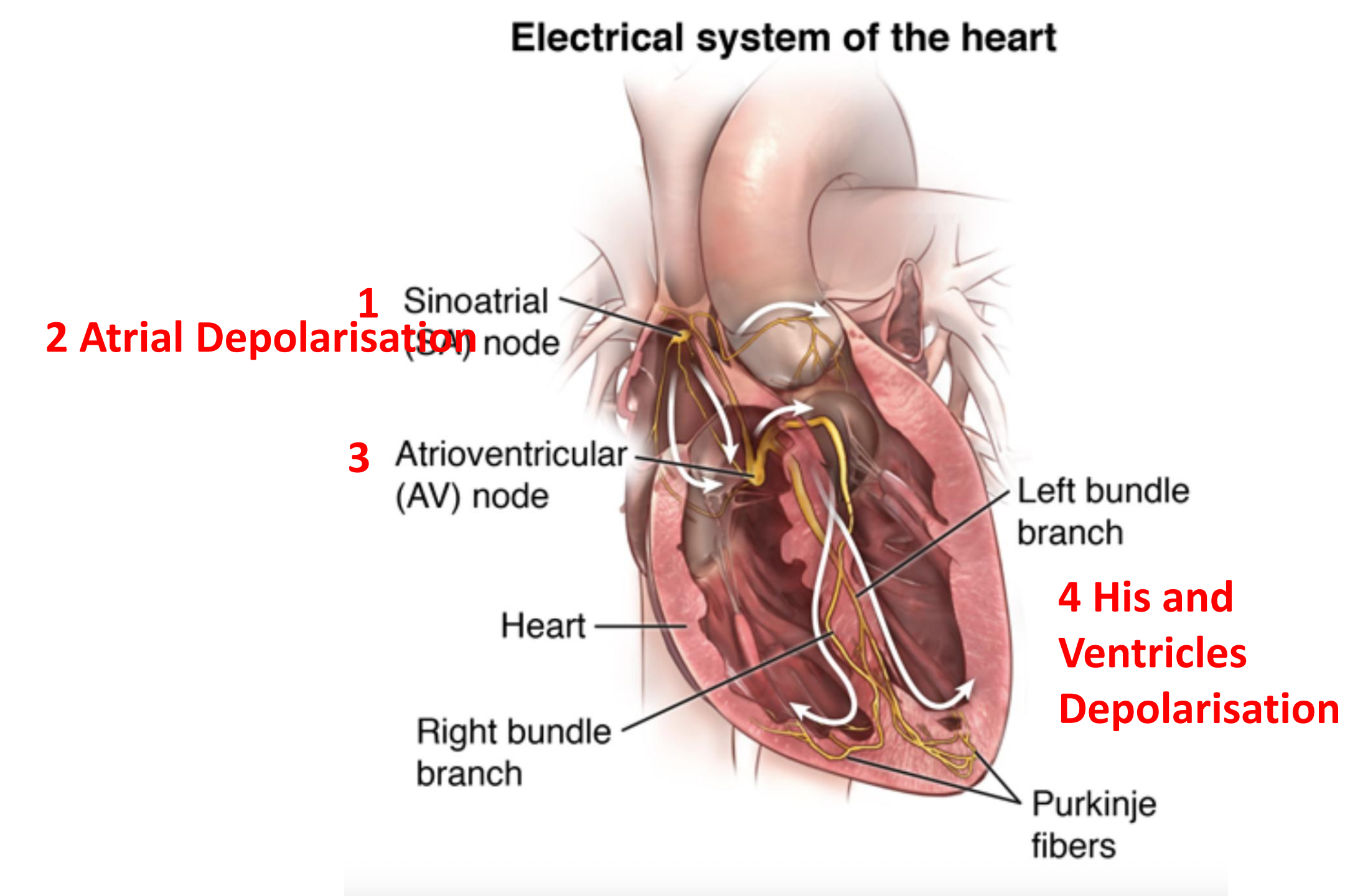


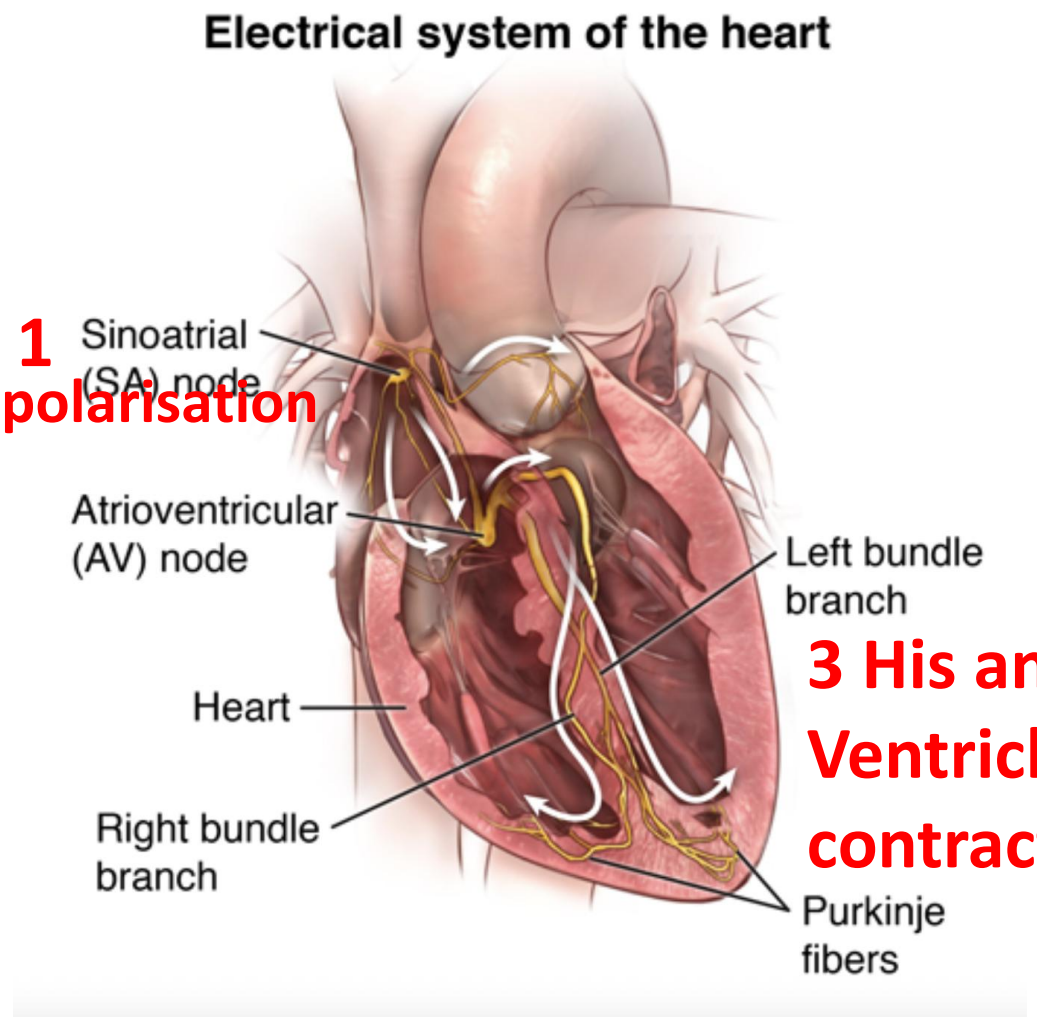

Figure 4. The prepotential is due to a slow influx of sodium ions until the threshold is reached followed by a rapid depolarization and repolarization. The prepotential accounts for the membrane reaching threshold and initiates the spontaneous depolarization and contraction of the cell. Note the lack of a resting potential.

## Myocardium




Electrical system of the heart
1 Sinoatrial (SA) node
2 Atrial Depolarisation
3 Atrioventricular (AV) node
Left bundle branch
4 His and Ventricles Depolarisation
Heart
Right bundle branch
Purkinje fibers

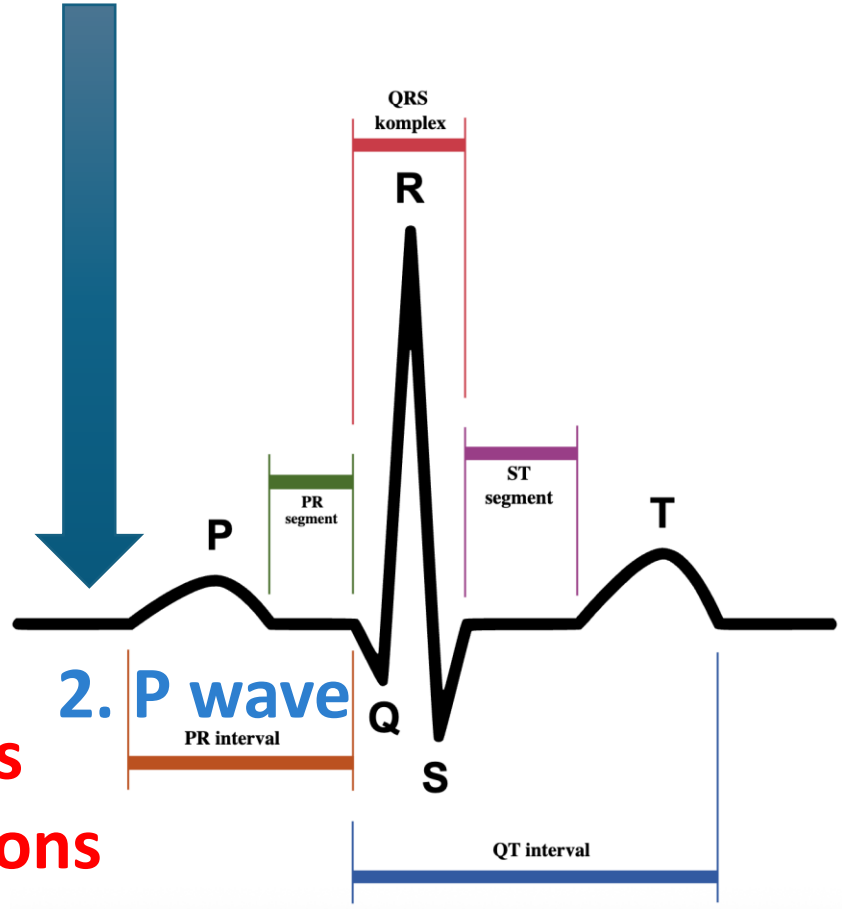
1. not seen




1

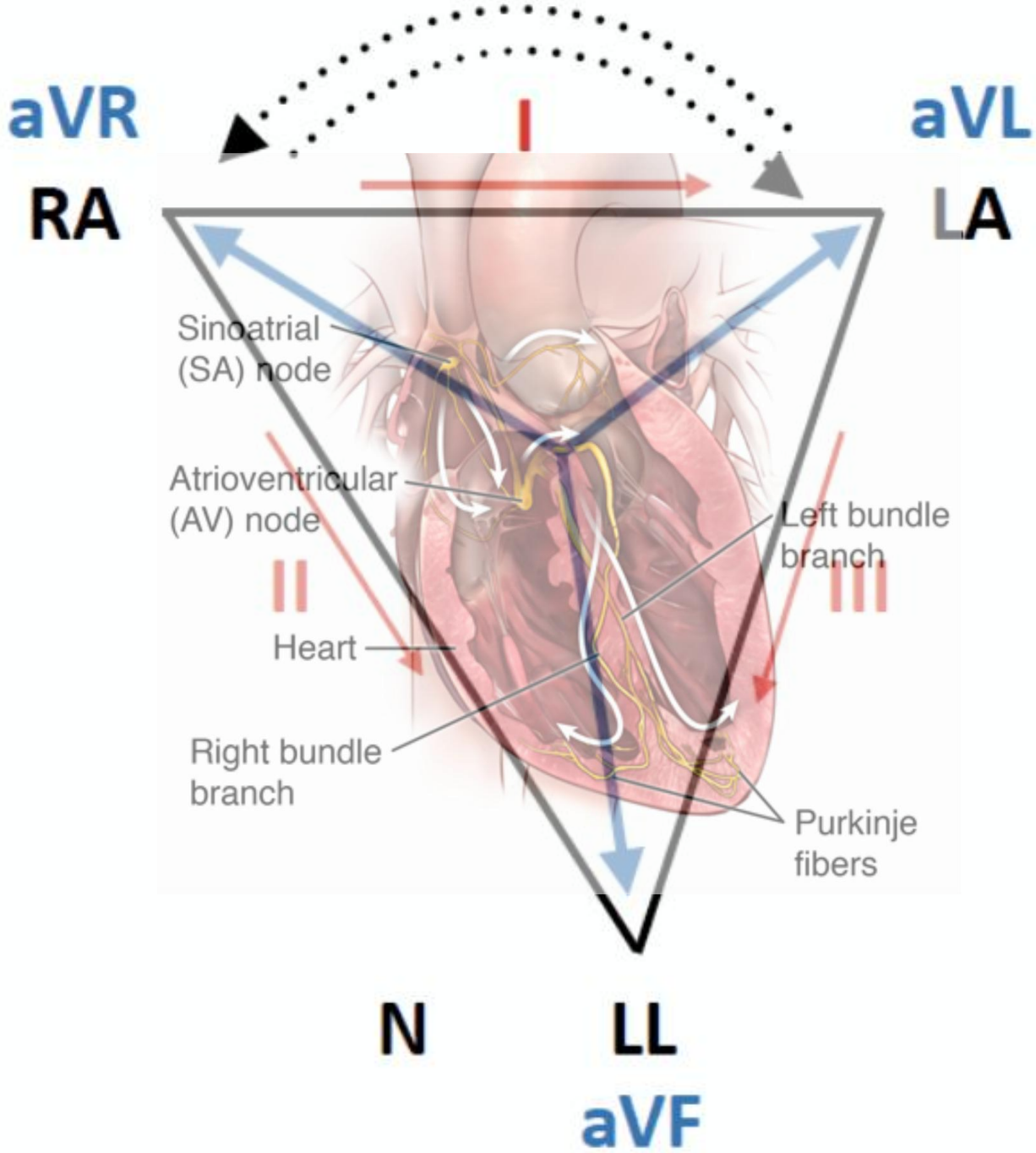
2 Atrial Depolarisation

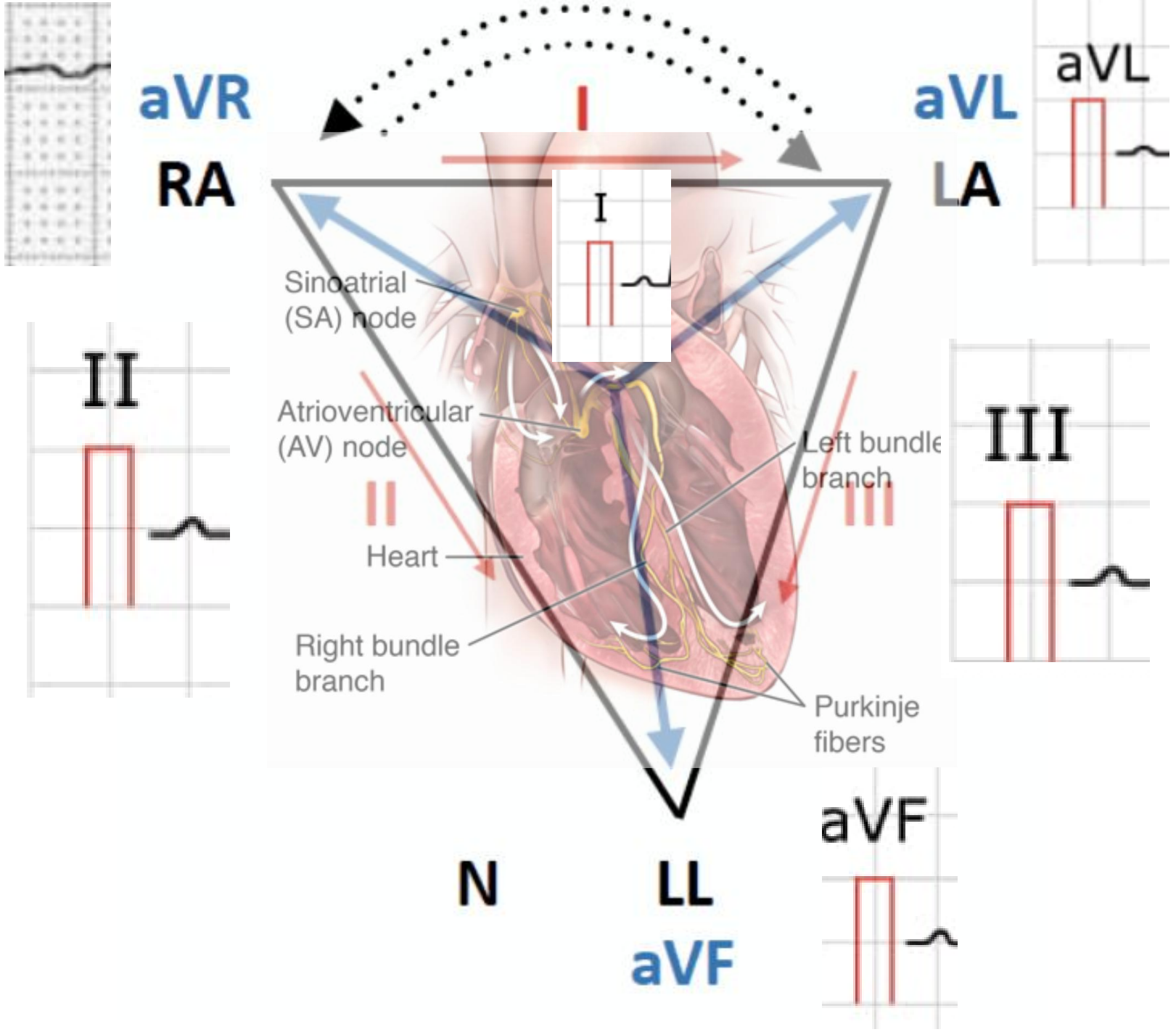
3 His and Ventricles contractions




2. P wave

3. Ventricular activation


aVR
I
aVL
RA
LA
Sinoatrial
(SA) node
Atrioventricular
(AV) node
II
III
Heart
Left bundle
branch
Right bundle
branch
Purkinje
fibers
N
LL
aVF


aVR
RA
I
aVL
LA
aVL
II
III
Sinoatrial
(SA) node
Atrioventricular
(AV) node
Heart
Right bundle
branch
Left bundle
branch
Purkinje
fibers
N
LL
aVF
aVF

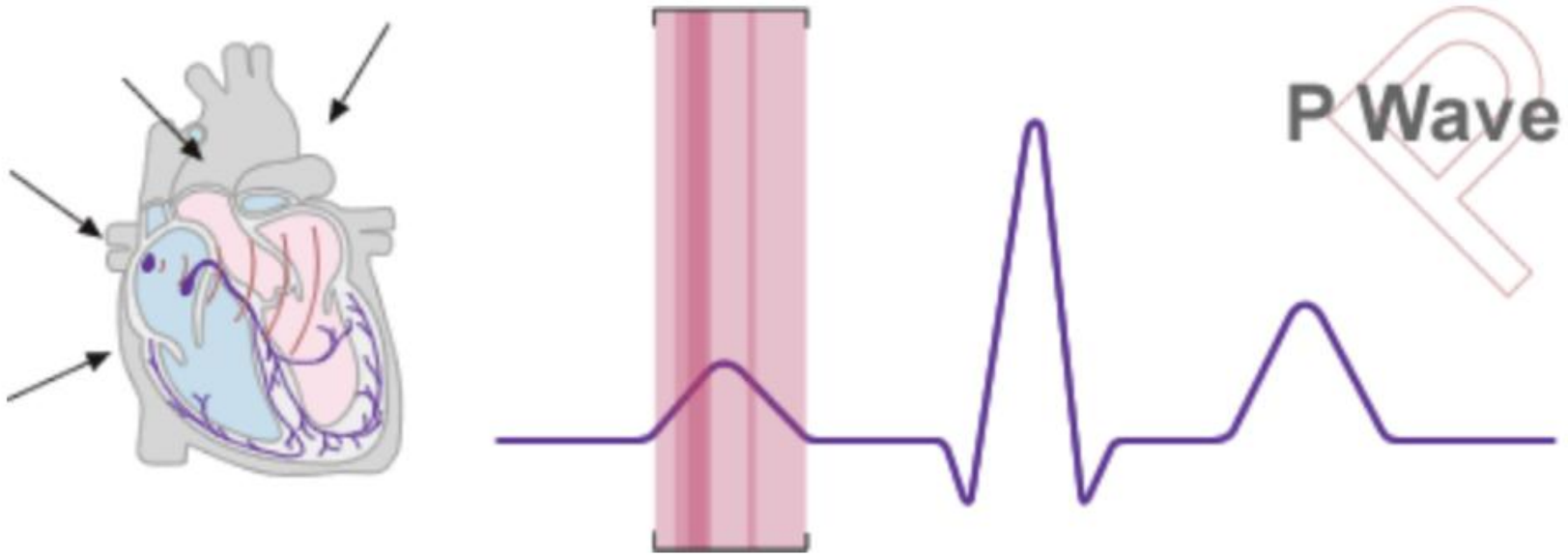
## The P Wave

Now look again at the sinus complex.

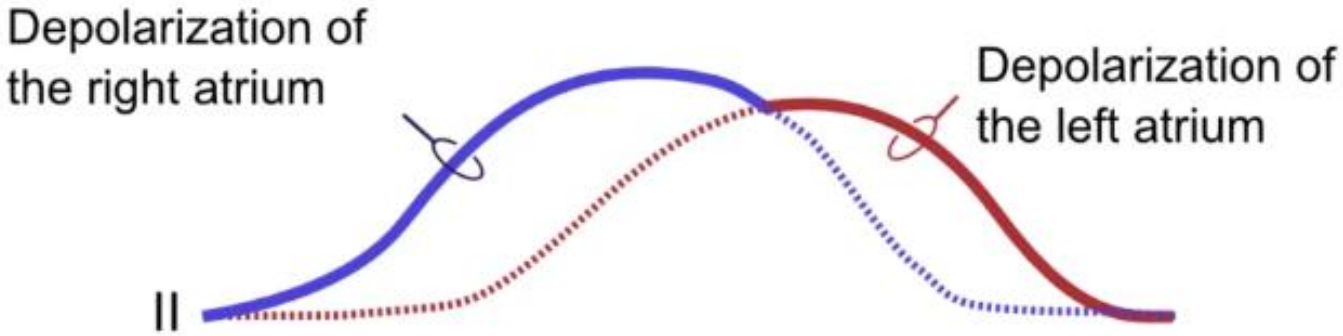
The first wave (p wave) represents atrial depolarisation. When the valves between the atria and ventricles open, 70% of the blood in the atria falls through with the aid of gravity, but mainly due to suction caused by the ventricles as they expand.

Atrial contraction is required only for the final 30% and therefore a relatively small muscle mass is required and only a relatively small amount of voltage is needed to contract the atria.

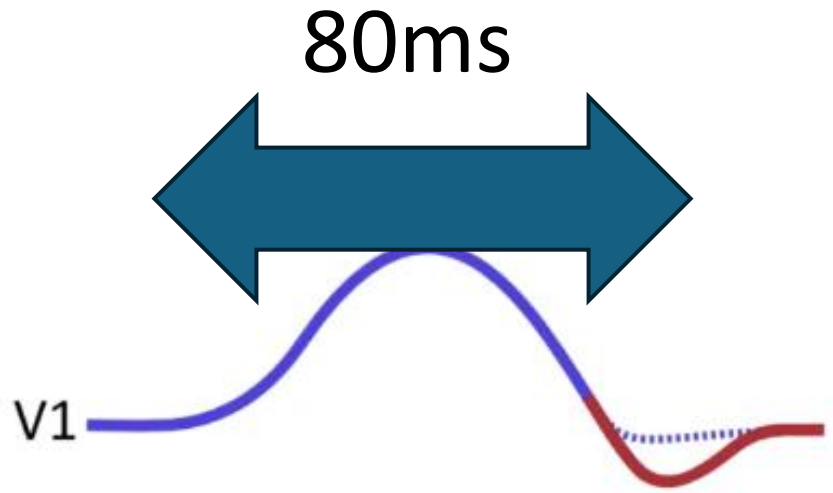
Image: The P Wave



## A The contour of the normal P-wave




The P-wave is always positive in lead II during sinus rhythm. It may exhibit two humps, which indicates the temporal separation of right and left atrial depolarization.

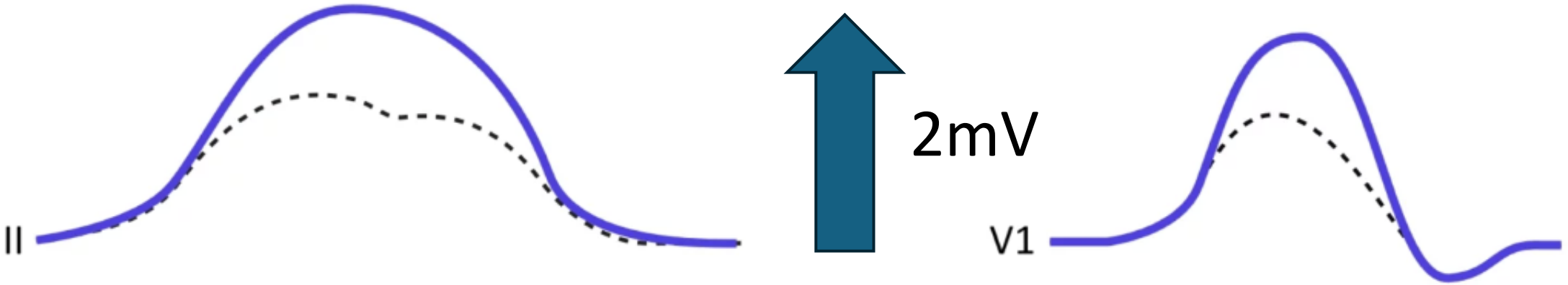



The P-wave in lead V1 is often biphasic due to a terminal negative deflection, caused by the depolarization of the left atrium.

- The first half of the P wave
  - Depolarisation of RA
- The second half of the P wave
  - Depolarisation of LA

## P-Pulmonale

P-pulmonale is caused by right atrial enlargement, often due to increased pulmonary vascular resistance, and less often due to pulmonary valve stenosis. Right atrial enlargement increases P-wave amplitude in leads II and V1.




Increased P-wave amplitude.

Increased P-wave amplitude.

# B Abnormal P-waves

## P-Mitrale

P-mitrale is caused by left atrial enlargement, often due to mitral valve stenosis. Enlargement of the left atrium amplifies its contribution to the P-wave.

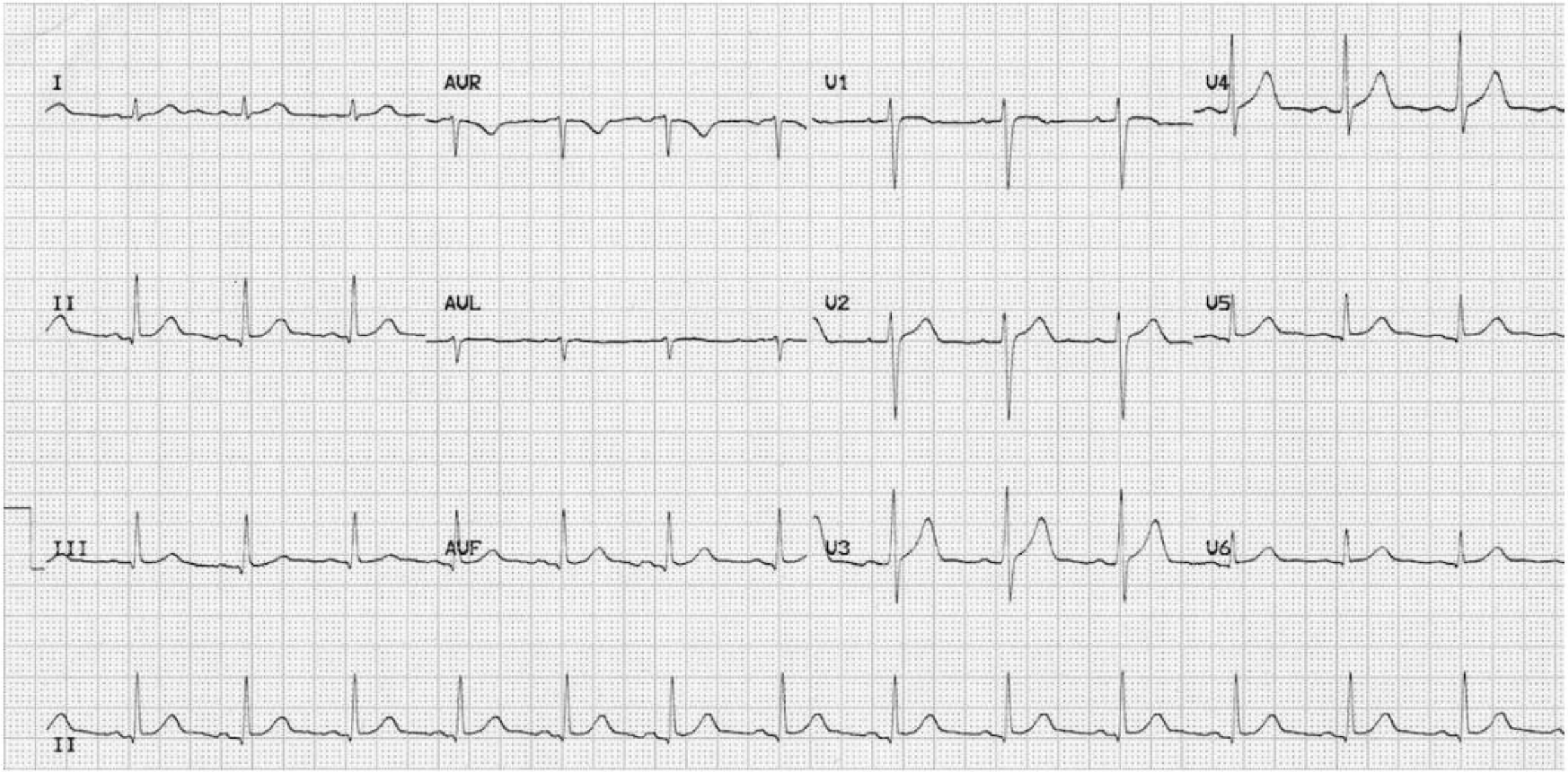



Enhanced second hump in lead II



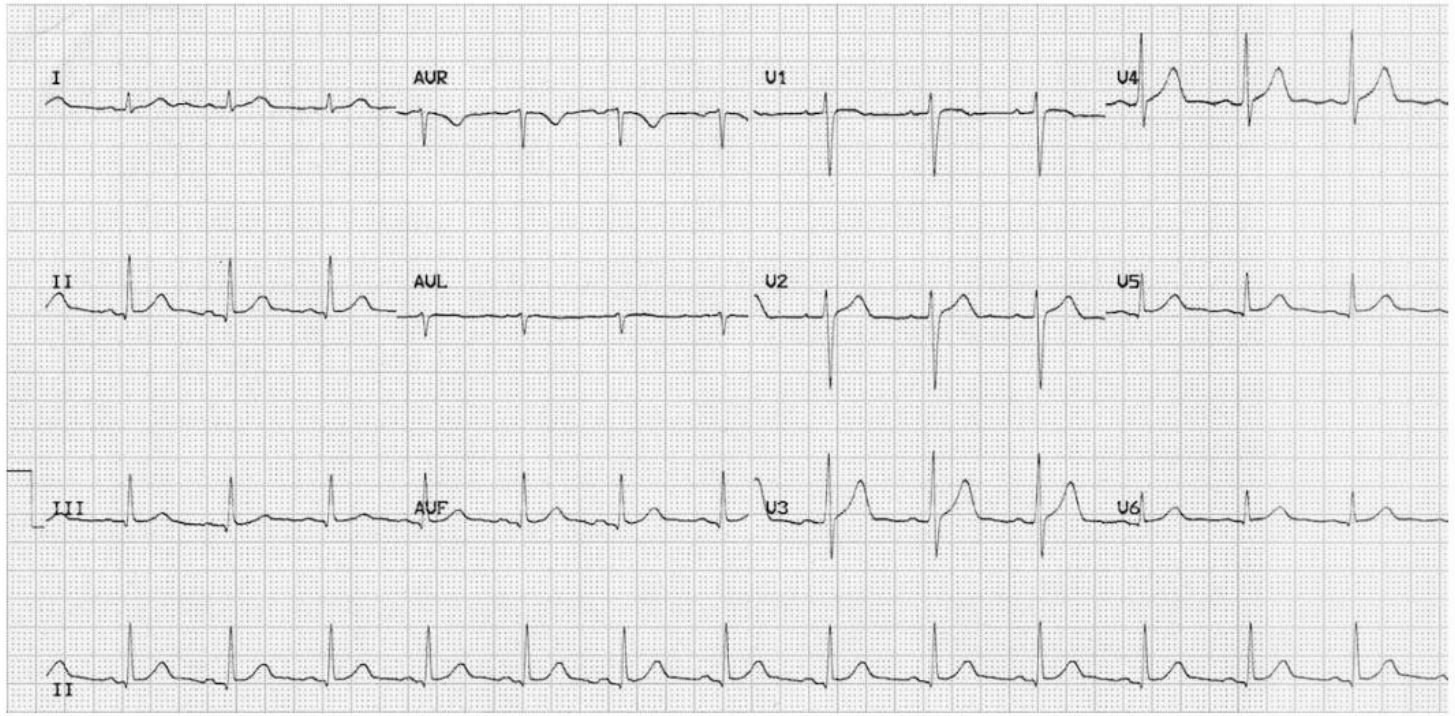

Enhanced negative deflection in lead V1

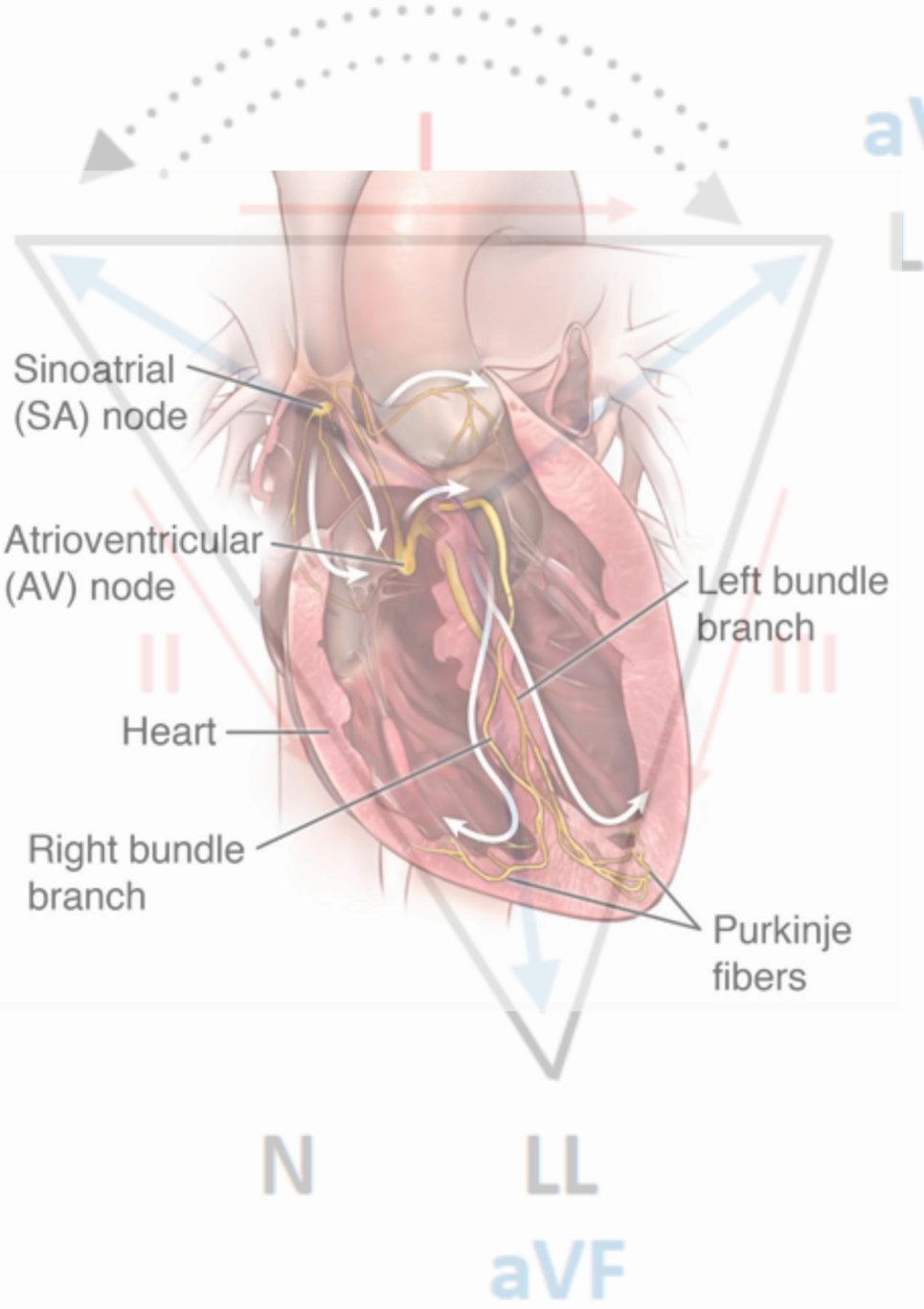
# Where is the origin ?



Positive P wave in the inferior leads

Positive wave in lead I and avL.



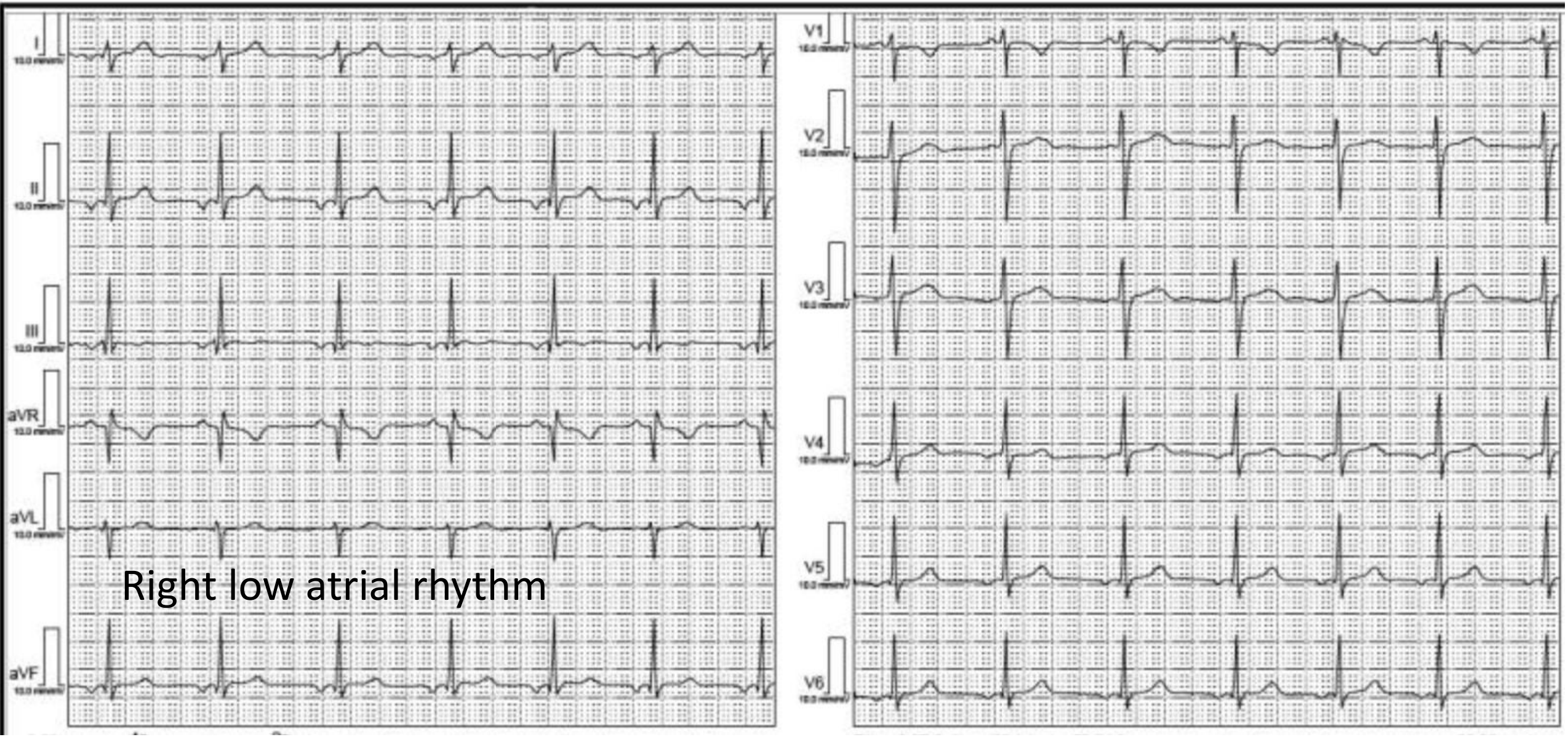




Right upper atrial rhythm

Sinus rhythm

Negative P wave in the inferior leads

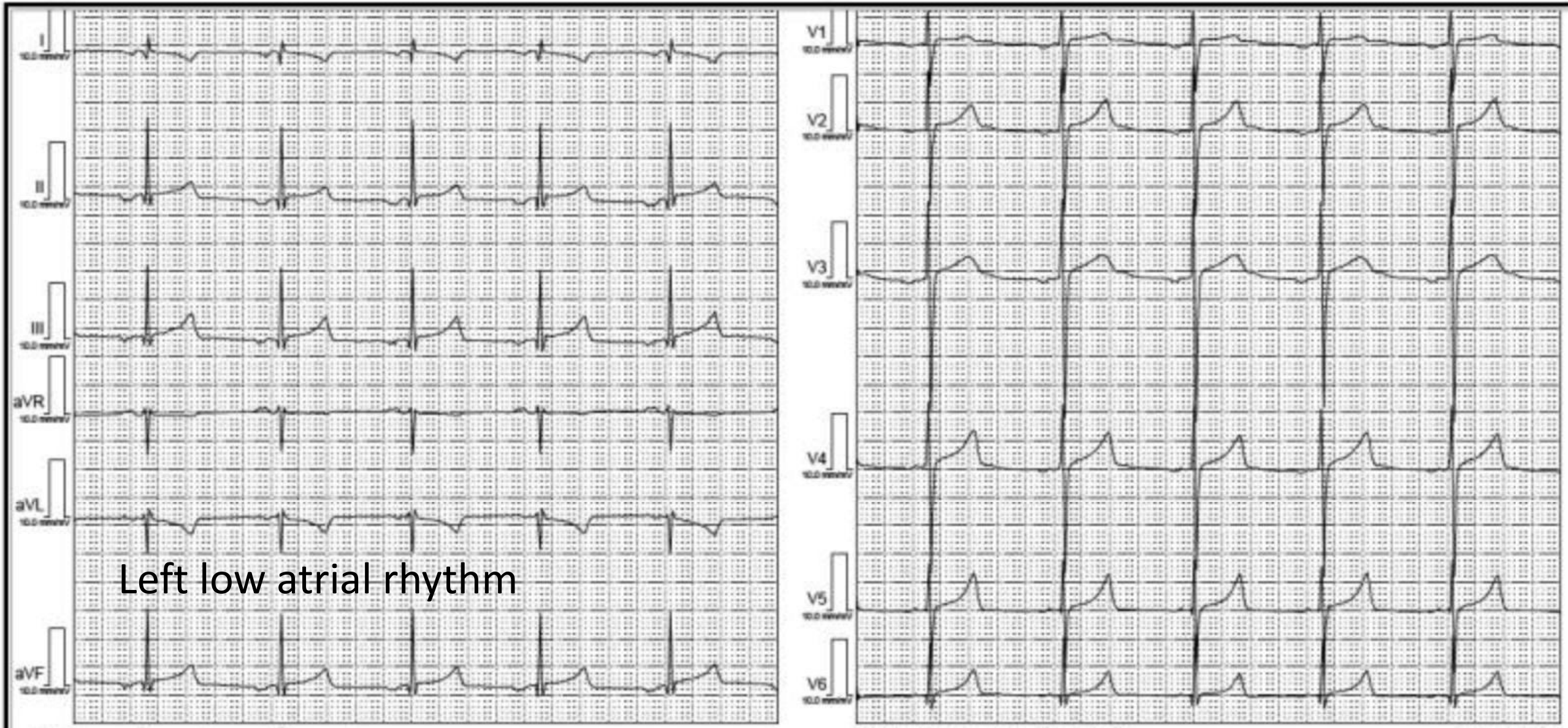
Positive wave in lead I and avL.



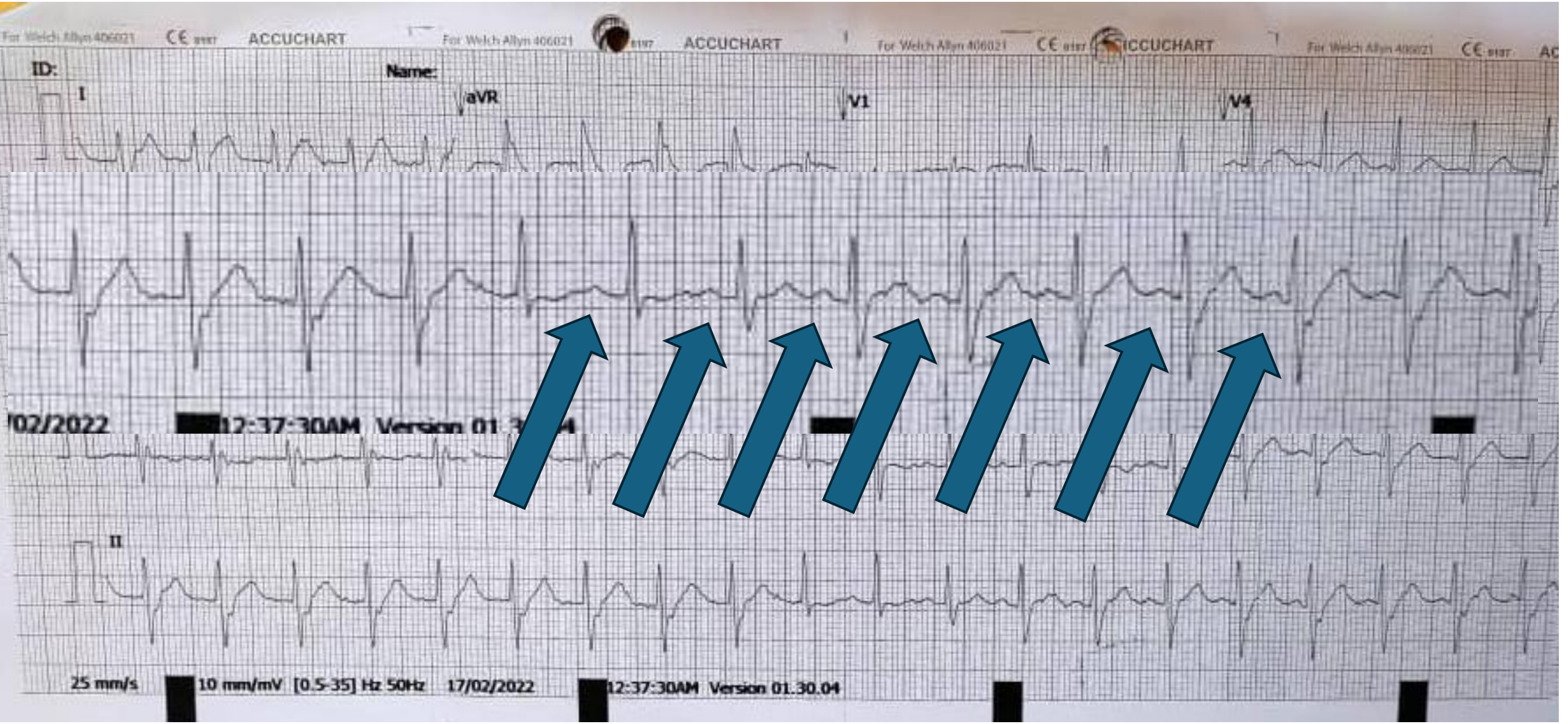

Right low atrial rhythm

Negative P wave in the inferior leads

Negative wave in lead I and avL.



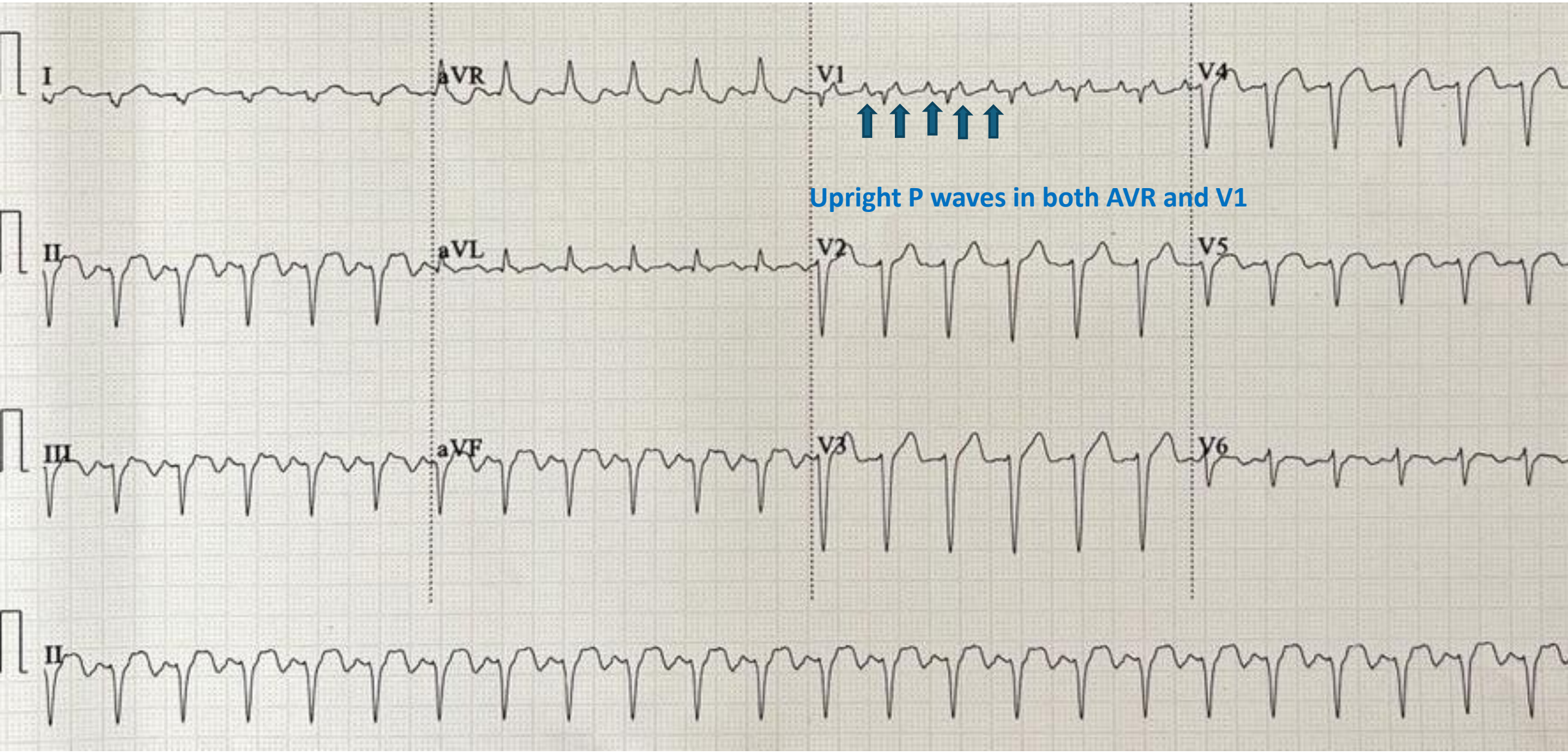

Left low atrial rhythm


ACCUCHART
ID:
Name:
I
aVR
V1
V4
II
25 mm/s
10 mm/mV [0.5-35] Hz 50Hz
17/02/2022
12:37:30AM Version 01.30.04

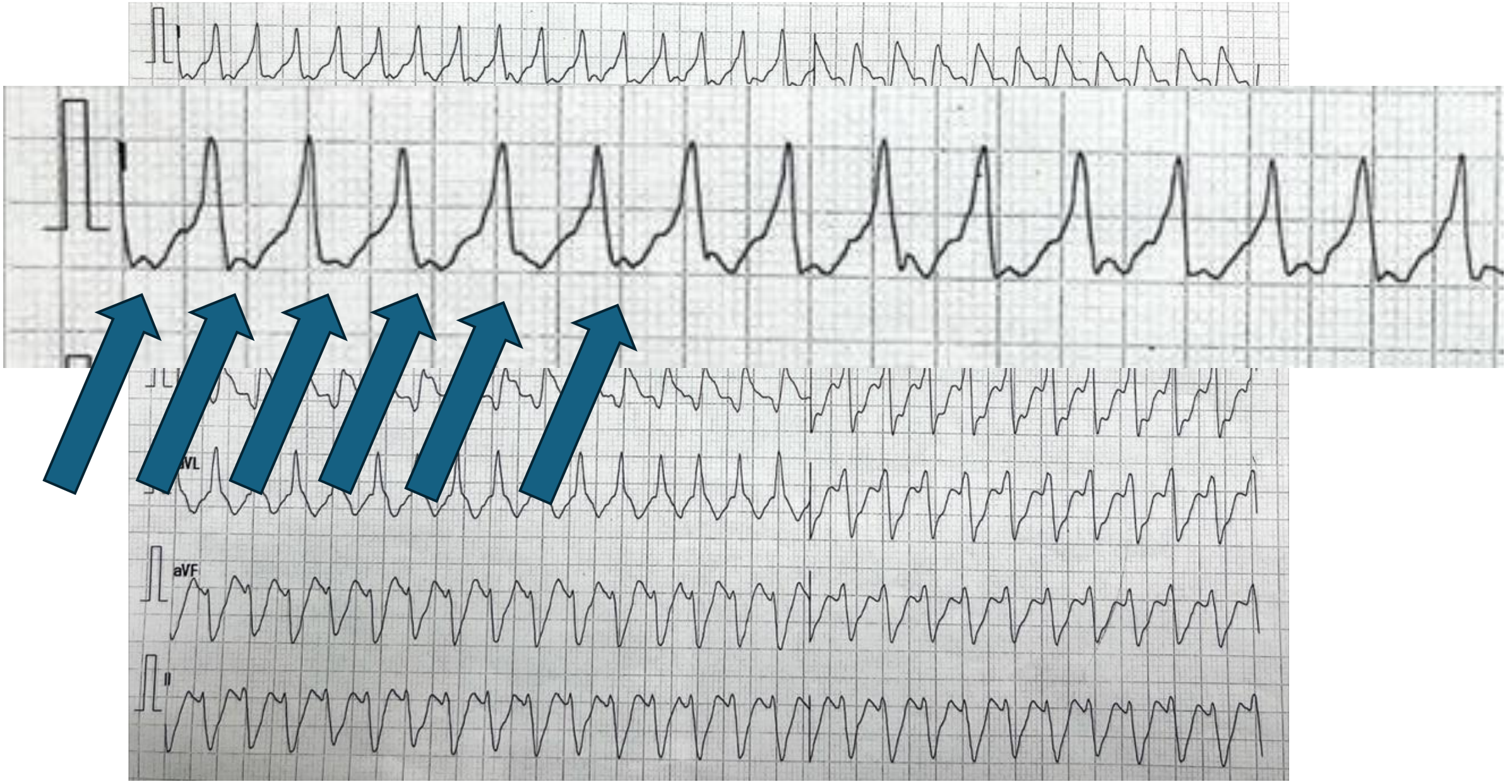
# Case

- 35 years old gentleman presented with shortness of breath
- Underlying functional class 3
- BP 120/80, HR 140-150
- On VM 60%, respiratory rate 30 per min

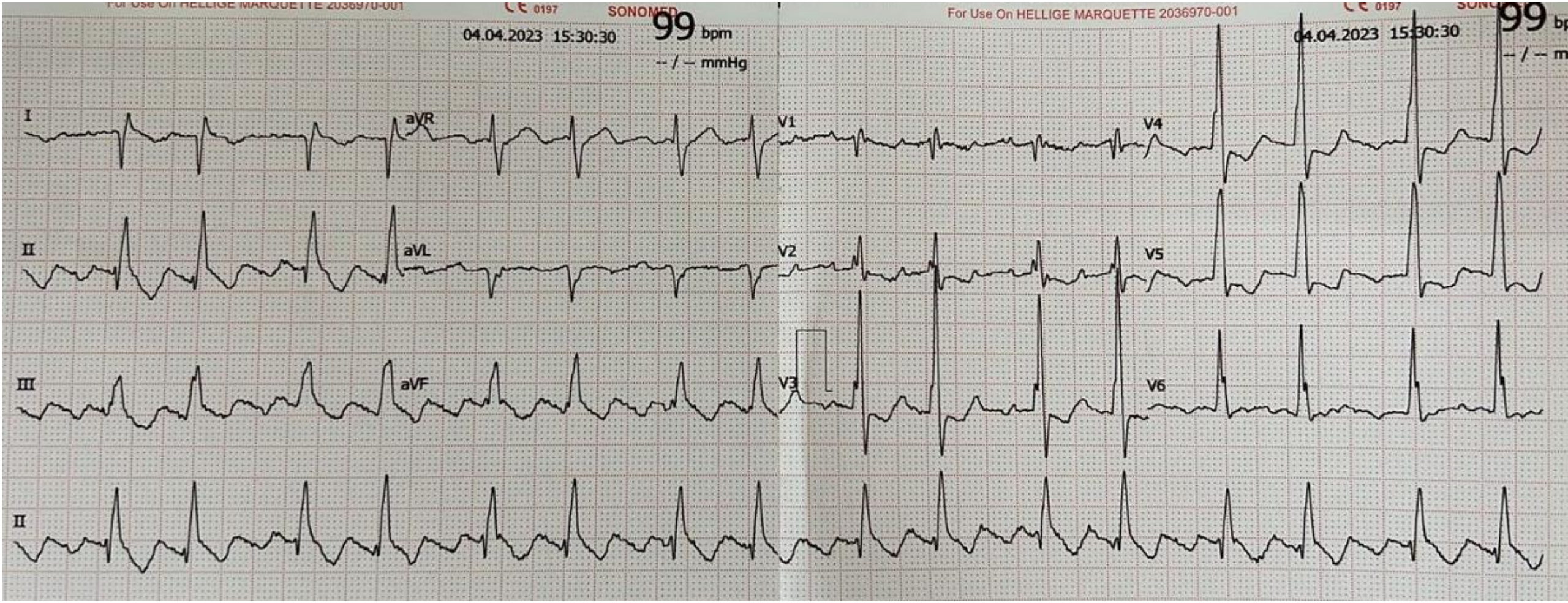
# Atrial tachycardia / flutter



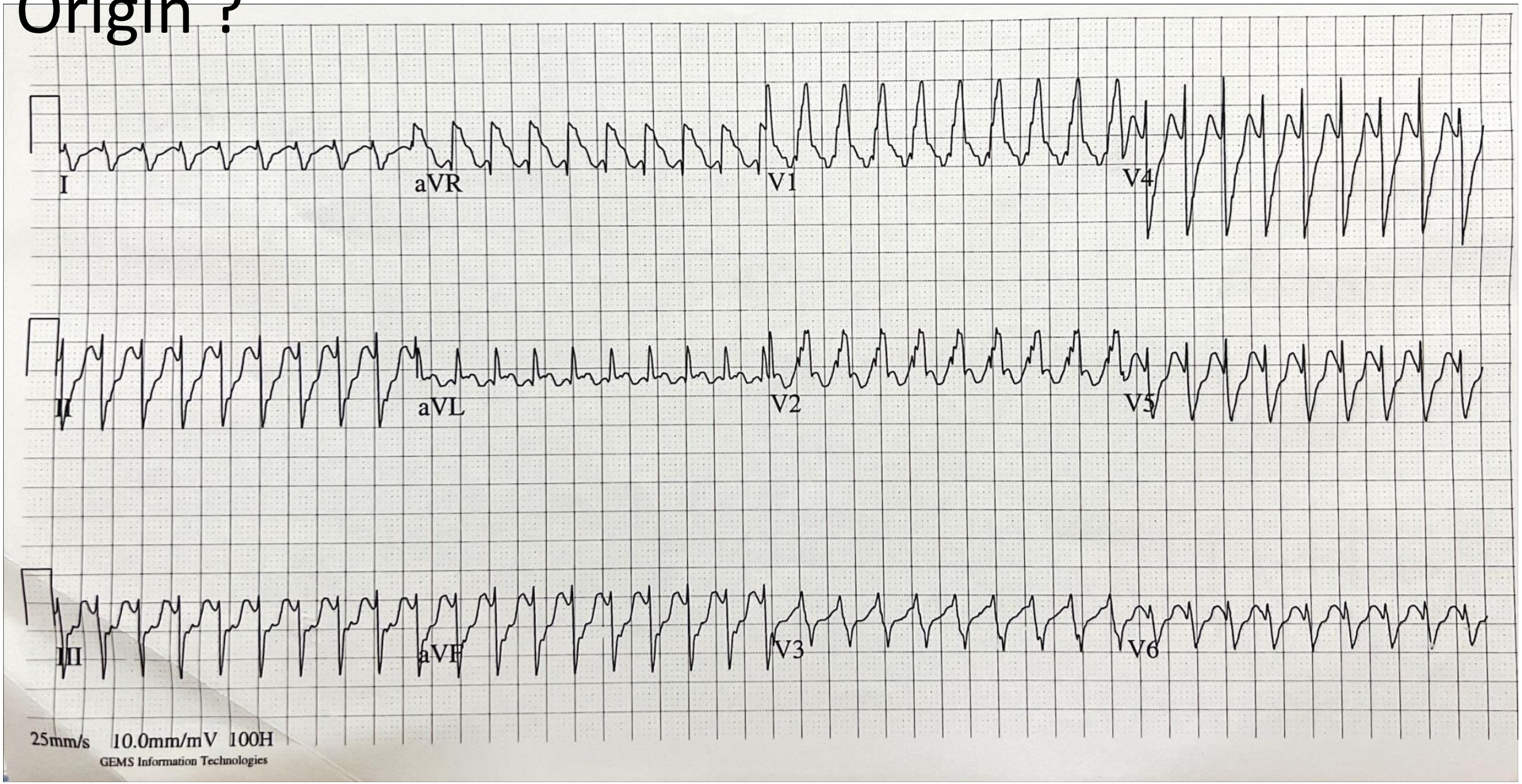
# P waves

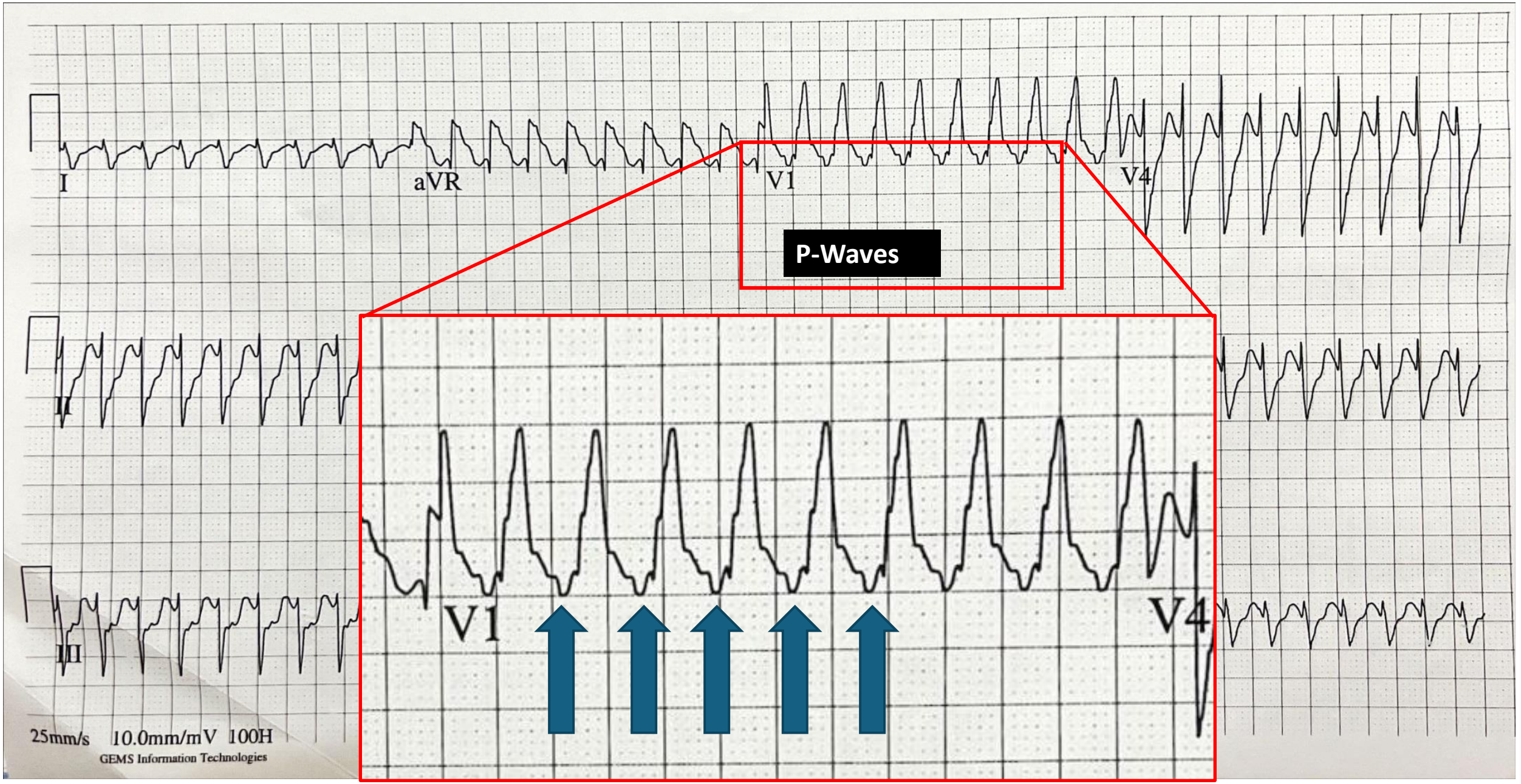


# Origin ?


For Use On HELLIGE MARQUETTE 2036970-001
SONOMED
04.04.2023 15:30:30
99 bpm
-- / -- mmHg
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II

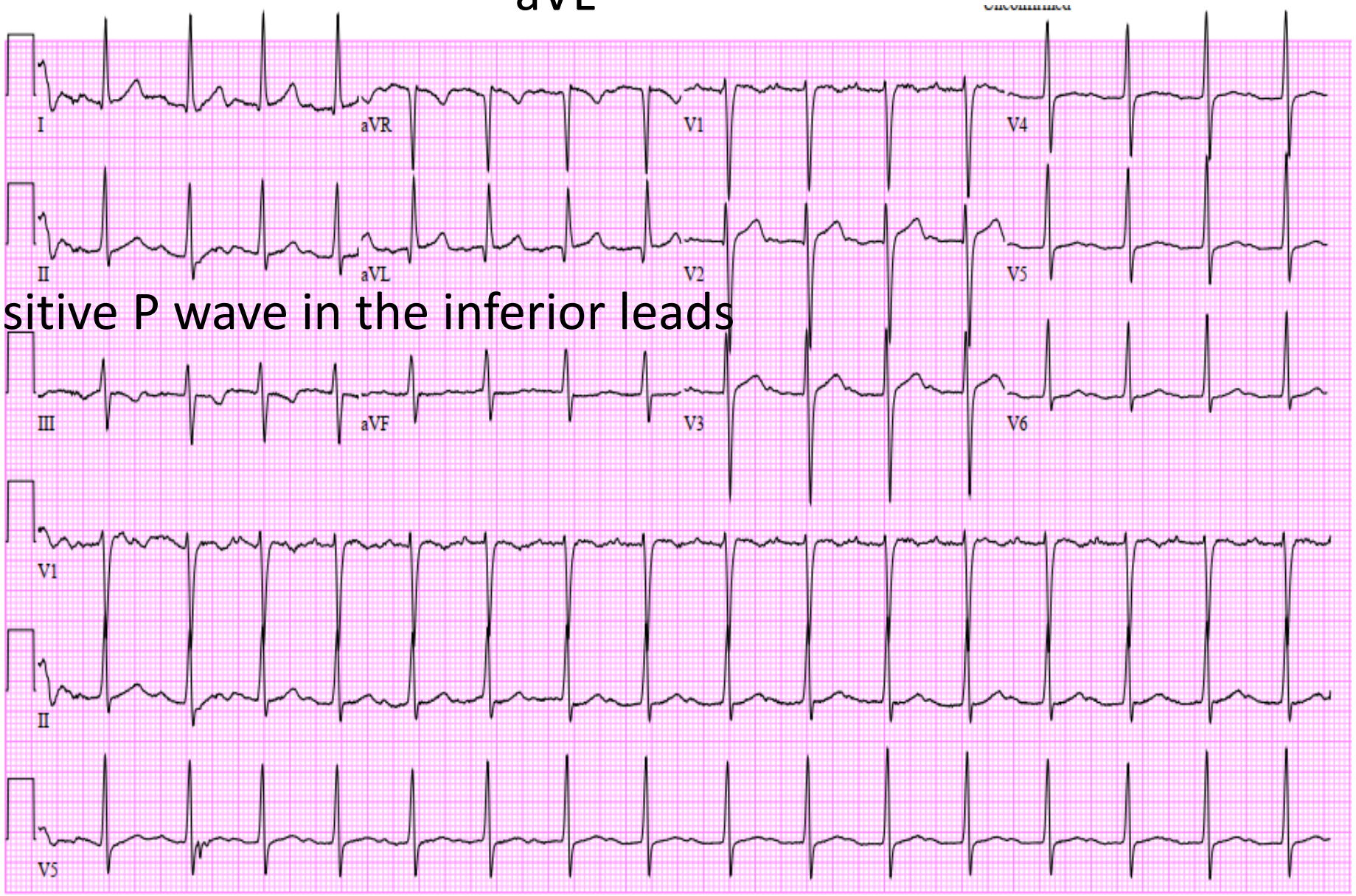
# Origin ?


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
25mm/s 10.0mm/mV 100H
GEMS Information Technologies


I
aVR
V1
V4
P-Waves
II
III
V1
V4
25mm/s 10.0mm/mV 100H
GEMS Information Technologies

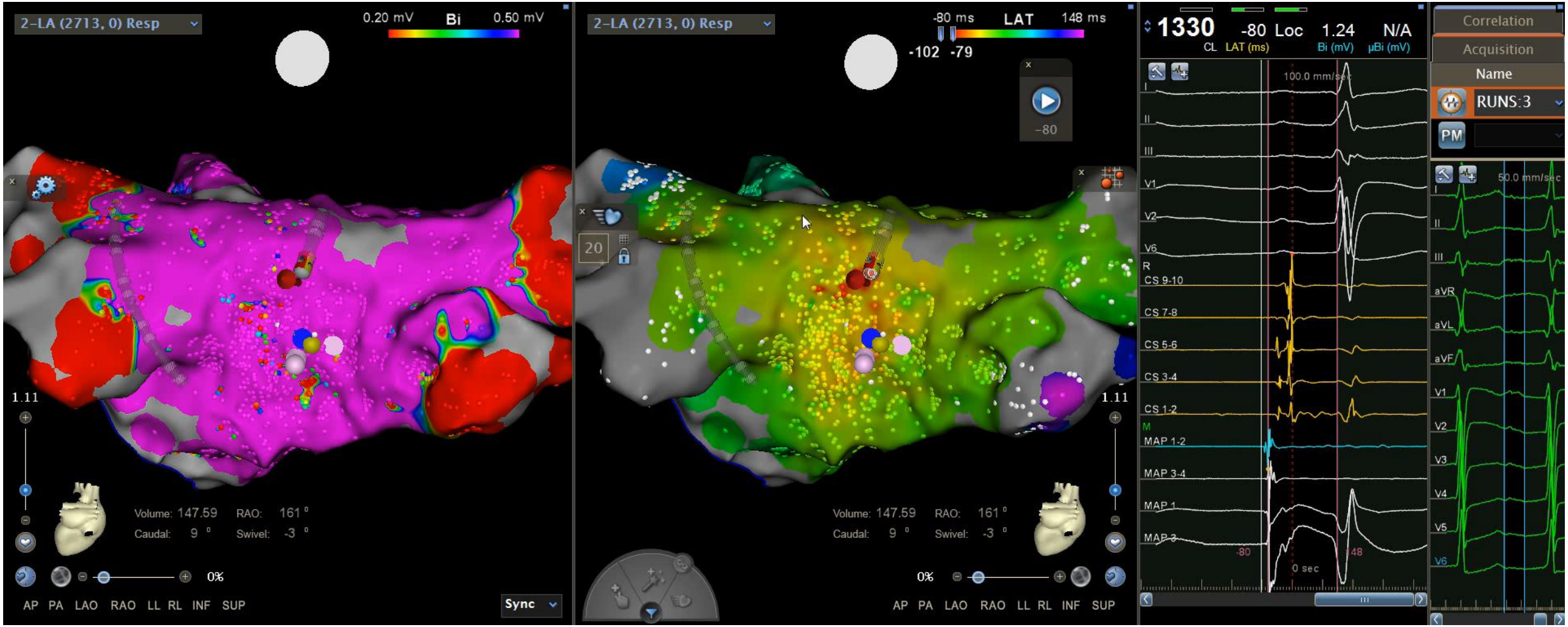
# The origin of P wave

Positive P wave in the I, negative in aVL



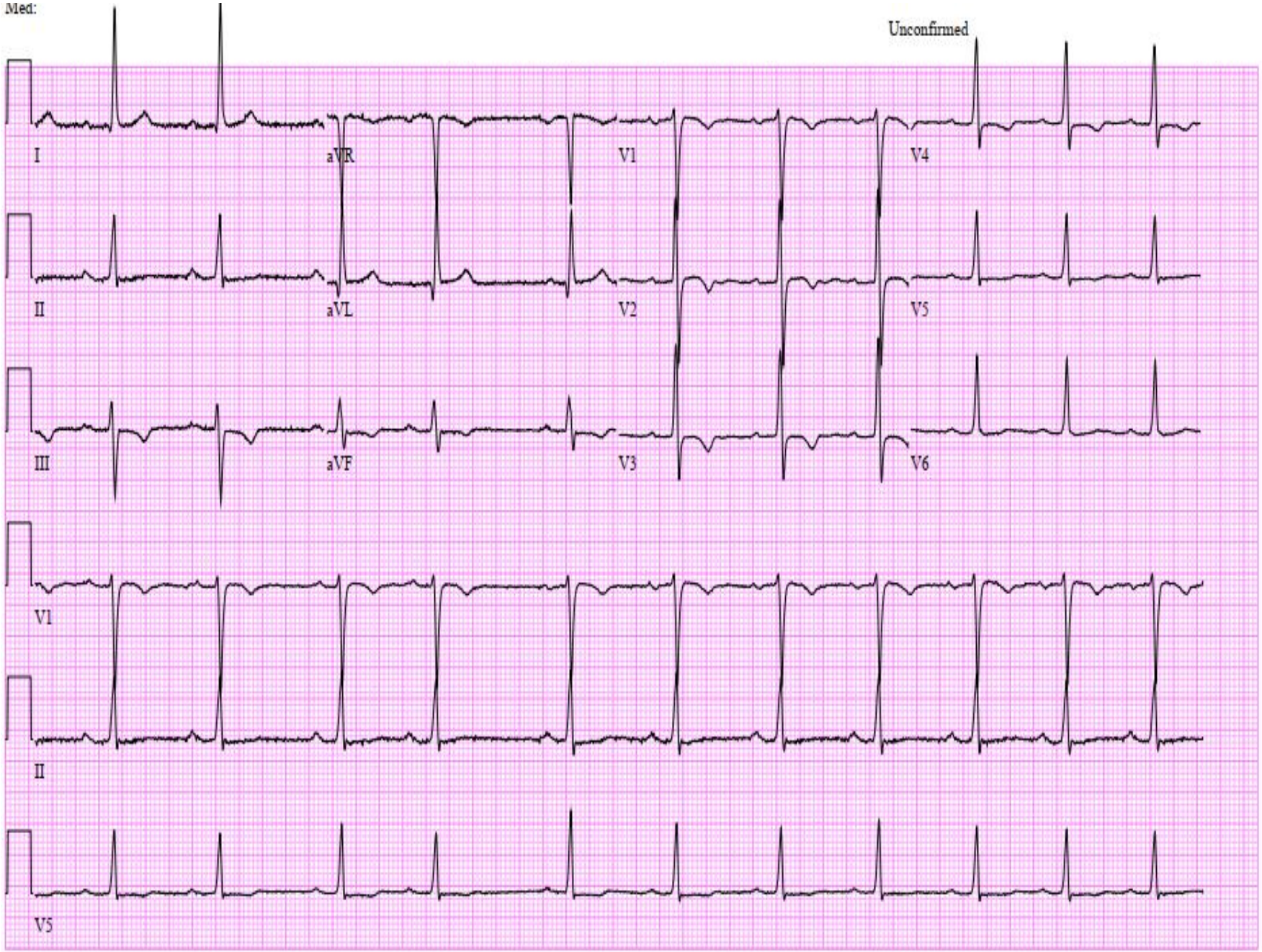

Positive P wave in the inferior leads

# Propagation Map of LA



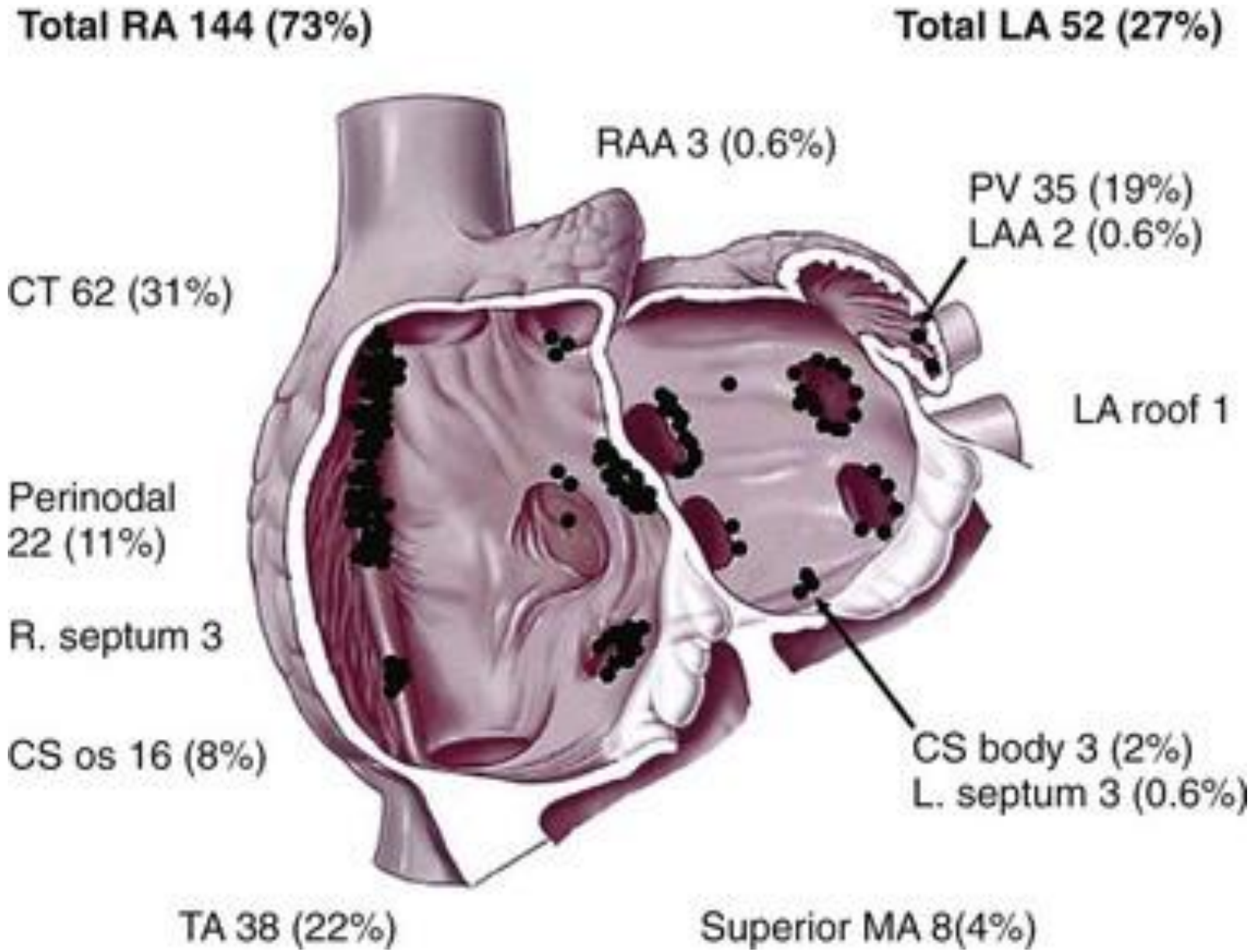
Med:

Unconfirmed




25mm/s 10mm/mV 40Hz 9.0.9 12SL 241 CID: 1

EID: EDT: ORDER:


Total RA 144 (73%)
Total LA 52 (27%)
RAA 3 (0.6%)
PV 35 (19%)
LAA 2 (0.6%)
CT 62 (31%)
LA roof 1
Perinodal
22 (11%)
R. septum 3
CS os 16 (8%)
CS body 3 (2%)
L. septum 3 (0.6%)
TA 38 (22%)
Superior MA 8(4%)

# In summary, P wave origin

- Labelled by Einthoven based on Decartes
- Reflects atrial depolarization
- Mainly Left atrium
- Starting point is Sinus node.
- When it s atypical, suspect focal atrial tachycardia.
- In arrhythmia, it could be antegrade/retrograde.