ECG´s Possible Numerous Waves

The ECG normal and pathologic can have up to 11 waves:

I) **Five normal and constant waves:** Einthoven (Einthoven 1895), using an improved electrometer and a correction formula developed independently of Burch, distinguishes five deflections which he names P, Q, R, S and T. The four deflections prior to the correction formula were labeled ABCD and the 5 derived deflections were labeled PQRST. The choice of P is a mathematical convention dating from Descartes (as used also by Du Bois-Reymond in his galvanometer's 'disturbance curve' 50 years previously) by using letters from the second half of the alphabet. N has other meanings in mathematics and O is used for the origin of the Cartesian coordinates. In fact Einthoven used O ..... X to mark the timeline on his diagrams. P is simply the next letter. A lot of work had been undertaken to reveal the true electrical waveform of the ECG by eliminating the damping effect of the moving parts in the amplifiers and using correction formulae. Einthoven chose the letters PQRST to separate the tracing from the uncorrected curve labeled ABCD. The letters PQRST undoubtedly came from the system of labeling used by Descartes to designate successive points on a curve. If you look at the diagram in Einthoven's 1895 paper you will see how close it is to the string galvanometer recordings and the ECGs we see today. The image of the PQRST diagram may have been striking enough to have been adopted by the researchers as a true representation of the underlying form. It would have then been logical to continue the same naming convention when the more advanced string galvanometer started creating ECG s a few years later.

II) **Normal, enigmatic, inconstant sixth wave of the ECG:** the U wave(Pérez Riera 2008) Einthoven identified the U later only in ECGs made with the string galvanometer.(Snellen 1995)

III) Normal and not visible wave: the Ta or Tp wave. Not visible because is hidden behind the QRS complex

Normal location of atrial repolarization (Ta or TP wave). It coincides with ventricular depolarization (QRS complex), what explains its absence for being concealed by the ventricular phenomenon. Ta wave usually not visible. It is concealed by QRS. It represents atrial repolarization.

Its polarity is opposite to the P wave and its magnitude is 100 to 200 mμV. Sometimes it may appear in the PR segment, ST segment and the T wave. During exercise, it may in theory, cause ST segment depression and resemble myocardial ischemia (Sapin 1991)

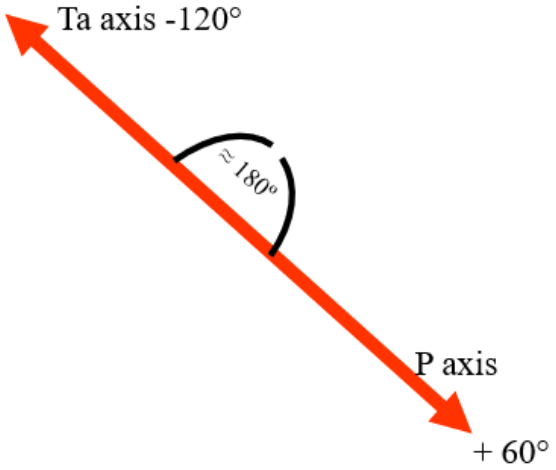
False positive must be suspected in the presence of:

Important PR segment depression in maximal strain;

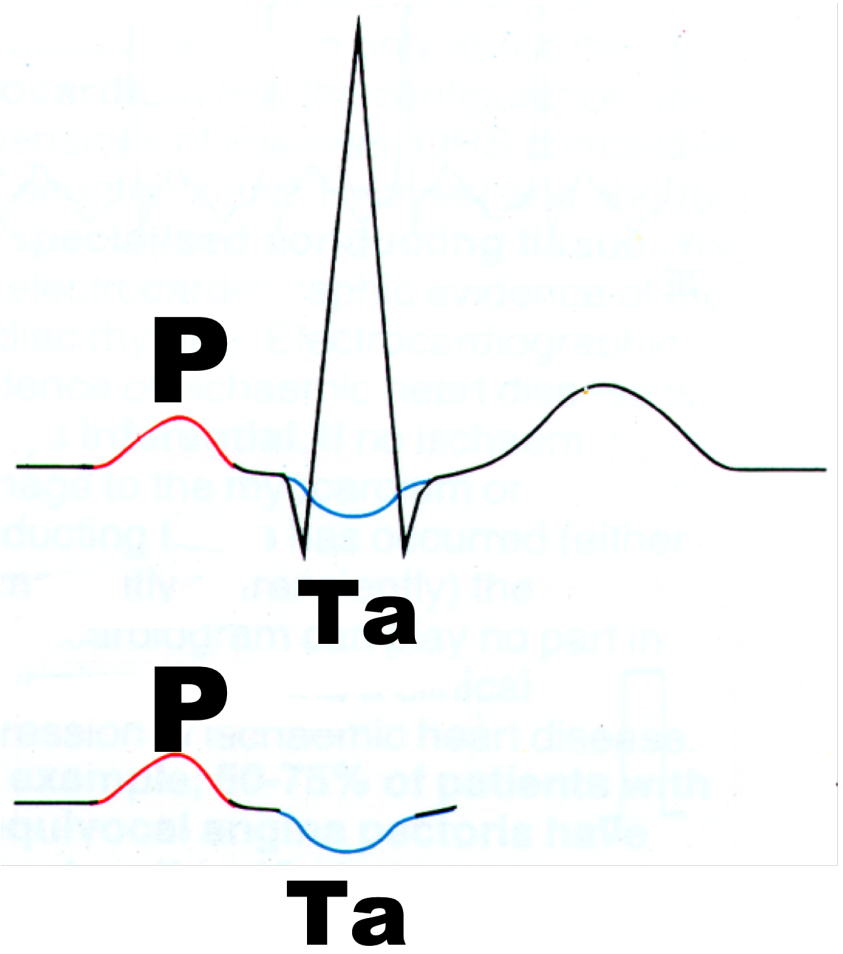
Longer time of exercise and maximal strain faster than those truly positive;

Absence of effort-induced pain;

P wave of voltage higher in maximal strain.



Ta wave has a saucer-like shape
Normal Ta wave axis is near
-120° ≈ 180º opposite to P axis



Hayashi et al (Hayashi 1976) studied the P and the Ta waves of two patient groups with AV block:

Group A: patients minimal clinical evidence of heart disease

Group B: patients with more severe disease.

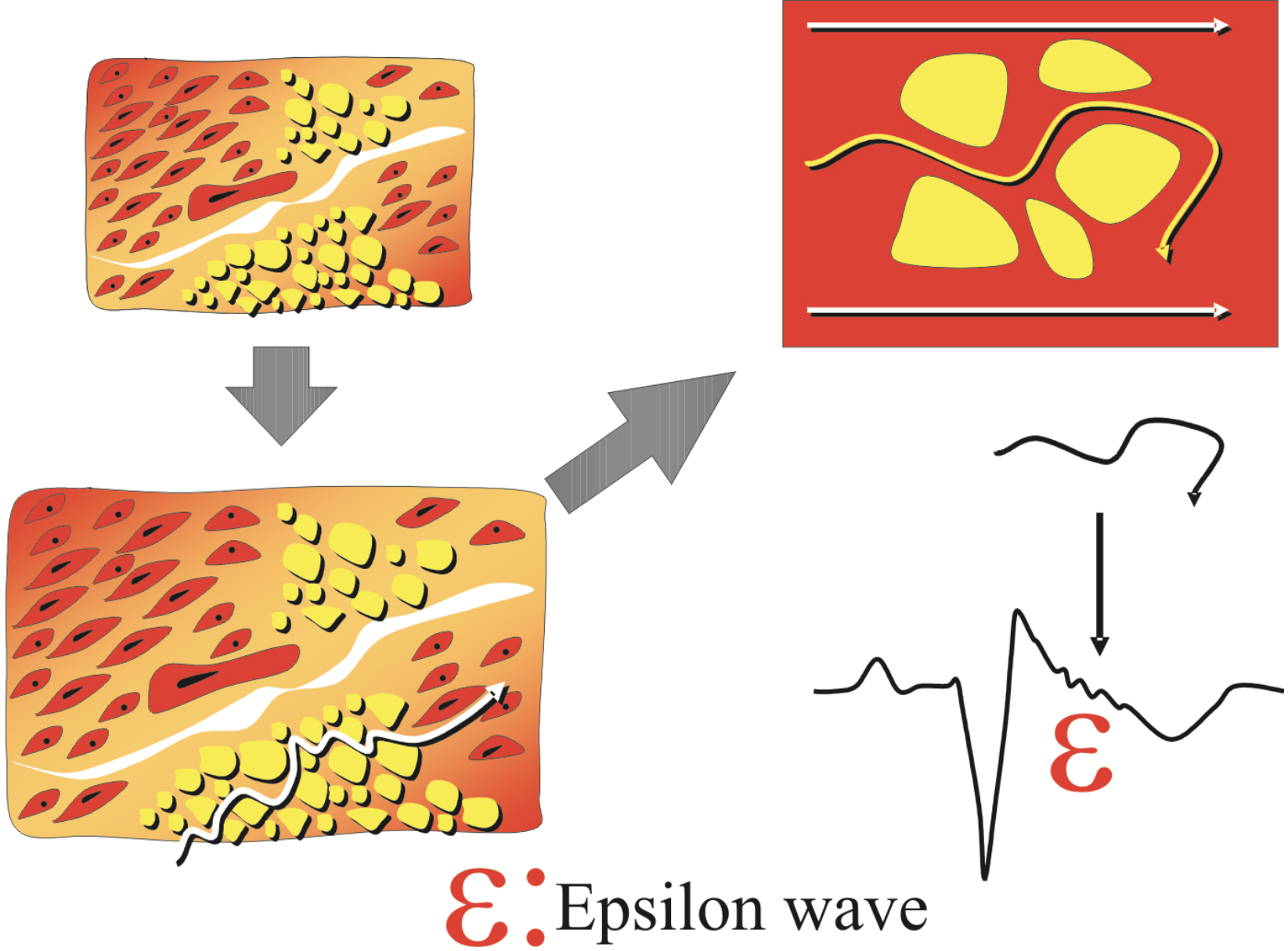
Waves were magnified with a direct-current amplifier and recorded at a high paper speed. The authors verified that in Group A the P and the Ta waves were recorded in the opposite direction (near 180º) in every lead and there was a linear relationship between the amplitude of the P and the Ta waves. The atrial gradient was nearly zero. There existed a positive correlation between the P + Ta time and the PP intervalIn Group B patients there were significant differences between P wave and Ta wave with respect to form, polarity, amplitude, duration, and the relationship between the Ta and the P waves. The atrial gradient was markedly large. Ta loop may be very useful in separating normal from diseased atria in individuals with AV block. There are some frequency differences between the Ta wave and the QRS complex. If the Ta wave could be extracted from the QRS complex by the use of some kind of filter when A-V block dose not exist, most of the Ta wave could be visualized. This, along with high fidelity recording techniques, may help detect atrial abnormalities in patients without AV block. Attention should be paid to the deviation of the PR segment caused by the Ta wave in daily ECG's to detect atrial abnormalities. The Ta wave extends into the ST segment and, while describing the deviation of the ST segment, the influence of the Ta wave should be kept in mind.

Holmqvist et al(Holmqvist 2009) studied, 40 consecutive patients with third-degree AV block to better analyze the Ta wave.

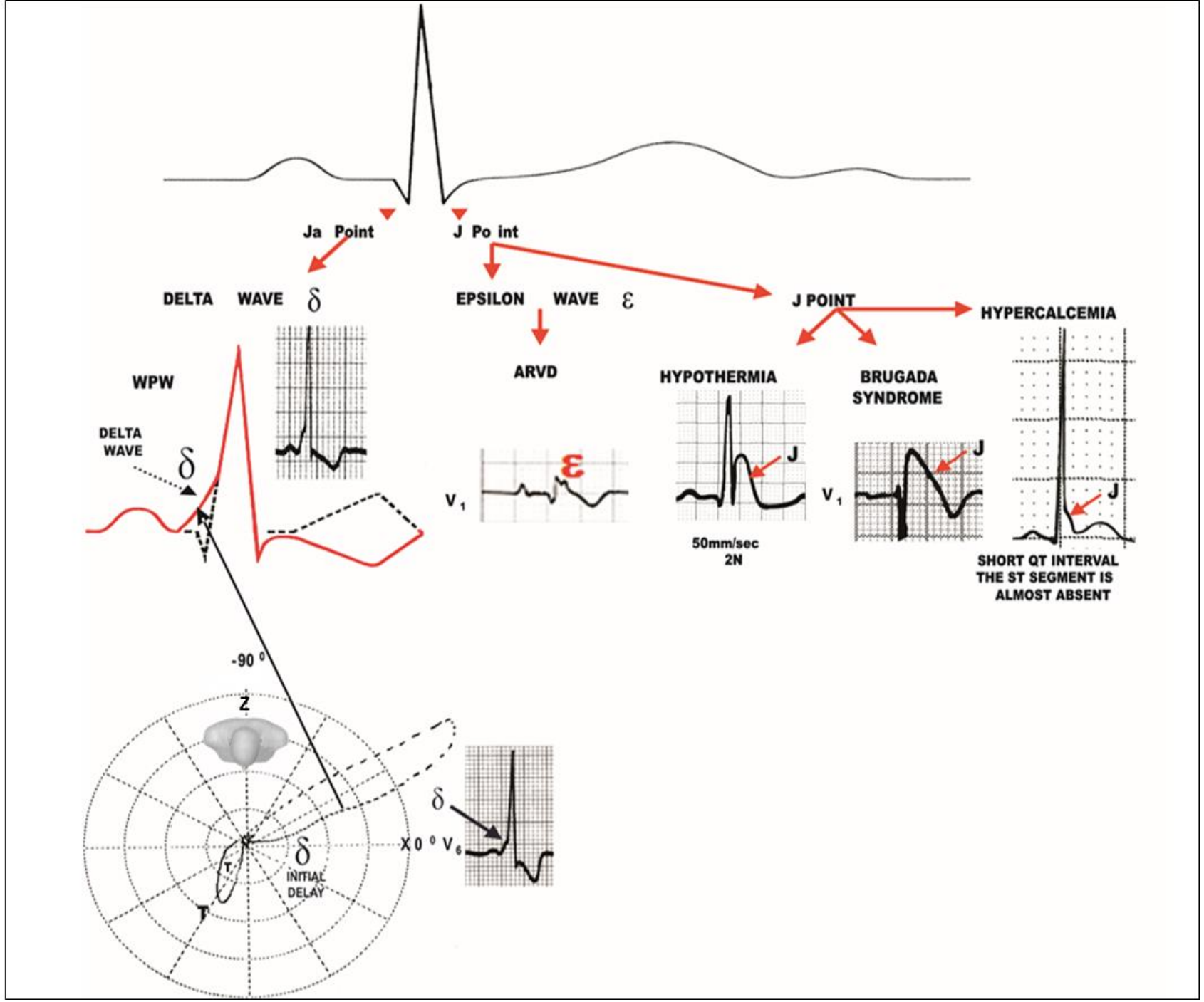
In this population the Ta wave had the opposite polarity, a duration two to three times that, of the P wave and Ta peak may occasionally be located in the PR interval during normal AV conduction, it is unlikely that enough information can be obtained from analysis of this segment to differentiate normal from abnormal atrial repolarization. Hence, an algorithm for QRST cancellation during sinus rhythm is needed to further improve analysis.

IV) Abnormal ECG-waves: This group is eventually registered in pathological circumstances

1. **The Delta(δ) wave**. It is caused by preexcitation of the ventricles via a congenital bypass tract.
2. **The J wave,**(Gussak 1995) also referred to as the **J deflection, "the camel's hump"/ camel-hump sign (Abbott 1976), "late delta wave", elevated J-point(Yan 1996), hathook junction, hypothermic wave, prominent J wave, K wave, H wave, current of injury or Osborn wave.**
    - Hipothermal or cool wave(Ortak 2007; Marutama 2004)
    - Normotermal
    - J-Waves Types: Notched and Slurring **The lambda or Gussak wave(λ). (Gussak 2004) correspond to J-slurring**
3. **The epsilon(ε) wave, right precordial epsilon potentials or Fontaine wave:** Its wave constitute a mayor criteria for the diagnosis of arrhythymogenic right ventricular cardiomyopathy/dysplasia (ARVC/D).(**Wu 2009**). In ECG, epsilon waves manifest as little notches or oscillations, varying in number (1, 2, 3, or more), located at the end of the QRS complex, at the J point or onset of the ST segment (there is no consensus about this) observed in the right precordial leads; however more rarely, they could be seen in the frontal plane leads, especially in the inferior leads.



Epsilon waves (ε) correspond to late potentials or low amplitude and short duration oscillations at the right ventricle free wall (dysplastic triangle) in patients with ARVC/D, and rarely in other entities, such as Brugada syndrome.


Ja Point
J Po int
DELTA WAVE δ
EPSILON WAVE ε
J POINT
HYPERCALCEMIA
WPW
DELTA WAVE
δ
ARVD
ε
V1
HYPOTHERMIA
J
50mm/sec
2N
BRUGADA SYNDROME
V1
J
J
SHORT QT INTERVAL
THE ST SEGMENT IS
ALMOST ABSENT
-90 0
Z
δ
INITIAL DELAY
T
T
X 0 0 V6
δ