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# TO THE QUESTION OF THE ETIOLOGY AND CLINICAL SIGNIFICANCE OF THE U WAVE OF THE ECG

# К ВОПРОСУ ЭТИОЛОГИИ И КЛИНИЧЕСКОГО ЗНАЧЕНИЯ ЗУБЦА U НА ЭКГ

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*Abstract.* This article reviews the etiology and clinical significance of the U wave of the ECG. The conclusion about the importance of competent interpretation of this wave in the treatment of such heart diseases as myocardial ischemia, hypocalcemia, hypokalemia, hypomagnesemia, coronary insufficiency and others. Advanced and proven mechanism of U wave.

*Аннотация.* В настоящей статье рассмотрены этиология и клиническое значение зубца U на ЭКГ. Сделан вывод о важности грамотной интерпретации данного зубца при лечении таких патологий сердца, как ишемия миокарда, гипокальциемия, гипокалиемия, гипомагниемия, коронарная недостаточность и другие. Выдвинут и доказан механизм возникновения зубца U.

*Keywords:* ECG, U wave.

*Ключевые слова:* ЭКГ, зубец U.

*Dedicated to the memory of V. Einthoven and A. F. Samoilov.*

Historically, the first ECG was recorded by G. Lippmann with mercury electrometer, but they broke monophasic in nature and only remotely resembled a normal ECG. The founder and father of modern method are that of W. Einthoven [1], designed the string galvanometer, which allows recording the ECG in the usual form. He also invented the modern notation and describe some disorders of the heart. For his discovery in 1924, he received the Nobel prize in medicine (MLA style: "The Nobel Prize in Physiology or Medicine 1924". *Nobelprize.org.* Nobel Media AB 2014. Web. 8 Oct 2016. Available at: http://www.nobelprize.org/nobel_prizes/medicine/laureates/1924/). His ideas continued to develop A. Samoilov [2], which, along with V. Zelenin, is considered the founder of ECG in Russia.

Today, the electrocardiogram (ECG) is the simplest and at the same time informative method of functional diagnostics of the heart. Usually, on the ECG you can see 5 waves: P, Q, R, S, T, and three of them — Q, R, S — form a complex, and the remaining two are separated.

Electrical impulse arising in the heart is formed of a plurality of micro–formed in a separate miocardiotit occurring in them are complex bioelectric processes. The wave P is caused at the time of depolarization of the myocardium of the Atria and precedes their contraction, the QRS complex — depolarization of ventricles, T wave (along with the ST segment) ventricular repolarization in ventricular myocardium.

However, some ECG after the T wave, it is possible to observe another wave — U wave. Unlike the others, the nature of the U wave has not been fully elucidated. Thus, according to R. Schimpf et al. [3] this wave electro–mechanical phenomenon, leading too low–amplitude, low–frequency deviations after the T wave.

According to many studies [4–8] U wave often fails to register in all leads except the V6, while most often in V2 and V3 with heart rate less than 96 beats per minute. Its amplitude often is 0.1–0.33 mV [6]. Particularly difficult is the allocation of the boundaries of the U wave on the background of the T wave and R wave, which may partial or complete (in the case of T wave) the merger. It is shown that higher values of heart rate or hypocalcemia U wave are superimposed on the T wave [9], and in tachycardia — merges with the R wave of the next cardiac cycle [3, 5, 10].

The views of researchers on the etiology of U wave diverge. Some believe that it is due to the repolarization papillary muscles [11, 12] or Purkinje fibers [13]; the other — that is associated with the entry of potassium ions into the cells of the myocardium during diastole [14].

Normally, the U wave is always positive [4]. The negative of the U wave may indicate myocardial ischemia (leads V4–V6), coronary insufficiency and hypertrophy of the left ventricle (leads I and II) [15]. The increase in U wave with respect to T wave (normally it is up to 50% of the T wave) may indicate subarachnoid hemorrhage, brain tumors [16], and in combination with sinus tachycardia may indicate overdose tricyclic antidepressants [17]. B. Surawicz [18] for hypokalemia believed convincing the amplitude of the U wave more than 1 mm. Pathological, the so–called "giant", the U wave in the chest leads are detected in 78% of patients with a lower serum potassium of 2.7 mEq/L; 35% — a level from 2.7 to 3.0 mEq/L; at the 10% level from 3.0 to 3.5 mEq/L. Such a U wave changes when to meet hypomagnesemia [19].

Thus, the interpretation U wave has important clinical significance. But back to its etiology, because the understanding of the mechanism of its occurrence may shed light as to the course of diseases and the action of the healthy heart.

The resistivity of stationary blood is expressed as $(Ht) = |_{Ht} \cdot (1 + \alpha Ht)$, where α — is a coefficient, Ht — is the hematocrit; at that time, as during acceleration of the blood flow occurs a sharp decrease in the longitudinal resistance with small relaxation times.

On the other hand, there are a number of factors affecting the resistivity of blood. Erythrocyte aggregation occurs at low shear rates and this leads to the conclusion that all vessels (with the exception of large venous) the effect of aggregation is irrelevant. In a blood vessel includes the near–wall layer of plasma (referred to as lubricant), whose size strictly depends on the Reynolds criterion and the shear rate. Given that the thickness of this layer in all blood vessels (except capillaries) is less than 5 microns, and the resistivity of the plasma is two times less than in blood, according to the scheme of parallel inserting is easy to estimate that the contribution of this layer to the resistivity is negligible. By reducing the speed of blood flow profiles of the dependence of Ht on the radius of the vessel becomes more elongated. However, at normal values of Ht, the effect is also an insignificant contribution. With enough shear rates the red blood cells susceptible to deformation. The contribution of this phenomenon is difficult to assess because it is present in the background of all the above effects. However, even the sum of all these factors has little effect on the resistivity of blood.

From this, it follows that at the time of ejection of blood from the left ventricular part of the pulse is carried away because there is no electrical resistivity of blood, which gradually increases high up in the coronary arteries and blood vessels. Thus, we can conclude that the U wave is the momentum carried by the blood in the coronary arteries and blood vessels. Further, it is possible to taking this momentum back to Purkinje fibers along the vessels of the myocardium. This idea is also proved by the fact that hypertrophy of the left ventricle, myocardial ischemia, coronary insufficiency has momentum there is no possibility to move on to the Purkinje fibers, therefore, the ECG recorded negative U wave.

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*References:*

1. Einthoven W. Galvanometrische registratie van het menschelijk electrocardiogram. Leiden, Eduard Ijdo, 1902, pp. 101–107.
2. Samoilov A. F. Selected Works. Moscow, Nauka, 1967, 307 p.
3. Schimpf R., Antzelevitch C., Haghi D. et al. Electromechanical coupling in patients with the short QT syndrome: further insights into the mechanoelectrical hypothesis of the U wave. Heart Rhythm, 2008, no. 2 (5), pp. 241–245.
4. Orlov V. N. Guide of the electrocardiography. MIA, 2007.
5. Galen S. Vagner. Marriott Practical electrocardiography. Tr. from English. St. Petersburg, Nevsky Dialect, Moscow, BINOM, 2002.
6. Lepeschkin E. The U wave of the electrocardiogram. Mod Concepts Cardiovasc Dis, 1969, no. 2 (38).
7. Kuberger M. B. Guide no clinical electrocardiography childhood. Moscow, Meditsina, 1983.
8. Functional diagnostics of cardiovascular diseases under. Ed. J. N. Belenkov, S. K. Ternovoy. Moscow, GEOTAR–Media, 2007.
9. Kishida H., Cole J. S., Surawicz B. Negative U wave: a highly specific but poorly understood sign of heart disease. Am J Cardiol, 1982, no. 49. pp. 2030–2036.
10. Chern–En Ch., Chieh–hung L., Shih–Kuei P., Chu–Pin L., Juan–Ming Yu., Hsiang–Ning L. Desflurane Inhibits U Wave in Electrocardiogram. Acta Cardiol Sin, 2005, no. 21, pp. 214–222.
11. Ker J. The Double U Wave–Should the Electrocardiogram be Interpreted. Echocardiographically. Clinical Medicine Insights: Cardiology, 2010, no. 4, pp. 77–83.
12. Ker J. The U wave and papillary muscle variants: revisiting an old association. Cardiovasc J Afr. 2009, no. 20 (4), pp. 256–257.
13. Conrath C., Opthof T. The patient U wave. Cardiovasc Res., 2005, no. 67 (2), pp. 184–186.
14. Zavyalov A. I. U wave of the electrocardiogram — “own” diastole of the ventricles. Fiziologiya cheloveka, 1983, no. 9 (6), pp. 935–938.
15. Girish M. P., Mohit D. G., Saibal M. Ja. Yu., Sunil R. T. N., Vijay T. U wave an Important Noninvasive Electrocardiographic Diagnostic Marker. Indian Pacing and Electrophysiology Journal, 2005, no. 5 (1), pp. 63–65.
16. Limankina I. N. Tserebrokardialny syndrome. Vestnik aritmologii, 2009, no. 58, pp. 26–34.
17. Handbook Vidal. Pharmaceuticals in Russia: handbook. Moscow, AstraFarmServis, 2010.
18. Surawicz B. U wave facts, hypotheses, misconceptions, and misnomers. J Cardiovasc Electrophysiol, 1998, no. 9, pp. 1117–1128.
19. Shkolnikova M. A. et al. The metabolism of magnesium and its therapeutic value of drugs. Moscow, Medpraktika, 2002.
20. Gorshkov–Cantacuzene V. A. The clinical significance of the ECG U wave. XV Congress of “Heart Failure — 2015” (10–11 December 2015, Krasnogorsk): abstract. Moscow, Society for Heart Failure, 2015.
21. Gorshkov–Cantacuzene V. A. Etiology and clinical significance of the ECG U wave // Russian National Congress of Cardiologists “Cardiology 2016: Challenges and Solutions, Section: Fundamental Research” (20–23 September 2016 Yekaterinburg): proceedings. Moscow, Russian Society of Cardiology, 2016, pp. 520–521.

*Список литературы:*

1. Einthoven W. Galvanometrische registratie van het menschelijk electrocardiogram. Leiden, Eduard Ijdo, 1902, pp. 101–107.
2. Самойлов А. Ф. Избранные труды / отв. ред. В. В. Парин. М.: Наука, 1967. 307 с.
3. Schimpf R., Antzelevitch C., Haghi D. et al. Electromechanical coupling in patients with the short QT syndrome: further insights into the mechanoelectrical hypothesis of the U wave. Heart Rhythm, 2008, no. 2 (5), pp. 241–245.

4. Орлов В. Н. Руководство по электрокардиографии. МИА, 2007.
5. Гален С. Вагнер. Практическая электрокардиография Марриотта / пер. с англ. СПб.: Невский Диалект. М.: БИНОМ, 2002.
6. Lepeschkin E. The U wave of the electrocardiogram. Mod Concepts Cardiovasc Dis, 1969, no. 2 (38).
7. Кубергер М. Б. Руководство по клинической электрокардиографии детского возраста. М.: Медицина, 1983.
8. Функциональная диагностика сердечно–сосудистых заболеваний / под. ред. Ю. Н. Беленкова, С. К. Тернового. М.: ГЭОТАР–Медиа, 2007.
9. Kishida H., Cole J. S., Surawicz B. Negative U wave: a highly specific but poorly understood sign of heart disease. Am J Cardiol, 1982, no. 49. pp. 2030–2036.
10. Chern–En Ch., Chieh–hung L., Shih–Kuei P., Chu–Pin L., Juan–Ming Yu., Hsiang–Ning L. Desflurane Inhibits U Wave in Electrocardiogram. Acta Cardiol Sin, 2005, no. 21, pp. 214–222.
11. Ker J. The Double U Wave–Should the Electrocardiogram be Interpreted. Echocardiographically. Clinical Medicine Insights: Cardiology, 2010, no. 4, pp. 77–83.
12. Ker J. The U wave and papillary muscle variants: revisiting an old association. Cardiovasc J Afr. 2009, no. 20 (4), pp. 256–257.
13. Conrath C., Opthof T. The patient U wave. Cardiovasc Res., 2005, no. 67 (2), pp. 184–186.
14. Завьялов А. И. Зубец U электрокардиограммы — «собственная» диастола желудочков. Физиология человека. 1983. № 9 (6). С. 935–938.
15. Girish M. P., Mohit D. G., Saibal M. Ja. Yu., Sunil R. T. N., Vijay T. U wave an Important Noninvasive Electrocardiographic Diagnostic Marker. Indian Pacing and Electrophysiology Journal, 2005, no. 5 (1), pp. 63–65.
16. Лиманкина И. Н. Цереброкардиальный синдром. Вестник аритмологии. 2009. №58. С. 26–34.
17. Справочник Видаль. Лекарственные препараты в России: справочник. М.: АстраФармСервис, 2010.
18. Surawicz B. U wave facts, hypotheses, misconceptions, and misnomers. J Cardiovasc Electrophysiol, 1998, no. 9, pp. 1117–1128.
19. Школьникова М. А. и др. Метаболизм магния и терапевтическое значение его препаратов. М.: Медпрактика, 2002.
20. Горшков–Кантакузен В. А. Клиническое значение зубца U на ЭКГ // XV Конгресс «Сердечная недостаточность 2015» (10–11 декабря 2015, г. Красногорск): тезисы. М.: Общество специалистов по сердечной недостаточности, 2015.
21. Горшков–Кантакузен В. А. Этиология и клиническое значение зубца U на ЭКГ // Российский национальный конгресс кардиологов «Кардиология 2016: вызовы и пути решения, Раздел: Фундаментальные исследования» (20–23 сентября 2016, г. Екатеринбург): материалы. М.: Российское кардиологическое общество, 2016. С. 520–521.

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