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Mechanopulseography and Biomedicine



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Abbreviations: HRV: Heart Rate Variability; HR: Heart Rate; PW: Pulse Waves

Introduction

The cardiovascular system of higher animals and humans is a complex multifunctional network system of heat and mass transfer and exchange. The level of comprehension of its-functions from the hemodynamics scientific analysis point of view has changed, but has not reached its final version, and, probably, will not become complete in the foreseeable future. The impulsive nature of blood flow, caused by contractions of heart, allots this system with unique features, which primarily characterize the movement of pressure waves called pulse waves (PW) or simply pulses. PW can be detected by fingers on large arteries, which allowed doctors of antiquity to create numerous tactile images and use them to transmit medical in-formation to students. The subtle art of pulsodiagnostics and meridional therapy formed the basis of eastern medicine and has now been almost completely lost.

Naturally, the physical meaning of meridians never been disclosed, and nowadays it is one of the greatest mysteries of nature. Being accessible and valuable biosignal, the pulse of the radial artery could become very popular in medicine, along with the signal of an electrocardiogram, especially taking into account the modern development of sensor technology and information transmission me-dia.

But in terms of metrological perception of PW, large problems derive from its small size and the difficulty of getting the sensor to the top of the artery (the problem of sensor positioning). In this regard, visual observation of the PW signal is available only to few researchers, and a cuff-free arterial tonometer remains only a dream, yet inaccessible to both doctors and patients. Only "Millar" US company and Mechanical Engineering Research Institute of the Russian Academy of Sciences (IMASH RAN), represented by the author of this article, came close

to solving the problem of creating a high-quality PW sensor. Figure 1 presents miniature fiber-optic sensors with a radial configuration, designed to complete a mobile medical device in the form of a wristwatch (the IMASH RAS development).



Figure 1: Console Fiber Optic Sensors

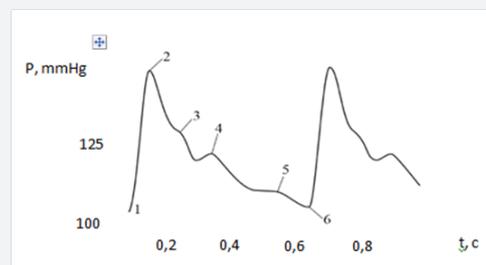


Figure 2: Beam artery pulse wave

1. The beginning of the cardio cycle;
2. The maximum pressure;
3. The trace of aortic valve closure;
4. Reflected response;
5. Repeated reflected response;
6. The beginning of the next cardiocycle

PW sensor of similar type first appeared in 1989. It was preceded by the author's re-research in this field since 1978 [1]. Fiber-optic sensorprobes solved the problem of undistorted PW measurement and became the basis of high-resolution sphagnography [2]. Let us briefly consider the main points that resulted from the PW observation and analysis. The first conclusion concerns the explanation of the structure of responses at the posterior sting of the PW, for example, the radial artery (Figure 2).

The opinion that exists in literature that the protuberance 4 on the posterior slope is the "arterioles" response and the protuberance 5 is the "capillaries" response, is untenable, taking into account that the PW propagation velocity lies in 4-15m/s range. Basic calculations show that the responses mentioned above are in the front slope zone and cannot be located on the back slope in any way. At the same time, if we assume that the main PW splash undergoes multiple reflection and travels along a certain closed trajectory, its appearance on the back slope in the form of response 4 (Figure 2) corresponds to the values of pulse wave propagation rate (SWRT).

Mean while, the time of location of the response 5 on the back PW slope corres-pond's to the real SWRT range, if we consider it as the reflection of the main splash again after a repeated passage along a closed path. That is also the location of the reflected main splash from the area of the loin-legs. Bearing in mind the reasoning presented above, it is not difficult to establish the interrelation between the PW form and the human anatomical structure. Thus, the nature has created a perfect blood supply system that ideally reflects the human anatomical structure, as the only upright creature.

Another interesting observation has been made through analyzing the 20-second re-cording of the PW series in terms

of heart rate variability (HRV). Until now, HRV has been considered from the standpoint of diagnostics mainly in space medicine. We hypothesized that HRV, which looks like a low-frequency modulation of the heart rate (HR), is nothing more than the creation of an information component in the blood flow through the vascular network that helps to create the address for local increasing of the blood flow. This scheme can be clearly seen on the example of the so-called respiratory arrhythmia: approximately 4-6 strokes of the heart per one cycle of breathing.

If this assumption is true, then another mystery of the pulse wave is uncovered and the light is shed on the nature of the eastern medicine meridians. It becomes clear why the pressure on the puncture points cause the recovery of certain human organs and systems. If to continue developing this idea, it is easy to assume that certain types of massage can direct the medicine with a flow of blood to a certain zone, for ex-ample, into an ischemic zone or into a zone of a cancerous tumor. Thus, the effectiveness of-the medicine will significantly increase. Thus, the PW registration and analysis can lead not only to the revival of oriental medicine, but also to the creation of new therapy based on the blood flow management. Accordingly, the role of mechano pulseography in medicine and biomedicine can become very promising, giving this ancient science a qualitative leap forward.

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