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Opinion

Sound and Electrical Heart Signals-Primary Cardiology Diagnostic Tools

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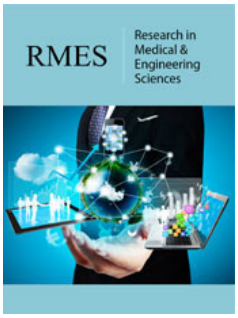

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Opinion

Recording, processing and analysis of biomedical signals and their display and interpretation are standard diagnostic procedures in modern medical practice. Understanding the links between pathological symptoms and signal parameters which represent those symptoms helps doctors to more easily study and understand them, which is very important for diagnosing but also for the procedure of therapy and treating the disease. Acoustic and electrical heart signals are a reflection of heart activity, therefore by interpreting those signals we interpret the work of the heart. Signals are displayed and interpreted in time and frequency. Biological activities of the heart initiate the flow of electricity through the heart (electrical activity of the heart). By displaying this activity through elapsed time, we get an electrical signal which shows the electrical activity of the heart. The flow of electricity through the heart initiates the mechanical activities of the heart which generate sounds, i.e. the acoustic activity of the heart. By converting the sounds of the heart into an electrical signal and displaying it through elapsed time, we get a recording of the heart's sound activity.

Speech, but also many other medical phenomena such as breathing, coughing, snoring, cracking joints and even muscle activity generate sound. The flow of blood through the heart and the work of the heart valves as mechanical activity in the heart generate the sound we hear as heart sound. The sound of a healthy heart, known as normal, has two sounds (called the first and second heart sound) produced by the closing of heart valves. The sound caused by heart diseases known as abnormal has extra sounds (noise) which can be heard through the systole or diastole. Listening and interpretation of the sounds made by the heart is a noninvasive technique for detecting the appearance of abnormal sounds in a cardiac cycle. Understanding those sounds provides valuable information on various heart diseases. By converting sounds into electrical signals, this information is mapped into certain signal values, i.e. those signals become carriers of sound information. The visual graphic representation of the sound of the heart as an idea of Robert Hooke dates back to the middle of the 17th century. This idea was realized after three centuries (in 1930), when equipment was made for the graphic display of heart sounds, and their standardization began in 1950. The heart sound signal known as the phonocardiogram and the acronym PCG is a temporal representation of the sequence of events of the acoustic activity of the heart. Spectrogram displays of heart sound signals enable a simultaneous time-frequency display of the content of heart sound signals. Changes in amplitudes and frequency values of signal over time respond to normal or abnormal sounds over that span of time.

Two hundred years have passed since René Théophile Hyacinthe Laennec (1781-1826) invented the stethoscope in 1816. and it was the very beginning of auscultation (Latin word for listening). The first stethoscope was made of wood. After two centuries of technological development today's generation of doctors can use electronic stethoscopes. The stethoscopes

allow doctors to combine auscultation with phonocardiography in the cardiac examination of patients. Software solutions with graphical displays of the heart sound signals are a good tool for doctors in cardiac diagnosis. With the development of electronics, especially computer technologies, the stethoscope has developed into a device for automatic diagnosis of heart sound signals.

Representations of the flow of electricity through the heart (heart action potential) through time in the form of curves (signals, i.e. the display of these signals) provide information about the regularity or irregularity of electrical cardiac activity, or about the correct or incorrect work of the heart muscle. Disruptions of the flow of electrical potential through cardiac structures, caused by certain heart problems and diseases, disrupt the normal course of events in the electrical cardiac cycle. Every change of heart action potential has its reflection in certain parameters of the signal. Therefore, certain heart problems and diseases change the normal form on the signal display. The signal of cardiac electrical activity is known by the name electrocardiogram and acronyms (EKG and ECG). As the signal is a reflection (image) of the movement of the electrical potential through the cardiac structures that initiate the contractions and relaxations of the heart, it is clear that the irregularity of the operation of certain cardiac structures will be reflected in the flow of electricity through the heart and this will manifest itself in certain segments and/or waves of the ECG signal.

One hundred and twenty years have passed since Willem Einthoven (1860-1927) invented (in 1895) and completed (in 1901) the first prototype of the first practical electrocardiograph. In 1903 he reported ECGs taken with his string galvanometer and it was the very beginning of electrocardiography. When he made the first record of electrical heart activity (electrocardiogram) on his electrocardiograph, Einthoven recognized its diagnostic potential and said the following: *„Now, we can record a heart's abnormal electrical activity... and compare it to the normal.*" The ECG has become one of the most commonly used tests in medical practice. Modern electrocardiographs are small, light and wearable portable devices that record a continuous ECG and monitor heart rate and other bodily functions. The first electrocardiograph device was huge as it filled two rooms and weighed some 270kg. Today, electrocardiographs use digital signal processing techniques to show and analyze ECG signals. Also, professional modern electrocardiographs have options of automated interpretation i.e. automated diagnosis of ECG signals.

Various displays of heart signals show the workings of the heart, i.e. they help doctors monitor and interpret events in the heart's activity cycles. Each event in the cardiac cycle has its reflection on a certain signal feature (events of the cycle of acoustic activity of the heart and acoustic heart signals, events of the cycle of electrical activity of the heart and ECG, etc.) so that each feature of the signal has a link with the corresponding event in the heart. By interpreting the displayed signals, doctors diagnose various heart diseases. Heart diseases that manifest as a deformation of the normal sound heart cycle are diagnosed by the interpretation of the sound (auscultation) and/or the interpretation of the signal that visualizes that sound. Through the ECG showing a record of cardiac electrical activity during time, it is evident that the ECG is a good tool for diagnosing heart diseases caused by electrical irregularities in heart activity.

The presentation of electrical signals of the heart, electrocardiogram - ECG, is a reflection of electrical events in the heart, i.e. the propagation of a wave of polarizing potential through the heart. Presentations of the acoustic signals of the heart, the temporal representation of the sound of the heart (phonocardiogram - PCG) and the spectogram of the sound of the heart, are a reflection of the mechanical events of sound generation during the biological cycle of the heart. Therefore, the representations of electrical and acoustic (sound) heart signals are not visual representations of the appearance of the heart (photographs of the heart) but representations of the heart's activity. By converting heart activities into signals, the sequence of cyclic events of heart activity is mapped into the corresponding sequence of cyclic (periodic) repetition of signal characteristics. Since the biological-electrical-mechanical-acoustic correlations and analogies with signal displays are precisely determined, it is possible to monitor the biological work of the heart based on the interpretation of heart signals. In this way, images of the functionality and coordination of cardiac structures can be imagined during the biological cycle of the heart.

The presentation of the electrical activity of the heart with an ECG signal provides a good insight into the biological phenomenon of the heart's work. Therefore, the display of electrical heart signals shows the description of the heart's work mechanism very well. Irregulariy of blood flow through the heart do to dysfunctional heart valves or some defects on the septum of the heart can be heard with a sthethoscope, but it can be seen even more clearly on a PCG or a spectrogram of the sound of the heart. By presenting the electrical and acoustic activity of the heart with an ECG or PCG and/or a spectrogram, a clear picture of the biological cycle of the heart can be obtained and the perception of medical cardiology can be enriched. Sound and electrical heart signals have been primary diagnostic tools in cardiology for more than half a century. Although the application of these signals was introduced long ago in diagnostic practice, they are still diagnostic potentials and a great challenge for doctors and engineers.