Application of the Hydrocuff Technology For Blood Pressure Evaluation

M. S. Gerashchenko  
Department of Medical Cybernetics and Informatics,  
Penza State University, 40 Krasnaya St., Penza 440026, Russia.

S. M. Gerashchenko  
Department of Medical Cybernetics and Informatics,  
Penza State University, 40 Krasnaya St., Penza 440026, Russia.

S. I. Gerashchenko  
Department of Medical Cybernetics and Informatics,  
Penza State University, 40 Krasnaya St., Penza 440026, Russia.

N. N. Yankina  
Department of Medical Cybernetics and Informatics,  
Penza State University, 40 Krasnaya St., Penza 440026, Russia.

Abstract  
The article describes a method for improving the accuracy of blood pressure measurement using the hydrocuff technology. Modern monitors with a pneumatic cuff have several disadvantages, and a monitor using the hydrocuff technology in addition to the oscillator one, can eliminate some of them. In particular, the ability to detect oscillations in compression and decompression modes, creates additional benefits: reducing the discharge pressure in the cuff to the level of the systolic blood pressure; lack of complete occlusion of the artery, and discomfort associated with it; the reduction of the measurement duration up to 10-15 seconds; high measurement accuracy due to the possibility of the oscillations amplitude change registration in the ascending and descending phase of the curve with an accuracy of up to 1%. A differential switching circuit of the pressure sensor for camera cuffs allows compensating noise and highlighting the difference signal of pressure measuring in the cuff chambers during pulse wave motion. The use of a dual-chamber compression cuff allows a differential switching circuit in the evaluation of fixing the start and the end of the oscillations. The hydrocuff allows fixing the start and the end of the pulse wave forming noise-robust high-amplitude oscillations, being linear in the range of 85-200 mmHg. The presence of two chambers arranged at a distance from each other, allows estimating the parameters of pulse wave dynamics. This creates conditions for the monitor functions increasing related to the evaluation of the hemodynamic parameters, such as pulse wave velocity, without complicating its design. The possibilities of this device are quite promising and require a further clinical study.

Keywords: hypertension, blood pressure, monitors, hydrocuff monitor.

Introduction  
According to the special literature analysis about 30-45% of the total population suffers from hypertension without any systemic trends to changes in blood pressure over the last decade [1]. High blood pressure is the main risk factor for major cardiovascular diseases, such as heart attack and stroke [2], which can be used as surrogate indicators of hypertension prevalence [3]. According to the World Health Organization (WHO) statistics there is a tendency in the Western countries to lower mortality from stroke in contrast to Eastern Europe, where the death rate from stroke is increasing [1, 4]. The studies carried out in several countries show that a significant part of patients with hypertension are unaware of their disease and the level of awareness of hypertension and the blood pressure control is growing very slowly or not growing at all [5-7]. One of the reasons for the low level of the blood pressure control is low treatment compliance, which may be increased by simplifying therapy and self-measurement of blood pressure [7].

The era of hypertension began in 1905, when N. S. Korotkov and M. Yanowsky developed the first public quantitative method for blood pressure measurement. It was in 1911 when E. Frank gave the first clinical definition of the disease according to which (for some unknown reason then) blood pressure rises chronically and eventually progresses with aggravation and remission, i. e. essential hypertension. In 1922 G. F. Lang russified the name, and then he proposed the concept of hypertensive heart disease, which was the most used one in the domestic literature [8].

Methods for blood pressure measurement  
Currently, there are different ways to measure blood pressure, which are conventionally divided into invasive and non-invasive ones. The non-invasive blood pressure measurement
The oscillometric technique is used in 80% of electronic automatic and semi-automatic blood pressure monitors. Its advantages over the auscultation method is a great resistance to the noise, the cuff movement along the arm, and the ability of measurement through thin clothing, as well as the presence of the auscultatory gap and the weak Korotkoff sounds. In modern devices it is possible to register the level of blood pressure in the auscultatory gap and the weak Korotkoff sounds. In modern devices it is possible to register the level of blood pressure in the compression phase, when there are no local circulatory disorders that occur during air bleeding. The oscillometric method is dependent less than the auscultatory method on the noise effect upon the measurement results. The source of the noise is the air pressure in the cuff during a smooth compression (decompression). The value of the air pressure in the cuff, at which there is a pulse, is considered to be the systolic blood pressure. Determination of the minimum pressure in this way involves considerable uncertainties. The reduction of the pulsations amplitude in decompression may be taken as the criterion of equality of the air pressure to the minimum value in the cuff. However, this criterion is not sufficiently precise and unambiguous for the automatic determination of blood pressure values. Satisfactory results can only be obtained using rheographic recording and manual data decoding [9].

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The selection of fluid as a working substance of the pressure source.

The difficulties arise with some anatomical and physiological characteristics of the patient, impeding blood pressure measurement with the auscultatory or the oscillometric method. For example, if there is atypical or deep location of blood vessels in the over-developed fat and muscle tissue, and weak pulse fluctuations, the readings of devices for measuring blood pressure may be distorted. The design features of modern blood pressure monitors cause a very low level of the transmitter output pressure fluctuations (the maximum oscillation amplitude being 1-3 mmHg), and a significant noise effect upon the measurement results. The source of the substantial error in blood pressure determining is air in the cuff of blood pressure monitors, which is a compressible medium, and a poor conductor of oscillations [11].

**A hydrocuff device for blood pressure measurement**

To reduce measurement errors in blood pressure, the hydrocuff is proposed to be used in devices for measuring blood pressure.

Using a liquid as the conductor and the oscillations amplifier generated by the pulse wave has been shown in the scientific literature since the 19th century. In 1880 a German physiologist Johannes Dogil used the machine filled with water, studying the effect of music on blood pressure. A hand of a tested patient was placed into a glass tube with warm water, sealed with a rubber cuff on the forearm, fluctuations in water pressure being done with a recorder [12].

Structuring of the proposed monitor using the hydrocuff technology is represented in Figure 1 and includes a dual-chamber (1, 2) compression cuff, the first (3) and the second (4) pressure sensors, a differential amplifier (6), a recording unit (7) and a display unit (8), a pressure source (5), the first control units (9) and (10); the compression cuff is pressurized through the control units (9) and (10); the compression cuff is pressurized, arteries and veins are occluded and the spread of the pulse wave is prevented; the liquid enters the pressure source (5) of the pulse from the first and the second chambers (1, 2) of the compression cuff through the control blocks (9, 10) of pressure control. The pressure source (5) comprises a container with a predetermined volume of liquid and a pump for supplying and pressurizing the liquid.

**Figure 1: A hydrocuff monitor block diagram**

The monitor works as follows: the compression cuff (1, 2) is set on the patient’s arm before starting the measurement; then the pressure is supplied from the source (5); the fluid enters the chambers (1, 2) of the compression cuff through the control units (9) and (10); the compression cuff is pressurized, arteries and veins are occluded and the spread of the pulse wave is prevented; the liquid enters the pressure source (5) of the pulse from the first and the second chambers (1, 2) of the compression cuff through the control blocks (9) and (10) of the pressure source.

The selection of fluid as a working substance of the incompressible medium increases the sensitivity of the oscillation evaluation, which significantly raises their amplitude. A differential switching circuit of the pressure sensor for camera cuffs allows compensating noise occurring from the heart, the lungs, movement of joints, the external noise and other acoustic effects during the measurement and provides a difference signal of pressure measurement in the...
cuff chambers during pulse wave motion. The use of a dual-chamber compression cuff allows a differential switching circuit in the evaluation of fixing the start and the end of the oscillations.

The high sensitivity of the oscillation evaluation creates a background for a qualitative assessment of the pulse wave form perception [13]. The presence of two chambers arranged at a distance from each other, allows estimating the parameters of pulse wave dynamics. This creates conditions for the monitor functions increasing related to the evaluation of the hemodynamic parameters, such as pulse wave velocity, without complicating its design[14].

Figure 2 shows the signal from the pressure sensor in the hydrocuff chamber during the compression. The signal is shown after its handling with a 16-bit ADC in the LabView program.

Figure 2: A recorded signal from the pressure sensor in the cuff chamber during the compression

The Figure shows that pressure oscillations in the cuff are practically noise-robust and in the range of 85-200 mmHg are linear. The maximum oscillation amplitude is 20 mmHg at pressure variation of 40 mmHg.

The results suggest the possibility of using the hydrocuff technology in the oscillator signal processing techniques. This method allows registering the oscillation in compression and decompression modes, which creates additional advantages:
- there is no need to pump air into the cuff above the systolic pressure level, total occlusion of the artery and discomfort associated with this;
- reducing the duration of the monitoring;
- greater accuracy of measurement due to the possibility of registering changes in the amplitude of the oscillations in the ascending and descending phase of the curve [14].

Figure 3 shows the oscillation graphs recorded with two hydrocuff chambers in the compression mode.

Figure 3: Graphs of oscillations recorded with two hydrocuff chambers

When placing the cuff on the patient’s shoulder, oscillations are formed in the upper and lower chambers during the compression. In the lower chamber oscillations occur before the compression of the artery with overpressure. This point corresponds to the value of 135 mm Hg in the graph.

Conclusion

Thus, the proposed solution creates a background for the implementation of easy-to-handle monitor having a high accuracy with an error of up to 1%, and the measurement duration of 10-15 seconds. The using of the hydrocuff technology combined with the oscillator one, allows recording the start and the end of the pulse wave formation that corresponds to the principle of determining the origin of the Korotkoff sounds. The possibilities of this device are quite promising and require a further clinical study.

References


