Non-Invasive Methods of Peripheral Pulse Detection: Advantages and Disadvantages

Bistra Draganova Nenova and Ivo Tsvetanov Iliev

Abstract - **In a series of resuscitation guidelines produced by authoritative international organizations is emphasized that checking the carotid pulse is an inaccurate method of confirming the presence or absence of circulation. A summary review of the most popular non-invasive methods of peripheral pulse detection is presented in this work – Photo-plethysmography, Impedance Plethysmography, Doppler Ultrasound, Arterial Tonometry and Oscillometric method. A comparative analysis of the methods highlights their advantages and disadvantages in view of applicability in emergency situations. Photoplethysmography and Impedance Plethysmography are estimated as having very good and good applicability. The usage of Doppler Ultrasound method for peripheral pulse detection is possible, but is associated with technological difficulties and high cost. In the rest of the methods substantial disadvantages stand out.**

Keywords – **Peripheral pulse detection, Non-invasive methods, Emergency**

I. Introduction

In a series of resuscitation guidelines produced by International Liaison Committee on Resuscitation (ILCOR), European Resuscitation Council (ERC) and American Heart Association (AHA) is emphasized that checking the carotid pulse by palpation (Fig.1.) is an inaccurate method of confirming the presence or absence of circulation [1,2]. The time for a single pulse check was limited to no more than 10 seconds for healthcare

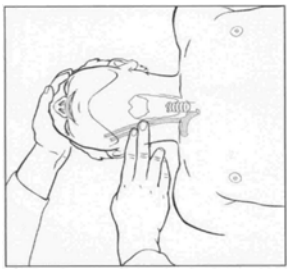

Fig.1. Palpatory method

providers. The pulse check was removed from training for lay rescuers and replaced with checking for "normal breathing" and "looking for signs of life". All this has given rise to wide discussion. The design and usage of a specialized pulse wave detector in an emergency would be of great diagnostic significance.

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The object of the present work is to make a comparative analysis of the advantages and disadvantages of the most popular methods of peripheral pulse detection in view of their applicability in emergency situations.

II. Non-Invasive Methods of Peripheral Pulse Detection

A. Photoplethysmography

Photoplethysmography [3] registers the intensity of transmitted through or reflected from tissues light, using a light emitter and a photodetector. The method is illustrated in Fig.2. The light intensity is modulated by the pulsating blood flow in the measurement site. The PPG waveform comprises a pulsatile ('AC') physiological waveform attributed to cardiac synchronous changes in the blood volume in vessels with each heart beat. Infrared light (800-960nm) is the commonly used one for pulse wave detection in commercially available PPG devices.

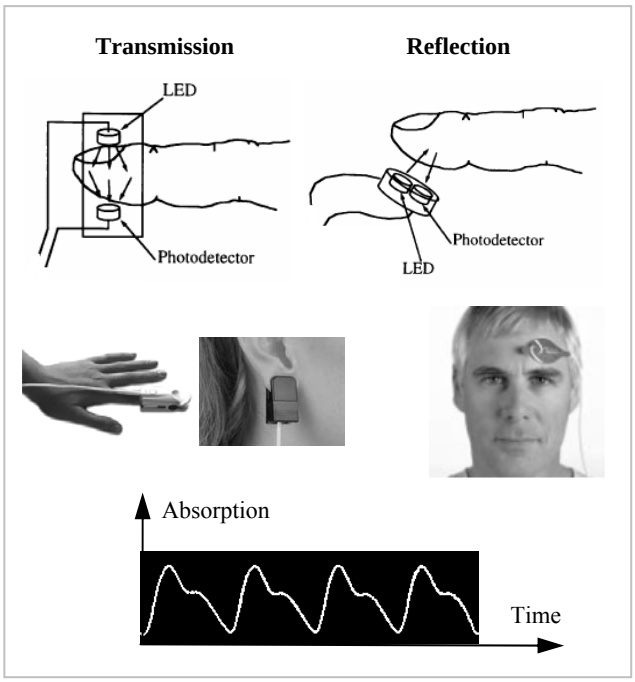

Fig.2. Photoplethysmography

B. Impedance Plethysmography

Blood is one of the best conductors in a body (ρ=1,5Ωm). Impedance Plethysmography [4,5] measures the variation in tissue impedance over the cardiac cycle due to blood circulation (Fig.3). A constant-amplitude high-frequency AC current is applied to a body segment via a couple of electrodes:

$$\begin{cases} I = 0.5 - 2\ mA\ rms \\ f = 50 - 150\ kHz \end{cases}$$

Most often a four-electrode technique is used, which main advantage is the reduced influence of the changes in the electrode-skin impedances. The outer electrodes supply the current, while the inner two are used to measure the potential difference.

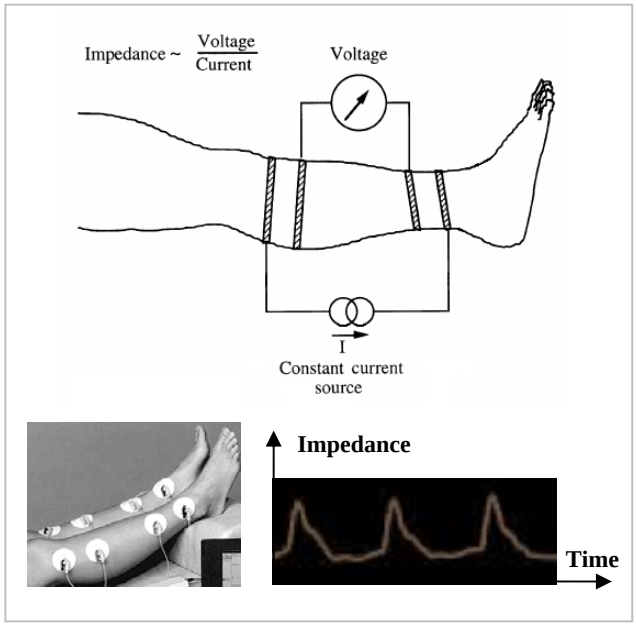

Fig.3. Impedance plethysmography

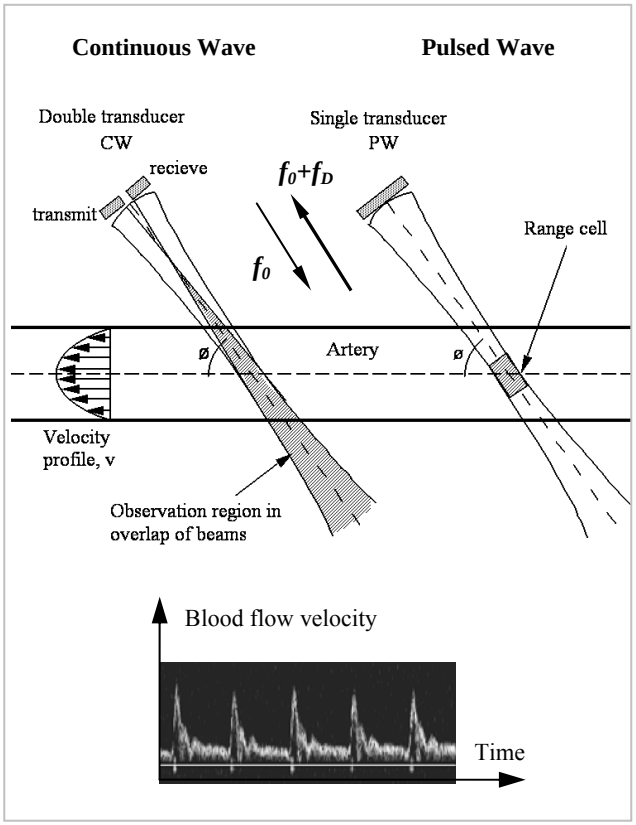

Fig.4. Doppler Ultrasound

C. Doppler Ultrasound

The blood cells scatter the ultrasonic waves diffusively. Doppler Ultrasound method [6,9] uses the Doppler effect when the moving blood cells are illuminated by a beam of ultrasound – Fig.4.

$$f_D = 2 f_0 \frac{v}{c} \cos\theta \qquad (1)$$

$$\left.\begin{array}{l} f_0 = 2 - 10\ MHz \\ c \approx 1540\ m/s \end{array}\right\} \ f_D = 1.3 - 13\ kHz\ ,$$

where f_D is the Doppler frequency, f_0 - the transmitted frequency, v - the blood velocity, c - the speed of sound, θ - the beam angle.

The spectral estimation of the received Doppler signal provides information about the pulsating changes in the blood flow velocity. In Pulsed Doppler a limited sample volume along the beam is defined from which data is collected. In Continuous Wave Doppler the signal comes from all scatterers within the ultrasound beam.

D. Arterial Tonometry

Arterial tonometry [7] registers the changes in the intra-arterial blood pressure over the cardiac cycle – Fig.5. When an artery is compressed and partially flattened the surrounding pressure equals the intra-arterial pressure. A

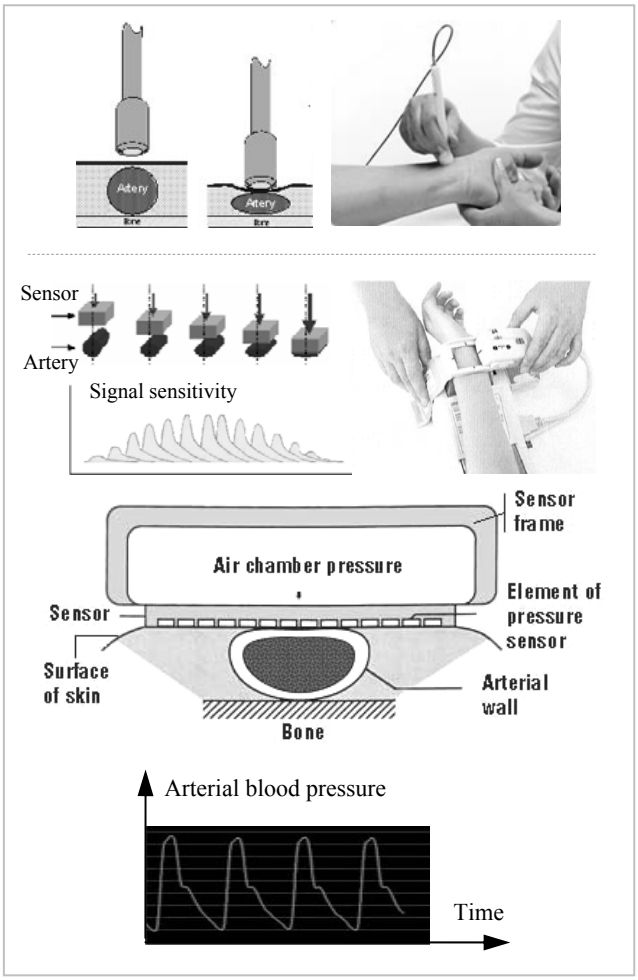

Fig.5. Arterial Tonometry

TABLE 1. COMPARATIVE ANALYSIS OF THE METHODS OF PERIPHERAL PULSE DETECTION

Method	Principle	Advantages	Disadvantages	Applica-bility
Photo-plethysmography	Detection of light intensity transmitted through or reflected from tissues > Light emitter > Photodetector	(+) High sensitivity in pulse wave detection (+) A simple and inexpensive method (+) Easy to handle, small-sized devices (+) Signals can be obtained from a greater number of body locations (+) Precise sensor positioning is not critical	(-) Sensitivity to movement artifacts (-) Sensitivity to poor peripheral perfusion (-) Sensitivity to changes in body and ambient temperatures (-) Ambient light influence	Very Good
Impedance Plethysmography	Body impedance measurement > 4 – electrode method	(+) Relatively inexpensive and simple (+) Precise positioning is not required (+) Possible signal detection from different body sites (whole body impedance, thoracic impedance, limbs)	(-) A large number of electrodes (-) Presence of considerable artifacts	Good
Doppler Ultrasound	Doppler effect when red blood cells are irradiated with ultrasound waves > Ultrasound transducer (single or double)	(+) Possibility to measure blood flow velocity <u>Continuous Wave Doppler</u> (+) Simpler hardware implementation (+) Lower cost (+) Ability to measure high blood flow velocities (+) Wide depth range <u>Pulsed Wave Doppler</u> (+) Measurement range definition	(-) Precise positioning over a large blood vessel at an appropriate angle (-) Expensive (-) Contact gel <u>Continuous Wave Doppler</u> (-) Measurement range ambiguity <u>Pulsed Wave Doppler</u> (-) For use by qualified personnel only (-) "Aliasing" artifacts at high blood flow velocities (-) Measurement depth limitations	Limited
Arterial Tonometry	An artery is partially flattened until the intra-arterial pressure equals the surrounding pressure (which is measured) > Pressure sensor(s)	(+) Accurately records the arterial blood pressure waveform	(-) Heavy restrictions on the measurement site (-) Very accurate sensor positioning is required (-) Powerful influence of movement artifacts (-) Requires certain operator skills (-) Relatively high cost (of automated devices)	Poor
Oscillometric	Detection of arterial blood pressure oscillations > Inflatable cuff > Pressure sensor	(+) A reliable measurement method	(-) The application is limited to limb areas (-) Cuff pressure between systolic and diastolic pressures (-) Slow and inconvenient (-) Sensitivity to movement artifacts	Poor

pressure sensor is pressed exactly against a superficial artery, which is preferably supported from below by a bone. The hold-down pressure is increased continuously and the measurements are made when the artery is half collapsed. In automated devices a linear array of miniature pressure sensors is used to facilitate the required precise positioning.

E. Oscillometic method

In the oscillometric method [8] the intra-arterial pulsation is transmitted via an inflatable cuff to a transducer (e.g. piezo-electric) – Fig.6. The cuff is wrapped around a limb and is inflated to a pressure between the systolic and diastolic pressures. Oscillations of the arterial blood pressure, superimposed on the cuff pressure are registered. The oscillations amplitude is at a maximum when the cuff pressure equals the mean arterial pressure. The main application of the method is for blood pressure measurements.

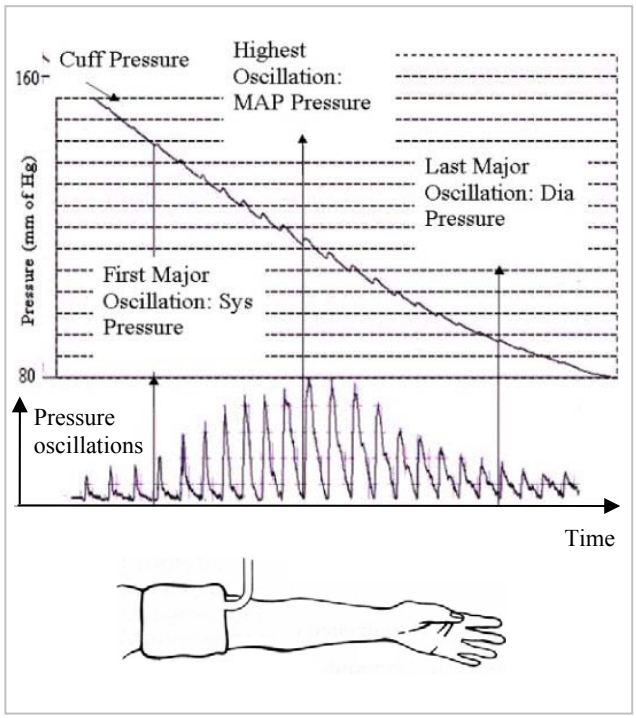

Fig.6. Oscillometric method

Other methods that have found little application in the peripheral pulse detection, like strain gauge plethysmography, are not included in the present review.

III. Comparative Analysis of the Methods: Advantages and Disadvantages

A summary review of the advantages and disadvantages of the peripheral pulse detection methods, in view of their applicability in an emergency, is presented in Table1.

Photoplethysmography has high sensitivity in detection of peripheral circulation – the arterial pulsations are clearly outlined. Signals can be obtained from a greater number of body locations, precise sensor positioning is not critical. The main disadvantages are sensitivity to poor peripheral perfusion and sensitivity to movement artifacts.

Impedance plethysmography is a relatively inexpensive and simple method that does not require precise positioning and signal acquisition is possible from different body sites. Disadvantages are the large number of electrodes and the presence of considerable artifacts.

Disadvantages of the Doppler Ultrasound method are the requirement of precise positioning over a large blood vessel at an appropriate angle, the usage of contact gel and the high cost. An advantade is the wide depth range in Continous Wave Doppler.

Arterial Tonometry accurately records the arterial blood pressure waveform. A great disadvantage, however, is that this method imposes heavy restrictions on the measurement site.

Oscillometry is a reliable measurement method, but it is slower and inconvenient, with application limited to the limb areas and the usage of an inflatable cuff is also needed.

IV. Conclusion

Different non-invasive methods of peripheral pulse detection have found practical application. The comparative analysis highlights their advantages and disadvantages. A conclusion is drawn about the applicability of the methods in emergency situations – Table1. Photoplethysmography and impedance plethysmography are estimated as having very good and good applicability. The usage of the Doppler Ultrasound method for peripheral pulse detection is possible, but is associated with technological difficulties and high cost. In the rest of the methods substantial disadvantages stand out.

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