Research Article
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Register to skin level of the dicrotic wave: ultrasound vs. biomagnetism

Abstract

The direct indicator of the number of pulsations recorded in a peripheral artery per unit of time of a person is the frequency of the cardiac pulse in the cardiovascular system, this pulse is manifested as a pressure wave caused by the expansion of the arteries changing from size and shape as they travel along the blood vessels.

Materials and methods: This is a comparative cross-sectional study, conducted over six months in the city of León, GTO, in which 30 volunteers without a history of cardiovascular disease (20 women and 10 men) in an age range between 25 to 40 years.

Results: 60 measurements of the pressure waves of the volunteers were recorded simultaneously, using ultrasound equipment and the cardiac pulse pressure (PPC), recording among them an important difference in obtaining the pulse waves through biomagnetism.

Conclusion: The results suggest that the measurement modality with the PPC, in addition to being a simple and easy to apply procedure to obtain the carotid pulse signal compared to the signal obtained with the carotid ultrasound, offers potential as an alternative technique for pressure and arterial wavelength records at skin level.

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Angélica Hernández Rayas,[1] Teodoro Córdova-Fraga,[1] Luis Antonio Rosas-Pacheco,[1] Mauricio Sánchez-Barajas,[2] Eduardo Perez-Careta,[3] Rafael Guzmán Cabrera[3]

[1]Division de Ciencias e Ingeniería, Universidad de Guanajuato, México
[2]Instituto Mexicano del Seguro social, México
[3]Departamento de Ingeniería Eléctrica, Universidad de Guanajuato, México

Correspondence: Rafael Guzmán Cabrera, Departamento de Ingeniería Eléctrica, Universidad de Guanajuato campus Irapuato-Salamanca km 3.5 Carr. Salamanca-Valle de Santiago + 1.8 Comunidad de Palo Blanco, GTO, México, Tel +52 4641239321, Email guzmanc@ugto.mx

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Introduction

The recording of the dicrotic wave involves talking about the pulse velocity of this inside the artery. As far as is known, it was Euler in 1775, who postulated the first model to evaluate the propagation of the velocity of the blood pressure wave, which he considered a finite velocity.[1] It is also known that, in the 19th century, Moens and Korteweg carried out an update of this formula where, the pulse wave velocity is related to blood density, modulus of arterial elasticity, thickness and parietal diameter.[2] Considering that the power source of the wave is in the heart, it is expected that the pulse generated in the left ventricle is delayed as it is transmitted through the arterial tree. This is shown when evaluating it as the simultaneous recording of pressure at different arterial points reflects a temporary lag between the waves, which is progressive proportionally to the distance of the points towards the periphery.[3] Therefore, the analysis of pulse waves has served to find early signs of preclinical physical diagnosis to detect vascular diseases in the preclinical stage and to prevent clinical deterioration in time.[4] The cardiovascular risk study is traditionally carried out by means of: the taking of blood pressure, the interrogation of life habits and the analysis of lipids in the blood. Without discarding these traditional techniques, pulse wave analysis has been added to them, which suggests new possibilities in the evaluation and early detection of cardiovascular diseases.[5] An increasing number of people in developing countries with traditional cardiovascular risk factors such as smoking, hypertension and diabetes mellitus, increase cardiovascular disease rates.[6–8]

The association between these risk factors (diabetes, hypertension and smoking) and coronary collateral circulation is controversial, since well-developed coronary collateral circulation improves cardiac function and decreases mortality. Given the confusing evidence on traditional cardiovascular risk factors in collateral circulation, several meta-analysis studies have been conducted to investigate the relationship between traditional risk factors for coronary artery disease and coronary collateral circulation.[9] Diabetes and hypertension are closely related due to similar risk factors, such as endothelial dysfunction, vascular inflammation, arterial remodeling, atherosclerosis, dyslipidemia and obesity. There is also a substantial overlap in the cardiovascular complications of diabetes and hypertension mainly related to microvascular and macro vascular disease.[10] The cardiovascular risk may be higher than indicated in sedentary people with central obesity; the increase in relative risk associated with being overweight is greater in younger people than in older people.[11] In a previous study, the normal arterial blood pressure waveforms, the dicrotic notch is placed above the level of morphology, which marks the diastolic pressure. In an atypical waveform morphology occasionally discovered, the dicrotic notch is in a different position. We refer to this as a “deep sign of dicrotic notch”; Dicrotic notch is depressed for a point at the same morphological level or even lower than that of diastolic pressure.[12]

Dicrotic notch is a small and brief increase in blood pressure which appears when the aortic valve is closed.[13]

Parameters of arterial stiffness, such as pulse wave velocity (VOP), have recently been proposed as independent risk factors for cardiovascular events.[14] Pulse wave velocity is an important measure of cardiovascular risk, and can be measured with several different techniques.[15] The measurement of arterial stiffness is traditionally performed using a pulse wave velocity (PWV) methodology that is an important and reliable measure of arterial stiffness. Specifically, PWV represents the stiffness of a specific arterial segment. The pulse wave is transmitted through the arterial vessels in a specific segment, and it’s velocity is inversely related to the viscoelastic properties of the wall itself, the PWV value increases with arterial stiffness.[16]

Among the devices for measuring the speed of the dicrotic wave is the tonometer, which is the most commonly used transducer, it rests on the palpation zone of the radial or carotid pulse and delivers a voltage proportional to the instantaneous value of the intra-arterial pressure. There are variants of this sensor, which are plethysmographic devices, which record the digital volumetric flow related to the same pressure.[17] In a study by Narimatsu K (2001), a new pulse wave velocity (PWV) measurement system was developed using a novel carotid multi-element tonometry sensor combined with a heart sound sensor. In this system, the PWV is derived from the time elapsed between the second cardiac sound (S2) obtained from the cardiac sound sensor and the dicrotic notch in the carotid pulse waveform, and the physical distance between the heart and neck.[18] Other ways to measure the velocity of the PWV pulse wave, consists of a measure of arterial stiffness, which can be estimated locally by determining the delay time of the pulse waveforms for a known distance measured in an ultrasound image.[19] The pulse wave velocity with the PWVdn (Pulse Wave Velocity and dicrotic notch) dicrotic notch is a non-invasive and adequate measure of arterial stiffness that provides good reproducibility and discriminates well between age groups, correlating with local compliance.

PWVdn does not require an additional evaluation of the distance or the local pulse pressure measured locally at a mean arterial pressure, which better reflects the effective arterial stiffness and determines the load to which the left ventricle is subjected when expelling blood.[20] Pulse pressure (PP) is the difference between systolic blood pressure (PAS) and diastolic blood pressure (PAD) that reflects pulsatile blood circulation, which unlike the average blood pressure which exhibits the constant blood circulation expressed in mmHg (millimeter of mercury) and is considered an indicator of arterial compliance (DA). From observational studies, such as Framingham's, it is known that PP increases with age, both in men and women, in parallel with the increase in SBP, especially in the population over 60 years.[21] The recording of the central pulse wave is identified at an inflection point (Pi) that separates the systole into two parts representing the maximum pressure rise: a) Peak pressure (Ppk) coincides with the maximum blood flow velocity ejected by the left ventricle, forming the highest percentage of the incident wave[22] b) second half of the systole where the pressure is maintained or decreased, corresponding in the Murgo classification to the C type of pressure wave. The purpose of this work is the measurement of the carotid pulse by comparing the records taken from the records of the measuring device called the PPC heart rate and ultrasound pulse.

Material and methods

The measurements were made in 30 subjects (20 women and 10 men) in an age range of 25 to 40 years, all without a history of chronic degenerative diseases, infectious diseases or cancer. The pulse heart rate (PPC) device used to make these records includes a cylindrical magnetic marker with 3 mm diameter and 4 mm high, the magnetic moment of which is 0.03 ± 0.01 Am^2. The magnetic field variation generated by the magnet was recorded with a KMZ10A resistor magnet, which has a magnetic field sensitivity in the order of the nano-tesla (nT). The acquisition stage was carried out for 60 seconds, during this time the volunteer remained at rest in a dorsal recumbent position with the head turned to the side, so that the carotid artery is exposed to be identified; just above where the carotid artery has been palpated, the magnetic marker is placed and at a distance of 2.5 cm the sensor is placed, that is, the sensor does not touch the patient. This sensor is connected to an analog-to-digital signal converter (ADC) circuit, after registration it enters a stage of amplification and band filtration to obtain the sensed pulse signal, which is acquired by a data acquisition module (DAQ) from where a voltage value is obtained that is graphically displayed on the LabVIEW platform, and in turn saves the data for later evaluation, this measurement contains the measured time and voltage data to finally have the measurement graph of the carotid pulse.

On the other hand, in Figure 1 (A), the procedure for obtaining ultrasound (US) records is shown, b) the patient is also placed in the dorsal or supine position with the head turned to the side, it was identified then the carotid artery using a linear transducer in configuration M, this is "Movement Mode" to observe the variations of the arterial diameter, in that position the linear transducer is maintained and c) the movement is displayed on the screen and the video is recorded by 60 seconds. After the video acquisition, a digital image processing started in the LabVIEW software was performed, the data analysis was complemented on the Matlab platform from which the time and amplitude signals could be obtained, which when plotted show the carotid pulse. Having time versus amplitude graphs for both techniques, a comparison of the PPC with the ultrasound was performed for each subject.

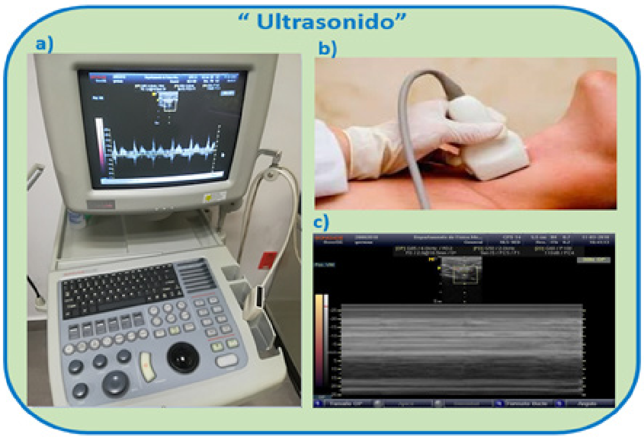

Figure 1 Ultrasound A) Sonoace equipment, B) Linear transducer over carotid artery, C) Mode M screen.

Results

Figure 2 shows a graph of the same patient for the records obtained with the PPC (upper table) and measurements by US (lower table). In a similar way for each patient, the behavior of the signals showed that the graph obtained through the ultrasound data offers less information or a curve that is not well defined with respect to the PPC graph, that is, no clear and relevant information is shown for the medical diagnosis if the US is used. That is, while the ultrasound technique is not able to provide the dicrota wave, whose record is the objective of this work, the PPC technique shows it clearly and reliably. In such a way that as observed in Figure 3, in the graph of the PPC in each carotid pulse it is possible to recognize the anachron wave, the percussion wave and the dicrota wave. The anachron, percussion and dicrotic wave is observed in each pulse. On the other hand, although some test subjects were identified as healthy individuals, in Figure 4 the alternating pulse is observed, which is characterized by a sequence of a pulse of normal amplitude, followed by another one of smaller amplitude, in the context of a regular rhythm. This medical condition is observable in advanced heart failure, so in one perspective of this work is the evaluation and clinical comparison of the results obtained.

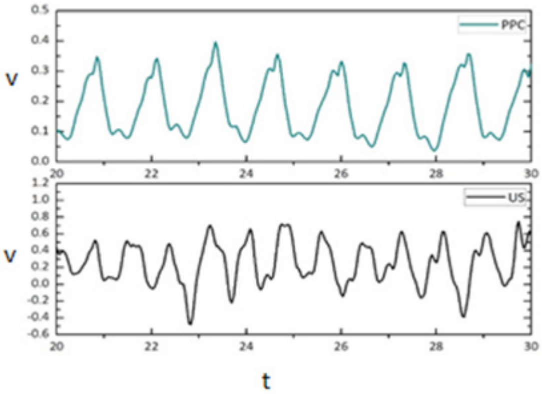

Figure 2 Ultrasound vs. comparison biomagnetism both records were made simultaneously (voltage (v) - time (t)).

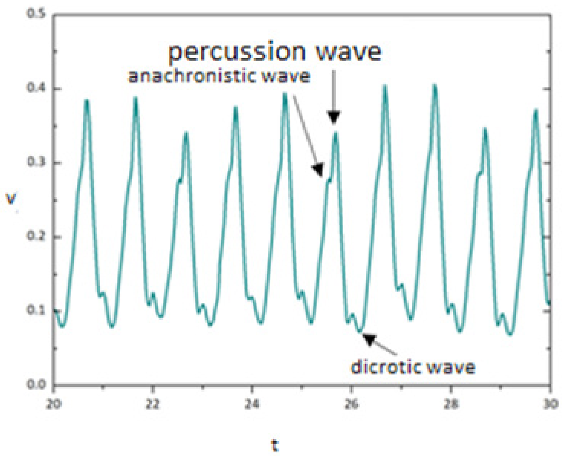

Figure 3 Pulse record of a healthy patient-14.

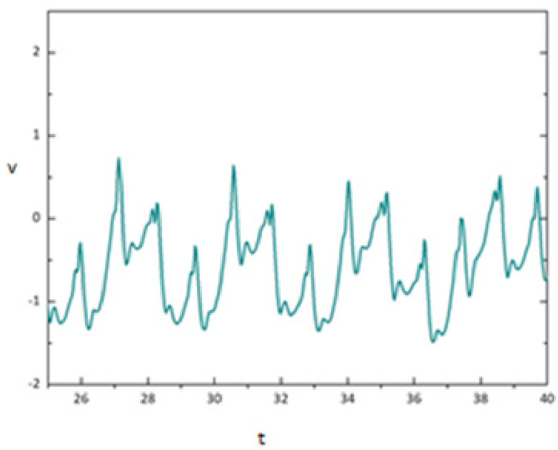

Figure 4 Alternating pulse. observable in considerably advanced heart failure.

Discussion

The comparison made between PPC and US, demonstrates the feasibility of the biomagnetic technique on ultrasound in the acquisition of carotid pulse signals, particularly for the recording of the dicrota wave. A considerable advantage offered by the PPC is that it is not subject to systematic errors, while in the US the angle at which the transducer is placed are sources of error, the precision with which it is held so as not to lose the lumen of the artery while the video is recorded, the pressure of this on the area, etc. The biomagnetic technique, PPC, was validated by the retest test method, with a mean correlation of 0.78 between the two measurements made to a sample of six patients. The above indicates that 78% of the data taken in two different measurements, in a longitudinal analysis, are coincident. This is a parameter that represents the reliability of the technique considering that there are tacit variables associated with the methodology that could significantly displace the pulse graph for these statistical calculations, however, irrelevant for the medical diagnosis.[23] The first instrumented techniques of pulse frequency and heart rate were developed in 1928 by Boas, however, it was Brouha who introduced this technique in the study of work. Wave analysis offers the possibility in the evaluation and early detection of cardiovascular diseases.[5] Measurements of pulse wave velocity (PWV) in human subjects have been proposed as a way to diagnose and evaluate the distensibility of large arteries. Since aortic stiffness is an important index that may reflect hypertension, arteriosclerosis, arterial aging and diabetes, several methods have been used to assess the distensibility of large arteries.[3–9] Among them, the least invasive systems are computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound-based equipment, such as Doppler measurement, echocardiography and high resolution echo-monitoring.[24]

Previous articles have assessed the pulse wave by means of the USG, but do not make a comparison with electromagnetism, which is a simple method of assessing the pulse wave at the carotid level. PWVdn is a non-invasive and adequate measure of arterial stiffness: it has good reproducibility, discriminates well between age groups and correlates with local compliance.[9] Aortic or carotid-femoral PWV, currently considered the gold standard for measuring arterial stiffness, has been well correlated with other cardiovascular risk factors and mortality. Previous studies showed that dicrotic notch is a good alternative as a time reference point for measuring PWV locally, because it is less susceptible to interference from peripheral reflections. Given that the level of dicrotic notch pressure is between mean and PAS, the PWV with dicrotic notch can be a promising non-invasive measure of local artery stiffness (i.e., carotid and femoral) in the systolic pressure range.[25,26] Pulse Wave Imaging (PWI) is an ultrasound-based method developed by our group to visualize non-invasively and map spacetime variations of vessel wall movement induced by the pulse wave. Dicrotic notch, reflected wave and several inflection points were qualitatively identified in the motion waveforms of the anterior wall of the carotid and the aorta and are shown in a representative subject.[27] Other authors report that the pulse wave velocity (PWV), a measure of arterial stiffness can be estimated locally by determining the delay time of the pulse waveforms for a known distance measured on an ultrasound image. For example, in,[28] three ultrasound-based methods for estimating local PWV based on the measurement of distension waveforms of diameter, displacement waveforms of the anterior wall and displacement waveforms of the displacement are compared. posterior wall, respectively, in human common carotid arteries in vivo. In this work, results obtained with electromagnetism are compared with those obtained with ultrasound. The validation of new blood pressure devices with easier use and faster data collection can facilitate the incorporation of these measures into clinical practice.

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Conflicts of interest

The author declares that there are no conflicts of interest.

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