IRAQI Academic Scientific Journals

Samarra Journal of Pure and Applied Science

SJPAS

www.sjpas.com

p ISSN: 2663-7405
e ISSN: 2789-6838

The influence of the digital pulse wave reference point on the pulse transit time measurement and variability

Suzan K. Adnan*, Feza Shalal Neda, Bassam T. Al-Gailani
Department of Physiology, College of Medicine, Mustansiriyah University, Baghdad, Iraq

https://doi.org/10.54153/sjpas.2023.v5i2.504

Article Information

Received: 23/03/2023
Revised : 25/05/2023
Accepted: 30/04/2023
Published: 30/09/2023

Keywords:

Vascular Stiffness, Cardiovascular Disease, Arteries, Blood Pressure, and Pulse Transit Time.

Corresponding Author

E-mail:
Suzankameran90@gmail.com

Abstract

By measuring pulse wave velocity (PWV) via an arterial route, one can determine the stiffness of the artery. The duration between the ECG R-wave climax and a reference point on the digital pulse wave (DPW) in the same cardiac cycle must be determined in order to determine the pulse transit time (PTT). The time it takes for a pulse wave to travel from the heart to a peripheral artery location is known as the PTT. To find out the best reference point on the DPW that is associated with the least beat-beat coefficient of variation (CV) of PWV. The study was carried out on 10 healthy young males aged 19 years. A two-minute recording of the left middle fingertip DPW signals (through piezoelectric Finger Pulse Transducer) and lead II ECG (through three surface electrodes) were carried out. PTT was calculated as follows: from the climax of the electrocardiogram R wave to the onset (foot) of the DPW (PTT1); from the apex to the onset points of the DPW at 10% of its amplitude (PTT2); and from the apex to the onset points of the DPW at 50% of its amplitude (PTT3). PTT1, PTT, and PTT3 were measured on each volunteer and on the same cardiac cycles.

Introduction

Measurements of vascular aging are thought to be an informative tool for determining cardiovascular risk. Cardiovascular disease has been linked to increased arterial stiffness [1]. The inability of an artery to expand and contract in response to pressure changes is known as arterial stiffness [2]. Techniques like the measurement PWV [3] are non-invasive, repeatable, and reasonably priced for measuring arterial stiffness. PTT is a physiological metric based on precisely specified properties of the pulse wave shape and is frequently generated from computations on ECG and PWD signals [4]. PTT is often computed as the interval between the R-climax of the ECG and a reference point on the pulse wave during the same cardiac cycle. It is defined as the amount of time it takes for a pulse wave to travel from the heart to the peripheral arteries. When calculating the PWV (PWV = PTT/D, where "D" is the artery length separating the heart from the point where the pulse wave arrives), pulse transit time (PTT) is a significant factor [5].

Various DPW reference points were selected [5, 6]. Among these reference points, the foot of the DPW is the one that was commonly used [7]. Other reference points that can be localized accurately are the climax of the second derivative [8, 9, 10] and the climax of the first derivative of the DPW [11], which correspond to 10% and 50% of the DPW amplitude, respectively. Very limited studies assessed the possibility of variation of PTT from beat-to-beat of cardiac cycle by using different reference points on the DPW.

The objective of the current research is to assess the possibility that beat-to-beat PWV dispersion is affected by the chosen reference point of PTT on the DPW.

Methods

The present cross-sectional study was conducted in the Department of Physiology, Al-Mustansiriyah University from November 1, 2022 to May 31, 2023. Ten healthy young males with an age of 19 years (first-year medical students) were recruited in the current study from. All were non-smokers, free from any medical illness, and were not taking any medications. Every participant was given a thorough explanation of the study before providing their written informed permission. All procedures and protocols were approved by the ethical committee in the Department of Physiology and the study followed the standard principles in the Declaration of Helsinki. Gender and other anthropometric measurements were registered.

Experimental setup

An automated sphygmomanometer was used to measure heart rate (HR) and right brachial artery blood pressure (BP) in the semi-prone posture following 10 minutes of full rest (Rossmax Swiss GmbH, Tramstrasse 16, CH-9442 Berneck, Switzerland). Up until stable values were attained, repeated HR and BP measurements were made. Throughout the technique, the individuals were instructed to maintain spontaneous breathing, and they were also advised to keep quiet while the data was being recorded. A hardware data acquisition unit 26T (Power Lab, AD Instruments Pty Ltd, New South Wales, Australia) was used to convert analog signals obtained from finger pulse transducer to digital computer signals (figure 1). A two-minute recording of the left middle fingertip DPW signals (through Finger Pulse Transducer) and lead II ECG (through three surface electrodes) were carried out. The LabChart Pro version 7.2 software was used for offline DPW analysis and computation.

Pulse Transit Time (PTT)

Three main methods were used to measure the PTT (figure 1). First method (PTT1) consisted in measuring the latency in time between the R climax of the ECG and a reference point of the DPW (the foot or the onset of the DPW. The second method (PTT2) was to measure the period of time between the peak of R of the ECG and a reference point of the DPW that corresponds to the “A” wave of the second derivative of DPW (SDDPW) (at which the DPW signal reaches 10% of the amplitude between the apex and the onset points of DPW). The third method (PTT3) for determining the PTT involved measuring the time latency between the R climax of the ECG and a reference point of the DPW such as the point that corresponds to the maximum positive wave of first derivative of DPW (FDDPW) (at which the DPW signal reaches 50% of the amplitude between the apex and the onset points of DPW). The LabChart software’s “peak detection” module was used to identify ECG “R” wave peaks,

SDDPW peaks, and FDDPW peaks. PTT1, PTT, and PTT3 were measured on each volunteer and on the same cardiac cycles. PWV is calculated as follow: PWV = PTT/D, where "D" is the artery length between the heart and the tip of the left middle finger (in meters) and is calculated as 0.5 x body height in meters [12] and PTT (in sec). We calculated the average of 30 to 40 successive cardiac cycles and the CV of these cardiac cycles for each volunteer for each specific method of PTT measurement.

Statistics

All of the results were expressed using the mean and standard deviation (SD). To compare data between variables, paired Student's t-test was used.

Result

The characteristics of the recruited volunteers are shown in table 1. It is clear that the PWV varied according to the reference point and was at its maximum value when the reference point was at the foot of the DPW (table 2). The shortest registered PWV in the present research was when the reference point was at 50% of the upstroke height of the DPW. PWV, which was measured with its reference point at 50% of the DPW height, was significantly lower than those PWVs whose reference points were at the wave foot or at 10% of the upstroke height of the DPW (by 17% and 16% respectively). The CV of the PWV extracted from PTT3 was significantly lower, by 57% and 23% relative to those PWVs calculated from PTT1 and PTT2, respectively.

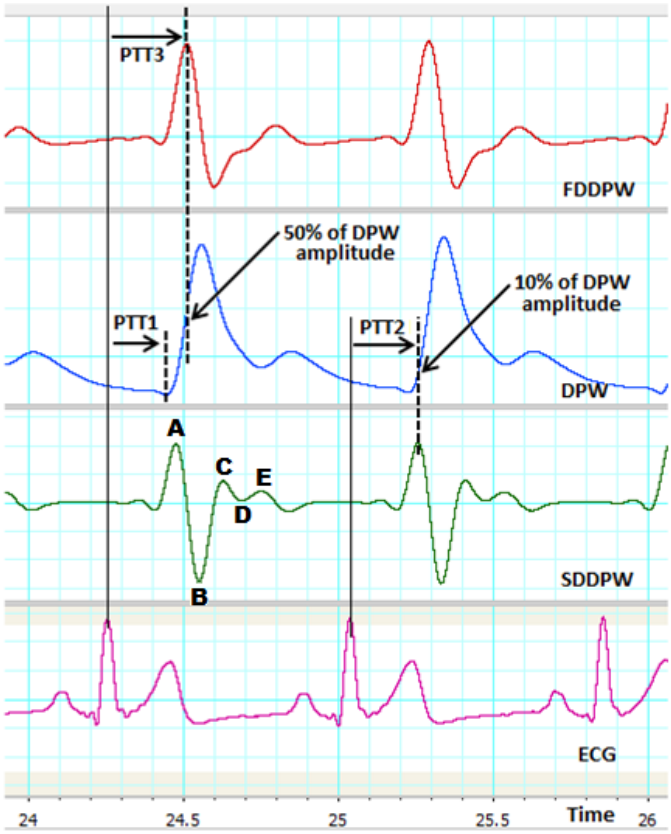

Fig. 1 Demonstrative representation of calculation of the pulse transit time (PTT). PTT1, PTT2, and PTT3 refer to methods used for measurement. DPW = Digital pulse wave. ECG =

Electrocardiograph. FDDPW = First derivative of digital pulse wave. SDDPW = Second derivative of digital pulse wave.

Table 1: The characteristics of the volunteers recruited in the study. N = 10.

Body mass index (BMI) (kg/m2)	23.0 ± 3.9
Systolic BP (mm Hg)	120.2 ± 5.7
Diastolic BP (mm Hg)	74.4 ± 8.3
Mean BP (mm Hg)	89.6 ± 6.6
Heart rate (HR) (beat/min)	76.4 ± 7.7

Table 2: Pulse wave velocity (PWV) determined by three different methods for calculating pulse transit time (PTT) using three reference points on the digital pulse wave (DPW). N = 10.

Methods of PTT measurement	PWV(m/sec)	Within subject CV%
PTT1 (0.212 ± 0.011 sec) ➔ R-ECG wave to the foot of DPW	4.2 ± 0.4	4.7 ± 2.2
PTT2 (0.211 ± 0.013 sec) ➔ R-ECG wave to the maximum positive wave ("A" wave) of the SDDPW	4.1 ± 0.3	2.6 ± 0.6*
PTT3 (0.248 ± 0.014 sec) ➔ R-ECG wave to the maximum positive wave of the FDDPE	3.5 ± 0.2!	2.0 ± 0.4+$
! P<0.0002 relative to PTT1 &PTT2.		
* P<0.02 relative to method PTT1.		
+ P<0.003 relative to PTT1.		
$ = P<0.009 relative to method PTT2.		

Discussion

The PWV extracted from PTT1 was in very good agreement with the values reported by others [13]. A CV similar to that reported in the current research was also recorded by Madhura and Sandhya (2014) [14] when the foot of DPW was used as a reference point for calculating the PWV. The variability coefficient was found to be higher when PTT measured with the reference point was at 10% of the DPW height compared to PTT measurement with the reference point defined at 50% and 90% of the DPW height, respectively [15]. The data of the latter authors correspond those reported by the present research. These findings imply a greater degree of variation in the PTT calculated from the position closest to the foot. The fast ascent of the systolic period may be the cause of this, resulting in a lower liability to sensor error at the top than at the foot [15].

Conclusion:

The least CV reported for PWV was when the time latency between the peak of R wave of the ECG and a reference point of the DPW is at 50% of the amplitude between the apex and the onset point of DPW (such point corresponds to the maximum positive wave of FDDPW). The measurement of PTT and CV is affected by the identification of the reference points on the

DPW, with points at higher levels on the upstroke of the DPW being less vulnerable to beat-to-beat CV.

References

1. Cecelja, M., & Chowienczyk, P. (2012). Role of arterial stiffness in cardiovascular disease. JRSM cardiovascular disease, *1*(4), 1-10. doi:10.1258/cvd.2012.012016
2. Weber, T., Auer, J., O'Rourke, M. F., Kvas, E., Lassnig, E., Berent, R., & Eber, B. (2004). Arterial stiffness, wave reflections, and the risk of coronary artery disease. *Circulation*, *109*(2), 184-189. doi: org/10.1161/01.CIR.0000105767.94169.E3
3. Vlachopoulos, C., Aznaouridis, K., Terentes-Printzios, D., Ioakeimidis, N., & Stefanadis, C. (2012). Prediction of cardiovascular events and all-cause mortality with brachial-ankle elasticity index: a systematic review and meta-analysis. *Hypertension*, *60*(2), 556-562.doi:10.1161/HYPERTENSIONAHA.112.194779
4. van Velzen, M. H., Loeve, A. J., Niehof, S. P., & Mik, E. G. (2017). Increasing accuracy of pulse transit time measurements by automated elimination of distorted photoplethysmography waves. *Medical & biological engineering & computing*, *55*, 1989-2000. doi:10.1007/s11517-017-1642-x
5. Radha, M., Zhang, G., Gelissen, J., de Groot, K., Haakma, R., & Aarts, R. M. (2017). Arterial path selection to measure pulse wave velocity as a surrogate marker of blood pressure. *Biomedical Physics & Engineering Express*, *3*(1), 015022. doi: 10.1088/2057-1976/aa5b40
6. Li, Y., Wang, Z., Zhang, L., Yang, X., & Song, J. (2014). Characters available in photoplethysmogram for blood pressure estimation: beyond the pulse transit time. *Australasian physical & engineering sciences in medicine*, *37*, 367-376. doi: 10.1007/s13246-014-0269-6
7. Selvaraj, N., Jaryal, A. K., Santhosh, J., Anand, S., & Deepak, K. K. (2009). Monitoring of reactive hyperemia using photoplethysmographic pulse amplitude and transit time. *Journal of clinical monitoring and computing*, *23*, 315-322. doi.org/10.1007/s10877-009-9199-3
8. Budidha, K., & Kyriacou, P. A. (2019). Photoplethysmography for quantitative assessment of sympathetic nerve activity (SNA) during cold stress. *Frontiers in Physiology*, *9*, 1863. doi: org/10.3389/fphys.2018.01863
9. Obeid, H., Khettab, H., Marais, L., Hallab, M., Laurent, S., & Boutouyrie, P. (2017). Evaluation of arterial stiffness by finger–toe pulse wave velocity: optimization of signal processing and clinical validation. *Journal of hypertension*, *35*(8), 1618-1625.doi*:* 10.1097/HJH.0000000000001371
10. Pilt, K., Meigas, K., Temitski, K., & Viigimaa, M. (2013). Second derivative analysis of forehead photoplethysmographic signal in healthy volunteers and diabetes patients. In *World Congress on Medical Physics and Biomedical Engineering May 26-31, 2012, Beijing, China* (pp. 410-413). Springer Berlin Heidelberg. doi.org/10.1007/978-3-642-29305-4_109
11. Djeldjli, D., Bousefsaf, F., Maaoui, C., Bereksi-Reguig, F., & Pruski, A. (2021). Remote estimation of pulse wave features related to arterial stiffness and blood pressure using a

camera. *Biomedical Signal Processing and Control*, *64*, 102242. doi.org/10.1016/j.bspc.2020.102242

12. Gesche, H., Grosskurth, D., Küchler, G., & Patzak, A. (2012). Continuous blood pressure measurement by using the pulse transit time: comparison to a cuff-based method. *European journal of applied physiology*, *112*(1), 309-315. doi.org/10.1007/s00421-011-1983-3
13. Cho, J., & Baek, H. J. (2020). A comparative study of Brachial–Ankle pulse wave velocity and Heart–Finger pulse wave velocity in Korean adults. *Sensors*, *20*(7), 2073. doi.org/10.3390/s20072073
14. Madhura, M., & Sandhya, T. A. (2014). Effect of different phases of menstrual cycle on reflection index, stiffness index and pulse wave velocity in healthy subjects. *Journal of clinical and diagnostic research: JCDR*, *8*(9), BC01. doi: 10.7860/JCDR/2014/7385.4778
15. Teng, X. F., & Zhang, Y. T. (2006). The effect of applied sensor contact force on pulse transit time. *Physiological measurement*, *27*(8), 675. doi: 10.1088/0967-3334/27/8/002

IRAQI Academic Scientific Journals
Samarra Journal of Pure and Applied Science
SJPAS
مجلة سامراء للعلوم البحتة والتطبيقية
www.sjpas.com
p ISSN: 2663-7405
e ISSN: 2789-6838

تأثير النقطة المرجعية لموجة النبضة الرقمية على قياس وتغير وقت عبور النبض

سوزان كاميران عدنان*، فزع شلال نده، بسام طالب الكيلاني
قسم الفسلجة، كلية الطب، الجامعة المستنصرية، العراق

معلومات البحث:
تأريخ الاستلام: 2023/03/23
تأريخ القبـــول: 2023/04/30
الكلمات المفتاحية:
تصلب الأوعية الدموية، أمراض القلب والأوعية الدموية، الشرايين، ضغط الدم، وقت عبور النبض

معلومات المؤلف
الايميل:

الخلاصة:
عن طريق قياس سرعة موجة النبض (PWV) عبر مسار شرياني، يمكن للمرء أن يحدد صلابة الشريان. يجب تحديد المدة بين ذروة الموجة R ECG ونقطة مرجعية على موجة النبض الرقمية (DPW) في نفس الدورة القلبية من أجل تحديد وقت عبور النبض (PTT). يُعرف الوقت الذي تستغرقه الموجة النبضية للانتقال من القلب إلى موقع الشريان المحيطي باسم PTT. لمعرفة أفضل نقطة مرجعية في DPW والتي ترتبط بأقل قدر من الضربات على معامل التباين (CV) لـ PWV. أجريت الدراسة على 10 ذكور أصحاء تتراوح أعمارهم بين 19 عامًا. تم إجراء تسجيل لمدة دقيقتين لإشارات DPW من طرف الإصبع الأوسط الأيسر (من خلال محول نبض الإصبع الكهرضغطية) وتخطيط القلب الثاني (من خلال ثلاثة أقطاب سطحية). تم حساب PTT على النحو التالي: من ذروة موجة مخطط القلب الكهربائي R إلى بداية (قدم) DPW (PTT1)؛ من القمة إلى نقاط بداية DPW بنسبة 10٪ من اتساعها (PTT2)؛ ومن القمة إلى نقاط بداية DPW عند 50٪ من اتساعها (PTT3). تم قياس PTT1 وPTT وPTT3 على كل متطوع وعلى نفس دورات القلب.