COMPARISON OF METHODS OF MEAN BLOOD PRESSURE CALCULATION USING AMBULATORY BLOOD PRESSURE MONITORING RESULTS

Vitaliy Syvolap
MD, DSci., Professor[1]

Svitlana Zhemanyuk[1]
zhemanyuk.s@gmail.com
Postgraduate student
[1]*Department of the Propedeutics to Internal Medicine*
Zaporizhzhia State Medical University
26 Mayakovskogo ave., Zaporizhzhia, Ukraine, 69035

Abstract: Ambulatory blood pressure monitoring (ABPM) is a modern method of BP investigation. However, only some ABPM parameters, as diurnal systolic BP (SBP) and diastolic BP (DBP), are used now as the diagnostic guide according to international recommendations. It is pure knowledge in clinical practice about usage and calculation of mean blood pressure (MBP). Such parameter is the steady flow of blood through the aorta and its arteries and equals the cardiac output multiplied by vascular resistance [1], according to some clinical studies may have predictable value as SBP or DBP, however there is no clinical evidence about these parameters, as information how to calculate in ABPM.

The **aim** of the study is to compare the mean blood pressure calculated by two methods using ABPM parameters.

We selected 20 ambulatory blood pressure monitoring (ABPM) patients (median of age 60 [56; 64] years, 65 % women). ABPM was recorded using a bifunctional device (Incart, S.-P., RF). We calculated MBP as [[(2×DBP)+SBP]/3] [2] and as [DBP+[0.01×exp(4,14-40,74/HR)]×PP] [3], Formula 1 and Formula 2, respectively. The analysis of difference between results of MBP measurements calculated by two methods was performed using the Bland and Altman method. The data show, that MBP calculated by Formula 1 and Formula 2 are as 87.7 [83.2–90.5] and 91.1 [85.4–93.5] mm Hg, respectively. The limits of agreements for the MBP were 0,49/5,91.

In general, based on the findings of the current study, the measurements of MBP calculated using different formulas show good agreement. Further studies need to have more clinical evidence to analyze the result.

Keywords: ambulatory blood pressure monitoring, ABMP, Blant-Altman plot, blood pressure, BP, mean blood pressure, MBP.

1. Introduction

Blood pressure (BP) has been identified as a risk factor for various health disorders, including stroke onsets [4]. Hypertension is one of the crucial heath problems among adult Ukrainians [5]. Due to the importance of elevated BP in stroke causality, BP measurement remains critical. Meanwhile, in some cases, like stroke or hypertensive emergencies it is highly recommended to evaluate mean pressure (MBP), as well as cardio monitoring. In general, BP is considered as a repetitive continuous wave and is more accurately described as consisting of a pulsatile component (pulse pressure, PP) and a steady component (mean BP, MBP) [6]. However, being one of the most used in clinical practice for monitoring BP parameters, only average BP values are the most important parameters obtained from ABPM data [5], it is limited information about MBP calculated based on ambulatory blood pressure monitoring (ABPM) data. Meanwhile, according to some clinical studies [7], this parameter may have predictable value as SBP or DBP for cardiovascular prognosis, however there is no information how to calculate MBP in ABPM.

The **aim** of the study is to compare the mean blood pressure calculated by two methods using ABPM parameters.

2. Methods

The study protocol was approved by the Medical ethics committee of the Zaporizhzhya state medical university. We examined patients admitted to the Zaporizhzhya clinical hospital № 6, Ukraine (2008–2013 yrs.). A researcher provided written and oral information on the study prior to examination. Information on demographics and clinical characteristics was extracted from patients' medical records and purpose-designed questions in the questionnaire. The measurement of brachial BP has been performed using aneroid-type sphygmomanometer and a health professional auscultating the Korotkoff sounds. All the patients underwent ABPM.

We selected 20 ambulatory blood pressure monitoring patients (median of age 60 [56; 64] years, 65 % women). We enrolled individuals older 18 years with previously no documented arterial hypertension, with sinus rhythm on electrocardiogram (ECG) monitoring, with valid ABPM results. ABPM was recorded using a bifunctional device (Incart, S.-P., RF), that recorded 24-h ABPM with continuous 24-h ECG simultaneously. After the baseline examination, participants were fitted with the recorder on their non-dominant arm if there were no considerable difference of BP results. Appropriate cuff bladder size was determined based on arm circumference. BP was measured at 20-min intervals from 07:01 to 23:00 and at 30-min intervals from 23:01 to 07:00. For analyzing matter, we defined awake and asleep periods as the fixed periods of time (from midnight to 06:00 AM for nighttime and from nighttime to 06:00 AM, respectively). The analysis was carried out using an oscillometric method. Quality of the ABPM studies was defined by the length of time that the monitor was actually working (≥21 hours) and the number of successful BP recordings (≥1 valid BP measured per two hours were acceptable for the analysis, so that there were 14 measures for daytime and at least 7 measurements – for nighttime period) [8]. Upon completion of the 24-h ABP recording, the data was downloaded and analyzed statistically to calculate BP averages for systolic BP (SBP), diastolic BP (DBP) and pulse pressure (PP) for 24-h, and also hart rate (HR). We calculated MBP as [[(2×DBP)+ +SBP]/3] [2] and as [DBP+[0.01×-exp(4.14−40.74/HR)]×PP] [3], that was previously described in the study (Moran et al., 2000), Formula 1 and Formula 2, respectively.

Statistical analysis was performed using Analyse-it for Microsoft Excel 4.80.1 (Analyze-it Software, Ltd.). The Shapiro-Wilk's test was used to test for deviation from normality. Categorical data are presented as percentages and continuous data as mean and standard deviation or medians and interquartile ranges as appropriate after testing for normality of distribution. The analysis of difference between results of MBP measurements calculated by two methods was performed using the Bland and Altman method [9]. Bland-Altman analysis was used to compare the two measurement techniques for MBP, which were calculated using SBP, DBP, PP and HR. Horizontal lines were drawn at the mean difference and at the limits of agreement, which are defined as the mean difference±1.96 times of the standard deviation of the differences. Then the mean of difference and limits of agreement (LoA) were drawn (upper and lower).

3. Results

The ABPM parameters, as the averages SBP 24-hour and DBP 24-hour were normal, as 122 [112–126] and 69 [67–74] mm Hg, respectively. We have MBP data calculated by Formula 1 and

Formula 2, as 87.7 [83.2–90.5] and 91.1 [85.4–93.5]mm Hg, respectively, and also the limits of agreement estimated by parametric method, as seen in Fig. 1.

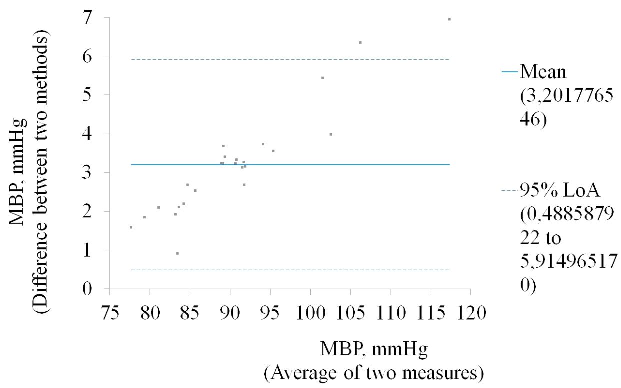

Fig. 1. The Bland-Altman plot

After calculating the mean difference (d, 3.2) and the standard deviation of the difference (sd, 1.4) based on Bland-Altman analysis, it was expected most of the differences lying between the limit of agreement (d-2sd and d+2sd). Resultant differences (d±2sd) have to be noticed as clinically important or not. And in the further case it could be used the two measurement methods interchangeably. The limits of agreement show that 4 % of the observations are above, with none the limits of agreement outside the lower limits of agreement. The difference plot shows an obvious systematic difference between the methods as all the differences are above the line of equality (zero). There is also a clear relationship between the difference and the mean, with the difference increasing as the level of MBP rises. The limits of agreement are rather stable at low and higher values (CI 95 % lower (–0.5; 1.48) and CI 95 % upper (4.9; 6.9), respectively).

So, total 24-h MBP using ABMP records estimated by the formula which calculated the MBP parameters in rest position of patients (Formula 1) and those, that calculated MBP during exercises (Formula 2) were 87,7 [83,2–90,5] and 91,1 [85,4–93,5] mm Hg, respectively. The limits of agreements for the MBP were 0,49/5,91.

4. Discussion

It is well established the association between systolic, diastolic and pulse pressure with cardiovascular disease (CVD). MBP is considered being the perfusion pressure, which shows the function of left ventricular contractility, hate frequency, vascular resistance and elasticity (11), and steady component of BP. Moreover, Safar (2000) and Yoshitoms Nagakura, and Miyauchi (2005) considered that more pathophysiologic approach to the aortic BP curve is to consider arterial pressure as the summation of a steady component and a pulsatile component. MBP is the pressure for the distribution of steady flow and oxygen to the tissues and organs. PP is the role of large conduit arteries to minimize the pulsatility [6, 10]. Also, MBP refers to peripheral vascular resistance and hence to the wall-to-lumen ratio of small arteries [10]. Nowadays MBP has not been extensively studied in clinical practice, except small studies, like the study conducted by Sesso (2000) that was found MBP as well as other BP parameters, like SBP and DBP, shown strong association with an increased CVD risk in young men. However, MBP was a weaker predictor than PP and was not associated with CVD mortality. According to Yoshitoms et al., MBP in hypertensive patients may be associated with BP control rather than, for instance PP [10].

ABPM being one of the modern method routinely used for research purpose and in clinical practice as the diagnostic guide according to international recommendations [4], provides investigation only of some ABPM parameters, like diurnal SBP and DBP. However, routinely calculation of other ABPM included MBP is demanded further scientific evidence, as the protocol of the calculation of these BP parameters [11]. Despite the existing different methods of calculation of MBP, no one is considered to be the gold standard for ABPM. Medical technology assessments are often compared with established techniques to be used interchangeably. In this case, any methods cannot be regarded as true value and their agreement is the matter to be known [12].

So, we have chosen the most popular and the simplest method of calculation of MBP, and more exaggerated one, that was described not so far. However, we not found any agreements for calculation MBP for ABPM recordings. As the standard method in the Bland-Altman plot, we have chosen the simplest formula. As known, Formula 1 used in most physiological study is rough described system in rest circumstances and according to Daniel Moral et. al. [3] cannot be used during exercises. Taking into account that assumption we have applied suggested model of calculation MBP, which D. Moral et al. recommended.

The B&A plot system do not say if the agreement is sufficient or suitable to use a method or the other indifferently. It simply quantifies the bias and a range of agreement, within which 95 % of the differences between one measurement and the other are included [13]. However, there is no clinical evidence about clinical acceptable margin to evaluate the results.

Overall, in the present study we have found that new technique of measuring the MBP using ABMP data is likely to the previous model of MBP measurement. However, the clinical values of MBP are still unclear, the further researches are needed to evaluate the potentially promising ones in clinical practice and distinguish whether MBP calculated by the new method can be an important predictor of CVD in different cohort group of patients, especially in emergency department. Also, the greater number of samples used for the evaluation the differences between the methods, the narrower might be the CIs.

There is no conflict of interest.

References

1. Safar, M. E. (1989). Pulse pressure in essential hypertension: clinical and therapeutical implications. Journal of Hypertension, 7 (10), 769–776. doi: 10.1097/00004872-198910000-00001
2. Ruoff, B. E., Katz, E. D. (2010). Commonly Used Formulas and Calculations. Clinical Procedures in Emergency Medicine. Amsterdam: Elsevier Mosby Publishing, 1333–1343. doi: 10.1016/b978-1-4160-3623-4.00072-9
3. Moran, D., Epstein, Y., Keren, G., Laor, A., Sherez, J., Shapiro, Y. (1995). Calculation of Mean Arterial Pressure During Exercise as a Function of Heart Rate. Applied Human Science, 14 (6), 293–295. doi: 10.2114/ahs.14.293
4. Mancia, G., Fagard, R., Narkiewicz, K., Redon, J., Zanchetti, A., Bohm, M. et. al. (2013). 2013 ESH/ESC Guidelines for the management of arterial hypertension: The Task Force for the management of arterial hypertension of the Europe-

an Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). Journal of Hypertension, 31 (7), 1281–1357. doi: 10.1097/01.hjh.0000431740.32696.cc

5. Kovalenko, V. M. (Ed.) (2016). Sertsevo-sudinni zakhvoriuvannia. Klasifikatsiia, standarty diagnostiki ta likuvannia [Cardiovascular diseases. Classification, practical protocols of diagnosis and treatment]. Ukrainian association of cardiology. Kyiv: Morion, 189.
6. Safar, M. E. (2000). Pulse pressure, arterial stiffness, and cardiovascular risk. Current Opinion in Cardiology, 15 (4), 258–263. doi: 10.1097/00001573-200007000-00009
7. Sesso, H. D., Stampfer, M. J., Rosner, B., Hennekens, C. H., Gaziano, J. M., Manson, J. E., Glynn, R. J. (2000). Systolic and Diastolic Blood Pressure, Pulse Pressure, and Mean Arterial Pressure as Predictors of Cardiovascular Disease Risk in Men. Hypertension, 36 (5), 801–807. doi: 10.1161/01.hyp.36.5.801
8. Benjamin, E. J., Blaha, M. J., Chiuve, S. E., Cushman, M., Das, S. R., Deo, R. et. al. (2017). Heart Disease and Stroke Statistics–2017 Update: A Report From the American Heart Association. Circulation, 135 (10), e146–e603. doi: 10.1161/cir.0000000000000485
9. Bland, J. M., Altman, D. G. (1999). Measuring agreement in method comparison studies. Statistical Methods in Medical Research, 8 (2), 135–160. doi: 10.1177/096228029900800204
10. Yoshitomi, Y., Nagakura, C., Miyauchi, A. (2005). Significance of Mean Blood Pressure for Blood Pressure Control. International Heart Journal, 46 (4), 691–699. doi: 10.1536/ihj.46.691
11. White, W. B. (Ed.) (2016). Blood Pressure Monitoring in Cardiovascular Medicine and Therapeutics. Cham: Humana Press, 418. doi: 10.1007/978-3-319-22771-9
12. Babaei Jandaghi, A., Shakiba, M., Nasseh, H., Korouji, Y., Esmaeili, S., Khadem Maboudi, A. A., Khorshidi, A. (2015). Application of Bland-Altman Method in Comparing Transrectal and Transabdominal Ultrasonography for Estimating Prostate Volume. Iranian Journal of Medical Sciences, 40 (1), 34–39.
13. Giavarina, D. (2015). Understanding Bland Altman analysis. Biochemia Medica, 25 (2), 141–151. doi: 10.11613/bm.2015.015