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Pulse Oximetry as an Alternative Means of Assessing Systolic Blood Pressure in Well Newborns: A Comparison with Two Methods of Blood Pressure Measurement

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Abstract

Background: Blood pressure measurement in newborns using conventional auscultatory and palpatory methods is technically difficult. As a result, different blood pressure measuring devices such as oscillometric and doppler devices have been developed. However, in resource challenged environments, these devices are not widely available unlike pulse oximeters which are relatively cheap and portable. Thus, the objective of this study was to investigate the reliability of using the pulse oximeter in measuring systolic blood pressure in normal, term neonates whilst comparing it to oscillometric and doppler/aneroid blood pressure measuring devices.

Methods: This was a prospective, cross-sectional study involving 192 healthy terms, appropriate for gestational age neonates who were recruited. Their systolic blood pressures were measured simultaneously using oscillometry, doppler/anaeroid sphygmomanometer and pulse oximetry at 12-hour intervals for the first 48 hours of life.

Results: One hundred and eighty-five babies were analyzed. Mean systolic blood pressure readings using doppler with anaeroid sphygmomanometer was 60.35(SD 2.27), by Oscillometric device, it was 69.83 (SD 12.55) and by pulse oximetry 55.08 (SD 2.11). Systolic blood pressure readings using a pulse oximeter were significantly lower compared to the other methods and the degree of absolute agreement between the rating instruments was poor especially with oscillometric measurements where the level of agreement further declined with time.

Conclusion: Pulse oximetry is a better alternative to oscillometry in systolic blood pressure measurement in newborns especially in resource challenged environments but it cannot be used interchangeably or substituted for doppler anaeroid systolic blood pressure measurement.

Key Words: Measurement, Neonates, Systolic blood pressure.

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1- INTRODUCTION

Blood Pressure (BP) is one of the cardinal signs of haemodynamic wellness in both children and adults alike. Measurement of blood pressure has been done for over a period of several centuries starting with the initial measurements by Stephen Hales in 1733 (1). Blood pressure measurement remains a challenge in our environment, especially in newborns. Intra-arterial blood pressure measurement remains the gold standard (2); however, this method is invasive and fraught with associated complications, hence there is a need for methods that are non-invasive. The peculiarities of newborns make using routine BP measurements using auscultatory and palpatory methods difficult, necessitating the need to use other methods of BP measurement such as doppler and oscillometric devices (3). In our environment, these doppler and oscillometric devices are still not yet widely available (4). In contrast, pulse oximeters have become increasingly available as portable devices used in measuring arterial oxygen saturation and heart rate.

Pulse oximeters are based on the Principle of Photoplethysmography (PPG) which measures the amount of light that is either absorbed or reflected from blood that is present in tissues and blood vessels depending on whether the blood is oxygenated or deoxygenated (5). The PPG signal is generated from the volume of blood detected over the sensor coverage area and measures both pulsatile and non-pulsatile components of the blood.

Because of the ready availability of pulse oximeters in our environment, this study seeks to investigate the reliability of using the reappearance of the plethysmographic waveform of the pulse oximeter in measuring Systolic Blood Pressure (SBP) in normal, term neonates whilst comparing it to oscillometric and doppler/aneroid blood pressure measuring devices using the doppler/aneroid as the gold standard for measurement.

2- MATERIALS AND METHODS

2-1. Design and participants

This was a prospective, cross-sectional study carried out on healthy, term, appropriate for gestational age, consecutively born babies at the post-natal ward of the University of Uyo Teaching Hospital, a 750-bed, tertiary healthcare facility located in Uyo the capital city of Akwa Ibom state and serving both residents and those from surrounding nearby states. Study participants were recruited over a three-month period from November 2021 to January 2022. Exclusion criteria were babies with known congenital anomalies especially those of cardiac and renal origin, and use of hypotensive or hypertensive drugs by the mothers of the index babies.

2-1-1. Sample size

The sample size was calculated (6) using the standard deviation of the outcome variable (systolic blood pressure) from a previous study which was 12.9 (7), with a error margin of 2 at 95% confidence interval with 20% attrition rate giving a total sample size of 192 neonates.

$$n = \left(\frac{1.96(12.9)}{2}\right)^2$$

$n = 159.82 \cong 160$

Plus 20% attrition rate = 32

Total Sample size = 160+ 32 = 192

2-2. Procedure

A study proforma was filled for each baby capturing the patient's demographic indices, gestational age, and anthropometry, blood pressure measurements using an automated oscillometric device, doppler ultrasound/aneroid and pulse oximeter with time of measurement, and temperature was noted each time BP was recorded.

Blood pressure was measured using three methods-the oscillometric using the Dinamap 8100 (Critikon, Inc, Tampa, Florida, USA), doppler/anaeroid (Vascular doppler VD-33) and the pulse oximeter (Nelcor brand) using a wraparound neonatal probe to minimize artifactual noise. An appropriately sized blood pressure cuff (neonatal) was placed on the right upper arm of the neonate and all three measurements were simultaneously taken at 12-hour intervals for the first 48 hours of life with each reading repeated thrice and the average of the three readings taken as the blood pressure recording at that time for each method.

The babies were placed in supine position with the measurements taken when they were awake but not crying and not breastfeeding, with their axillary temperature between 36.5-37.4^{o}C. The cuff was wrapped around the baby's right upper arm and connected via a conjugated system with two Y-connectors and a three-way arm to the oscillometric device and the aneroid sphygmomanometer which is positioned at eye level with the investigator to avoid parallax error.

The doppler probe was placed on the antecubital fossa after application of conducting gel with the baby's arm extended and immobilized by the investigator while the pulse oximeter probe was applied on the right thumb of the hand on whose arm the cuff was applied. Subsequently, the doppler machine was turned on and the brachial arterial flow was auscultated. The oscillometric device was then turned on by an assistant and the cuff automatically inflated leading to occlusion of the brachial artery with no sounds heard from the doppler equipment. Simultaneously, the assistant also switched on the pulse oximeter to observe the waveform of the oximeter.

Following deflation of the cuff, the point at which the doppler signal and pulse oximeter waveform returned signified the systolic blood pressure which was noted on the calibrated and mounted anaeroid sphygmomanometer by the investigator and the assistant respectively. The systolic, mean arterial and diastolic blood pressures and heart rate were automatically recorded on the digital display of the oscillometric device while heart rate and oxygen saturation were also recorded on the pulse oximeter display.

2-3. Data analysis

The International Business Machine-Statistical Package for Social Sciences (IBM-SPSS, Armonk, New York, USA) version 23 was used to analyze the data. The difference in SBP between pulse oximetry and Doppler with aneroid methods, as well as between pulse oximetry and oscillometric methods, was compared using a paired t-test at different measurement intervals. Intra-class correlation was used to assess the inter-rater reliability (absolute agreement) between the two methods (pulse oximetry vs. Doppler with aneroid and pulse oximetry vs. oscillometric approaches). Scores of < 0.5, 0.5 - 0.75, 0.75 - 0.90, and >0.90, respectively, were regarded as poor, moderate, good, and excellent agreement. All tests were two-tailed at 95% confidence interval; p-value was considered significant if < 0.05.

3- RESULTS

A total of 192 neonates were recruited into the study; however, 185 completed the study and were analyzed with a M: F ratio of 0.98:1. Mean anthropometric measurements and the mean of the systolic BP measurements taken at 12, 24, 36 and 48 hours of life were computed for each method of measurement as shown in **Table 1**.

Table 2 compares the SBP readings obtained using a pulse oximeter and Doppler with an aneroid sphygmomanometer.

Table-1: Characteristics of study participants/newborns

Study variable	Mean (standard deviation)		Frequency (%)
Sex	Male	-	92 (49.7)
	Female	-	93 (50.3)
Birth weight (kg)		3.51 (2.65)	-
Length (cm)		50.20 (1.55)	-
Systolic BP (DAM)		60.35 (2.27)	-
Systolic BP (OS)		69.83 (12.55)	-
Systolic BP (POM)		55.08 (2.11)	-

DAM- doppler with anaeroid method, OS – oscillometric method, POM – pulse oximeter method

Table-2: Comparison of the systolic blood pressure values between pulse oximeter and Doppler with aneroid sphygmomanometer (the gold standard) and degree of agreement between them (N = 185)

SBP values (mmHg)	Time (hours)	Mean (SD)	MD	t-test	p-value	Level of agreement using Intra-class correlation coefficient (ICC)
SBP using POM SBP using DAM	12	52.92 (2.10) 57.75 (2.66)	-4.83	-31.02	<0.001	0.36
SBP using POM SBP using DAM	24	53.95 (2.86) 59.20 (2.94)	-5.26	-28.47	<0.001	0.41
SBP using POM SBP using DAM	36	55.78 (2.68) 61.08 (3.04)	-5.32	-36.68	<0.001	0.44
SBP using POM SBP using DAM	48	57.67 (3.49) 63.37 (3.70)	-5.70	66.86	<0.001	0.49

SD = standard deviation, MD = mean difference, t = paired t-test, POM = pulse oximeter method, DAM = doppler with aneroid method, SBP=systolic blood pressure.

As can be seen in the table, the SBP values obtained using a pulse oximeter were significantly lower than the values obtained using Doppler with an aneroid sphygmomanometer over the intervals of observations ($p < 0.001$). The degree of absolute agreement between the two rating instruments was poor at all the intervals of measurement (intra-class correlation coefficient < 0.5).

Similarly, as shown in **Table 3**, the SBP values as measured with pulse oximeters were significantly lower when compared with the oscillometric method at different points of measurement ($p < 0.001$).

The inter-rater reliability between the two rating methods was poor (intra-class correlation coefficient < 0.5). The level of agreement further declined with time.

4- DISCUSSION

The measurement of blood pressure in the paediatric age group and especially in neonates has been associated not only with technical difficulties but also differences in measurement accuracy between various methods of blood pressure measurement. The gold standard for measurement of BP is intra-arterial BP measurement; however, because of its invasiveness, measurement of blood pressure using noninvasive

methods such as the mercury sphygmomanometer has been the gold standard until recently. Due to the mercury's environmental risks of toxicity, this method of blood pressure measurement has gradually been phased out and has been replaced by using the Anaeroid sphygmomanometer, oscillometric BP devices and very recently mobile application-based BP devices, the accuracy of which is yet to be extensively tested in the paediatric population (8).

Table-3: Comparison of the systolic blood pressure values between pulse oximeter and automated oscillometric methods and degree of agreement between them (N = 185)

SBP values (mmHg)	Time (hours)	Mean (SD)	MD	t-test	p-value	Level of agreement using Intra-class correlation coefficient (ICC)
SBP using POM SBP using AOM	12	52.92 (2.10) 63.77 (4.93)	-10.85	-32.86	<0.001	0.39
SBP using POM SBP using AOM	24	53.95 (2.86) 67.06 (4.77)	-13.11	-41.06	<0.001	0.29
SBP using POM SBP using AOM	36	55.78 (2.68) 70.70 (4.49)	-14.92	-59.94	<0.001	0.14
SBP using POM SBP using AOM	48	57.67 (3.49) 73.99 (4.84)	-16.32	-77.55	<0.001	0.17

SD = standard deviation, MD = mean difference, t = paired t-test, POM = pulse oximeter method, AOM = automated oscillometric method, SBP=systolic blood pressure.

In the index study, there was a wide variation in the mean of systolic blood pressure measured by oscillometry compared to measurements obtained by the doppler anaeroid method which was used as a standard. This finding has been noted by different researchers as reported in a systematic review of 34 studies done by Dionne et al. demonstrating that measurement of systolic BP by oscillometric methods had the likelihood of overestimating intra-arterial systolic BP particularly in neonates with a mean arterial pressure <30 mmhg (2). Based on the recommendations in the protocol of the Association for the Advancement of Medical Instrumentation for BP device validation, the mean BP difference between methods should be ≤5 mmhg with a SD ≤8 mmhg which is contrary to the findings of this study where mean BP difference was 9.47mmhg (SD-12.15mmhg) (9). Also, in a study by Raju and Isaac, it was found that pulse oximetry was a more reliable method of assessing systolic BP. It also corroborates an earlier study by Langbaum where oscillometry indicating that it was less accurate than pulse oximetry (10, 11). Measurement of the systolic BP at reappearance of the plethysmographic waveform in pulse oximetry was also found to be more accurate than oscillometry in a study by Vinayak and is similar to what was done in the index study (12).

In this study, it was also observed that there was a significant difference between SBP readings obtained by pulse oximetry which were much lower compared to the doppler anaeroid method although the readings were closer when compared to those obtained by oscillometric measurement. Several important factors may be responsible for this variation, and these include intra observer error and an inherent error in pulse oximetry measurements which are based on 2–5 mm Hg pressure increments (13). Other factors

noted to affect the accuracy of pulse oximeters such as rapid fluctuations in readings when oxygen saturation falls below 90% and when there is poor perfusion (14) were not of significance in this study as the study population included well neonates.

Moreover, it is of note that previous studies evaluating BP measurements compared pulse oximetry with intra-arterial BP measurement as the gold standard which is different from what was done in this study and thus might also explain the differences observed. The use of the doppler/anaeroid BP measurement used as the gold standard in this study was based on the finding that it most closely correlated with intra-arterial BP measurement when compared with other non-invasive methods of BP measurement (15).

4-1. Limitations of the study

The major limitation of this study was the inability to do intra-arterial SBP measurement which is the gold standard because of its level of invasiveness which is unjustifiable in well newborns.

5- CONCLUSION

In conclusion, measuring systolic blood pressure by pulse oximetry is a better alternative to oscillometric SBP measurement in newborns especially in resource challenged settings; however, it cannot be used interchangeably or substituted for doppler anaeroid SBP measurement in newborns because of the poor degree of agreement noted between the two methods of BP measurement.

6- ETHICAL CONSIDERATIONS

Ethical approval for this study was obtained from the Health, ethics and research committee of the University of Uyo Teaching hospital (UUTH/AD/S/96/VOL.XXI/575, 22/07/21) and the study was carried out in accordance with The World Medical Association (Declaration of Helsinki) for experiments involving humans, and Uniform Requirements for manuscripts submitted to Biomedical journals and informed consent was obtained from the mothers.

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