OBJN
ONLINE BRAZILIAN JOURNAL OF NURSING
ISSN: 1676-4285

ORIGINAL

Oscillometric blood pressure measurement in a neonatal intensive care unit: a cross-sectional study*

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Submission: 10/08/2021
Approved: 07/27/2022

ABSTRACT

Objective: The study aimed to evaluate how neonatal blood pressure measurement with the oscillometric method is performed by a nursing team, including patient preparation, documentation, materials, and equipment. **Method:** This cross-sectional study was conducted in a neonatal intensive care unit (NICU) through direct observation of procedures performed by nursing staff. A systematic script was used for observation and documentation of the procedure, patient reparation, and handling of equipment. The results were analyzed through inferential statistics. **Results:** In a total of 150 observations, 60% or more of steps were classified as correct in 13 of the 26 target items. There was no difference between RNs and nurse technicians concerning the procedure´s success rate ($p = 0.3933$). Blood pressure measurement was obtained in the first attempt, according to the procedure´s adequacy ($p < 0.0001$). **Conclusion:** Published recommendations for oscillometric blood pressure measurement were not followed completely. Continuing education should focus on routine procedures to ensure essential aspects of care.

Descriptors: Blood Pressure Measurement; Newborns; Intensive Care Units, Neonatal.

INTRODUCTION

Blood pressure measurement (BPM) is a relevant component of nursing care and is widely performed by healthcare teams in neonatal intensive care units (NICUs)[1]. Thanks to improvements in health technology, the procedure has become increasingly efficient and automated[2]. However, healthcare professionals' performance remains an essential factor, potentially impacting blood pressure (BP) values and thus subsequent clinical decisions that support interventions.

Automatic oscillometry and auscultation are recommended for neonatal BPM, and both involve applying a cuff around the patient's limb[2]. Oscillometric measurement is the most common technique in neonates since it is easy to perform[2] and minimizes observer errors. It also requires less manipulation of the patient compared to other techniques[3]. Invasive BPM is only recommended in cases of greater hemodynamic instability because the technique is associated with technical difficulties and potential complications such as ischemia and thrombosis[4].

The oscillometric technique is based on the relationship between low-amplitude pressure pulses, detected with a pressurized inflatable cuff. The highest amplitude pulse corresponds to the mean arterial pressure. Encompassing the mean arterial pressure and other recorded pulses, an algorithm calculates the systolic and diastolic pressures. The technique requires the same preparation as for auscultatory measurement. After adequate placement of the cuff, the instrument needs to be activated by the proper method, which may differ from one device to another. The device then displays the systolic and diastolic pressure values[2].

The oscillometric technique should be performed in neonates when auscultatory measurement is not possible[1]. The latter method should be prioritized. Guidelines recommend that when hypertension is detected with an oscillometric device, confirmation should be done by auscultatory measurement[1,2].

However, auscultatory BPM is difficult to perform in neonates.

BPM performed according to standard guidelines provides reliable estimates. It can provide relevant information for hemodynamic assessment in the neonatal context[5], influencing medical interventions, especially in cases of hypotension, a common condition in preterm newborns[6], and hypertension. Estimated prevalence of hypertension is approximately 2% in neonates discharged from the NICU, reaching up to 3% in all neonates[7]. As with older children, BPM in neonates should preferably be performed on the right arm, except in cases of abnormal aortic arch and upper limb abnormalities[1,2].

Adequate positioning is essential for neonatal BPM, as in adults[8-9]. However, no previous research has been published on the impact of neonatal positioning on BP values. Meanwhile, two studies have reported the influence of cuff size and behavioral status on BPM[4,10].

Although neonatal BPM is commonly performed by nurses, it requires further investigation and improvement, since the procedure may not always follow best practices in all units. There is a lack of published research on factors related to nursing professionals´ performance during the procedure. Knowledge gaps include factors that can impact BP values, especially in neonates, challenges regarding body weight and limb circumference, requirements for specific equipment (e.g., monitors and cuffs), and patient´s behavioral status during the procedure. Given the relevance of BPM for critical reasoning and decision-making in clinical care, the current study aimed to assess how oscillometric neonatal BPM is performed by a nursing team, focusing on patient preparation, documentation, materials, and equipment.

METHOD

This was a descriptive cross-sectional study in a NICU in a public teaching hospital in Greater Metropolitan Campinas, São Paulo, Brazil. The unit has a total of 30 beds (15 intensive care and 15 semi-intensive care). The nursing staff includes 34 registered nurses (RNs) and 68 nurse technicians, all with at least one year of work in the NICU and eligible to participate. The study was approved by the Institutional Review Board of the University of Campinas (protocol 2.981.492/2018) prior to starting data collection. Data were collected from January to May 2019. The first author observed the RNs and nurse technicians performing BPM with the oscillometric method as part of routine care of the newborns. Observations were performed after the RNs, nurse technicians, and parents of the newborns agreed to participate in the study. The researcher explained the study´s objectives and procedures to the professionals, who signed the consent form if they agreed to be observed. The consent process took place in the three weeks prior to the start of data collection to minimize the Hawthorne effect[11], which is an unintended effect of the observer's presence on the observed individual´s behavior. Parents also received explanations concerning the study and signed the consent form for the newborn to be observed during BPM.

Data were collected through direct observation, consisting of systematic viewing and recording[11] of the entire oscillometric BPM. The researcher also collected data from the newborns´ medical records: weight and days of life on the day of the procedure and gestational age. At the beginning of each week, the newborns' limb circumferences were measured by the researcher to determine the appropriate cuff size.

Observations were performed by convenience, without probabilistic sampling, based on the opportunity to observe a member of the nursing staff verifying BP as part of routine care, with no interference from the observer. To ensure that all shifts were observed equally, the observations were distributed across the four NICU shifts: morning, afternoon, night A, and night B.

Sample size was calculated according to the number of times the procedure was performed in intensive care and the opportunity of observing it in each patient during a 24-hour period. Thus, the sample calculation method was used to estimate a proportion[12,13]. In the context of this specific NICU, BPM is performed routinely every six hours in each patient, totaling four procedures per day per patient. A minimum of four observations per day of data collection was planned to be performed by a single observer: the first author. Thus, a finite universe of 240 procedures was considered for the calculation, considering four opportunities to observe the BPM procedure in the NICU per day of data collection in the two-month period. All things considered, a sample of 148 procedure observations was required[11,12], and a 5% sampling error and 5% significance were assumed.

Each observation was recorded using a script for BPM observation. A 26-item script was de-

veloped previously for this study, based on the ideal steps in oscillometric measurement in neonates and hospitalized infants, as described in the literature[1,14]. The independent variables were the recommendations for the procedure: handwashing by the healthcare professional, absence of painful procedures performed in the previous 30 minutes, absence of feeding in the previous 30 minutes, measurement of vital signs as the first step, patient's legs uncrossed, patient's limb free of clothing and devices, patient's limb supported at heart level, patient in dorsal decubitus, strategies implemented to keep the patient calm and/or asleep for at least five minutes before the procedure, patient swaddled or under elastic restraint, strategies for keeping the patient calm during the procedure, offer of non-nutritive sucking, absence of external damage to the monitor, palpation of the artery to confirm its location, correct adjustment of the cuff to the limb, compressive area of the cuff centered on the limb´s artery, absence of damage to the cuff, cuff positioned on the limb for at least five minutes before measurement, verification of cuff size adequacy in relation to limb circumference, monitor calibrated less than six months previously, cuff kept on the limb if it was necessary to repeat the procedure, a one-minute interval between measurements if it was necessary to repeat the procedure, recording of exact BP values (without approximations), recording of limb on which the measurement was taken, and recording of patient's behavioral status during the procedure.

Since no specific recommendations were available for oscillometric BPM in neonates, adaptations were made. The script was presented to 10 experts from a Research Group on Blood Pressure before data collection began, and adaptations were made according to their suggestions. The script was tested on a sample of 10 observations of the procedure, followed by adjustments and adoption for the data collection (these preliminary observations were not included in the study´s final results).

Descriptive statistics were used to describe each step´s accuracy, namely items in the procedure that were performed properly by the healthcare professional. The final number of correct steps for each patient was obtained through the sum of affirmative answers in the script, divided by the total number of steps, excluding the items that were not applicable for each patient, and the result of this operation was multiplied by 100.

Mann-Whitney test was used to compare the performance of RNs and nurse technicians in obtaining the BP measurement on the first attempt, recording the number of correct steps during the procedure[15]. Using this same test, the number of steps performed correctly was analyzed in relation to gestational age. Kruskal-Wallis test was used to compare the four work shifts (morning, afternoon, night A, and night B) in relation to the number of correct steps. Unpaired Student's t test was used to compare the limbs used for placement of the cuff (upper/lower). Data distribution was assessed with the Shapiro-Wilk test[15]. Statistical Analysis System (SAS), version 9.4, and Statistical Package for Social Sciences (SPSS), version 22.0, were used for the analyses.

RESULTS

A total of 150 oscillometric blood pressure measurements were observed: 36 (24%) during the morning shift, 39 (27%) in the afternoon, 37 (24.6%) in night shift A, and 38 (24.4%) in night shift B. Of these, 45 (30%) procedures were performed by RNs and 105 (70%) by nurse technicians. Of the total of 102 nursing professionals in the NICU, 44 (43.1%) were observed during the study: 15 RNs and 29 nurse technicians. All the professionals had worked at least one year in the NICU.

The observed procedures were performed in 43 patients. Patients´ mean age was 31.2 ±25.5 days (range 0 to 117 days) on the day of observation. Mean weight was 1,579.1g ±792g (range 620 to 4,065g). Mean gestational age at birth was 29.6 ±4.7 weeks (range 25.1 to 40.4 weeks). Mean brachial circumference was 7 cm ±2.1 cm (range 4.5 to 13 cm).

Data from the observation script were divided into four categories: preparation prior to BPM (Table 1); patient positioning and soothing (Table 2); handling of material and equipment (Table 3); and documentation of the procedure (Table 4). The respective tables show the corresponding rates, featuring 60% or more of correct steps in 13 of the 26 target items.

There was no significant difference between RNs and nurse technicians ($p = 0.3933$), work shifts ($p = 0.6867$), or limbs on which the measurement was performed ($p = 0.1962$) in terms of correct steps in the BPM. However, there was a difference between RNs and nurse technicians in the rate of correct steps in the procedure

Table 1 - Rates of recommended preliminary preparations performed before blood pressure measurement (n=150). Campinas, SP, Brazil, 2019

Steps	Yes n (%)	No n (%)
Handwashing by the nursing professional	146 (97.3)	04 (2.7)
No painful procedures performed in the previous 30 minutes	122 (81.3)	28 (18.7)
Patient fed more than 30 minutes previously	113 (75.3)	37 (24.7)
Measurement of vital signs as the first step	92 (61.3)	58 (38.7)

Source: Prepared by the authors, 2021.

Table 2 – Rates of recommended steps performed with patient positioning and soothing for blood pressure measurement (n=150). Campinas, SP, Brazil, 2019

Care	Yes n (%)	No n (%)	NA* n(%)
Patient's legs uncrossed	147 (98.0)	03 (2.0)	-
Patient's limb free of clothing and devices	138 (92.0)	12 (8.0)	-
Patient's limb supported at heart level	134 (89.3)	16 (10.7)	-
Patient in dorsal decubitus	129 (86.0)	21 (14.0)	-
Strategies implemented to keep patient calm and/or asleep for at least five minutes before the procedure	105 (70.0)	45 (30.0)	-
Patient swaddled or under elastic restraint	26 (17.3)	41 (27.3)	83 (55.4)
Strategies to keep patient calm during the procedure	15 (10.0)	47 (31.3)	88(58.7)
Non-nutritive sucking offered	5 (3.3)	53 (35.3)	92 (61.4)

* NA = step "not applicable" because the patient did not require it.
Source: Prepared by the authors, 2021.

Table 3 – Rates of recommended steps performed, involving handling of materials and equipment for blood pressure measurement (n=150). Campinas, SP, Brazil, 2019

Step	Yes n (%)	No n (%)	NA n(%)
Absence of external damage to the monitor	146 (97.3)	04 (2.7)	-
Correct adjustment of BP cuff to the limb	128 (85.3)	22 (14.7)	-
Compressive area of the cuff centered on the artery	88 (58.7)	62 (41.3)	-
Absence of damage to the cuff	75 (50.0)	75 (50.0)	-
Cuff positioned on the limb for at least five minutes before measurement	16 (10.7)	134 (89.3)	-
Verification of the adequacy of cuff size in relation to limb's circumference	05 (3.3)	145 (96.7)	-
Palpation of artery to confirm its location	05 (3.3)	145 (96.7)	-
Cuff positioned on the limb at least five minutes before procedure	07 (4.7)	58 (38.7)	85 (56.7)
Monitor calibrated less than six months previously**	09 (6.0)	72 (48.0)	69 (46.0)
If necessary to repeat the procedure, the cuff was kept on the limb	43 (28.7)	11 (7.3)	96 (64.0)
If necessary to repeat the procedure, a one-minute interval was used between measurements	03 (2.00)	47 (31.3)	100 (66.7)

* NA = step "not applicable" because the patient did not require it.
** Item verified by the observer.
Source: Prepared by the authors, 2021.

Table 4 - Documentation of the blood pressure measurement procedure by the nursing professional (n=150). Campinas, SP, Brazil, 2019

Recording of steps	Yes n (%)	No n (%)
Documentation of exact BP values, without approximations	118 (78.7)	32 (21.3)
Documentation of limb on which BP measurement was taken	61 (40.7)	89 (59.3)
Documentation of patient's behavioral status during the procedure	0 (0.0)	150 (100.0)

Source: Prepared by the authors, 2021.

and obtaining BP values on the first attempt (p <0.0001). There was no significant difference in relation to gestational age (p = 0.3395).

Notes taken during the observations provided additional data on BP measurement:

In 12 procedures (8%), the nursing professionals had difficulty with the proper cuff placement due to small limb circumference. Some cuffs were also made of stiff material, making it impossible to surround the limb adequately.

Some cuffs at the unit were disposable but were maintained for reuse. These cuffs did not adhere properly to the patients' limbs in 22 procedures (14.7%), and the staff opted to use adhesive tape to keep the cuff closed and proceed with BPM.

In 16 procedures (10.7%), the attending staff pressed the cuff with their fingers and kept the limb elevated during inflation and BPM reading.

In 30 procedures (20%), the monitor took a long time to show the BP readout and the cuff inflation was maintained, resulting in transient cyanosis to the patient's limb and marks on the skin due to prolonged pressure.

One nursing professional recorded the BP values incorrectly during the documentation, with the systolic and diastolic values in the wrong places.

There were difficulties with properly adjusting the cuff extension to the equipment´s connection, due to variations in equipment brands. The nursed professionals improvised by using "caps" from intravenous therapy devices or even knots to occlude the unused cuff extension in 26 procedures (17.3%).

During 22 BP measurements (14.6%), the neonate continued to receive milk through an enteral tube, and other nursing care procedures were performed, such as oral hygiene and diaper changes.

In 72 (48%) of the observations, the monitor´s calibration date was expired, and 69 (46%) of the monitors had no calibration seal.

Three nursing professionals spontaneously approached the researcher to report that measuring BP was a stressful procedure, due to the insufficient number of devices in the NICU with a functional BP monitor, as well as to the long time the equipment took to perform the BP readout.

DISCUSSION

In the 150 observations of the BPM procedure, most steps recommended in the literature[1,2,14,16,17] were followed: 60% or more of correct steps were seen in 13 of the 26 items observed. Since there were no other studies with which to compare these results, we assumed that 60% or more of correct steps was satisfactory.

Handwashing is essential for preventing infection in neonatal care. Although it was performed in 97.3% of the cases, ideally it should have occurred in 100% of the BPM procedures. It is worth noting that in 38.7% of the procedures, verification of vital signs was not the first step performed (Table 1). Healthcare professionals should be aware that handling patients before measuring vital signs may affect the BP values[17]. Patient handling also occurred during BPM itself, including nursing professionals performing hygiene, soothing, and feeding.

Regarding positioning and soothing strategies (Table 2), all the steps were correct in 70% or more of the cases. If the action was not necessary during the procedure, especially if the newborn was already calm before BPM, soothing was recorded as not applicable: patient swaddled or under elastic restraint; use of strategies to keep the newborn calm during the procedure, and encouragement for non-nutritive sucking. This may be explained by the focus on individualized newborn care to promote the best possible development for the patient, thus favoring less agitated behavioral status over time, regardless of the performance of procedures[18]. Meanwhile, in 47 procedures (31.3%), patients were awake and restless, but no strategies were used to calm them. In 15 procedures (10%), nursing professionals implemented soothing and comforting strategies during BPM in awake and restless patients (Table 2). Thus, in a total of 62 proce-

dures with restless patients, only 15 presented professionals´ strategies to calm them, which demonstrates an inadequacy. This inadequacy relates to both the potential impact on blood pressure values and the care performed for patient comfort.

The results also suggest inadequacies in the handling of materials and equipment. The cuff had only been positioned on the limb at least five minutes before starting the procedure in 10.7% of the observed procedures. The minimum 5-minute limit is recommended because it facilitates the newborn's adaptation to the cuff´s presence, favoring calmer behavior during the procedure[14], as described previously in other studies on oscillometric BPM[14,16,17].

Of the 25 observations (16.6%) in which a second BPM was required due to failure on the first attempt, the one-minute interval between measurements was overlooked in 17 (66.7%) of the repeat procedures. Furthermore, the cuff was only kept on the same limb in 28.7% of these procedures.

The cuffs were fit for use in 50% of the observed procedures. This proportion should have been higher since proper cuffs are essential for obtaining reliable BP measurements. Finally, the nursing professionals only verified the adequacy of cuff size in relation to the limb´s circumference in five observed procedures (3.3%), also suggesting noncompliance with recommendations in the literature[1,2,4].

There were unexpected additional findings besides the systematic observations in the script and that may have compromised the BP values, such as the use of adhesive tape to close the cuff, compressing the cuff with the professional's fingers during inflation and reading, and maintaining the patient's limb above heart level. Such procedures are inconsistent with the established recommendations[1,2].

The use of cuffs not indicated by the monitor's manufacturer can also lead to measurement errors. In addition, reuse of disposable cuffs and other workarounds by the team can damage the material, increase the procedure time, and result in inaccurate BP estimates, causing stress for both the nursing team and patients. It is thus essential to standardize monitors and cuff brands employed in the NICU, as well as to use appropriate materials for neonatal patients.

Palpation of the artery to confirm its location and to better position the cuff on the limb, a key item, was observed in only 3.3% of the procedures. In oscillometric measurement, placing the compressive portion of the cuff over the artery is essential for capturing pulse oscillations and reading BP[3].

A total of 97.3% of the procedures were performed with monitors that were apparently unbroken and in good condition, but in only 6% of the observed procedures the device had been recalibrated in the previous six months. In 46% of the observed procedures, BP was measured by devices with no specification of calibration date or recent preventive maintenance (both of which are recommended every six months)[2]. Proper functioning of the equipment is essential for obtaining reliable BP values, besides enabling faster procedures, providing less discomfort to the patient[28] and decreasing the risk of injury to the limb.

The exact BP values were recorded by the nursing professionals on the patient´s medical record in 78.7% of observed procedures. The limb on which BP was measured was recorded in only 40.7% of the observations. Importantly, the nursing professionals failed to record the newborns' behavioral status. Comprehensive and accurate records are still challenging in healthcare. These records guide the health team's critical reasoning and clinical conduct, besides providing valuable data from a legal perspective.

Our analyses showed a significant association between the number of items correctly performed during the procedure and the success in obtaining a BP value on the first attempt. Therefore, continuing education is a relevant strategy for effective performance of this procedure in the clinical setting.

The study's findings highlight some limitations in relation to recommendations for BP measurement in newborns and infants: lack of adequately sized cuffs for the newborn´s limb circumference; difficulty in adjusting the cuffs to the patient´s limb; performance of other procedures during BPM; maintaining the target limb above heart level during BP measurement; and failure to perform measures to calm patients[1,2,14]. Unreliable BP values can result in any of these limitations or a combination thereof. In addition, some nursing professionals expressed dissatisfaction with the conditions in which they perform BPM, as observed during data collection. The literature emphasizes that providing respectful care in a NICU includes educational opportunities for the health team, besides the provision of an appropriate setting and equipment to promote safe,

quality care[18].

Feeding during BPM in newborns and infants should be investigated further. The literature recommends not feeding during the BP procedure and a minimum prior interval of 30 minutes[2]. However, in the neonatal context, feeding can influence behavioral status, resulting in calming and facilitation of the procedure[19].

The study´s limitations include the lack of similar and recent studies to support comparison and discussion, the non-probabilistic sample, observations performed by a single researcher, and the impossibility of randomly selecting the observed NICU beds. Another limitation is the fact that the study was developed at only one NICU, so that the results may not reflect practice by nursing teams elsewhere.

The current study´s findings show that even in a teaching hospital, recommendations for BP measurement are not followed completely, despite being described in the literature as essential[1,2,7,8]. This is worrisome because BPM is a frequent procedure in assessing patient´s status and is inherent to nursing care, having been considered easy to perform, with low complexity. However, it has not always been performed properly. Thus, this topic and its implications for clinical practice should be investigated further and discussed in studies on quality improvement, both in the NICU and in other contexts of care to improve the nursing team´s performance and the care provided.

The most frequently followed steps involved patient preparation for the procedure, as well as patient positioning and soothing, with rates of 60% or greater. The recommendations were less likely to be followed with the handling of cuffs and equipment, as well as clinical records, which highlights need for improvement. Incorrect performance of the steps can interfere in the BP values and increase time spent with the procedure, which can be associated with discomfort for the patient and healthcare team.

BPM is an essential part of NICU care, but there are numerous gaps in knowledge and clinical practice. Thus, standardized approaches that address specific aspects of neonatal care should be developed, based on a philosophy of comprehensive, humanized care that provides a calm and welcoming environment for patients and families and adheres to clear technical recommendations. Technological innovation is also indispensable for developing affordable materials and equipment for neonatal needs, aimed at improving neonatal care.

CONCLUSION

Direct observation of 150 BPM procedures allowed concluding that recommendations for measurement by the oscillometric method were not followed entirely, although the majority were: 60% or more of correct steps were seen in 13 of the 26 items observed.

Additional studies on neonatal BPM are needed to support educational interventions by healthcare teams, to improve the procedure´s accuracy in the clinical setting, and to inspire further research planning and execution.

*Paper extracted from the master thesis "Oscillometric blood pressure measurement in a neonatal intensive care unit: observation of the procedure performed by nursing professionals", presented to the State University of Campinas, Campinas, SP, Brazil.

ACKNOWLEDGMENTS

The authors wish to thank Henrique Ceretta Oliveira for his collaboration in the data analysis and interpretation.

CONFLICT OF INTERESTS

The authors have declared that there is no conflict of interests.

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