Comparison of noninvasive oscillometric and intra-arterial blood pressure measurements in children admitted to the pediatric intensive care unit

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ABSTRACT

Introduction: Non-invasive blood pressure measurement (NIBP) is accepted as the standard monitoring modality in most clinical settings. However, whenever there is a need for accurate, reliable, beat-to-beat monitoring of blood pressure, an intra-arterial catheter (IBP) is considered the gold standard. The perceived superiority of such invasive monitoring helps justifies the placement of intra-arterial catheters and leads some intensivists to forego NIBP monitoring in patients once such a catheter is placed.

Objective: To study the correlation between non-invasive blood pressure (NIBP) measurements and invasive arterial blood pressure (IBP) measurements in critically ill children admitted to a Pediatric Intensive Care Unit (PICU).

Methods: Data collected from critically ill children with arterial BP monitoring admitted to the PICU, Lotus Hospital for Women and Children, Hyderabad over one-year duration. Both noninvasive and invasive readings of BP including systolic, diastolic and mean BP were recorded and tabulated for comparison and statistical analysis.

Results: Systolic and diastolic blood pressure values recorded at 8AM, 4PM and 12 midnight by IBP and NIBP correlate with each other significantly. The correlation values for SBP are 0.997, 0.993 and 0.991 respectively with P values being less than 0.001 at every recording while for DBP the correlation values are 0.989, 0.994 and 0.991 respectively with P values being less than 0.001 at every recording.

Conclusion: Significant correlation was observed between BP measured by invasive (IBP) and noninvasive method (NIBP) in patients admitted to a pediatric intensive care unit in a tertiary care center.

Keywords: Blood pressure, Monitoring, NIBP, IBP.
Introduction;
Accurate and timely BP measurement is a critical parameter in many clinical settings including ICUs, medical and surgical inpatient wards, emergency rooms and many pre-hospital settings. Non-invasive blood pressure measurement (NIBP) is accepted as the standard monitoring modality in most clinical settings. However, whenever there is a need for accurate, reliable, beat-to-beat monitoring of blood pressure, an intra-arterial catheter (IBP) is considered the gold standard. The perceived superiority of such invasive monitoring helps justify the placement of intra-arterial catheters and leads some intensivists to forego NIBP monitoring in patients once such a catheter is placed.

Although non-invasive technique is widely practiced owing to low cost and easy availability, in the clinical setting of pediatric ICUs where round the clock monitoring of critically ill children is necessary, the invasive technique is considered more important in monitoring blood pressure to establish or reassess efficacy of ongoing therapies as well as trend values to assess hemodynamic status accurately. Different systems derive systolic (SAP), diastolic (DAP), and mean (MAP) arterial pressure parameters based on different physical events, which are different for different modes of measurements of BP. These events are the maximal oscillations of a cuff pressure curve for oscillometric devices (OBP), the Korotkoff tones for aneroid manometers (ABP), and direct electronic measurement for invasive arterial blood pressure (IBP).

IBP monitoring (arterial cannulation with continuous pressure transduction and waveform display) is the reference standard for BP monitoring in intensive care unit (ICU) patients. However, it is expensive, carries an increased risk of complications, and requires more clinical expertise than noninvasive monitoring. The auscultatory technique is seldom used in critically ill patients and it is prone for errors too due to attached ventilator and poor peripheral pulses, except in some situations like emergencies or transports where it may be the only available method.

Unfortunately, NIBP monitoring is influenced by factors related to the procedure, to the instruments themselves, and to inter-observer variability. Non-invasive methods may not be sufficiently accurate in critically ill patients, leading to erroneous interpretations of BP and possible errors in clinical decisions.

ABP, OBP, and IBP are not derived from the same physiological observation and measurement with different devices may produce different results. So, it is hard to establish what is the “true” blood pressure, that is, the one on which to base clinical choices and derive data for calculating various scores. Even standardizing the technique and limiting inter-observer variability, both studied noninvasive methods (auscultatory and oscillometric) can be inaccurate among critically ill patients specially when patients are children. In settings where IBP monitoring is not possible and only noninvasive techniques are available, BP values detected by noninvasive methods may be shown randomly and unpredictably very different values from the real ones. In these cases MAP appears to be the most reliable parameter, especially if assessed by the auscultatory method.

Since NIBP monitoring is normally available in every ICU, its use should be recommended in addition to IBP monitoring. If the data obtained by the two methods differ markedly and/or are not consistent with the patient’s clinical condition, the operator should maintain a suspicious eye and check the reliability of the instruments, especially before
undertaking any therapeutic decisions. When IBP is not measured in the ICU for any reason, a comparison of ABP and OBP values is of utmost importance.

Noninvasive measurement of arterial blood pressure holds importance for clinical and basic research because blood pressure usually changes significantly within a few seconds, noninvasive continuous measurement of blood pressure is more important in determining cardiovascular status during sleep studies and the head-up tilt test.

Material and Methods:

It was a prospective observational study of one year duration (December 2014 to November 2015) which is conducted in a PICU in a tertiary care hospital (Lotus Hospital for Women and Children, Lakdikapul, Hyderabad). Sample size is 90 where we have 80% power to detect 10 mm of Hg difference between the two measurements. In children satisfying the criteria, baseline BP was recorded in both the limbs to rule out any difference between two upper limbs. The selected artery was catheterized under all aseptic measures using an appropriate sized cannula. The cannula was connected to an Edwards pressure monitoring set which is a continuous heparinized fluid filled system connected to an electronic pressure transducer and a display system of Philips IntelliVue MP60 Light Monitor.

For noninvasive BP, Philips IntelliVue MP60 system of noninvasive BP monitoring was used. It consisted of cuffs of different sizes and a display monitor. An appropriate sized cuff (at least 70% of the arm circumference to be covered by the bladder of the cuff) was selected after measuring the mid arm circumference which was wrapped around the extremity and readings including systolic and diastolic BP were obtained on the display monitor and recorded.

Afterwards, the NIBP and arterial BP are displayed continuously on the same monitor. Both noninvasive and invasive readings of BP including systolic, diastolic and mean were recorded at 8 AM, 4 PM and 12 midnight (average of 3 readings recorded at an interval of 5 minutes was entered the data analysis sheet) and tabulated for the purpose of comparison and statistical analysis.

Results:

Mean age for the sample size was 32.5(± 39.3) months and boys constituted (56) (62%). Central nervous system was the predominant primary system affected in the monitored patients(46 patients) (51.1%), followed by respiratory system in 21 patients(23.4%). Multi-organ dysfunction (failure of more than one system at presentation) was seen in 10 patients (11.1%). (graph 1) Average PRISM score was 10.3(± 6.2). 82 patients (91.1%) required intubation and the average duration on mechanical ventilation was 5.8 days. The average duration of stay in the PICU was 7.6 days. Mortality was 33% (30 patients). (Table I). (Figure 1)

Systolic and diastolic blood pressure values recorded at 8AM, 4PM and 12 midnight by IBP and NIBP correlate with each other significantly. The correlation values for SBP are 0.997, 0.993 and 0.991 respectively with P values being less than 0.001 at every recording while for DBP the correlation values are 0.989, 0.994 and 0.991 respectively with P values being less than 0.001 at every recording. (Figure 2,3 and 4).

Mean Blood pressure values recorded at 8AM, 4PM and 12 midnight by IBP and NIBP correlate with each other significantly. The correlation values are 0.894, 0.985 and 0.990 respectively with P values Being significant (<.001) at every recording. (Figure 5)
Table 1: Characteristics of Study Population with Clinical Course and Outcome

<table>
<thead>
<tr>
<th>S. No</th>
<th>Variable</th>
<th>Mean ± SD / Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Average PRISM Scores at Presentation</td>
<td>10.3 ± 6.2</td>
</tr>
<tr>
<td>2.</td>
<td>Number of Patients who Required Intubation (%)</td>
<td>82 (91.1%)</td>
</tr>
<tr>
<td>3.</td>
<td>Average Duration on Mechanical Ventilation (Days)</td>
<td>5.8 ± 4.8</td>
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<td>4.</td>
<td>Mean Length of Stay Pediatric Intensive Care Stay (Days)</td>
<td>7.6 ± 6.9</td>
</tr>
<tr>
<td>5.</td>
<td>Average Length of Stay in Hospital (Days)</td>
<td>11.5 ± 9.0</td>
</tr>
<tr>
<td>6.</td>
<td>Number of Deaths (%)</td>
<td>30 (33.3%)</td>
</tr>
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</table>

Figure 1: Distribution of cases according to system affected
Graph 2: correlation for systolic and diastolic blood pressure measured at 8 am (n=250)

Graph 3: correlation for systolic and diastolic blood pressure measured at 4 pm (n=250)
Graph 4: correlation for systolic blood and diastolic pressure measured at 12 midnight (n=250)

Graph 5: correlation for mean arterial pressure measured at 8am, 4pm and 12 midnight (n=250)
Discussion:

Blood pressure is an important parameter in the assessment of survival and prognosis of critically ill children. Accurate measurement of arterial blood pressure is therefore essential for the rational management of critically ill children.

Direct measurements of blood pressure in ICU settings via an intra-arterial catheter are the gold standard, although arterial cannulation is associated with complications and needs technical expertise. Multiple clinical research studies have demonstrated that when BP measured by NIBP monitors is compared to simultaneously measured IBP, the two values may vary from each other. In our study, we found that if taken in appropriate manner and in control conditions both noninvasive and invasive BP approximate each other very closely which will decrease the need of invasive BP monitoring.

In a study conducted by Ali Araghiet al.\textsuperscript{11}, on overweight critically ill adult patients with BMI >25 kg/m\textsuperscript{2}, direct intra-arterial BP was compared with NIBP measurements obtained using auscultatory and oscillometric methods. It was seen that automated oscillometric measurements of blood pressure were inaccurate. They concluded that NIBP can be inaccurate among overweight critically ill patients. Probable reason for the same results being inappropriateness of BP cuff and its relation to arm circumference. We were not able to show any variability in BP with respect to BMI as most of our patients were having BMI 85 percentile for the corresponding age and gender and we have taken stringent precautions in using the appropriate sized BP cuffs.

Another study was by EfstathiosManiosa et al.\textsuperscript{12}, in which non-invasive oscillometric and intra-arterial invasive BP measurements were compared in patients. In this study, it was shown that non-invasive automatic oscillometric BP measurements underestimate direct SBP recordings and overestimate direct DBP readings. It also came into notice that the magnitude of discrepancy between intra-arterial and oscillometric ABP recordings is even more prominent in patients with critically elevated SBP levels\textsuperscript{12} contrary to our study where we found that when taken appropriately noninvasive BP almost equilibrate with invasive BP and if taken well there is no need of invasive BP monitoring.

A retrospective study by Wax DB et al.\textsuperscript{2}, in anesthetized patients found that the BP values from OBP were higher than those recorded by IBP monitoring during periods of hypotension but lower during periods of hypertension\textsuperscript{2}. In our study, BP values measured either with oscillometric (NIBP) or arterial line (IBP) were often comparable and almost similar. This is because most of our patients included in our study were initially stabilized in the emergency room (ER) and then shifted to the PICU. Arterial lines were introduced in the PICU after volume resuscitation and initiation of treatment. Blood pressure readings were recorded subsequently. BP readings were in the normotensive range as patients have already received intravenous fluid bolus/es in the ER, however lot of patients in our study also had hypotension and were on inotropic support while taking readings.

Noninvasive methods are still used commonly in the Pediatric ICUs, especially in developing countries, where the cost of treatment and the availability of technical expertise is a limiting factor\textsuperscript{13}. Our study is in contrast to other studies conducted in the past\textsuperscript{5,11,14}, that noninvasive methods are inferior to invasive blood pressure monitoring among critically ill children. In
particular, our study data shows that noninvasive methods are a suitable replacement for invasive ones wherever the later are not available. One of the reason for these contrary results could be the difference of BP between the two methods chosen to be clinically relevant; as in our study we have taken this value as 10mm of mercury. Unfortunately, available literature is also variable about the range of accuracy that can be regarded as acceptable in critically ill children. In anesthetized patients, Gibbs et al. suggest that differences greater than 10 mmHg should be regarded as clinically relevant and that they become clinically unacceptable in excess of 20 mmHg. However, it should be highlighted that the clinical relevance of BP discrepancies should vary based on a case to case basis and overall hemodynamic status of the child. A difference of more than 5 mmHg in an infant with a MAP <50 mmHg is clinically more relevant than the same difference with a MAP of 70 mmHg, in the same infant. In our study, also we have found that the NIBP and IBP differ significantly in children who had MODS and severe shock refractory to the usual dosages of inotropes, and eventually they succumbed to their illnesses. These results imply that the overall result of our study should not be generalized and that one needs to keep in mind that the values of NIBP and IBP correlated well in less sick children, as compared to those in whom shock responded to fluids and/or minimal inotropic requirement.

In a study from Takci et al. where IBP monitoring was compared to OBP in 27 critically ill preterm infants, oscillometric MAP was found to be significantly higher in the presence of hypotension, while no statistically significant difference was shown for normal or high pressure values as in our study.

Clinical decisions are often based on the BP values that are available, regardless of the method (NIBP or IBP). The authors conclude that concomitant use of NIBP and IBP monitoring should be recommended wherever facilities are available for authentic interpretation of BP abnormalities, which is prerequisite for clinical decision-making.

Our study has certain shortcomings. Firstly, we could include only a few patients with BP values representing severe hypotension and hypertension and most of the BP values in our cohort lie at the extremes of normal range; that is why we want to conclude that more research is needed in severely hypotensive and hypertensive patients, where the decision-making is particularly important. Secondly, the children enrolled in the study differed in terms of their age, sex, weight and most importantly underlying diagnosis. However, data from previous studies have demonstrated that underlying diseases did not contribute to the differences between different methods.

**Conclusion:**

Statistically significant close correlation was observed between BP measured by invasive (IBP) and non-invasive method (NIBP) in patients admitted to the PICU in a tertiary care centre. In peripheral hospitals and centers where invasive BP monitoring is often not possible, NIBP can be used as a reliable method for monitoring blood pressure but wherever available IBP is recommended for BP monitoring and clinical decision making especially in very sick children with MODS and severe hypo or hypertension and further study needs to be done to evaluate comparability of NIBP and IBP in children with severe hypo and hypertension.

**Conflict of Interest:** None   **Source of Funding:** None
References


