

# Is blood pressure measurement important in children?

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## Introduction

The importance of blood pressure (BP) monitoring in the perioperative and intensive care setting is very clear. Data from adult and paediatric victims of trauma have suggested that systolic blood pressure (SBP) is a predictor of mortality. In many other settings, the mean arterial pressure (MAP) has been used as a surrogate for tissue perfusion<sup>1</sup> and cardiac output (MAP = cardiac output x systemic vascular resistance). Routine monitoring of BP has thus been set as one of the recommended standards of care by the American Society of Anesthesiologists (ASA).<sup>1</sup> Paediatric anesthesiologists routinely monitor the BP of their patients and make major diagnostic and therapeutic decisions, e.g. blood transfusion and the commencement of inotropes and resuscitation, based on deviations from "normal".

However, there is a large variation in the threshold values that are used to define hypertension and hypotension. Standard BP tables use values that are obtained in the awake, unanaesthetised child. They do not take into account such variables as anxiety, the effects of anaesthetic agents on organ flow, and changes in metabolism, temperature and surgical stress.<sup>2</sup> This is further confounded by the fact that these devices may not have been adequately validated for use in the paediatric population. The following is a brief discussion on the controversies that exist.

## General issues in blood pressure measurement

"The critical need for a standard methodology for BP measurement stems from the recognition that both high and low BP is a pervasive problem in the present era".<sup>1,3</sup> Unfortunately, most information on paediatric BP measurement is obtained via extrapolations from adult data.

These issues relate to the following:

- **Patient factors:** The subject should be sleeping (infants and toddlers) or sitting (with the back supported and the feet flat on the floor) in a quiet environment for five minutes.<sup>4</sup> Initially, the BP should be measured on the right arm. Special note should be made of the fact that there is normal diurnal variation in BP readings and variations caused by ambient temperature.<sup>5</sup>

- **Observer factors:** Basic principles to follow include placement of the cuff on the bare limb. Restricting clothes should not be placed above the cuff BP.<sup>5</sup> It is necessary to be aware of the differences in measurements taken on the arm, forearm and calf. Differences in the arterial pressure on the arm and forearm commonly occur because the forearm BP is more sensitive to body temperature and positioning, so this may give false readings. Forearm pressure often overestimates systolic, diastolic and mean values, anywhere from 10-33 mmHg.<sup>4</sup> Lower limb readings are higher in adults and lower in children under eight years of age.<sup>5</sup>
- **Equipment:** Equipment must be functional, maintained, calibrated and validated for use in the paediatric population.

## Selection of the proper cuff size

Current recommendations, greatly influenced by the 2004 *Fourth report on the diagnosis, evaluation and treatment of high blood pressure in children and adolescents*, state the following:<sup>5,6</sup>

- The inflatable bladder must have a width of at least 40% of the arm circumference, as measured from a point that is midway between the olecranon and acromium.
- The length must encircle at least 80% of the arm circumference.

Under-cuffing (use of a small cuff) leads to erroneously high BP measurements,<sup>4</sup> but the converse is less well established. It has been suggested that too large a cuff will underestimate the true BP. A larger, rather than smaller, cuff, should be used if a suitable one is not available.<sup>5</sup>

## Methods of blood pressure measurement

Variable methods have been discussed for noninvasive BP measurement. The ones that are relevant to our discussion will be covered.

### Auscultatory methods

These devices are subject to significant observer issues:

- Korotkoff 4 (K4) sound is usually heard 10 mmHg above the actual diastolic blood pressure (DBP). Korotkoff 5

(K5) is considered to occur 2 mmHg below the DBP. Controversy still exists over whether K4 or K5 should be used as the measure of DBP. The argument is that data have reported normal K5 values in younger children. However, it has also been suggested that K4 DBP that is measured in childhood is a better predictor of adult hypertension.<sup>4</sup>

- Mercury sphygmomanometry is considered to be the gold standard against which other noninvasive measures are compared. It is likely that it will be phased out, not for reasons of inaccuracy or device failure, but for environmental ones.

### Oscillometry methods

Oscillometric devices are rapidly replacing conventional sphygmomanometry in many medical centres. The cuff is inflated to a pressure in excess of the systolic arterial pressure, and released by an electrically operated pump and valve. As the cuff pressure decreases, oscillations of the arterial wall increase in amplitude and reach a maximum. This is where cuff pressure approaches MAP. With further deflation, oscillations diminish and eventually disappear. This measured MAP is computed and then placed into a complicated algorithm that varies from one device to another. These algorithms have been considered as proprietary information and are kept in confidence, making it impossible for investigators to verify the underlying physiological principle. Therefore, "calculated" rather than "measured" SBP and DBP is obtained. This means that two different oscillometric devices could yield different BP results.

What is clear from studies that have compared conventional sphygmomanometers and oscillometers is that these two methods of BP measurement should not be used interchangeably as they may measure different biological parameters.

### Intra-arterial method

Invasive BP measurement provides accurate beat-to-beat information and is considered to be the gold standard. It is favoured because it regularly assesses arterial perfusion to the major organs, and evaluates cardiac function, circulating blood volume and physiological response

to treatment. The potential for complications, such as a spasm or emboli in the limb, has made the placement of these lines daunting, especially when the miniature size of the vessels makes cannulation difficult. General recommendations are to use peripheral sites, e.g. radial and posterior tibial arteries which have good collaterals, consider the umbilical artery in neonates, and use femoral or brachial arteries only if no other site is available. The SBP has been found to be slightly higher (5 mmHg), and the DBP lower (10 mmHg) using the intra-arterial method, than that found when using other noninvasive methods.

## The importance of blood pressure measurement

### Hypertension

The epidemiology of childhood hypertension varies from a low of 0.8% to a high of 5%.<sup>3,7</sup> Although there is a low prevalence of hypertension, the clinical impact of BP monitoring in children should by no means be considered to be negligible. This is based on the premise that BP "tracks" hypertension from childhood to adulthood. Persistently elevated BP readings, high body mass index (BMI), excessive weight gain and a family history of hypertension have a higher risk of long-term morbidity and mortality.<sup>5</sup> The long-term adverse consequences such as left ventricular hypertrophy, heart failure, strokes and intracranial hemorrhage, are almost entirely preventable with early intervention. Recognising this association, the National Heart Lung and Blood Institute and the American Academy of Pediatrics has long advocated the routine monitoring of BP in all children older than three years of age on an annual basis, or at least when conducting routine examinations.<sup>3,7</sup> The relevance for anaesthetists is that we are often the first to take the BP of an otherwise asymptomatic child.

Hypertension in children is diagnosed when resting BP (three repeated readings where "white coat hypertension" has been excluded) exceeds the 95<sup>th</sup> centile for age<sup>6</sup> (Table I). This guideline has proved to be useful in clinical practice, but ignores the changes which occur in BP over 24 hours, and the variability of the devices used. However if nothing else, these readings serve as a trend for early detection and follow-up.<sup>6</sup>

**Table I:** Classification of hypertension in children and adults<sup>8</sup>

Classification	Frequency of blood pressure measurement	
Normal	< 90 <sup>th</sup> percentile	Recheck at next scheduled physical examination.
Pre-hypertension	90 <sup>th</sup> to < 95 <sup>th</sup> percentiles or ≥ 120/80 at any age	Recheck in six months.
Stage 1 hypertension	> 95 <sup>th</sup> and < 99 <sup>th</sup> percentile, plus 5 mmHg	Recheck in 1-2 weeks, or sooner if patient is symptomatic. If persistently elevated on two additional occasions, evaluate or refer to hypertension specialist within one month.
Stage 2 hypertension	> 99 <sup>th</sup> percentile, plus 5 mmHg	Evaluate or refer to paediatric hypertension specialist, e.g. paediatric nephrology or paediatric cardiology, within one week or immediately, if symptomatic

There have been strong associations with paediatric hypertension in various clinical situations, including prematurity, chronic renal failure, obstructive sleep apnoea, obesity, neurocognitive function and hypotension.

### Prematurity

Johansson et al<sup>9</sup> reported that SBP and DBP is inversely associated with birthweight. So far, the underlying mechanisms are insufficiently understood. It is postulated that growth-restricted foetuses are exposed to adverse stress in utero. Such exposure may cause lasting activation of the sympathoadrenal tree. Similarly, low-birthweight infants have demonstrated increased heart rates and higher levels of circulating catecholamines, which bind and activate beta adrenergic receptors in the heart, and alpha receptors in the periphery, resulting in increased contractility and peripheral vasoconstriction, e.g. a rise in BP. The resultant state may manifest through infancy, even into adulthood. Interestingly, most of these studies were carried out using automated devices.

### Chronic renal failure

Hypertension is a common complication of chronic renal failure. The cause is multifactorial and includes volume overload and hormonal abnormalities, such as increased secretion of renin. The initial response to the fluid overload is an increase in cardiac output. Later, the cardiac output returns to normal, but the peripheral resistance becomes elevated because of peripheral vasoconstriction, resulting in hypertension. Intrinsic renal abnormalities, instead of fluid overload, may play a primary role in other children. Cardiovascular complications, e.g. left ventricular failure and pericarditis, are the most common cause of death in children receiving dialysis. Accurate BP measurement is especially crucial in this population. The oscillometric device has often been found to overestimate both SBP (by approximately 9 mmHg) and DBP (by roughly 6 mmHg) in the child with chronic renal failure.<sup>4,8</sup> This overestimation has led to an inappropriate classification of the child being hypertensive. Given these findings, auscultation should be used as a confirmatory measure in chronic kidney disease.

### Obstructive sleep apnoea

Childhood obstructive sleep apnoea (OSA) is widely recognised. It is noted that with an increase of severity of obstruction, there is also BP elevation. This is thought to be owing to a number of factors, particularly sympathetic nervous system activation that is secondary to arousal, and to some degree, chronic hypoxaemia. In a study conducted by Marcus et al,<sup>10</sup> respiratory disturbance independently predicted DBP, and BMI indicated SBP. In addition, evidence supports the assumption of potential endothelium dysfunction in children with OSA. This is most likely to be as a result of initiation and propagation of inflammatory responses within the microvasculature. McConnell et al<sup>11</sup> found that there was a decrease in

sympathetic variability associated with OSA in post-tonsillectomy. This points to the potential reversibility of the pathology if it is detected early.

### Obesity

There has been a worldwide increase in paediatric obesity. This has major health and economic implications. The Centers for Disease Control and Prevention has suggested the usage of percentile charts for BMI for individuals aged 2-20 years of age.<sup>12</sup> Children with a BMI between the 85<sup>th</sup> and 95<sup>th</sup> percentile should be regarded as overweight, those between the 95<sup>th</sup> to 99<sup>th</sup> percentile as obese, and those > 99<sup>th</sup> percentile as extremely obese. Obesity is a leading cause of hypertension and is often associated with type 2 diabetes mellitus (17%) and dyslipidaemia. This presents challenges in BP measurement, especially when using the percentile charts. The concern with these patients is the accelerated atherosclerosis and its complications in young adulthood.

### Neurocognitive dysfunction

Adams et al<sup>13</sup> conducted a study that found that children with a diagnosis of primary hypertension had higher rates of learning disabilities (28% in the hypertensive sample vs. 5% in the nonhypertensive sample), which were not accounted for by the usage of stimulants in the treatment of associated disorders. The reason for this dysfunction is not known. It is postulated from adult studies that essential hypertension may cause regional changes in the frontal lobe integrity. These changes may correlate positively with disease duration. Needless to say, although we are not often confronted with hypertension in children as anaesthetists, this forms part of the population of patients who can ill afford episodes of hypotension.

### Hypotension

Simple estimations of hypotension are based on the following in Table II.

However, most published work defines hypotension in children as a SBP below the 5<sup>th</sup> percentile for age. This is based on healthy children at rest, using the auscultatory method. Children who undergo general anaesthesia are not in their "normal" state of health, and intraoperative BP is most commonly recorded by the oscillometric method.<sup>1,14</sup> Recent studies have suggested that these values are inappropriate in critically ill or injured children.

**Table II:** Hypotension estimations<sup>2</sup>

Age	Blood pressure
Premature neonates	MAP < postconceptual age
Term neonates	SBP < 60 mmHg
Infants (1-12 months)	SBP < 70 mmHg
Children (1-10 years)	SBP < 70 mmHg + (2 x age)
Children > 10 years	SBP < 90 mmHg

MAP: mean arterial pressure, SBP: systolic blood pressure

The other question is whether or not SBP, DBP or MAP should be considered.

Nafiu et al<sup>1</sup> performed a survey of British and American paediatric anaesthetists to try establish the BP thresholds that are used to identify and treat intraoperative hypotension (IOH). Seventy-two per cent of the respondents worked at an academic institution, and 50% of them had been practising paediatric anaesthesia for > 10 years. Most indicated they used MAP or SBP to define IOH. Baseline BP was noted to be essential in defining clinically significant hypotension, and a majority reported that a 20-30% decrease in SBP from baseline indicated significant hypotension. Lack of a documented baseline BP, because of poor patient cooperation, and the fact that the procedure was an emergency, were some of the noted limitations. Their findings suggest that there is lack of evidence and knowledge on the definition of significant hypotension. It was felt that further studies were warranted.

In a different study, Nafiu<sup>14</sup> identified multiple risk factors for pre-incision hypotension. This included such factors as prolonged induction, difficulty with intravenous access, propofol and ASA classification  $\geq 3$ . In our environment, poor adherence to fasting guidelines and the potential of poor nutritional status may worsen the occurrence.

Furthermore, a higher percentage of published studies of hypotension use absolute or relative decreases in SBP values. There are very few objective data on the value of MAP nomograms for clinicians to use as a reference. Haque and Zaritsky<sup>13</sup> developed new estimates for values of a 5<sup>th</sup> percentile SBP (Table III), and created a table of normal MAP values as a reference. Their data suggest that the current values for hypotension are not evidence based and may need to be adjusted for patient height, but more importantly, for clinical condition. They found that most recommended values were lower than those in their study. The clinical formulas for the calculation of SBP and MAP in normal children are as follows.

Myers et al<sup>15</sup> compared absolute and relative rules with which to identify hypotension in children during anaesthesia. In their literature review, they found at least 50 different definitions for the incidence of hypotension in adults. These varied in type of BP (SBP vs. MAP), absolute and/or relative changes, and the duration of change. The conclusion of this study has shown that absolute definitions inadequately detect hypotension in children under anaesthesia, whereas relative rules provide robust mechanisms of detection.

Stricker et al,<sup>16</sup> who examined heart rate variability during hypotension in children younger than two years of age

**Table III:** Haque and Zaritsky's estimates

SBP (5 <sup>th</sup> percentile at 50 <sup>th</sup> height percentile) = 2 x age in years + 65
MAP (5 <sup>th</sup> percentile at 50 <sup>th</sup> height percentile) = 1.5 x age in years + 40
MAP (50 <sup>th</sup> percentile at 50 <sup>th</sup> height percentile) = 1.5 x age in years + 55

MAP: mean arterial pressure, SBP: systolic blood pressure

undergoing craniofacial surgery, defined hypotension as MAP < 40 mmHg for at least three computerised anaesthesia record entries. This yielded results similar to those by Haque and Zaritsky. Needless to say, most of the studies have not been able to establish a common definition that is tailored to a specific patient group or surgery, nor the duration and severity required for significant morbidity.

## Conclusion

BP measurement is not a simple matter of two numbers. It is a diagnostic medical tool which often derives from automated devices. Invasive intra-arterial measurement is often more precise, but has been found to be unpopular and difficult to use in normal day-to-day practice. It is also known that although MAP may serve as a surrogate, it does not directly reflect tissue perfusion. Perhaps, in current practice, it is important to remember not to rely only on the numbers that are read, but also on the clinical presentation of patients.

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