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**PAEDIATRIC NEPHROLOGY UNIT**

***In Association With***

IPNA
International Pediatric Nephrology Association

# PAEDIATRIC NEPHRO UROCON 2023

## PRE-CONFERENCE WORKSHOP

## BP MODULE

## 31/03/2023, FRIDAY

# HYPERTENSION IN CHILDREN AND ADOLESCENTS

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## Introduction

Hypertension in children and adolescents is becoming a significant global health problem due to an epidemic of obesity in the younger generation. Though secondary hypertension is common in younger age group, primary hypertension is also showing increasing trend. The prevalence of clinical hypertension in children and adolescents is approximately 3.5%. BP values are given based on gender, age, height and provided as $50^{th}$, $90^{th}$ and $95^{th}$ percentile. Normal blood pressure is defined as average systolic or diastolic blood pressure values below $90^{th}$ percentile (or < 120/80 mm Hg in children more than 13 years) for gender, age and height.

## Ideal BP measurement practices

1. The child should be seated with back support and feet on the floor in a quiet room for 3–5 min before measurement
2. BP should be checked in the right arm for consistency as well as to avoid false low value in case of coarctation of aorta. The arm should be at the level of heart, supported, and uncovered above the cuff. Patient and observer should not speak while measuring BP.
3. The correct cuff bladder length should cover 80–100% circumference of the arm, and the width should be at least 40%.
4. Check the disappearance of radial pulse by palpatory method and note down the BP. For auscultatory BP, keep the bell of stethoscope over the brachial artery in the antecubital fossa. The lower end of the cuff should be 2–3 cm above the antecubital fossa. Inflate the BP cuff to 20–30 mm Hg above the level at which the radial pulse disappears. Then the cuff should be deflated at a rate of 2–3 mm Hg per second. The first (phase I Korotkoff) and last (phase V Korotkoff) audible sounds should be taken as systolic and diastolic BP. If the Korotkoff sounds are heard till 0 mm Hg, then the muffled (phase IV Korotkoff) should be taken as the diastolic BP.
5. To measure lower limb BP, the child should be in the prone position. An appropriately sized cuff should be placed midthigh and the stethoscope over the popliteal artery. The systolic BP in the legs is usually 10%–20% higher than the brachial artery pressure. Definition and staging of hypertension have been listed in table 1. Screening BP values in

children is given in table 2. They need further evaluation if the BP cut off exceed these values. Common causes of hypertension are listed in table 3.

**Table 1: Definitions of hypertension**

| | **Children aged 1-13years** | **Children aged ≥13years** |
|---|---|---|
| Normal blood pressure (BP) | Systolic and diastolic BP <90$^{th}$ percentile | Systolic and diastolic BP < 120/80mmHg |
| Elevated blood pressure | BP between 90$^{th}$ to 95$^{th}$ percentile | 120/80 to 129/80 mmHg |
| Stage 1 hypertension | ≥95$^{th}$ percentile to <95$^{th}$ percentile + 12mmHg or 130/80 to 139/89mmHg (whichever is lower) | 130/80 to 139/89mmHg |
| Stage 2 hypertension | ≥95$^{th}$ percentile + 12mmHg or ≥140/90mmHg (whichever is lower) | ≥140/90mmHg |
| White coat hypertension | Child with BP levels above the 95th percentile in a physician's office who is normotensive outside the clinic | |
| Masked hypertension | Child with BP levels above the 95th percentile outside the physician's office who shows normal BP measurement in the clinic | |

**Table 2: BP values in children requiring further evaluation**

| **Age in years** | **Boys** | | **Girls** | |
|---|---|---|---|---|
| | Systolic BP | Diastolic BP | Systolic BP | Diastolic BP |
| 1 | 98 | 52 | 98 | 54 |
| 2 | 100 | 55 | 101 | 58 |
| 3 | 101 | 58 | 102 | 60 |
| 4 | 102 | 60 | 103 | 62 |
| 5 | 103 | 63 | 104 | 64 |
| 6 | 105 | 66 | 105 | 67 |
| 7 | 106 | 68 | 106 | 68 |
| 8 | 107 | 69 | 107 | 69 |
| 9 | 107 | 70 | 108 | 71 |
| 10 | 108 | 72 | 109 | 72 |
| 11 | 110 | 74 | 111 | 74 |
| 12 | 113 | 75 | 114 | 75 |
| ≥13 | 120 | 80 | 120 | 80 |

**Table 3: Common causes of hypertension in children**

| Age group | Common causes |
|---|---|
| Neonates | Thrombosis of renal artery or vein<br>Autosomal recessive polycystic kidney disease<br>Coarctation of aorta<br>Broncho pulmonary dysplasia |
| Children | Renal parenchymal disease (Acute glomerulonephritis, hemolytic uremic syndrome, reflux nephropathy)<br>Renovascular disease (renal artery stenosis, renal vein thrombosis)<br>Coarctation of aorta<br>Neuroendocrine tumors |
| Adolescents | Renal parenchymal disease<br>Renovascular disease<br>Endocrine causes of hypertension (hyperthyroidism, cushing syndrome, diabetes mellitus)<br>Primary hypertension<br>Drug induced/ Substance abuse<br>(Sympathomimetics, cortico steroids, anabolic steroids, calcineurin inhibitors, cocaine) |
| Transient hypertension in any age group | Increased intra cranial pressure, infection related glomerulonephritis, acute tubular necrosis, Guillain-Barre syndrome |

**Pathophysiology of hypertension**

Blood pressure is the product of cardiac output and total peripheral vascular resistance. Autoregulatory mechanisms maintain the blood flow of tissues according to their needs. Hypertension is classified as primary (essential) or secondary hypertension. Secondary form of hypertension is common in children and adolescents. The pathogenesis of essential hypertension is multifactorial including genetics, activation of sympathetic nervous system and renin-angiotensin-aldosterone system, obesity and increased salt intake in diet. Causes of secondary hypertension varies with different age group and the pathophysiology depends upon the underlying system involvement.

**Clinical features**

Childhood hypertension may present with failure to thrive, irritability, anorexia and poor growth. Hematuria, oliguria, skin rash, arthritis, edema, nasal bleed, palpitation, flushing, headache, seizures and altered sensorium are suggestive of glomerular causes of hypertension. Preterm/low birth weight babies and use of umbilical artery catheter in new born are at risk to develop hypertension. Obesity, sleep disturbance may give a clue towards

obstructive sleep apnoea causing hypertension. Excess intake of sodium, fructose, caffeinated beverages may predispose the children to hypertension. Physical examination should include growth assessment with body mass index and BP in both upper & lower limb. Look for malar rash, neurocutaneous markers, syndromic facies, hypertensive fundus changes, renal bruit/palpable kidneys and radio femoral delay.

**Screening investigations**

Urine analysis, complete blood count, renal function test and ultra sound abdomen are the screening investigations for all children with hypertension. Serum uric acid, HbA1c, fasting lipid panel, plasma glucose, thyroid function test, liver enzymes are needed in an obese child with hypertension. Complement C3, C4, antinuclear antibody (ANA), anti dsDNA, antineutrophil cytoplasmic antibody (ANCA), anti-glomerular basement (GBM) antibodies and renal biopsy are the specific investigations to find out the renal parenchymal and complement mediated vasculitis etiology. Plasma rennin activity, renal doppler, CT/MR angiography will be helpful in suspected reno vascular hypertension. DMSA and VCUG may be needed in suspected vesico ureteric reflux and reflux nephropathy. ECG and ECHO are needed to find out long standing hypertensive changes like left ventricular hypertrophy. Plasma or urine metanephrines, I-MIBG scan and CT/MRI abdomen have to be done in suspected pheochromocytoma. Plasma and urine steroid levels should be done in endocrine causes of hypertension. Polysomnography in obstructive sleep apnea, drug screening in suspected drug induced hypertension and genetic studies in suspected monogenic hypertension are the other tests needed depending upon the underlying clinical conditions.

**Management of hypertension in children and adolescents**

The goal of treatment is to reduce the BP to $<90^{th}$ percentile or <130/80mmHg whichever is lower. Dietary approach to stop hypertension (DASH) is one of the important therapeutic life style changes. Regular healthy diet with salt restriction (2 to 3g salt/day), intake of fresh fruits and vegetables in the diet should be ensured. Avoid calorie dense snacks, fatty dairy products, smoking and drug abuse. Moderate to vigorous physical activity for 30 to 60min/day for 3 to 5 days in a week and reduction of sedentary activity should be insisted. BP chart in percentile has been given for various age group, gender along with height percentile in table 5 and 6.

**Pharmacotherapy**

Children with symptomatic hypertension, hypertension due to secondary causes, co morbid conditions like diabetes mellitus, kidney diseases and failure of response to non-pharmacological measures are the candidates for antihypertensive medications. Commonly used anti-hypertensive medications are listed in table 4.

**Table 4: Antihypertensive drugs and dosages**

| **Drug** | Dosage | Adverse effects |
|---|---|---|
| **Calcium channel blockers** | | |
| Amlodipine | 0.1 to 0.6mg/kg/day up to 10mg/day (Maximum adult dose 20mg/day) | Flushing, peripheral edema, dizziness and rarely angioedema |
| Short-acting Nifedipine | Initial: 0.25 mg/kg /dose Q6 to 8hrly Maximum: 0.5 mg/kg /dose Q6 to 8hrly (Maximum adult dose 20mg Q6 to 8hrly) | |
| Extended-release Nifedipine | Initial: 0.25–0.5 mg/kg /day Q12hrly (Maximum adult dose 120 mg/day) | |
| **ACE inhibitors** | | |
| Captopril | Initial: 0.3–0.5 mg/kg/dose Q8hly to 6mg/kg/day (Maximum adult dose 450 mg/day) | Teratogenic drug. Cough and angioedema are common with captopril than the other drugs of this group. Check serum potassium, creatinine within 2 weeks of starting treatment and periodically once in 3 months. Discontinue if the fall in eGFR >30% from the baseline or eGFR is < 30ml/min/1.73m$^2$ |
| Enalapril | Initial: 0.08 mg/kg/ day up to 0.6 mg/kg/day Q12 to 24hrly (Maximum adult dose 40 mg/day) | |
| Fosinopril (≥6yrs of age) | 0.1 mg/kg/day (up to 5 mg per d) | |
| Lisinopril (≥6yrs of age) | 0.07 mg/kg/day (up to 5 | |

| | | |
|---|---|---|
| | mg per d) | |
| **Angiotensin receptor blocker** | | |
| Candesartan | 0.02 mg/kg/day (up to 4 mg per d) | |
| Losartan (≥6yrs of age) | Initial: 0.7 mg/kg /day up to 1.4 mg/kg /day Q24hrly (Maximum adult dose 100 mg/day) | |
| **β-Blocker** | | |
| Atenolol | Initial: 0.5–1 mg/kg /day to 2 mg/kg/ day Q12 to 24hrly (Maximum adult dose 100 mg/day) | Should not be used in asthma, heart failure and diabetes mellitus |
| Propranolol | Initial: 0.5–2 mg/kg /day Q 12hrly up to 4 mg/kg/ day (Maximum adult dose 240 mg/day) | |
| **Diuretics** | | |
| Hydrochlorothiazide | Initial: 1 mg/kg /day to 3 mg/kg / day Q12 to24hrly (Maximum adult dose 50 mg/day) | Periodic electrolytes measurement is needed. Potassium supplement may be needed. |

## CASE SCENARIO 1

**History**:
13years old boy presented with headache for a week and seizure one episode. No history of fever, edema, joint pain, rashes or hematuria. History of recurrent urinary tract infection in the past. He received multiple antibiotic courses in the past.

1. What are the differential diagnoses?
2. Plot the BP centile
3. Investigations
4. Management

| | | | |
|---|---|---|---|
| Hematuria, edema, sore throat/ healed impetiginous lesions<br>**Infection related glomerulonephritis** | Skin rash, arthralgia and hypertension<br>**Connective tissue disorder** | Recurrent UTI, growth retardation, rickets, hypertension<br>**Chronic kidney disease** | Sweating, flushing, headache<br>**Endocrine/Cardiac causes** |

**On examination**

His BP was180/120mmHg, height and weight were 125cm and 26kg. Peripheral pulses were well felt. After recovering from seizures, system examination was normal.

**Analysis of history and examination**

He had stage 2 hypertension. His height and weight were < 3$^{rd}$ centile.

**Diagnosis**

Stage 2 hypertension secondary to chronic kidney disease, hypodysplastic kidneys

**Investigations**

CBC – normal, S.Creatinine – 3.4mg/dL, S.Electrolytes (Na/K/$Cl_2$/$Hco_3$) – 142/5/103/12mEq/L

USG: RK: 6cm; LK: 7cm. Increase in Echogenecity. UB-Normal. ECHO- Left ventricular hypertrophy with ejection fraction of 65%. MCU: B/L Gr V VUR

2. A 10 years old male is brought to the ER with h/o cola urine, periorbital edema, oliguria, occipital headache, dizziness and vomiting for 2 days. Child had recently been diagnosed have impetigo and had undergone treatment.

- What is the possible diagnosis?
- Plot the BP centile
- Investigations
- Management

3. 7years old boy child is diagnosed to have steroid resistant nephrotic syndrome. His BP is 130/90mmHg. What is the cause of hypertension? RFT: BUN: 18; S.Creatinine: 0.6mg/dL. How will you manage?

4. 10years old boy child on routine school check found to have BP of 140/80mmHg. His height and weight are >90$^{th}$ centile. RFT, USG abdomen: Normal. What other investigations will you do?

5. 5yrs old girl presented with headache, vomiting. Both height and weight are on the 3$^{rd}$ centile. BP: 150/90mmHg. No significant BP discrepancies between limbs. S. Creatinine: 0.6, S.Electrolytes: 135/3.2/98/23. Urine routine: Normal. USG: RK: 7cm, LK: 5cm. What is the possible diagnosis? Plot the BP centile. Investigations and management

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## INVASIVE BP MONITORING

**Dr Raja Kumar P S and Dr Nikitha Abirami**

### INTRODUCTION

Intra-arterial catheters are often inserted for invasive blood pressure (BP) monitoring and intravascular access for blood sampling in high-risk surgical and critically ill patients. The most common way to do this is arterial pressure monitoring via the cannulation of a peripheral artery. Each cardiac contraction exerts pressure, which results in mechanical motion of flow within the catheter. The mechanical motion is transmitted to a transducer via a rigid fluid-filled tubing. The transducer converts this information into electrical signals, which are transmitted to the monitor. The monitor displays a beat-to-beat arterial waveform as well as numerical pressures. This provides the care team with continuous information about the patient's cardiovascular system and can be used for diagnosis and treatment

### INDICATIONS

- Critically ill patients in the ICU who require close monitoring of hemodynamics.
- Patients being treated with vasoactive medications, to titrate the medication to the desired blood pressure effect safely.
- Surgical patients at increased risk of morbidity or mortality, either because of preexisting comorbidities (cardiac, pulmonary, anemia, etc.) or because of more complicated procedures.
- Identification of abnormal arterial waveform patterns

- Evaluation of respirophasic variations in the arterial pressure waveform to predict fluid responsiveness – Visual estimates or manual calculations of systolic pressure variation (SPV) or pulse pressure variation (PPV) are possible
- Frequent blood sampling

## CONTRAINDICATION

- Infection
- Lack of collateral circulation resulting in vascular insufficiency
- Formation of a hematoma
- Formation of an arteriovenous (AV) fistula
- Stenosis of vessel

## SITE SELECTION

- The initial step in selection of a catheterization site is the location of a palpable arterial pulse.
- Common sites include peripheral arteries (radial [most common], or dorsalis pedis sites) and central arteries (femoral [most common] or axillary sites).

### Checking for collateral flow

Prior to radial arterial catheterization, a check for collateral flow to the hand is performed to identify possible risks for an ischemic complication.

A physical examination that includes the Allen test or modified Allen test is often employed, although there is significant interobserver variability, and the test lacks predictive accuracy for subsequent hand ischemia. Color Doppler ultrasonography can also be used

- Immobilization after insertion for maintenance of catheter integrity.

## INSERTION TECHNIQUES

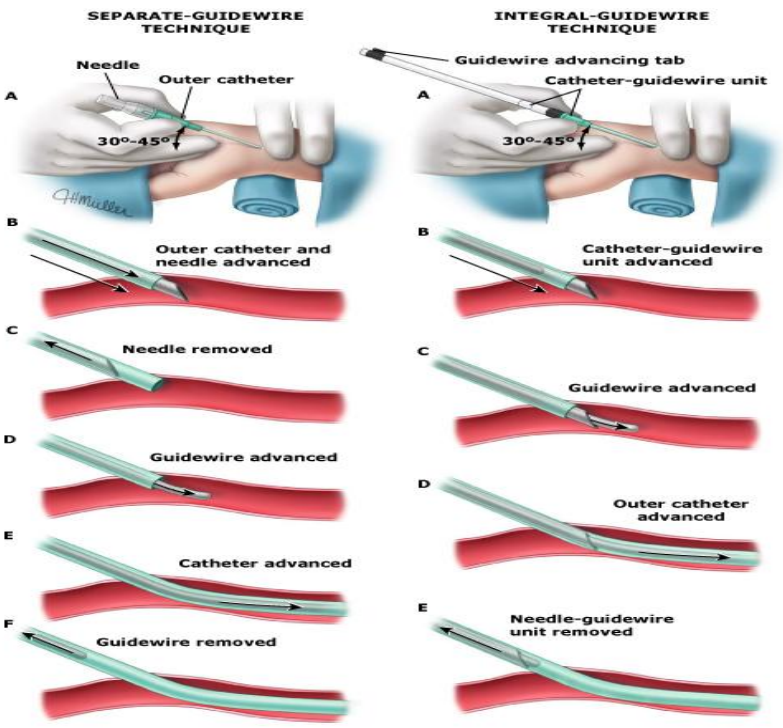
Arterial catheterization should be performed using standard sterile precautions

*Local anesthetic injection* — use local anesthesia at the site of insertion in conscious patients; may reduce vasospasm

*Use of ultrasound guidance* — decrease risk of hematoma formation or presence of a pseudoaneurysm or arteriovenous fistula, prevent injury to nearby structures.

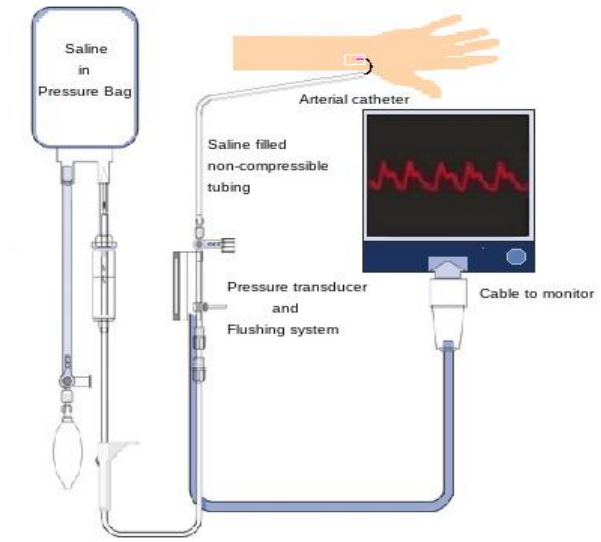
For all approaches to arterial catheterization, the operator's nondominant hand gently palpates the artery, while the dominant hand manipulates the intravascular catheter (an outer catheter over a needle).

*Specific approaches include*:



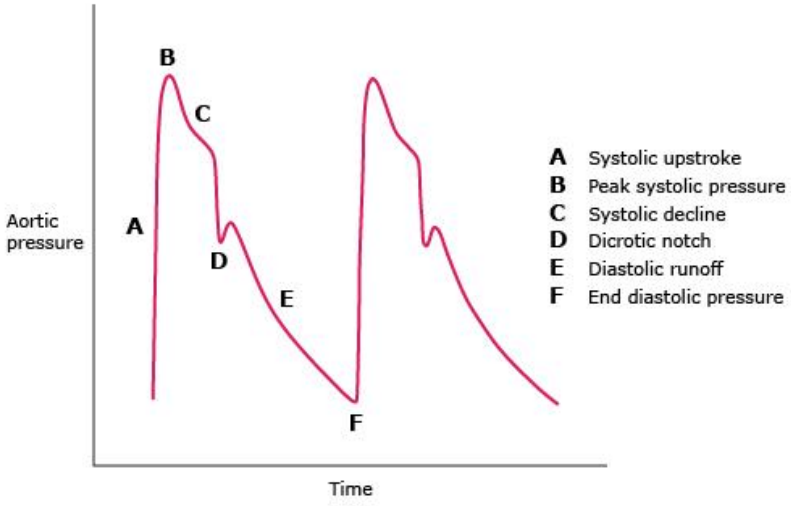

*Direct puncture* – For the direct puncture approach, while the nondominant hand gently palpates the artery, the intravascular needle-catheter unit is inserted by the dominant hand at a 30-to-45-degree angle and advanced slowly until pulsatile blood return is obtained. Then the angle of the needle-catheter unit is decreased, so that the needle-catheter unit is more parallel to the skin. The needle-catheter unit is then slowly advanced another millimeter or two, assuring that blood return continues and that not only the inner needle tip, but also the catheter tip is now within the arterial lumen. The outer catheter is then advanced into the artery directly from the needle without the aid of a guidewire, and the needle is removed.

*Catheter stabilization* — All equipment should be prepared in advance, including syringes with flush solution and the tubing that will be connected to the arterial catheter. Once the catheter is advanced into the artery, the needle is removed. The artery should be compressed proximal to the catheter to prevent bleeding after removing the needle and during connection of the pre-flushed arterial tubing. Finally, the catheter should be secured via sutures or with a transparent adhesive dressing.



## MONITORING BLOOD PRESSURE

Interpretation of the arterial waveform tracing — The arterial waveform results from ejection of blood from the left ventricle into the aorta during systole, followed by peripheral runoff during diastole.




The systolic upstroke represents the systolic ventricular ejection. The peak systolic pressure is followed by a rapid decrease in pressure as ventricular contraction ends (ie, the systolic decline). The dicrotic notch (ie, the incisura) represents the closure of the aortic valve, which indicates the start of diastole. The pressure throughout diastole is the primary determinant of left ventricular blood flow.

- *Mean arterial pressure*

  MAP is the mean pressure averaged over several cardiac cycles at the measurement site. It represents the area under the curve during a single beat.

- *Pulse pressure*

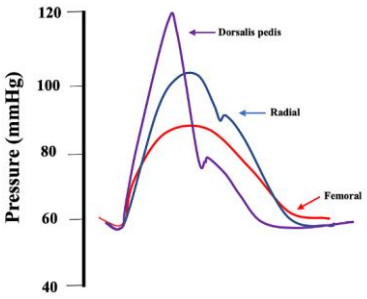
  Pulse pressure is the difference between systolic and diastolic pressures. Decreases in a patient's pulse pressure relative to baseline are typically caused by hypovolemia, decreases in stroke volume (SV), or increases in systemic vascular resistance (SVR). Increases in a patient's pulse pressure relative to baseline are caused by increases in SV and/or decreases in SVR (eg, during exercise).

  Pulse pressure variation (PPV) may be used to assess intravascular volume status.

- *Additional systolic and diastolic pressure parameters*

  •The slope of the systolic upstroke is generally related to left ventricular contractility, although other hemodynamic variables affect this relationship. For example, this slope becomes steeper as the waveform is measured further from the aorta.

  •The slope of the diastolic decline in pressure (i.e., diastolic runoff) varies with resistance in the arterial tree. If stroke volume is constant, diastolic runoff decreases sharply if SVR is low (e.g., vasodilator therapy, septic shock), but is more gradual if SVR is high (e.g., vasoconstrictor therapy, severe heart failure)

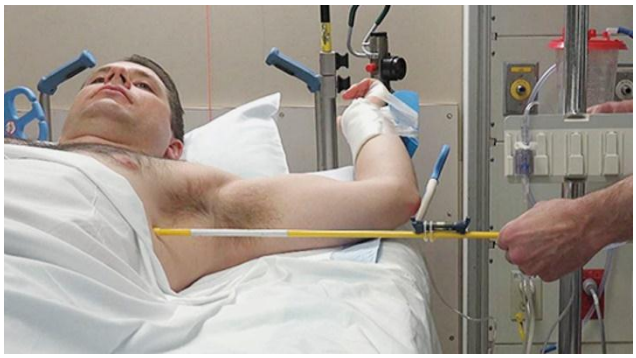



**Factors affecting measurement of blood pressure —**

**Site of arterial catheterization**

- Arterial pressure waveforms change as the pressure wave moves from the aorta to the periphery.

- Peripheral arterial waveforms have a higher systolic BP, steeper systolic upstroke, lower diastolic BP, lower and later dicrotic notch, and wider pulse pressure compared with measurements obtained at the aortic root. These changes are the result of the decreased diameter of peripheral blood vessels, their elasticity, and wave reflections off the peripheral vessel branch points and walls.



**Transducer level** — The pressure transducer should be leveled to a point that corresponds with the level of the heart, aiming for 5 cm behind the sternum in a supine patient. Alternatively, the mid-axillary line is used as an appropriate reference level. In either right or left lateral decubitus position, the transducer should be leveled at the mid-sternum

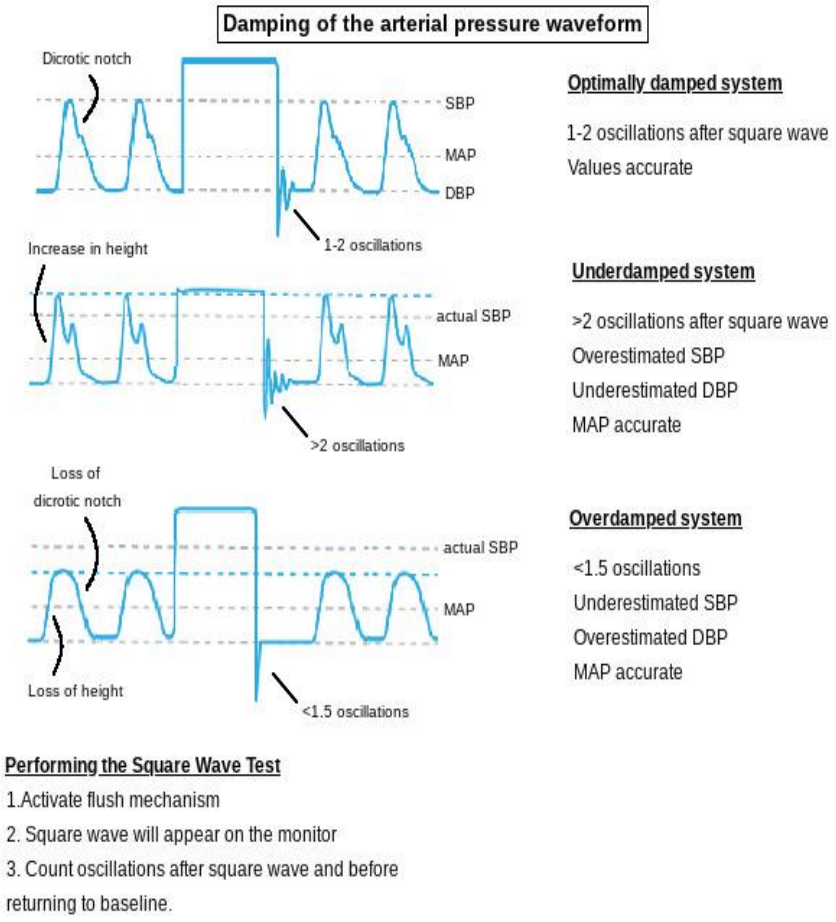
The bedside monitor pressure zero button is then selected, which assigns atmospheric pressure to be zero. The stopcock is then closed to air and adjusted to the height that will best align it with the level of the heart as described above. Note that the pressure transducer need not be re-zeroed when transducer height is adjusted slightly to align it appropriately with the patient. However, the transducer must always be zeroed before monitoring begins, whenever the electronic pressure monitoring cable is disconnected, and when BP accuracy is in question

Over-damping or under-damping of the pressure tracing — The arterial catheter, noncompliant tubing, and three-way stopcocks used for invasive monitoring each change the degree of damping of the pressure waveform between the artery and the transducer that measures it

**Rapid flush test**

Whether the degree of damping (ie, dynamic response) in a monitoring system is appropriate can be assessed at the bedside by the rapid-flush test. This test is performed by briefly opening and closing the valve in the continuous flush device (rapid flushing), which produces a square wave on the monitor. The square wave is followed by, "ringing" (rapid oscillations in pressure), then a return to baseline. Over- or under-damping may be present.

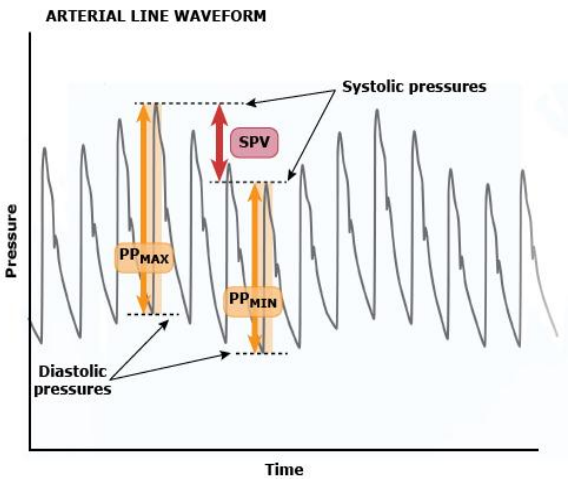
Intravascular pressure tracings obtained during the rapid flushing of a monitoring catheter.




A. Optimal damping in which rapid flushing produces a rapid upstroke in pressure followed by recovery characterized by a fall in pressure to below baseline with less than three beats of ringing.
B.Over-damping – No ringing is observed after a rapid flush of an over-damped system. Common causes of over-damping include air bubbles or clots in the connecting tubing, loose connections, kinks, or arterial spasm.
C.Under-damping – Excess ringing is observed after a rapid flush in an under-damped system. Common causes of under-damping include excessive tubing length, tubing connected with stopcocks, and patient factors such as tachycardia, high cardiac output, or hypothermia

## MONITORING INTRAVASCULAR VOLUME STATUS

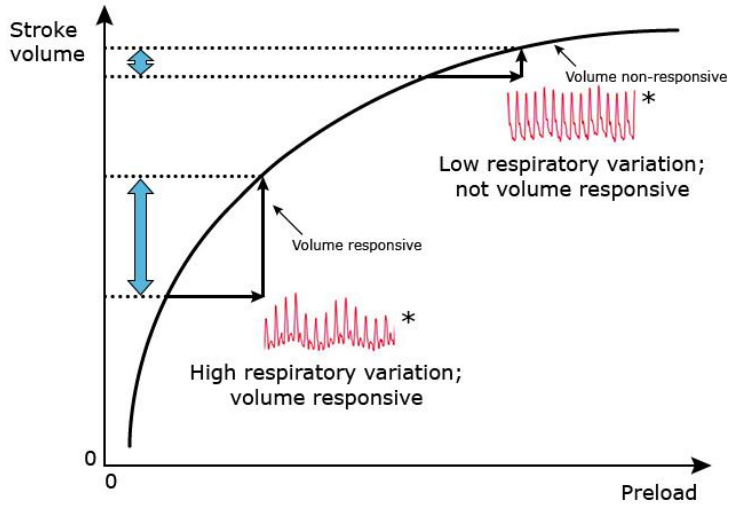
Interpretation of respiratory variation — Variations in the arterial waveform that occur during respiration (eg, pulse pressure variation [PPV] or systolic blood pressure variation [SPV], stroke volume variation [SVV]) can be observed or measured to assess responses to fluid challenges.




Respiratory variations in arterial pressure **during positive pressure mechanical ventilation with Tidal volume 8ml/kg in heavily sedated patients without spontaneous breathing and in sinus rhythm.**

SPV is a direct measurement of the difference between the highest systolic blood pressure ($SBP_{MAX}$) and lowest systolic blood pressure ($SBP_{MIN}$) values occurring over a respiratory cycle and is reported in mmHg. In contrast, PPV is reported as a percentage and is equal to the difference between the maximal PP ($PP_{MAX}$)

and the minimal pulse pressure ($PP_{MIN}$) divided by the average of these two values ($PP_{MEAN}$ = [$PP_{MAX}$ + $PP_{MIN}$]/2). To account for slight variations between respiratory cycles, both SPV and PPV are usually measured over three or more breaths, and an average value is then reported.




## COMPLICATIONS

- Bruising, pain, swelling, hematoma or bleeding at the insertion site
- Local or systemic infection
- Vasospasm — initial sign in arteries that develop thrombosis. Vasospasm is identified by pain in the extremity, decrease in arterial blood pressure (BP), severe damping of the arterial waveform, loss of the arterial pulse.
- Thrombosis — Arterial thrombosis can be suspected in patients with decreased distal pulses, dampened or lost arterial waveform, or cyanotic digits. In rare cases, gangrene may occur.

  Risk factors for thrombosis include
  1. Increased duration of catheterization (ie, >72 hours)
  2. Larger catheters
  3. Smaller blood vessels
  4. Low flow states (eg, low cardiac output)
  5. Peripheral artery disease
  6. Vasospastic disorders (eg, Raynaud phenomenon)

Use of heparinized solution flushed with continuous pressure at a heparin dose of 1 to 2 international units/mL helps in maintaining patency. Saline flushes can also be used.

- Particulate embolism
- Air embolism — 2 mL of air injected into the radial artery with a standard pressurized infusion apparatus results in clinically significant cerebral air emboli
- Accidental intra-arterial injection of medications — may lead to limb or other end-organ ischemia or damage due to formation of drug crystals, hemolysis and platelet aggregation due to vessel intima damage, or profound vasoconstriction and subsequent thrombosis (eg, due to norepinephrine injection)
- Dissection, pseudoaneurysm, arteriovenous fistula — It presents as a pulsatile mass and typically occurring after local site bleeding and/or hematoma formation. Such damage to the arterial wall is associated with multiple cannulation attempts, larger sheath size, anticoagulation, and catheter infection

- Local or systemic infection — poor aseptic technique during insertion, insertion by surgical cut-down, and longer duration of use (≥4 days)
- Iatrogenic blood loss
- Site-specific complications
  Radial artery - peripheral neuropathy
  Femoral artery - retroperitoneal hematoma
  Axillary artery - brachial plexopathy

**Removal** - For patients with known coagulopathy, compression times should be increased to ten minutes over the radial artery and 15 to 20 minutes over the femoral artery. If oozing continues, the artery should be compressed for five additional minutes and rechecked.

**HYPERTENSION IN PICU**

- Hypertension in PICU can be due to:

1. Vasoconstriction from hypothermia, low cardiac output, vasopressors
2. Pain, Anxiety, consciousness
3. Fluid overload
4. Hypercarbia
5. Hypoglycaemia
6. Full bladder
7. Seizures

- Never assume that hypertension is due to a hyperdynamic LV. It may be due to vasoconstriction associated with a low cardiac output. Withdrawal of inotropes may lead to rapid deterioration in cardiac output.
- Volume to increase preload will often be needed as vasodilators are introduced.

**Management:**

(1) Examine chest (movement, air entry), abdomen (full blader), pupils/ eyes (fits). Check Blood gas (CO2) and glucose.
(2) Analgesia/ Sedation – Give Fentanyl bolus and reassess; Give Midazolam bolus and reassess.
(2) If hypothermic, active rewarming
(3) Control shivering
(4) **Drugs**

**Definitions and Staging of Hypertension**

If percentiles of systolic and diastolic pressures are different, the higher percentile is used for defining and staging hypertension.

| | |
|---|---|
| **Normal BP** | < $90^{th}$ centile |
| **Prehypertension/Elevated BP** | 90-$95^{th}$ centile |
| **Hypertension – stage I** | >$95^{th}$ but < ($95^{th}$ + 12mm) |
| **Hypertension – stage II** | >($95^{th}$ + 12mm) |

Centile BP should be seen from chart based on sex, weight and height.

## ACUTE HYPERTENSIVE CRISIS

**Hypertensive emergency** - Stage 2 hypertension with acute, life threatening target organ damage involving central nervous system (encephalopathy, seizures), heart (pulmonary edema) or kidneys (acute renal failure).
Hypertensive encephalopathy is characterized by lethargy, dullness, headache, seizures and visual disturbances including blindness. Cerebral infarction, hemorrhage and facial nerve palsy may occur. Neuroimaging shows features of white matter degeneration in the parieto-occipital area (posterior leukoencephalopathy), which are reversible with treatment. Examination of the retina might shows hemorrhages, exudates or papilledema. Acute left ventricular failure is another life-threatening complication of severe hypertension.

**Hypertensive urgency** – Stage 2 hypertension but no evidence of acute target organ damage. There is less dramatic symptoms (*e.g.*, headache and/or vomiting), but are at risk for progression to hypertensive emergencies.
The occurrence of these complications is related to the rate of rise and duration of hypertension, rather than absolute blood pressure values. While hypertensive **emergencies** require reduction of blood pressure within hours, the same can be achieved slowly in patients with hypertensive **urgencies**.

**Management of Hypertensive emergencies**
Blood pressure levels are usually 5-15 mm above the 99th percentile, and should be reduced to safe levels. Rapid reduction of blood pressure might, however, compromise blood flow and result in ischemic complications in the brain, retina, spinal cord and kidneys. Blood pressure reduction, therefore, must be regulated in order to prevent end organ damage to these organs.

| Calculate difference between observed and desired ($95^{th}$ centile) = X | |
|---|---|
| First 3-4 hours | 25-30% of X (desired reduction) |
| Next 24 hours | Another 25-30% of X (desired reduction) |
| Next 2 days | Reduction to desired level ($95^{th}$ centile) |

1) Agents of choice include short acting, intravenous (IV) preparations that are titrated to response (sodium nitroprusside, nitroglycerine, labetalol and nicardipine).
2) Therapy with enteral antihypertensive drugs should be instituted within 6-12 hr of parenteral therapy, and the latter gradually withdrawn over the next 12-24 hr.

**Sodium nitroprusside** is the agent with the longest track record, readily available and the least expensive of all parenteral drugs. Initially infused at a rate of 0.5-1 mics/kg per minute, the dose may be increased in increments of 0.5 mics/kg per minute, every 15 minutes, if the desired reduction is not achieved, upto 10 mcg/kg/min. Blood pressure is continuously monitored by IBP monitoring. pupillary reflexes, visual acuity and level of consciousness are also monitored. Loss of pupillary reflex to light is an early indicator of retinal vascular ischemia, requiring immediate infusion of normal saline. Patients receiving nitroprusside at doses exceeding 2-3 mics/kg per minute for longer than 48 hr (or > 1 mg/kg over 12 -24 hrs) are at risk of cyanide toxicity, and even earlier if there is hepatic or renal dysfunction. SNP syringe and tubing must be covered with black foil as it is photosensitive.

**Nitroglycerine** (0-5 mcg/kg/min). It can be rapidly increase to 5mcg/kg/min. It is predominanatly venodilatory, less potent vasodilator.

**Nifedepine** The risks of side effects due to sudden fall of blood pressure are limited, particularly if the dose of nifedipine is between 0.1-0.25 mg/kg. The response to short acting nifedipine might be inconsistent and unpredictable (requiring more than one dose) or uncontrolled (sudden fall of blood pressure).

**Diuretics** Diuretics should be avoided unless specifically indicated for volume overload as occurs in glomerulonephritis coexisting pulmonary edema.

**Enalapril:** 0.1-0.6 mg/kg/day 6hrly

**Metoprolol** 1-2 mg/kg BD PO esp if tachycardic and hypertensive

**Hypertensive urgencies**
Controlled reduction of blood pressure, using oral medications, over several hours-days is desirable. Effective oral agents include nifedipine, clonidine and labetalol.

**Nifedepine** - The onset of action of nifedipine (0.25 mg/kg, maximum 10 mg) administered orally is within 5-10 min, peaks at 30-60 min and lasts for 2-6 hr. Children show reflex tachycardia

**Clonidine** - Oral administration of clonidine (0.05-0.1 mg) is also effective, although the onset of action (30-60 min) and peak effect (2-4 hr) is delayed. Sedation and orthostatic hypotension occurs in many patients.
Patients with hypertensive urgencies should be observed closely, since use of IV medications might be required.

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2. Joseph T. Flynn, David C. Kaelber, Carissa M. Baker-Smith, Douglas Blowey, Aaron E. Carroll, Stephen R. Daniels, Sarah D. de Ferranti, Janis M. Dionne, Bonita Falkner, Susan K. Flinn, Samuel S. Gidding, Celeste Goodwin, Michael G. Leu, Makia E. Powers, Corinna Rea, Joshua Samuels, Madeline Simasek, Vidhu V. Thaker, Elaine M. Urbina, SUBCOMMITTEE ON SCREENING AND MANAGEMENT OF HIGH BLOOD PRESSURE IN CHILDREN; Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents. *Pediatrics* September 2017; 140 (3): e20171904. 10.1542/peds.2017-1904.
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**Case Scenario 1:**

9-year-old girl admitted with h/o cola colored urine *2days, c/o reduced urine output, c/o periorbital puffiness* 2 days; h/o seizures- GTCS lasting 5mins, post ictal less than 15 mins; regained normal sensorium. O/E: HR- 130/min; BP- 150/90mmHg; +++/++; CRT < 2secs; RR- 18/min, No added sounds. GCS- 11/15; B/L PERL.

a. Assessment?
b. Staging of Hypertension?
c. Is it Hypertensive Emergency or Urgency?
d. What drug you want to start?
e. How will you monitor?
f. How to set target BP and how fast to reduce BP?
g. If the same child presents without CNS symptoms but only headache- What will be the management plan?

**Case Scenario 2:**

7 year old boy referred to our hospital with Bi-Cytopenia and elevated total counts (TC 1,30,300/$mm^3$). O/E: HR- 110/min; BP- 100/60mmHg; +++/++; CRT < 2secs; RR- 20/min, No added sounds. GCS- 15/15; B/L PERL. Evaluated for leukemia. Peripheral smear showed 30% Blasts with Hb- 7g%; TC- 2Lakhs/$mm^3$; Plt- 9000/$mm^3$. Child was started on supportive measures, hyperhydration, chemotherapy and platelet transfusions, as needed. Same day evening, child developed posturing with unequal pupils; HR-62/min; BP- 160/110mmHg and child was intubated and ventilated in view of low GCS.

a. What is the cause of HTN?
b. Staging?
c. How do you treat?
d. How to set target BP & how fast to reduce BP?

**Case scenario 3:**

4month old baby with h/o fever & lethargy, poor feeding * 3 days. Last passed urine- last night. O/E: HR- 192/min; +++/+; CRT – 2 secs; Warm peripheries; BP- 76/30mmHg; RR- 55/min; SpO2- 93% in RA; T- 102.2 F; Wt- 5kg.

a. Assessment?
b. Type of shock?
c. How to treat?
d. How to monitor?

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# Blood pressure variations in neonates

## Dr.S.Md.Shafi Jan, Associate professor, Department of neonatology

**Introduction:**

Monitoring, management of blood pressure (BP) and cardiovascular assessment in a neonate is challenging due to the presence of multiple disease processes, unpredictable adaptation to extrauterine life, and difficulty assessing organ perfusion. Neonatal hypotension is usually because of the abnormal peripheral vaso regulation or myocardial dysfunction. It is very rarely due to hypovolemia. The definition of hypotension in neonates varies. Hypotension is associated with an increased likelihood of adverse outcomes. Low blood pressure in extreme preterm (EPT) infants with adequate perfusion may not be an independent risk factor for poor outcome. Till date the threshold for intervention and benefits of intervention are not well established.

**Management of Hypotension in the Neonate**

**Definition of Hypotension:** Blood pressure (BP) is used as a marker of systemic perfusion. But blood pressure correlates weakly with cardiac output.

Adequate peripheral perfusion – Signs of adequate peripheral perfusion include warm, pink skin with capillary refill <4 seconds and strong pulses to all extremities, good urine output, no laboratory evidence of end-organ dysfunction (eg, lactic acidosis).

Poor peripheral perfusion – Signs of poor peripheral perfusion may include delayed capillary refill, mottling of the skin, cool extremities, weak pulses, oliguria, metabolic acidosis, and elevated serum lactate level.

**Preterm neonates:** Various definitions of hypotension are used in preterm infants.

- Mean arterial blood pressure (MAP) below the 10th centile for gestation/birth weight and postnatal age.
- MAP below an infant's gestation age in weeks.
- Isolated hypotension in a stable preterm neonate with no signs of poor perfusion is considered as permissive hypotension.

**Table -1: MAP & 10th Percentile BP by hours of postnatal age**

| Wt grams | Hours postnatal age | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 |
| 500 | 35/23 | 36/24 | 37/25 | 38/26 | 39/28 | 41/29 | 42/30 | 43/31 | 44/33 |
| 600 | 35/24 | 36/25 | 37/26 | 39/27 | 40/28 | 41/29 | 42/31 | 44/32 | 45/33 |
| 700 | 36/24 | 37/25 | 38/26 | 39/28 | 42/29 | 42/30 | 43/31 | 44/32 | 45/34 |
| 800 | 36/25 | 37/26 | 39/27 | 40/28 | 41/29 | 42/31 | 44/32 | 45/33 | 46/34 |
| 900 | 37/25 | 38/26 | 39/27 | 40/29 | 42/30 | 43/31 | 44/32 | 45/34 | 47/35 |
| 1000 | 38/26 | 39/27 | 40/28 | 41/29 | 42/31 | 43/32 | 45/33 | 46/34 | 47/35 |
| 1100 | 38/27 | 39/27 | 40/29 | 42/30 | 43/31 | 44/32 | 45/34 | 46/35 | 48/36 |
| 1200 | 39/27 | 40/28 | 41/29 | 42/30 | 43/32 | 45/33 | 46/34 | 47/35 | 48/37 |
| 1300 | 39/28 | 40/29 | 41/30 | 43/31 | 44/32 | 45/33 | 46/35 | 48/36 | 49/37 |
| 1400 | 40/28 | 41/29 | 42/30 | 43/32 | 44/33 | 46/34 | 47/35 | 48/36 | 49/38 |
| 1500 | 40/29 | 42/30 | 43/31 | 44/32 | 45/33 | 46/35 | 48/36 | 49/37 | 50/38 |

**Term neonates:**

Hypotension in term neonates is less common than preterm neonates and has a wider range of reasons than in preterm infants. Isolated hypotension is uncommon in term neonates thus permissive hypotension in term babies is not considered normal.

**Term neonates - First 48-72 hours of life (transition period):**

MAP below the third percentile for the the gestational age is considered as hypotension. If a large patent ductus arteriosus (PDA) is present the MAP may be reduced significantly, in which case the systolic blood pressure may be a more accurate marker of the baby's cardiovascular stability.

**After the first 48-72 hours of life (post transition):**

BP Values for different gestational ages are as given in table -2.

| Corrected Gestational Age (wks) | Systolic Blood Pressure (mmHg) | Mean Blood Pressure (mmHg) |
|---|---|---|
| **23-26** | 35-45 | 30 |
| **27-32** | 40-55 | 35 |
| **33-36** | 45-55 | 40 |
| **37-42** | 55-65 | 45 |

**Measurement of Blood Pressure**

**Oscillometric cuff measurement**

The commonest and most widely used non-invasive method for measuring blood pressure in the neonatal intensive care unit is the automated oscillometry. This device detects the maximum blood pressure oscillations from the arterial blood flow as mean blood pressure

(MBP), which is then converted into the projected systolic and diastolic BP by utilizing standard proprietary algorithms.

The oscillometric BP measurements generally correlate well with the invasive intra-arterial readings. It may overestimate the intra-arterial SBP values by 3 to 8 mm Hg, thereupon over-diagnosing hypertension. It may become inaccurate when MAP drops below E30 mm Hg, thus missing hypotension. The device may also underestimate SBP in small for gestational age infants.

**For accuracy**, the optimum cuff width is suggested to be in a ratio of 0.45 to 0.70 with the arm circumference, cover 80% of the length of the arm, and the size should be standardized for uniformity in the results. The BP becomes erroneously high if the cuff size is too small.

**At the time of measurement**, the infant should be lying in a supine position, quietly awake, calm, preferably sleeping, and about 1 to 1.5 hours postprandial. A minimum of three readings, 2 minutes apart, should be taken in the right arm as the preferred site.

**Sphygmomanometer** is not recommended because the Korotkoff sounds are not loud enough to be reliably audible in this age group of infants.

**Ultrasound Doppler** is rarely used as a regular BP monitoring device as it can underestimate the SBP values.

**Invasive Method**

The gold standard for blood pressure measurement and continuous monitoring is invasive intra-arterial monitoring of blood pressure using an indwelling catheter in one of the umbilical, radial, or the posterior tibial arteries. It should be connected to a pressure transducer and to the multichannel display patient monitor. The associated and significant risks of arterial line should be considered before insertion of an arterial line. This method is generally reserved for sick and unstable infants, and for those who are extremely premature.

**The following precautions should be taken while measuring the blood pressure intra-arterially with the transducer**.

- The transducer should be positioned at the level of the heart.
- The transducer should be irrigated with a continuous heparin infusion.
- The umbilical catheter should be of appropriate size.
- A narrow catheter will falsely decrease the systolic blood pressure (SBP).
- A dicrotic notch should be seen on the arterial waveform.
- There should be no air bubbles in the tube, as their presence might increase DBP and decrease SBP.
- Tubing should be of low compliance and the smallest acceptable length, as an increase in the length will falsely decrease the values.
- The pressure transducer should be set at zero atmospheric pressure as the reference point.
- The umbilical artery catheter should be removed, preferably after 5 to 7 days, as prolonged catheterization may increase the risk of thrombus formation, leading to false readings.

**Etiology for Hypotension**

- Prematurity
- Sepsis
- Haemorrhage – APH, cord prolapse, twin to twin transfusion syndrome, large intracranial haemorrhage, large pulmonary haemorrhage
- Positive pressure ventilation (particularly with high mean airway pressures and HFOV)
- Large Patent Ductus Arteriosus – ductal steal can reduce MAP and coronary artery blood flow
- Congenital cardiac disease
- Adrenal insufficiency
- Hypoxic ischaemic encephalopathy (HIE).
- Persistent Pulmonary Hypertension of the Newborn (PPHN)
- Drugs – morphine infusions, maternal labetalol treatment
- Lack of antenatal steroids prior to delivery
- Surgical intervention

**Diagnosis**

**Clinical assessment of signs and symptoms of inadequate tissue perfusion may include:**

 Low blood pressure for gestational age, Urine output (alone is a poor indicator but useful if associated with other features), Base deficit >5, Lactate >2mmol/L, Pallor,  Tachycardia , Cold extremities, Weak pulses (femoral palpation best in hypotensive infants), Apnoea and Bradycardia

**Monitoring Infants with hypotension should ideally be monitored closely:**

 Continuous monitoring of mean arterial pressure (if arterial access available)

 Cuff BP set to 15 minute readings (if arterial access not available)

 Continuous heart rate and saturation monitoring

 Central capillary refill time (In neonates it is assessed only over sternum)

 Urine output

 Core-peripheral temperature gap (>2$^{o}$Cis abnormal)

 Regular blood gas/lactate monitoring

**Echocardiography (if expertise is available) may detect the presence of:**

PDA (which may be contributing to hypotension), pulmonary hypertension (PPHN), poor cardiac contractility, congenital cardiac disease (duct dependent heart disease)

**Consider contributing causes**

Blood loss / hypovolemia, Pneumothorax, Sepsis, PDA. High mean airway pressure compromising venous return to the heart and Adrenocortical insufficiency

**Complications of Hypotension**

Intraventricular haemorrhage,

Periventricular leukomalacia,

Long term neurological impairment,

End-organ dysfunction

**Management of Hypotension:**

Intervention should be considered particularly in infants with clinical evidence of poor perfusion associated with hypotension. In babies with isolated hypotension and no signs of cardiovascular compromise, no intervention is needed unless it is isolated severe hypotension (MAP≤GA-5).

**Volume expansion**

Volume expansion should be given only if there is significant clinical suspicion of hypovolaemia, increased capillary leak or blood loss. Giving fluid boluses can be counterproductive if there is an already poorly functioning myocardium or a PDA. Early use of Dopamine is more successful than colloid in increasing the blood pressure. Sodium chloride, 10mls/kg should be given over 20-30 minutes if volume is chosen to treat hypotension. Blood or Fresh Frozen Plasma should only be considered instead of sodium chloride if the baby is actively bleeding, thought to have lost significant blood volume or has deranged coagulation

**Inotropes:**

**Dopamine** at lower doses (2-4 microgram/kg/mins) increases myocardial contractility and renal blood flow. At higher doses (10-20 microgram/kg/min) it increases vascular resistance. Dopamine is more effective than Dobutamine in the short term at raising the blood pressure in preterm infants, but this may not correlate with improving organ perfusion. **Dobutamine** is a direct-acting inotropic agent which stimulates the ß-receptors of the heart and blood vessels causing increased cardiac output, vasodilation and reduced vascular resistance. **Adrenaline** at low doses causes systemic and pulmonary vasodilation with an increase in the heart rate, stroke volume and contractility.

**Corticosteroids**

Adrenal corticoid insufficiency typically presents as severe refractory hypotension in preterm infants. It is reasonable to use hydrocortisone in infants who are still hypotensive despite treatment with dual inotropes. Hydrocortisone has been used successfully for treating refractory hypotension in preterm infants leading to stabilisation of blood pressure within 6-8 hours and to successful weaning from inotropes within 72 hours.

Blood cortisol levels can be useful in babies with refractory hypotension, if taken before giving hydrocortisone, and for assessing response to therapy. Though it is useful to

have the cortisol level, the decision to start hydrocortisone should not depend on the result which may take hours. An unstimulated cortisol level < 200nmol/L is suggestive of a degree of adrenal insufficiency. An initial dose of Hydrocortisone 2.5mg/kg can be repeated at 4 hours if required, followed by 2.5mg/kg every 6 hours for 48hrs or until BP recovers. Then reduce treatment over at least 48 hrs.

**Management of Shock**

Successful management of neonatal shock requires rapid intervention to restore perfusion regardless of the underlying etiology. During the initial stabilization, evaluation to determine the etiology should occur concomitantly in order to direct subsequent therapy.

**Initial stabilization:**

1. Respiratory support – may need intubation
2. Vascular access – need for sampling and fluid resuscitation.
3. Fluid resuscitation – depending on the cause of shock (cardiogenic shock may not respond).
4. Empirical antibiotic therapy (Antiviral depending on the clinical suspicion)
5. Continue monitoring for other physiologic disturbances which may occur in neonates with shock, and if present, should be promptly corrected.
   **These may include:**
   Abnormal glucose levels
   Hypothermia
   Electrolyte disturbances.
   Thrombocytopenia
   Coagulopathy
   Tension pneumothorax
   **If no response**, start vasopressor therapy to support cardiac output and improve vascular tone. We need to perform additional evaluation and intervention targeting the etiology of shock.
   Example: Administration of hydrocortisone with refractory shock or suspected adrenal insufficiency.

**Summary and Challenges**

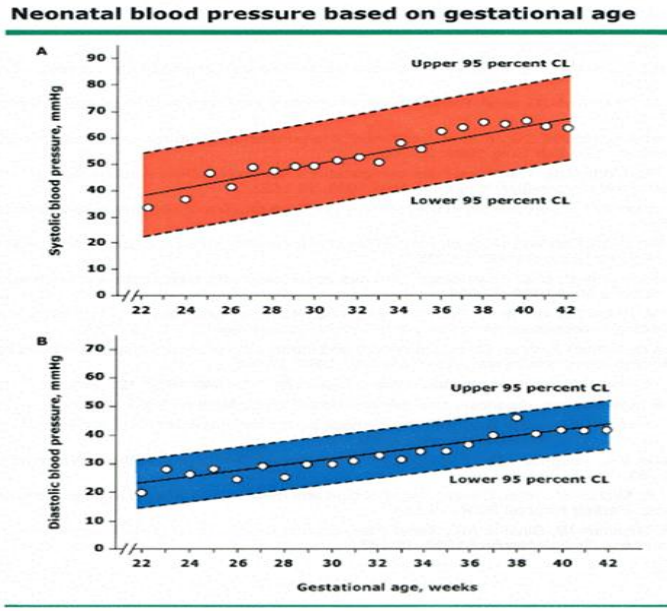
1. There is a lack of consensus regarding the definition for low blood pressure BP.
2. Physiologic changes – BP values in infants vary considerably depending on the birth weight (BW), GA, and postnatal age.
3. Difficulty in obtaining reliable measurements.
4. Limitations of normative BP ranges – Most infants have at least one systolic BP, diastolic BP, or mean arterial pressure (MAP) below the $5^{th}$ or $10^{th}$ percentile during the first 72 hours after birth. Thus, labelling a BP value as pathologic because it falls below these thresholds is problematic.
5. BP is an insufficient measure of perfusion – In EPT infants, BP alone is not an accurate assessment of global perfusion since BP correlates poorly with organ perfusion, particularly cerebral perfusion.
6. Distinguishing normal physiologic changes from shock – BP values that are lower than published normative values usually are transient, reflect normal physiologic changes following delivery, and are not a sign of an underlying disease process. However, infants with low BP and evidence of poor peripheral perfusion are in shock and require urgent intervention to restore adequate perfusion.

# Neonatal hypertension

Neonatal hypertension is commonly under-diagnosed and has non-specific presentation. However, in the last few years, with the advancing technology in NICU, there is increased identification and awareness of this condition in neonates.

- NH is diagnosed when the systolic or diastolic BP (DBP) values, as measured on 3 separate occasions, are over or equal to the 95th percentile for the infant's post-conceptual age.
- Systolic BP (SBP) over the 99th percentile suggests severe hypertension and indicates the need to initiate antihypertensive therapy and specific investigations to identify etiopathogenesis.
- Zubros chart - Systolic and diastolic BP (MeanBP with 95%CI) at various gestations is shown in figure-1.

**Figure -1: Systolic and diastolic BP (Mean BP with 95%CI) at various gestations**




- The normative data for BP at 2 weeks in the neonates are presented in table-4.

| PMA | BP percentile | Systolic BP ( mmHg) | Diastolic BP (mmHg) | MAP (mmHg) |
|---|---|---|---|---|
| 42-44 weeks | | | | |
| | 50th | 85-88 | 50-50 | 62-63 |
| | 95th | 98-105 | 65-68 | 76-80 |
| | 99th | 102-110 | 70-73 | 81-85 |
| 38-40 weeks | | | | |
| | 50th | 77-80 | 50-50 | 59-60 |
| | 95th | 92-95 | 65-65 | 74-75 |
| | 99th | 97-100 | 70-70 | 79-80 |
| 34-36 weeks | | | | |
| | 50th | 70-72 | 40-50 | 50-57 |
| | 95th | 85-87 | 55-65 | 65-72 |
| | 99th | 90-92 | 60-70 | 70-77 |
| 30-32 weeks | | | | |
| | 50th | 65-68 | 40-40 | 48-49 |
| | 95th | 80-83 | 55-55 | 63-64 |
| | 99th | 85-88 | 60-60 | 68-69 |
| 26-28 weeks | | | | |
| | 50th | 55-60 | 30-38 | 38-45 |
| | 95th | 72-75 | 50-50 | 57-58 |
| | 99th | 77-80 | 54-56 | 63-63 |

**History and physical examination**

Neonatal hypertension is usually asymptomatic. In NICU, hypertension in neonates is detected by routine BP monitoring. Symptoms are non-specific and are varied. Those who are symptomatic may present with feeding intolerance, poor feeding efforts, irritability, hypotonia, hypertonia, vomiting, apnea, respiratory distress, oxygen desaturations, and in severe cases, tachycardia, congestive heart failure, cardiogenic shock, and seizures.

The history of oligohydramnios may suggest congenital renal anomalies, and the infant may be born with typical features in severe cases.A detailed clinical examination including dysmorphism for syndromic association is mandatory. Physical features of congestive heart failure like tachycardia, murmur, mottling, and cyanosis may be present. Palpation of the abdomen may reveal a mass in conditions of polycystic kidney disease, renal tumors, hydronephrosis, and renal vein thrombosis. The genitourinary examination may reveal congenital anomalies or ambiguous genitalia in congenital adrenal hyperplasia.

**Epidemiology**

The incidence of neonatal hypertension is reported to be 0.2% in term new-born infants and up to 3% in the infants admitted in the NICU. It is reported that 1.4% of preterm infants require antihypertensive therapy during their NICU stay compared to 1% in term infants. In infants with BPD the incidence of NH is demonstrated to be 13% to 43%.The American Academy of Paediatrics does not recommend routine screening of children for hypertension until three years of age unless there is any risk factor.

**Etiology and investigations:**

Common causes of neonatal hypertension are renovascular or renal parenchymal diseases and relevant investigations are given in the **table-5.**

**Table-5:** Common causes of neonatal hypertension

| Cause | Condition | Evaluation |
|---|---|---|
| Renal | ● Renal artery thrombosis (particularly if a UAC has been in place)<br>● Renal vein thrombosis<br>● Renal artery stenosis or compression (e.g. tumour, post tight abdominal wall closure)<br>● Parenchymal renal disease - congenital (ARPKD and ADPKD) or acquired (ATN from inadequate perfusion e.g. sepsis, asphyxia)<br>● Renal hypoplasia<br>● Severely obstructed urinary tract<br>● Congenital rubella syndrome<br>● VLBW babies - low renal mass /impaired nephrogenesis/ nephrocalcinosis | Urine analysis, blood urea nitrogen, and serum creatinine, Electrolytes, and calcium,<br>Voiding cystourethrogram,<br>Captopril renal scintigraphy,<br>dimercaptosuccinic acid renal scan,<br>Abdominal MRI, Computed tomographic angiography to evaluate renal artery and the aorta, |
| Cardio -vascular | ● Coarctation of the aorta<br>● Interrupted aortic arch | Aortic and renal ultrasonography with a Doppler study. |

| | | |
|---|---|---|
| | ● Distal aortic thrombosis (particularly if a UAC has been in place)<br>● Fluid overload | |
| Endocrine | ● Congenital Adrenal Hyperplasia<br>● Hyperaldosteronism<br>● Hyperthyroidism<br>● Adrenal haemorrhage<br>● Hypercalcaemia<br>● Pheochromocytoma<br>● Neuroblastoma | Thyroid function test, Serum cortisol levels, Serum aldosterone, and plasma renin activity, Plasma and urine catecholamines and metanephrines, Serum 11 deoxycortisol, and 11 deoxycorticosterone.<br>Urinary 17-hydroxysteroid and 17-ketosteroid, Vanillyl mandelic acid and homovanillic acid, |
| Respiratory | ● Chronic Lung Disease- May manifest late after discharge. | Chest X ray |
| Medications | ● Dexamethasone<br>● Adrenergic agents<br>● Bronchodilators<br>● Caffeine<br>● TPN through salt and water overload or hypercalcaemia | Check the medication history |
| Neurological | ● Pain<br>● IVH<br>● Seizures<br>● Drug Withdrawal<br>● HIE | Head ultrasonography |
| Multifactorial | ● ECMO | |

**Evaluation**

The initial investigations include urine analysis, blood urea nitrogen, and serum creatinine, electrolytes, and calcium as the reno-vascular or renal parenchymal disorders account for the majority of cases of NH. The urine should be tested for vanillyl mandelic acid and homovanillic acid. The initial workup should also include the aortic and renal ultrasonography with a Doppler study.

**Further investigation is guided by history and clinical suspicion as suggested in table 5**

## Treatment

In most infants with NH, treating the correctable causes usually resolves the condition. The umbilical catheter should be removed as soon as possible. Hypercalcemia or excessive fluids intake should be corrected with fluid restriction and/or diuretics. Doses of medications like inotropes, steroids, or caffeine should be adjusted or the drug discontinued. Surgical conditions should be addressed as needed. Analgesia may be considered for the relief of pain. Appropriate hormonal therapy should be administered for endocrinal disorders. If hypertension persists above the 99th percentile of the normative data despite these measures, the antihypertensive therapy should be initiated.

- **Mild hypertension:** These infants can be regularly monitored and closely observed. If hypertension does not resolve spontaneously, then they can be treated with a thiazide (preferred) or a loop diuretic agent.
- **Moderate hypertension:** These infants have blood pressure readings between 95th to 99th percentiles for the age without signs of end-organ involvement. They can be treated with diuretics (first line), hydralazine, or propranolol.
- **Severe hypertension:** If the blood pressure is greater than the 99 percentiles, treatment with continuous intravenous drug infusion is warranted. A rapid reduction in blood pressure should be avoided. Close monitoring of blood pressure with an intra-arterial catheter is preferred in these patients.

**Surgical intervention** is indicated in conditions such as coarctation of the aorta, renal artery or vein occlusion, urinary tract or ureteropelvic junction obstruction, polycystic kidney disease, neuroblastoma, or Wilms tumor, among others.

**Differential Diagnosis**

NH is a manifestation of specific disorders pertaining to various organ systems. The etiopathogenic disease entities leading to NH should be differentiated by appropriate investigations. As the clinical presentation of NH with symptoms like respiratory distress, hypotonia, irritability, feeding intolerance, tachycardia, among others are nonspecific, all other neonatal causes for such symptoms should be ruled out.

**Prognosis**

The outcome of NH depends on the etiology and severity of the condition. NH associated with renal venous thrombosis, umbilical catheterization, or acute renal tubular necrosis are transient and resolve as the underlying disorder is corrected. The presence of end-organ damage is associated with poor prognosis.

**Complications**

Infants with untreated severe hypertension may develop multiple end-organ damages and suffer from vascular injury, left ventricular hypertrophy, dilation, and/or dysfunction, encephalopathy, nephropathy and hypertensive retinopathy. Early, aggressive and effective treatment should be provided in such conditions. Recent evidence suggests that childhood hypertension is associated with a higher risk for adulthood hypertension.

**Summary**

1. Neonatal hypertension is often missed or undiagnosed in infants admitted to the new-born nursery and is picked up incidentally on routine follow up visits.
2. Early diagnosis and timely treatment are important in this population to prevent end-organ damage and adverse long-term sequelae.
3. Pharmacological management is a challenge for neonatologists.
4. Lack of the normative data and definition adds to the uncertainties in managing hypertension presenting during the neonatal period and infancy.
5. In moderate NH, starting treatment with oral and in severe NH introducing IV therapy is recommended. As most infants require short term therapy (10 days on average) and many ameliorate spontaneously with time.
6. A judicious approach based on the infant's condition and other associated factors should be considered.
7. The management of NH requires a multi-disciplinary approach with a team that includes the primary care paediatrician, neonatologists, paediatric nephrologists, and cardiologists.
8. The prognosis depends on the cause and the presence of end-organ dysfunction.
9. To improve the outcomes, prompt recognition and management by a group of specialists are suggested.

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## ABPM – Dr Mohamed Azarudeen and Dr Vidhya P S

*Ambulatory Blood Pressure Monitoring Study Report*

**Patient Information**:

| | | |
|---|---|---|
| **Name: Yogashree** | **DOB: 15/7/2000 (15 years)** | **OP No: 2529876** |
| **Date of Study: 1/8/15**<br>**Date of Interpretation:3/8/15**<br><br>**History of CKD : Yes** | **Height:** 125cm ( %ile) **Weight:** 33 Kg ( %ile) **BMI:** 21 kg/m2( %ile) | **Details: S/p Transplant in May**<br><br>**2013Native Disease FSGS** |

**Current Medications**: No antihypertensive medications

**Indication for the Study**: Possible Masked HTN

**Clinic Blood Pressure**: 120 /80 mmHg : Systolic BP is just at the 90$^{th}$ percentile. Diastolic BP is between 90 -95$^{th}$ %ile

**Technical Analysis**:

| | |
|---|---|
| Duration of Study: 23 hours | Number of Successful Readings: 64 (88 %) Awake: 37 Asleep: 27 |

**Analysis of Blood Pressure Data:** The ***abnormal values are italicized***

| Blood Pressure Values | 24 hour BP | Awake BP | Sleep BP |
|---|---|---|---|
| Upper Limit of normal Ambulatory Blood Pressure | 95$^{th}$ percentile: | 95$^{th}$ percentile | 95$^{th}$ percentile |
| Patient's mean Ambulatory BP | | | |

| | | |
|---|---|---|
| **Nocturnal Dip** (normal > 10%) | | |

**Interpretation**:

Adequacy:

BP interpretation:

| Timing | SBP | DBP |
|---|---|---|
| 24 Hr | | |
| Daytime | | |
| Night time | | |

**Nocturnal Dip:**

**Conclusion**:

***Patient Name:** Yogashree Bindu *UHID no: 2529876

## 24 Hour Summary:

| Parameter | Avg | SD | Min | Max | Dipping |
|---|---|---|---|---|---|
| **SBP** | 135 | 4.44 | 121 | 140 | 1.0% |
| **DBP** | 80 | 3.12 | 68 | 92 | <1.0% |
| **MAP** | 91 | 5.02 | 85 | 100 | |
| **Pulse pressure** | 51 | 8.31 | 42 | 59 | |
| **Heart Rate** | 80 | 5.13 | 70 | 90 | |

## Awake period:

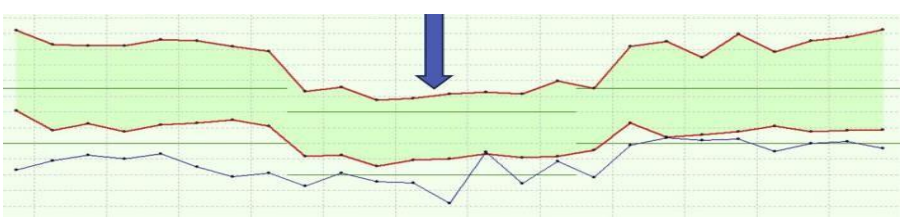
**No of Wake period readings (% successful readings): 37**

| Parameter | Avg | SD | Min | Max |
|---|---|---|---|---|
| **SBP** | 142 | 4.33 | 128 | 155 |
| **DBP** | 88 | 3.32 | 70 | 92 |
| **MAP** | 93 | 5.21 | 85 | 100 |
| **Pulse pressure** | 45 | 2.34 | 42 | 53 |
| **Heart Rate** | 80 | 4.31 | 70 | 90 |

## Sleep Period:

**No of sleep period readings (% successful readings): 27**

| Parameter | Avg | SD | Min | Max |
|---|---|---|---|---|
| **SBP** | 121 | 2.51 | 116 | 130 |
| **DBP** | 81 | 5.49 | 68 | 85 |
| **MAP** | 90 | 3.36 | 85 | 100 |
| **Pulse pressure** | 46 | 3.07 | 42 | 50 |
| **Heart Rate** | 78 | 4.28 | 70 | 83 |



# *Ambulatory Blood Pressure Monitoring Study Report*

**Patient Information**:

| | | |
|---|---|---|
| **Name: Mariyam Aarij** | **DOB: 27/06/2005 ( 15 years)** | **OP No: 4188472** |
| **Date of Study: 19/09/2022**<br><br>**History of CKD : Yes** | **Height:** 150 cm ( %ile)<br>**Weight:** 50 Kg ( %ile)<br><br>**BMI**: 22.0 | **Diagnosis : ESRD on HD** |

**Current Medications**: T. Carvedilol 3.125mg BD, T. Amlodipine 5mg BD, T. Prazosin 2mg TID, T Metoprolol 25mg OD, T. Enalapril 5mg–0–7.5mg, T. Hydralazine 25mg TID.

**Indication for the Study**: Evaluate BP Control.

**Clinic Blood Pressure**: 125 /78 mmHg

**Interpretation:Technical Analysis**:

| | |
|---|---|
| **Duration of Study**: 24 hours | **Number of Successful Readings**: 71 **Awake**: 48 **Asleep**: 23 |

**Analysis of Blood Pressure Data:**

| **Blood Pressure Values** | **24 hour SBP** | **Awake SBP** | **Sleep SBP** |
|---|---|---|---|
| Upper Limit of normal Ambulatory Blood Pressure | 95$^{th}$ percentile: | 95$^{th}$ percentile | 95$^{th}$ percentile |
| Patient's mean Ambulatory SBP | | | |
| **Interpretation** | | | |
| **Blood Pressure Values** | **24 hour DBP** | **Awake DBP** | **Sleep DBP** |
| Upper Limit of normal Ambulatory Blood Pressure | 95$^{th}$ percentile: | 95$^{th}$ percentile | 95$^{th}$ percentile |
| Patient's mean Ambulatory DBP | | | |
| **Interpretation** | | | |

| | | |
|---|---|---|
| **Nocturnal Dip** (normal > 10%) | ***Neg 3%*** | ***Neg 11%*** |
| **Interpretation** | | |

**Interpretation**:Adequacy:

BP interpretation:

| Timing | SBP | DBP |
|---|---|---|
| 24 Hr | | |
| Daytime | | |
| Night time | | |

**Nocturnal Dip:Conclusion**:

***Patient Name:** Mariyam Aarij *__UHID no__: 4188472 **24 Hour Summary:**

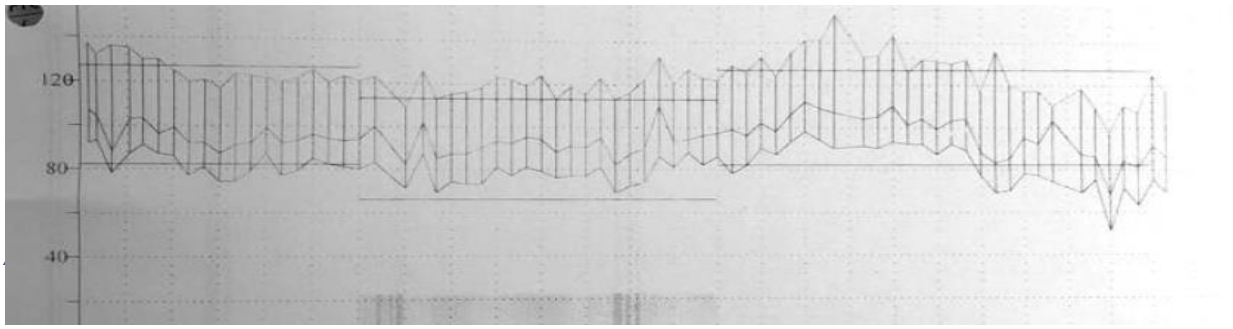
| Parameter | Avg | SD | Min | Max | Dipping |
|---|---|---|---|---|---|
| **SBP** | 124 | 9.44 | 97 | 153 | 4.8% |
| **DBP** | 81 | 8.62 | 51 | 98 | 4.9% |
| **MAP** | 95 | 8.29 | 68 | 112 | 4.2% |
| **Pulse pressure** | 43 | 5.81 | 34 | 67 | |
| **Heart Rate** | 81 | 9.86 | 67 | 128 | |

**Awake period:** **No of Wake period readings (% successful readings): 48**

| Parameter | Avg | SD | Min | Max |
|---|---|---|---|---|
| **SBP** | 126 | 10.34 | 97 | 153 |
| **DBP** | 82 | 9.55 | 51 | 98 |
| **MAP** | 96 | 8.85 | 68 | 112 |
| **Pulse pressure** | 44 | 6.69 | 34 | 67 |
| **Heart Rate** | 82 | 10.28 | 69 | 128 |

**Sleep Period:** **No of sleep period readings (% successful readings): 23**

| Parameter | Avg | SD | Min | Max |
|---|---|---|---|---|
| **SBP** | 120 | 5.51 | 109 | 133 |
| **DBP** | 78 | 5.49 | 69 | 88 |
| **MAP** | 92 | 6.36 | 82 | 110 |
| **Pulse pressure** | 42 | 3.07 | 37 | 48 |
| **Heart Rate** | 78 | 8.28 | 67 | 100 |



| | | |
|---|---|---|
| **Name: Musaifa** | **DOB: 20/11/2011 ( 10years)** | **OP No: 4391660** |
| **Date of Study: 17/02/2022History of CKD : No** | **Height:** 138 cm ( %ile)<br>**Weight:** 55 Kg ( %ile)<br>**BMI**: 28.9 | **Diagnosis :** ? White Coat Hypertension. |

**Current Medications**: Nil

**Indication for the Study**: ? White Coat Hypertension

**Clinic Blood Pressure**: 100 /64 mmHg **Interpretation:Technical Analysis**:

| | |
|---|---|
| **Duration of Study**: 24 hours | **Number of Successful Readings**: 62 **Awake**: 41 **Asleep**: 21 |

**Analysis of Blood Pressure Data:**

| **Blood Pressure Values** | **24 hour SBP** | **Awake SBP** | **Sleep SBP** |
|---|---|---|---|
| Upper Limit of normal Ambulatory Blood Pressure | 95$^{th}$ percentile: | 95$^{th}$ percentile | 95$^{th}$ percentile |
| Patient's mean Ambulatory SBP | | | |
| **Interpretation** | | | |
| **Blood Pressure Values** | **24 hour DBP** | **Awake DBP** | **Sleep DBP** |
| Upper Limit of normal Ambulatory Blood Pressure | 95$^{th}$ percentile: | 95$^{th}$ percentile | 95$^{th}$ percentile |
| Patient's mean Ambulatory DBP | | | |
| **Interpretation** | | | |

| | | |
|---|---|---|
| **Nocturnal Dip** (normal > 10%) | ***Neg 3%*** | ***Neg 11%*** |
| **Interpretation** | | |

**Interpretation**:Adequacy:

BP interpretation:

| Timing | SBP | DBP |
|---|---|---|
| 24 Hr | | |
| Daytime | | |
| Night time | | |

**Nocturnal Dip:Conclusion**:

***Patient Name:** Musaifa ***UHID no:** 4391660 **24 Hour Summary:**

| **Parameter** | **Avg** | **SD** | **Min** | **Max** | **Dipping** |
|---|---|---|---|---|---|
| **SBP** | 101 | 11.40 | 73 | 122 | 11.5% |
| **DBP** | 60 | 10.13 | 41 | 85 | 17.5% |

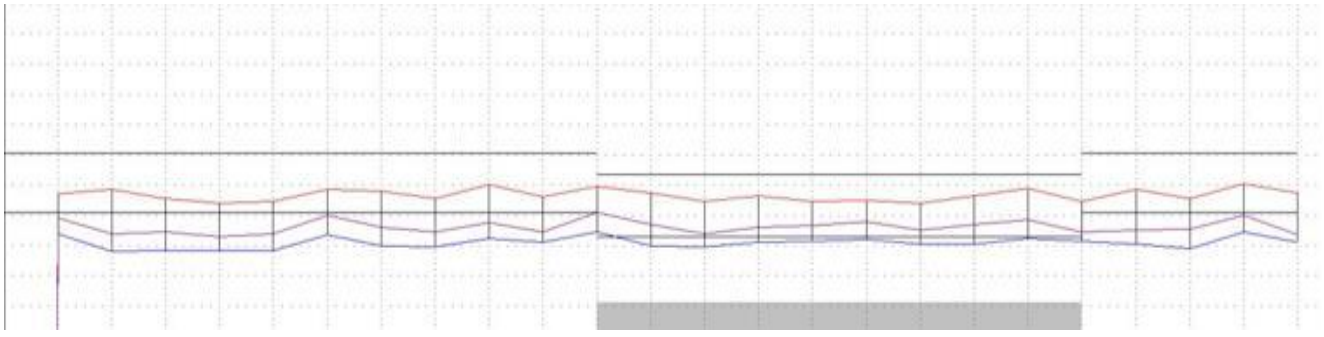
| | | | | | |
|---|---|---|---|---|---|
| **MAP** | 75 | 9.73 | 49 | 97 | 14.0% |
| **Pulse pressure** | 42 | 7.14 | 24 | 58 | |
| **Heart Rate** | 85 | 14.92 | 61 | 119 | |

**Awake period: No of Wake period readings (% successful readings): 41**

| Parameter | Avg | SD | Min | Max |
|---|---|---|---|---|
| **SBP** | 105 | 9.89 | 73 | 122 |
| **DBP** | 63 | 9.67 | 46 | 85 |
| **MAP** | 79 | 9.12 | 49 | 97 |
| **Pulse pressure** | 42 | 7.71 | 24 | 58 |
| **Heart Rate** | 92 | 12.33 | 67 | 119 |

**Sleep Period: No of sleep period readings (% successful readings): 21**

| Parameter | Avg | SD | Min | Max |
|---|---|---|---|---|
| **SBP** | 93 | 9.61 | 79 | 118 |
| **DBP** | 52 | 5.96 | 41 | 63 |
| **MAP** | 68 | 6.98 | 55 | 82 |
| **Pulse pressure** | 41 | 6.01 | 27 | 56 |
| **Heart Rate** | 72 | 9.63 | 61 | 101 |



# Ambulatory Blood Pressure Monitoring Study Report

**Patient Information**:

| | | |
|---|---|---|
| **Name: Rakshitha** | **DOB: 13/07/2004 ( 14 years)** | **OP No: 4598237** |
| **Date of Study: 28/01/2023History of**<br><br>**CKD : No** | **Height:** 152 cm ( %ile)<br>**Weight:** 50 Kg ( %ile)<br><br>**BMI**: 21.6 | **Diagnosis : Takayasu Arteritis (Type III)** |

**Current Medications**: T. Prazosin XL 5mg BD, T. Amlodipine 5mg BD, T. Metoprolol 25mg OD,
**Indication for the Study**: Evaluate BP Control.

**Clinic Blood Pressure**: 117 /73 mmHg **Interpretation:Technical Analysis**:

| | |
|---|---|
| **Duration of Study**: 24 hours | **Number of Successful Readings**: 57 **Awake**: 34 **Asleep**: 23 |

**Analysis of Blood Pressure Data:**

| **Blood Pressure Values** | **24 hour SBP** | **Awake SBP** | **Sleep SBP** |
|---|---|---|---|
| Upper Limit of normal Ambulatory Blood Pressure | 95$^{th}$ percentile: | 95$^{th}$ percentile | 95$^{th}$ percentile |
| Patient's mean Ambulatory SBP | | | |
| **Interpretation** | | | |
| **Blood Pressure Values** | **24 hour DBP** | **Awake DBP** | **Sleep DBP** |
| Upper Limit of normal Ambulatory Blood Pressure | 95$^{th}$ percentile: | 95$^{th}$ percentile | 95$^{th}$ percentile |
| Patient's mean Ambulatory DBP | | | |
| **Interpretation** | | | |

| | | |
|---|---|---|
| **Nocturnal Dip** (normal > 10%) | ***Neg 3%*** | ***Neg 11%*** |
| **Interpretation** | | |

**Interpretation**:Adequacy:

BP interpretation:

| Timing | SBP | DBP |
|---|---|---|
| 24 Hr | | |
| Daytime | | |
| Night time | | |

**Nocturnal Dip:Conclusion**:

***Patient Name:** Rakshitha *UHID no: 4598237 **24 Hour Summary:**

| **Parameter** | **Avg** | **SD** | **Min** | **Max** | **Dipping** |
|---|---|---|---|---|---|

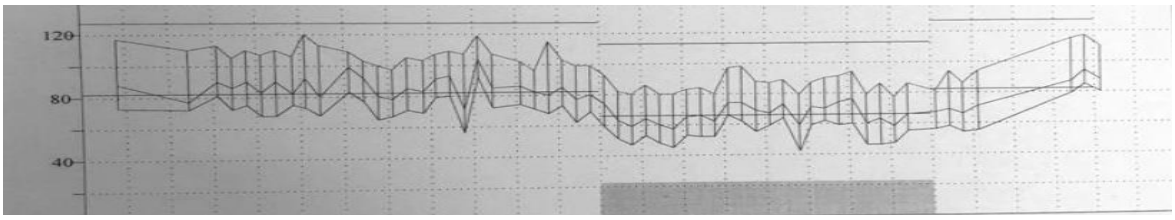
| | | | | | |
|---|---|---|---|---|---|
| **SBP** | 98 | 12.45 | 77 | 120 | 18.9% |
| **DBP** | 64 | 11.70 | 42 | 92 | 24.0% |
| **MAP** | 77 | 11.63 | 57 | 104 | 21.5% |
| **Pulse pressure** | 33 | 5.74 | 25 | 51 | |
| **Heart Rate** | 70 | 15.64 | 53 | 132 | |

**Awake period:** **No of Wake period readings (% successful readings): 34**

| Parameter | Avg | SD | Min | Max |
|---|---|---|---|---|
| **SBP** | 106 | 8.91 | 81 | 120 |
| **DBP** | 71 | 8.88 | 54 | 92 |
| **MAP** | 84 | 8.75 | 66 | 104 |
| **Pulse pressure** | 34 | 6.78 | 25 | 51 |
| **Heart Rate** | 78 | 15.83 | 58 | 132 |

**Sleep Period:** **No of sleep period readings (% successful readings): 23**

| Parameter | Avg | SD | Min | Max |
|---|---|---|---|---|
| **SBP** | 86 | 5.98 | 77 | 98 |
| **DBP** | 54 | 6.80 | 42 | 66 |
| **MAP** | 66 | 6.06 | 57 | 76 |
| **Pulse pressure** | 32 | 3.37 | 25 | 40 |
| **Heart Rate** | 58 | 3.47 | 53 | 67 |



# *Ambulatory Blood Pressure Monitoring Study Report*

**Patient Information**:

| | | |
|---|---|---|
| **Name: Naveen Biradar / Male** | **DOB: 27/10/03 ( 11years)** | **OP No: 3342126** |
| **Date of Study: 2/4/15**<br>**Date of Interpretation:10/4/15**<br><br>**History of CKD : Yes** | **Height:** 125cm<br>**Weight:** 23Kg ( %ile) | **Details: ESRD on maintenance HD.**<br>**ABPM done on a non-dialysis day** |

**Current Medications**: Amlodipine , Minipress XL, Atenolol, Minoxidil , Nimodipine
**Indication for the Study**: Evaluate HTN control

**Clinic Blood Pressure**: 119 /78 mmHg
**Technical Analysis**:

| | |
|---|---|
| Duration of Study: 24 hours | Number of Successful Readings: 74 (100 %) Awake: 41 Asleep: 33 |

**Analysis of Blood Pressure Data:**

| Blood Pressure Values | 24 hour BP | Awake BP | Sleep BP |
|---|---|---|---|
| Upper Limit of normal Ambulatory Blood Pressure | 95$^{th}$ percentile: | 95$^{th}$ percentile | 95$^{th}$ percentile |
| Patient's mean Ambulatory BP | | | |

| | | |
|---|---|---|
| **Nocturnal Dip** (normal > 10%) | | |

**Interpretation**:

Adequacy:
BP interpretation:

| Timing | SBP | DBP |
|---|---|---|
| 24 Hr | | |
| Daytime | | |
| Night time | | |

**Nocturnal Dip:**

**Conclusion**:
***Patient Name:** Naveen Birdar *UHID no: 3342126

| Parameter | Avg | SD | Min | Max | Dipping |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| **SBP** | 118 | 8.44 | 110 | 142 | 3.0% |
| **DBP** | 76 | 8.12 | 65 | 86 | 11.0% |
| **MAP** | 91 | 8.02 | 81 | 105 | |
| **Pulse pressure** | 44 | 3.41 | 38 | 56 | |
| **Heart Rate** | 80 | 6.23 | 70 | 90 | |

## 24 Hour Summary:

## Awake period:

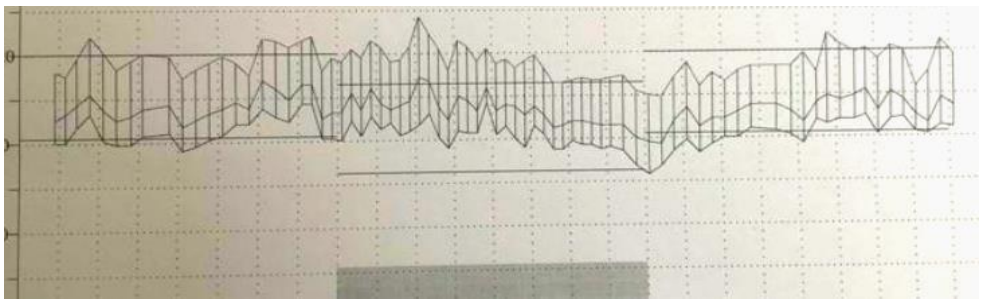
**No of Wake period readings (% successful readings): 41**

| Parameter | Avg | SD | Min | Max |
|---|---|---|---|---|
| **SBP** | 120 | 5.33 | 112 | 142 |
| **DBP** | 80 | 4.34 | 70 | 86 |
| **MAP** | 93 | 6.23 | 85 | 105 |
| **Pulse pressure** | 44 | 2.32 | 38 | 56 |
| **Heart Rate** | 85 | 4.35 | 72 | 90 |

## Sleep Period:

**No of sleep period readings (% successful readings): 33**

| Parameter | Avg | SD | Min | Max |
|---|---|---|---|---|
| **SBP** | 115 | 4.51 | 110 | 130 |
| **DBP** | 78 | 5.49 | 65 | 86 |
| **MAP** | 92 | 6.36 | 81 | 101 |
| **Pulse pressure** | 42 | 2.07 | 39 | 45 |
| **Heart Rate** | 78 | 4.28 | 70 | 83 |



## Table 5. BP levels for boys by age and height percentile

| BP (percentile) | Systolic BP (mmHg) | | | | | | | Diastolic BP (mmHg) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Height percentile or measured height | | | | | | | Height percentile or measured height | | | | | | |
| | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 5% | 10% | 25% | 50% | 75% | 90% | 95% |
| **1 year** | | | | | | | | | | | | | | |
| Height (in) | 30.4 | 30.8 | 31.6 | 32.4 | 33.3 | 34.1 | 34.6 | 30.4 | 30.8 | 31.6 | 32.4 | 33.3 | 34.1 | 34.6 |
| Height (cm) | 77.2 | 78.3 | 80.2 | 82.4 | 84.6 | 86.7 | 87.9 | 77.2 | 78.3 | 80.2 | 82.4 | 84.6 | 86.7 | 87.9 |
| 50th | 85 | 85 | 86 | 86 | 87 | 88 | 88 | 40 | 40 | 40 | 41 | 41 | 42 | 42 |
| 90th | 98 | 98 | 99 | 100 | 100 | 101 | 101 | 52 | 52 | 53 | 53 | 54 | 54 | 54 |
| 95th | 102 | 102 | 103 | 103 | 104 | 105 | 105 | 54 | 54 | 55 | 55 | 56 | 57 | 57 |
| 95th+12mmHg | 114 | 114 | 115 | 115 | 116 | 117 | 117 | 66 | 66 | 67 | 67 | 68 | 69 | 69 |
| **2years** | | | | | | | | | | | | | | |
| Height (in) | 33.9 | 34.4 | 35.3 | 36.3 | 37.3 | 38.2 | 38.8 | 33.9 | 34.4 | 35.3 | 36.3 | 37.3 | 38.2 | 38.8 |
| Height (cm) | 86.1 | 87.4 | 89.6 | 92.1 | 94.7 | 97.1 | 98.5 | 86.1 | 87.4 | 89.6 | 92.1 | 94.7 | 97.1 | 98.5 |
| 50th | 87 | 87 | 88 | 89 | 89 | 90 | 91 | 43 | 43 | 44 | 44 | 45 | 46 | 46 |
| 90th | 100 | 100 | 101 | 102 | 103 | 103 | 104 | 55 | 55 | 56 | 56 | 57 | 58 | 58 |
| 95th | 104 | 105 | 105 | 106 | 107 | 107 | 108 | 57 | 58 | 59 | 59 | 60 | 61 | 61 |
| 95th+12mmHg | 116 | 117 | 117 | 118 | 119 | 119 | 120 | 69 | 70 | 71 | 71 | 72 | 73 | 73 |
| **3years** | | | | | | | | | | | | | | |
| Height (in) | 36.4 | 37 | 37.9 | 39 | 40.1 | 41.1 | 41.7 | 36.4 | 37 | 37.9 | 39 | 40.1 | 41.1 | 41.7 |
| Height (cm) | 92.5 | 93.9 | 96.3 | 99 | 101.8 | 104.3 | 105.8 | 92.5 | 93.9 | 96.3 | 99 | 101.8 | 104.3 | 105.8 |
| 50th | 88 | 89 | 89 | 90 | 91 | 92 | 92 | 45 | 46 | 46 | 47 | 48 | 49 | 49 |
| 90th | 101 | 102 | 102 | 103 | 104 | 105 | 105 | 58 | 58 | 59 | 59 | 60 | 61 | 61 |
| 95th | 106 | 106 | 107 | 107 | 108 | 109 | 109 | 60 | 61 | 61 | 62 | 63 | 64 | 64 |
| 95th+12mmHg | 118 | 118 | 119 | 119 | 120 | 121 | 121 | 72 | 73 | 73 | 74 | 75 | 76 | 76 |
| **4years** | | | | | | | | | | | | | | |
| Height (in) | 38.8 | 39.4 | 40.5 | 41.7 | 42.9 | 43.9 | 44.5 | 38.8 | 39.4 | 40.5 | 41.7 | 42.9 | 43.9 | 44.5 |
| Height (cm) | 98.5 | 100.2 | 102.9 | 105.9 | 108.9 | 111.5 | 113.2 | 98.5 | 100.2 | 102.9 | 105.9 | 108.9 | 111.5 | 113.2 |
| 50th | 90 | 90 | 91 | 92 | 93 | 94 | 94 | 48 | 49 | 49 | 50 | 51 | 52 | 52 |
| 90th | 102 | 103 | 104 | 105 | 105 | 106 | 107 | 60 | 61 | 62 | 62 | 63 | 64 | 64 |
| 95th | 107 | 107 | 108 | 108 | 109 | 110 | 110 | 63 | 64 | 65 | 66 | 67 | 67 | 68 |
| 95th+12mmHg | 119 | 119 | 120 | 120 | 121 | 122 | 122 | 75 | 76 | 77 | 78 | 79 | 79 | 80 |
| **5years** | | | | | | | | | | | | | | |
| Height (in) | 41.1 | 41.8 | 43 | 44.3 | 44.4 | 46.7 | 47.4 | 41.1 | 41.8 | 43 | 44.3 | 44.4 | 46.7 | 47.4 |
| Height (cm) | 104.4 | 106.2 | 109.1 | 112.4 | 115.7 | 118.6 | 120.3 | 104.4 | 106.2 | 109.1 | 112.4 | 115.7 | 118.6 | 120.3 |
| 50th | 91 | 92 | 93 | 94 | 95 | 96 | 96 | 51 | 51 | 52 | 53 | 54 | 55 | 55 |
| 90th | 103 | 104 | 105 | 106 | 107 | 108 | 108 | 63 | 64 | 65 | 65 | 66 | 67 | 67 |
| 95th | 107 | 108 | 109 | 109 | 110 | 111 | 112 | 66 | 67 | 68 | 69 | 70 | 70 | 71 |
| 95th+12mmHg | 119 | 120 | 121 | 121 | 122 | 123 | 124 | 78 | 79 | 80 | 81 | 82 | 82 | 83 |
| **6years** | | | | | | | | | | | | | | |
| Height (in) | 43.4 | 44.2 | 45.4 | 46.8 | 48.2 | 49.4 | 50.2 | 43.4 | 44.2 | 45.4 | 46.8 | 48.2 | 49.4 | 50.2 |
| Height (cm) | 110.3 | 112.2 | 115.3 | 118.9 | 122.4 | 125.6 | 127.5 | 110.3 | 112.2 | 115.3 | 118.9 | 122.4 | 125.6 | 127.5 |
| 50th | 93 | 93 | 94 | 95 | 96 | 97 | 98 | 54 | 54 | 55 | 56 | 57 | 57 | 58 |
| 90th | 105 | 105 | 106 | 107 | 109 | 110 | 110 | 66 | 66 | 67 | 68 | 68 | 69 | 69 |
| 95th | 108 | 109 | 110 | 111 | 112 | 113 | 114 | 69 | 70 | 70 | 71 | 72 | 72 | 73 |
| 95th+12mmHg | 120 | 121 | 122 | 123 | 124 | 125 | 126 | 81 | 82 | 82 | 83 | 84 | 84 | 85 |
| **7years** | | | | | | | | | | | | | | |
| Height (in) | 45.7 | 46.5 | 47.8 | 49.3 | 50.8 | 52.1 | 52.9 | 45.7 | 46.5 | 47.8 | 49.3 | 50.8 | 52.1 | 52.9 |
| Height (cm) | 116.1 | 118 | 121.4 | 125.1 | 128.9 | 132.4 | 134.5 | 116.1 | 118 | 121.4 | 125.1 | 128.9 | 132.4 | 134.5 |
| 50th | 94 | 94 | 95 | 97 | 98 | 98 | 99 | 56 | 56 | 57 | 58 | 58 | 59 | 59 |
| 90th | 106 | 107 | 108 | 109 | 110 | 111 | 111 | 68 | 68 | 69 | 70 | 70 | 71 | 71 |
| 95th | 110 | 110 | 111 | 122 | 114 | 115 | 116 | 71 | 71 | 72 | 73 | 73 | 74 | 74 |
| 95th+12mmHg | 122 | 122 | 123 | 124 | 126 | 127 | 128 | 83 | 83 | 84 | 85 | 85 | 86 | 86 |
| **8years** | | | | | | | | | | | | | | |
| Height (in) | 47.8 | 48.6 | 50 | 51.6 | 53.2 | 54.6 | 55.5 | 47.8 | 48.6 | 50 | 51.6 | 53.2 | 54.6 | 55.5 |
| Height (cm) | 121.4 | 123.5 | 127 | 131 | 135.1 | 138.8 | 141 | 121.4 | 123.5 | 127 | 131 | 135.1 | 138.8 | 141 |
| 50th | 95 | 96 | 97 | 98 | 99 | 99 | 100 | 57 | 57 | 58 | 59 | 59 | 60 | 60 |
| 90th | 107 | 108 | 109 | 110 | 111 | 112 | 112 | 69 | 70 | 70 | 71 | 72 | 72 | 73 |
| 95th | 111 | 112 | 112 | 114 | 115 | 116 | 117 | 72 | 73 | 73 | 74 | 75 | 75 | 75 |
| 95th+12mmHg | 123 | 124 | 124 | 126 | 127 | 128 | 129 | 84 | 85 | 85 | 86 | 87 | 87 | 87 |
| **9years** | | | | | | | | | | | | | | |
| Height (in) | 49.6 | 50.5 | 52 | 53.7 | 55.4 | 56.9 | 57.9 | 49.6 | 50.5 | 52 | 53.7 | 55.4 | 56.9 | 57.9 |
| Height (cm) | 126 | 128.3 | 132.1 | 136.3 | 140.7 | 144.7 | 147.1 | 126 | 128.3 | 132.1 | 136.3 | 140.7 | 144.7 | 147.1 |
| 50th | 96 | 97 | 98 | 99 | 100 | 101 | 101 | 57 | 58 | 59 | 60 | 61 | 62 | 62 |
| 90th | 107 | 108 | 109 | 110 | 112 | 113 | 114 | 70 | 71 | 72 | 73 | 74 | 74 | 74 |
| 95th | 112 | 112 | 113 | 115 | 116 | 118 | 119 | 74 | 74 | 75 | 76 | 76 | 77 | 77 |
| 95th+12mmHg | 124 | 124 | 125 | 127 | 128 | 130 | 131 | 86 | 86 | 87 | 88 | 88 | 89 | 89 |

| 10years | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Height (in) | 51.3 | 52.2 | 53.8 | 55.6 | 57.4 | 59.1 | 60.1 | 51.3 | 52.2 | 53.8 | 55.6 | 57.4 | 59.1 | 60.1 |
| Height (cm) | 130.2 | 132.7 | 136.7 | 141.3 | 145.9 | 150.1 | 152.7 | 130.2 | 132.7 | 136.7 | 141.3 | 145.9 | 150.1 | 152.7 |
| 50th | 97 | 98 | 99 | 100 | 101 | 102 | 103 | 59 | 60 | 61 | 62 | 63 | 63 | 64 |
| 90th | 108 | 109 | 111 | 112 | 113 | 115 | 116 | 72 | 73 | 74 | 74 | 75 | 75 | 76 |
| 95th | 112 | 113 | 114 | 116 | 118 | 120 | 121 | 76 | 76 | 77 | 77 | 78 | 78 | 78 |
| 95th+12mmHg | 124 | 125 | 126 | 128 | 130 | 132 | 133 | 88 | 88 | 89 | 89 | 90 | 90 | 90 |
| 11years | | | | | | | | | | | | | | |
| Height (in) | 53 | 54 | 55.7 | 57.6 | 59.6 | 61.3 | 62.4 | 53 | 54 | 55.7 | 57.6 | 59.6 | 61.3 | 62.4 |
| Height (cm) | 134.7 | 137.3 | 141.5 | 146.4 | 151.3 | 155.8 | 158.6 | 134.7 | 137.3 | 141.5 | 146.4 | 151.3 | 155.8 | 158.6 |
| 50th | 99 | 99 | 101 | 102 | 103 | 104 | 106 | 61 | 61 | 62 | 63 | 63 | 63 | 63 |
| 90th | 110 | 111 | 112 | 114 | 116 | 117 | 118 | 74 | 74 | 75 | 75 | 75 | 76 | 76 |
| 95th | 114 | 114 | 116 | 118 | 120 | 123 | 124 | 77 | 78 | 78 | 78 | 78 | 78 | 78 |
| 95th+12mmHg | 126 | 126 | 128 | 130 | 132 | 135 | 136 | 89 | 90 | 90 | 90 | 90 | 90 | 90 |
| 12years | | | | | | | | | | | | | | |
| Height (in) | 55.2 | 56.3 | 58.1 | 60.1 | 62.2 | 64 | 65.2 | 55.2 | 56.3 | 58.1 | 60.1 | 62.2 | 64 | 65.2 |
| Height (cm) | 140.3 | 143 | 147.5 | 152.7 | 157.9 | 162.6 | 165.5 | 140.3 | 143 | 147.5 | 152.7 | 157.9 | 162.6 | 165.5 |
| 50th | 101 | 101 | 102 | 104 | 106 | 108 | 109 | 61 | 62 | 62 | 62 | 62 | 63 | 63 |
| 90th | 113 | 114 | 115 | 117 | 119 | 121 | 122 | 75 | 75 | 75 | 75 | 75 | 76 | 76 |
| 95th | 116 | 117 | 118 | 121 | 124 | 126 | 128 | 78 | 78 | 78 | 78 | 78 | 79 | 79 |
| 95th+12mmHg | 128 | 129 | 130 | 133 | 136 | 138 | 140 | 90 | 90 | 90 | 90 | 90 | 91 | 91 |
| 13years | | | | | | | | | | | | | | |
| Height (in) | 57.9 | 59.1 | 61 | 63.1 | 65.2 | 67.1 | 68.3 | 57.9 | 59.1 | 61 | 63.1 | 65.2 | 67.1 | 68.3 |
| Height (cm) | 147 | 150 | 154.5 | 160.3 | 165.7 | 170.5 | 173.4 | 147 | 150 | 154.5 | 160.3 | 165.7 | 170.5 | 173.4 |
| 50th | 103 | 104 | 105 | 108 | 110 | 111 | 112 | 61 | 60 | 61 | 62 | 63 | 64 | 65 |
| 90th | 115 | 116 | 118 | 121 | 124 | 126 | 126 | 74 | 74 | 74 | 75 | 76 | 77 | 77 |
| 95th | 119 | 120 | 122 | 125 | 128 | 130 | 131 | 78 | 78 | 78 | 78 | 80 | 81 | 81 |
| 95th+12mmHg | 131 | 132 | 134 | 137 | 140 | 142 | 143 | 90 | 90 | 90 | 90 | 92 | 93 | 93 |
| 14years | | | | | | | | | | | | | | |
| Height (in) | 60.6 | 61.8 | 63.8 | 65.9 | 68 | 69.8 | 70.9 | 60.6 | 61.8 | 63.8 | 65.9 | 68 | 69.8 | 70.9 |
| Height (cm) | 153.8 | 156.9 | 162 | 167.5 | 172.7 | 177.4 | 180.1 | 153.8 | 156.9 | 162 | 167.5 | 172.7 | 177.4 | 180.1 |
| 50th | 105 | 106 | 109 | 111 | 112 | 113 | 113 | 60 | 60 | 62 | 64 | 65 | 66 | 67 |
| 90th | 119 | 120 | 123 | 126 | 127 | 128 | 129 | 74 | 74 | 75 | 77 | 78 | 79 | 80 |
| 95th | 123 | 125 | 127 | 130 | 132 | 133 | 134 | 77 | 78 | 79 | 81 | 82 | 83 | 84 |
| 95th+12mmHg | 135 | 137 | 139 | 142 | 144 | 145 | 146 | 89 | 90 | 91 | 93 | 94 | 95 | 96 |
| 15years | | | | | | | | | | | | | | |
| Height (in) | 62.6 | 63.8 | 65.7 | 67.8 | 69.8 | 71.5 | 72.5 | 62.6 | 63.8 | 65.7 | 67.8 | 69.8 | 71.5 | 72.5 |
| Height (cm) | 159 | 162 | 166.9 | 172.2 | 177.2 | 181.6 | 184.2 | 159 | 162 | 166.9 | 172.2 | 177.2 | 181.6 | 184.2 |
| 50th | 108 | 110 | 112 | 113 | 114 | 114 | 114 | 61 | 62 | 64 | 65 | 66 | 67 | 68 |
| 90th | 123 | 124 | 126 | 128 | 129 | 130 | 130 | 75 | 76 | 78 | 79 | 80 | 81 | 81 |
| 95th | 127 | 129 | 131 | 132 | 134 | 135 | 135 | 78 | 79 | 81 | 83 | 84 | 85 | 85 |
| 95th+12mmHg | 139 | 141 | 143 | 144 | 146 | 147 | 147 | 90 | 91 | 93 | 95 | 96 | 97 | 97 |
| 16years | | | | | | | | | | | | | | |
| Height (in) | 63.8 | 64.9 | 66.8 | 68.8 | 70.7 | 72.5 | 73.4 | 63.8 | 64.9 | 66.8 | 68.8 | 70.7 | 72.5 | 73.4 |
| Height (cm) | 162.1 | 165 | 169.6 | 174.6 | 179.5 | 183.8 | 186.4 | 162.1 | 165 | 169.6 | 174.6 | 179.5 | 183.8 | 186.4 |
| 50th | 111 | 112 | 114 | 115 | 115 | 116 | 116 | 63 | 64 | 66 | 67 | 68 | 69 | 69 |
| 90th | 126 | 127 | 128 | 129 | 131 | 131 | 132 | 77 | 78 | 79 | 80 | 81 | 82 | 82 |
| 95th | 130 | 131 | 133 | 134 | 135 | 136 | 137 | 80 | 81 | 83 | 84 | 85 | 86 | 86 |
| 95th+12mmHg | 142 | 143 | 145 | 146 | 147 | 148 | 149 | 92 | 93 | 95 | 96 | 97 | 98 | 98 |
| 17years | | | | | | | | | | | | | | |
| Height (in) | 64.5 | 65.5 | 67.3 | 69.2 | 71.1 | 72.8 | 73.8 | 64.5 | 65.5 | 67.3 | 69.2 | 71.1 | 72.8 | 73.8 |
| Height (cm) | 163.8 | 166.5 | 170.9 | 175.8 | 180.7 | 184.9 | 187.5 | 163.8 | 166.5 | 170.9 | 175.8 | 180.7 | 184.9 | 187.5 |
| 50th | 114 | 115 | 116 | 117 | 117 | 118 | 118 | 65 | 66 | 67 | 68 | 69 | 70 | 70 |
| 90th | 128 | 129 | 130 | 131 | 132 | 133 | 134 | 78 | 79 | 80 | 81 | 82 | 82 | 83 |
| 95th | 132 | 133 | 134 | 135 | 137 | 138 | 138 | 81 | 82 | 84 | 85 | 86 | 86 | 87 |
| 95th+12mmHg | 144 | 145 | 146 | 147 | 149 | 150 | 150 | 93 | 94 | 96 | 97 | 98 | 98 | 99 |

[Use percentile values to stage BP readings as in the table. (Elevated BP ≥ 90th percentile, stage 1 hypertension ≥ 95th percentile and stage 2 hypertension ≥ 95th percentile + 12mmHg. The 50th, 90th and 95th percentiles were derived by using quartile regression on the basis of normal weight children (BMI <85th percentile)]

(Source: Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents.2017. American Academy of Pediatrics)

## Table 6. BP levels for girls by age and height percentile

| BP (percentile) | Systolic BP (mmHg) | | | | | | | Diastolic BP (mmHg) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Height percentile or measured height | | | | | | | Height percentile or measured height | | | | | | |
| | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 5% | 10% | 25% | 50% | 75% | 90% | 95% |
| **1 year** | | | | | | | | | | | | | | |
| Height (in) | 29.7 | 30.2 | 30.9 | 31.8 | 32.7 | 33.4 | 33.9 | 29.7 | 30.2 | 30.9 | 31.8 | 32.7 | 33.4 | 33.9 |
| Height (cm) | 75.4 | 76.6 | 78.6 | 80.8 | 83 | 84.9 | 86.1 | 75.4 | 76.6 | 78.6 | 80.8 | 83 | 84.9 | 86.1 |
| 50th | 84 | 85 | 86 | 86 | 87 | 88 | 88 | 41 | 42 | 42 | 43 | 44 | 45 | 46 |
| 90th | 98 | 99 | 99 | 100 | 101 | 102 | 102 | 54 | 55 | 56 | 56 | 57 | 58 | 58 |
| 95th | 101 | 102 | 102 | 103 | 104 | 105 | 105 | 59 | 59 | 60 | 60 | 61 | 62 | 62 |
| 95th+12mmHg | 113 | 114 | 114 | 115 | 116 | 117 | 117 | 71 | 71 | 72 | 72 | 73 | 74 | 74 |
| **2years** | | | | | | | | | | | | | | |
| Height (in) | 33.4 | 34 | 34.9 | 35.9 | 36.9 | 37.8 | 38.4 | 33.4 | 34 | 34.9 | 35.9 | 36.9 | 37.8 | 38.4 |
| Height (cm) | 84.9 | 86.3 | 88.6 | 91.1 | 93.7 | 96 | 97.4 | 84.9 | 86.3 | 88.6 | 91.1 | 93.7 | 96 | 97.4 |
| 50th | 87 | 87 | 88 | 89 | 90 | 91 | 91 | 45 | 46 | 47 | 48 | 49 | 50 | 51 |
| 90th | 101 | 101 | 102 | 103 | 104 | 105 | 106 | 58 | 58 | 59 | 60 | 61 | 62 | 62 |
| 95th | 104 | 105 | 106 | 106 | 107 | 108 | 109 | 62 | 63 | 63 | 64 | 65 | 67 | 66 |
| 95th+12mmHg | 116 | 117 | 118 | 118 | 119 | 120 | 121 | 74 | 75 | 75 | 76 | 775 | 78 | 78 |
| **3years** | | | | | | | | | | | | | | |
| Height (in) | 35.8 | 36.4 | 37.3 | 38.4 | 39.6 | 40.6 | 41.2 | 35.8 | 36.4 | 37.3 | 38.4 | 39.6 | 40.6 | 41.2 |
| Height (cm) | 91 | 92.4 | 94.9 | 97.6 | 100.5 | 103.1 | 104.6 | 91 | 92.4 | 94.9 | 97.6 | 100.5 | 103.1 | 104.6 |
| 50th | 88 | 89 | 89 | 90 | 91 | 92 | 93 | 48 | 48 | 49 | 50 | 51 | 53 | 53 |
| 90th | 102 | 103 | 104 | 104 | 105 | 106 | 107 | 60 | 61 | 61 | 62 | 63 | 64 | 65 |
| 95th | 106 | 106 | 107 | 108 | 109 | 110 | 110 | 64 | 65 | 65 | 66 | 67 | 68 | 69 |
| 95th+12mmHg | 118 | 118 | 119 | 120 | 121 | 122 | 122 | 76 | 77 | 77 | 78 | 795 | 80 | 81 |
| 4years | | | | | | | | | | | | | | |
| Height (in) | 38.3 | 38.9 | 39.9 | 41.1 | 42.4 | 43.5 | 44.2 | 38.3 | 38.9 | 39.9 | 41.1 | 42.4 | 43.5 | 44.2 |
| Height (cm) | 97.2 | 98.8 | 101.4 | 104.5 | 107.6 | 110.5 | 112.2 | 97.2 | 98.8 | 101.4 | 104.5 | 107.6 | 110.5 | 112.2 |
| 50th | 89 | 90 | 91 | 92 | 93 | 94 | 94 | 50 | 51 | 51 | 53 | 54 | 55 | 55 |
| 90th | 103 | 104 | 105 | 106 | 107 | 108 | 108 | 62 | 63 | 64 | 65 | 66 | 67 | 67 |
| 95th | 107 | 108 | 109 | 109 | 110 | 111 | 112 | 66 | 67 | 68 | 69 | 70 | 70 | 71 |
| 95th+12mmHg | 119 | 120 | 121 | 121 | 122 | 123 | 124 | 78 | 79 | 80 | 815 | 82 | 82 | 83 |
| 5year | | | | | | | | | | | | | | |
| Height (in) | 40.8 | 41.5 | 42.6 | 43.9 | 45.2 | 46.5 | 47.3 | 40.8 | 41.5 | 42.6 | 43.9 | 45.2 | 46.5 | 47.3 |
| Height (cm) | 103.6 | 105.3 | 108.2 | 111.5 | 114.9 | 118.1 | 120 | 103.6 | 105.3 | 108.2 | 111.5 | 114.9 | 118.1 | 120 |
| 50th | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 52 | 52 | 53 | 55 | 56 | 57 | 57 |
| 90th | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 64 | 65 | 66 | 67 | 68 | 69 | 70 |
| 95th | 108 | 109 | 109 | 110 | 111 | 112 | 113 | 68 | 69 | 70 | 71 | 72 | 73 | 73 |
| 95th+12mmHg | 120 | 121 | 121 | 122 | 123 | 124 | 125 | 80 | 81 | 82 | 83 | 84 | 85 | 85 |
| 6years | | | | | | | | | | | | | | |
| Height (in) | 43.3 | 44 | 45.2 | 46.6 | 48.1 | 49.4 | 50.3 | 43.3 | 44 | 45.2 | 46.6 | 48.1 | 49.4 | 50.3 |
| Height (cm) | 110 | 111.8 | 114.9 | 118.4 | 122.1 | 125.6 | 127.7 | 110 | 111.8 | 114.9 | 118.4 | 122.1 | 125.6 | 127.7 |
| 50th | 92 | 92 | 93 | 94 | 96 | 97 | 97 | 54 | 54 | 55 | 56 | 57 | 58 | 59 |
| 90th | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 67 | 67 | 68 | 69 | 70 | 71 | 71 |
| 95th | 109 | 109 | 110 | 111 | 112 | 113 | 114 | 70 | 71 | 72 | 72 | 73 | 74 | 74 |
| 95th+12mmHg | 121 | 121 | 122 | 123 | 124 | 125 | 126 | 82 | 83 | 84 | 84 | 85 | 86 | 86 |
| 7years | | | | | | | | | | | | | | |
| Height (in) | 45.6 | 46.4 | 47.7 | 49.2 | 50.7 | 52.1 | 53 | 45.6 | 46.4 | 47.7 | 49.2 | 50.7 | 52.1 | 53 |
| Height (cm) | 115.9 | 117.8 | 121.1 | 124.9 | 128.8 | 132.5 | 134.7 | 115.9 | 117.8 | 121.1 | 124.9 | 128.8 | 132.5 | 134.7 |
| 50th | 92 | 93 | 94 | 95 | 97 | 98 | 99 | 55 | 55 | 56 | 57 | 58 | 59 | 60 |
| 90th | 106 | 106 | 107 | 109 | 110 | 111 | 112 | 68 | 68 | 69 | 70 | 71 | 72 | 72 |
| 95th | 109 | 110 | 111 | 112 | 113 | 114 | 115 | 72 | 72 | 73 | 73 | 74 | 74 | 75 |
| 95th+12mmHg | 121 | 122 | 123 | 124 | 125 | 126 | 127 | 84 | 84 | 85 | 85 | 86 | 86 | 87 |
| 8years | | | | | | | | | | | | | | |
| Height (in) | 47.6 | 48.4 | 49.8 | 51.4 | 53 | 54.5 | 55.5 | 47.6 | 48.4 | 49.8 | 51.4 | 53 | 54.5 | 55.5 |
| Height (cm) | 121 | 123 | 126.5 | 130.6 | 134.7 | 138.5 | 140.9 | 121 | 123 | 126.5 | 130.6 | 134.7 | 138.5 | 140.9 |
| 50th | 93 | 94 | 95 | 97 | 98 | 99 | 100 | 56 | 56 | 57 | 59 | 60 | 61 | 61 |
| 90th | 107 | 107 | 108 | 110 | 111 | 112 | 113 | 69 | 70 | 71 | 72 | 72 | 73 | 73 |
| 95th | 110 | 111 | 112 | 113 | 115 | 116 | 117 | 72 | 73 | 74 | 74 | 75 | 75 | 75 |
| 95th+12mmHg | 122 | 123 | 124 | 125 | 127 | 128 | 129 | 84 | 85 | 86 | 86 | 87 | 87 | 87 |
| 9years | | | | | | | | | | | | | | |
| Height (in) | 49.3 | 50.2 | 51.7 | 53.4 | 55.1 | 56.7 | 57.7 | 49.3 | 50.2 | 51.7 | 53.4 | 55.1 | 56.7 | 57.7 |
| Height (cm) | 125.3 | 127.6 | 131.3 | 135.6 | 140.1 | 144.1 | 146.6 | 125.3 | 127.6 | 131.3 | 135.6 | 140.1 | 144.1 | 146.6 |
| 50th | 95 | 95 | 97 | 98 | 99 | 100 | 101 | 57 | 58 | 59 | 60 | 60 | 61 | 61 |
| 90th | 108 | 108 | 109 | 111 | 112 | 113 | 114 | 71 | 71 | 72 | 73 | 73 | 73 | 73 |
| 95th | 112 | 112 | 113 | 114 | 116 | 117 | 118 | 74 | 74 | 75 | 75 | 75 | 75 | 75 |
| 95th+12mmHg | 124 | 124 | 125 | 126 | 128 | 129 | 130 | 86 | 86 | 87 | 87 | 87 | 87 | 87 |

| 10years | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Height (in) | 51.1 | 52 | 53.7 | 55.5 | 57.4 | 59.1 | 60.2 | 51.1 | 52 | 53.7 | 55.5 | 57.4 | 59.1 | 60.2 |
| Height (cm) | 129.7 | 132.2 | 136.3 | 141 | 145.8 | 150.2 | 152.8 | 129.7 | 132.2 | 136.3 | 141 | 145.8 | 150.2 | 152.8 |
| 50th | 96 | 97 | 98 | 99 | 101 | 102 | 103 | 58 | 59 | 59 | 60 | 61 | 61 | 62 |
| 90th | 109 | 110 | 111 | 112 | 113 | 115 | 116 | 72 | 73 | 73 | 73 | 73 | 73 | 73 |
| 95th | 113 | 114 | 114 | 116 | 117 | 119 | 120 | 75 | 75 | 76 | 76 | 76 | 76 | 76 |
| 95th+12mmHg | 125 | 126 | 126 | 128 | 129 | 131 | 132 | 87 | 87 | 88 | 88 | 88 | 88 | 88 |
| 11years | | | | | | | | | | | | | | |
| Height (in) | 53.4 | 54.5 | 56.2 | 58.2 | 60.2 | 61.9 | 63 | 53.4 | 54.5 | 56.2 | 58.2 | 60.2 | 61.9 | 63 |
| Height (cm) | 135.6 | 138.3 | 142.8 | 147.8 | 152.8 | 157.3 | 160 | 135.6 | 138.3 | 142.8 | 147.8 | 152.8 | 157.3 | 160 |
| 50th | 98 | 99 | 101 | 102 | 104 | 105 | 106 | 60 | 60 | 60 | 61 | 62 | 63 | 64 |
| 90th | 111 | 112 | 113 | 114 | 116 | 118 | 120 | 74 | 74 | 74 | 74 | 74 | 75 | 75 |
| 95th | 115 | 116 | 117 | 118 | 120 | 123 | 124 | 76 | 77 | 77 | 77 | 77 | 77 | 77 |
| 95th+12mmHg | 127 | 128 | 129 | 130 | 132 | 135 | 136 | 88 | 89 | 89 | 89 | 89 | 89 | 89 |
| 12years | | | | | | | | | | | | | | |
| Height (in) | 56.2 | 57.3 | 59 | 60.9 | 62.8 | 64.5 | 65.5 | 56.2 | 57.3 | 59 | 60.9 | 62.8 | 64.5 | 65.5 |
| Height (cm) | 142.8 | 145.5 | 149.9 | 154.8 | 159.6 | 163.8 | 166.4 | 142.8 | 145.5 | 149.9 | 154.8 | 159.6 | 163.8 | 166.4 |
| 50th | 102 | 102 | 104 | 105 | 107 | 108 | 108 | 61 | 61 | 61 | 62 | 64 | 65 | 65 |
| 90th | 114 | 115 | 116 | 118 | 120 | 122 | 122 | 75 | 75 | 75 | 75 | 76 | 76 | 76 |
| 95th | 118 | 119 | 120 | 122 | 124 | 125 | 126 | 78 | 78 | 78 | 78 | 79 | 79 | 79 |
| 95th+12mmHg | 130 | 131 | 132 | 134 | 136 | 137 | 138 | 90 | 90 | 90 | 90 | 91 | 91 | 91 |
| 13years | | | | | | | | | | | | | | |
| Height (in) | 58.3 | 59.3 | 60.9 | 62.7 | 64.5 | 66.1 | 67 | 58.3 | 59.3 | 60.9 | 62.7 | 64.5 | 66.1 | 67 |
| Height (cm) | 148.1 | 150.6 | 154.7 | 159.2 | 163.7 | 167.8 | 170.2 | 148.1 | 150.6 | 154.7 | 159.2 | 163.7 | 167.8 | 170.2 |
| 50th | 104 | 105 | 106 | 107 | 108 | 108 | 109 | 62 | 62 | 63 | 64 | 65 | 65 | 66 |
| 90th | 116 | 117 | 119 | 121 | 122 | 123 | 123 | 75 | 75 | 75 | 76 | 76 | 76 | 76 |
| 95th | 121 | 122 | 123 | 124 | 126 | 126 | 127 | 79 | 79 | 79 | 79 | 80 | 80 | 81 |
| 95th+12mmHg | 133 | 134 | 135 | 136 | 138 | 138 | 139 | 91 | 91 | 91 | 91 | 92 | 92 | 93 |
| 14years | | | | | | | | | | | | | | |
| Height (in) | 59.3 | 60.2 | 61.8 | 63.5 | 65.2 | 66.8 | 67.7 | 59.3 | 60.2 | 61.8 | 63.5 | 65.2 | 66.8 | 67.7 |
| Height (cm) | 150.6 | 153 | 156.9 | 161.3 | 165.7 | 169.7 | 172.1 | 150.6 | 153 | 156.9 | 161.3 | 165.7 | 169.7 | 172.1 |
| 50th | 105 | 106 | 107 | 108 | 109 | 109 | 109 | 63 | 63 | 64 | 65 | 66 | 66 | 66 |
| 90th | 118 | 118 | 120 | 122 | 123 | 123 | 123 | 76 | 76 | 76 | 76 | 77 | 77 | 77 |
| 95th | 123 | 123 | 124 | 125 | 126 | 127 | 127 | 80 | 80 | 80 | 80 | 81 | 81 | 82 |
| 95th+12mmHg | 135 | 135 | 126 | 137 | 138 | 139 | 139 | 92 | 92 | 92 | 92 | 93 | 93 | 94 |
| 15years | | | | | | | | | | | | | | |
| Height (in) | 59.7 | 60.6 | 62.2 | 63.9 | 65.6 | 67.2 | 68.1 | 59.7 | 60.6 | 62.2 | 63.9 | 65.6 | 67.2 | 68.1 |
| Height (cm) | 151.7 | 154 | 157.9 | 162.3 | 166.7 | 170.6 | 173 | 151.7 | 154 | 157.9 | 162.3 | 166.7 | 170.6 | 173 |
| 50th | 105 | 106 | 107 | 108 | 109 | 109 | 109 | 64 | 64 | 64 | 65 | 66 | 67 | 67 |
| 90th | 118 | 119 | 121 | 122 | 123 | 123 | 124 | 76 | 76 | 76 | 77 | 77 | 78 | 78 |
| 95th | 124 | 124 | 125 | 126 | 127 | 127 | 128 | 80 | 80 | 80 | 81 | 82 | 82 | 82 |
| 95th+12mmHg | 136 | 136 | 137 | 138 | 139 | 139 | 140 | 92 | 92 | 92 | 93 | 94 | 94 | 94 |
| 16years | | | | | | | | | | | | | | |
| Height (in) | 59.9 | 60.8 | 62.4 | 64.1 | 65.8 | 67.3 | 68.3 | 59.9 | 60.8 | 62.4 | 64.1 | 65.8 | 67.3 | 68.3 |
| Height (cm) | 152.1 | 154.5 | 158.4 | 162.8 | 167.1 | 171.1 | 173.4 | 152.1 | 154.5 | 158.4 | 162.8 | 167.1 | 171.1 | 173.4 |
| 50th | 106 | 107 | 108 | 109 | 109 | 110 | 110 | 64 | 64 | 65 | 66 | 66 | 67 | 67 |
| 90th | 119 | 120 | 122 | 123 | 124 | 124 | 124 | 76 | 76 | 76 | 77 | 78 | 78 | 78 |
| 95th | 124 | 125 | 125 | 127 | 127 | 128 | 128 | 80 | 80 | 80 | 81 | 82 | 82 | 82 |
| 95th+12mmHg | 136 | 137 | 137 | 139 | 139 | 140 | 140 | 92 | 92 | 92 | 93 | 94 | 94 | 94 |
| 17years | | | | | | | | | | | | | | |
| Height (in) | 60 | 60.9 | 62.5 | 64.2 | 65.9 | 67.4 | 68.4 | 60 | 60.9 | 62.5 | 64.2 | 65.9 | 67.4 | 68.4 |
| Height (cm) | 154.4 | 154.7 | 158.7 | 163 | 167.4 | 171.3 | 173.7 | 154.4 | 154.7 | 158.7 | 163 | 167.4 | 171.3 | 173.7 |
| 50th | 107 | 108 | 109 | 110 | 110 | 110 | 111 | 64 | 64 | 65 | 66 | 66 | 66 | 67 |
| 90th | 120 | 121 | 123 | 124 | 124 | 125 | 125 | 76 | 76 | 77 | 77 | 78 | 78 | 78 |
| 95th | 125 | 125 | 126 | 127 | 128 | 128 | 128 | 80 | 80 | 80 | 81 | 82 | 82 | 82 |
| 95th+12mmHg | 137 | 137 | 138 | 139 | 140 | 140 | 140 | 92 | 92 | 92 | 93 | 94 | 94 | 94 |

[Use percentile values to stage BP readings as in the table. (Elevated BP ≥ 90th percentile, stage 1 hypertension ≥ 95th percentile and stage 2 hypertension ≥ 95th percentile + 12mmHg. The 50th, 90th and 95th percentiles were derived by using quartile regression on the basis of normal weight children (BMI <85th percentile)]

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