

Blood Pressure and Hypertension

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Written by: Gail Moss
Peer reviewer: Noreen West
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Purpose

To guide the measurement and assessment of blood pressure and identification of those who are hypertensive. To guide the investigation and management of hypertension.

Intended Audience

All who care for children.

Contents of Guideline

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Summary of principles and important points

1. Measure blood pressure correctly (section 2).
2. Interpret blood pressure measurements using centile charts for age and height (sections 4, 10,11 (neonatal))
3. Repeated blood pressure measurements are required to diagnose hypertension – the method, timing, frequency and length of period of observation depends on circumstances. Ideally hypertension should be confirmed where possible by manual measurement (manual sphygmomanometer and appropriate cuffs available in OPD, M1, M2, Medical Daycare and AAU).
4. In possible or diagnosed chronic hypertension, clinic measurements of blood pressure are ideally accompanied by home monitoring of blood pressure (using home monitors validated by British Hypertension Society) or ambulatory measurement (only possible in Sheffield via cardiology at STH and where possible to use adult cuff, NB different centiles to assess ambulatory readings, Section 12).
5. Investigation of hypertension is required when the cause is not known. Primary hypertension is a diagnosis of exclusion. The details and extent of investigation depends on the clinical history, examination, circumstances and level of hypertension. Where possible blood and urine samples should be collected for investigations prior to initiating any treatment (sections 5,6,7).
6. Hypertensive crisis and symptomatic hypertension require urgent treatment (sections 8,9).
7. Hypertension should never be corrected rapidly (sections 8,9).
8. Do NOT lower blood pressure if intracranial hypertension is raised or is a possibility – the intracranial hypertension needs to be managed as an emergency.
9. Acute severe asymptomatic hypertension, where systolic blood pressure is > 99th centile plus 5 mmHg (Stage II hypertension), will usually require treatment which depends on the cause. Treatment for acute asymptomatic hypertension where systolic blood pressure is between 95th centile and 99th centile plus 5 mmHg (Stage I hypertension) should be considered depending on circumstances. Fluid overload should be managed with appropriate fluid restriction and diuretics. If required, nifedipine (or amlodipine) is often a good first line antihypertensive agent if no contraindication. An ACE inhibitor or Angiotensin II receptor blocker should NOT be used to treat acute hypertension or where renal artery stenosis may be possible (sections 8,9).
10. Chronic hypertension should be assessed and investigated where the cause is not known but subsequent management and treatment depends on the severity and cause (sections 7,8,9).

1. Introduction

Hypertension in children is common, occurring in 5% of the paediatric population. Although often asymptomatic, a significant proportion of children will have an underlying cause so investigation is usually justified. The measurement of blood pressure (BP) itself in children is challenging and hypertension will only be identified if children have their blood pressure checked appropriately. The long-term health risks for hypertensive children and adolescents can be substantial and so it is important to seek out and treat hypertension.

2. Measurement of Blood Pressure

The indirect measurement of blood pressure in children can be extremely difficult and needs the following considerations:

i. Method of measurement

All standards for blood pressure are based on auscultatory or similar measurements. Therefore, whilst automated oscillometric devices are convenient and may minimise observer error, they do NOT produce measurements that are identical to those obtained by auscultation and may overestimate blood pressure. Thus, ideally high blood pressure should be confirmed by measurement with a standard sphygmomanometer. This may be difficult due to lack of access to an appropriate device or skills to measure BP with this method, difficulty in using this method in certain clinical situations and in those under 3 years of age. Nevertheless, the standard is to check possible raised blood pressure using a sphygmomanometer in those where auscultation is possible. Mercury manometers are not often available, aneroid manometers are accurate when calibrated appropriately. Manual sphygmomanometers and appropriate cuffs are available in OPD, AAU, Medical Daycare, M1 and M2.

ii. Cuff size

An inappropriate cuff size may produce an inaccurate result whichever method of blood pressure is used. By convention, the appropriate cuff size is one which should be 2/3 the length of the arm, the inflatable BLADDER should cover 80 – 100 % of the circumference of the arm. The pragmatic approach is to use the cuff that is the largest one that can be used which would leave room to auscultate at the antecubital fossa. If necessary, the preference is to use a slightly larger cuff than one which is too small.

iii. Circumstances of measurement

Ideally, the individual should have been sitting/resting quietly for 5 minutes. The blood pressure should be measured in the right arm where possible, supported with the brachial artery at heart level. The sphygmomanometer should also be at heart level.

iv. Technique of auscultatory measurement

The brachial artery should be palpated as the bladder is inflated to obtain an approximate systolic BP. Auscultation should then be performed as the pressure in the bladder is decreased. The first Korotkov sound (K1) is taken as systolic BP and diastolic BP when the sounds disappear (K5). However, where the sounds do not disappear, muffling of the sounds (K4) can be taken as diastolic BP.

v. Home monitoring and ambulatory measurements

Clinic measurements only give isolated reading which may not give a reliable indication of the individuals "usual" blood pressure. Where there is concern that blood pressure may be high further readings should be obtained. Possible ways include:

1. A period of observation on Medical Daycare.
2. Home monitoring of blood pressure using a home monitor obtainable from large pharmacists etc – should be marked as validated by The British Hypertension Society (NB usually only possible with an adult cuff).
3. Measurement at GP surgery (NB check if possible if paediatric cuff of any size required and not usually possible if < 3 years old).
4. Ambulatory measurements (organised via cardiology at STH, only if adult cuff required, NB different centiles in use for ambulatory readings)

3. Standards for blood pressure

The definition of hypertension in childhood and adolescents is a statistical one. Blood pressure centiles for systolic (SBP) and diastolic (DBP) values are provided relative to age, sex and height in the percentile tables within the "Fourth Report On The Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents" (See below for tables and Ref)

4. Definitions and classification of hypertension (Fourth Task Force Report) – see end of guideline for centile charts

- **Normal blood pressure:**
 - SBP/DBP < 90th percentile
- **Prehypertension (or high normal blood pressure):**

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- Average SBP and /or DBP greater or equal to the 90th percentile but below the 95th percentile on three or more occasions over weeks to months depending on clinical circumstances.
- Adolescents (aged 10-19 years) with blood pressure above 120/80mmHg should be considered prehypertensive.
- **Stage I Hypertension:**
 - Average SBP and /or DBP equal to the 95th percentile to the 99th percentile plus 5 mmHg for age, sex and height on three or more occasions over days to weeks depending on clinical circumstances
- **Stage II Hypertension:**
 - Average SBP and /or DBP greater than 5mmg about the 99th percentile for age, sex and height on three or more occasions. NB In the presence of acute, severe or extremely high blood pressure, repeat measurement should be undertaken within a very short period of time depending on the clinical circumstances.
- **White Coat Hypertension:**
 - A patient with BP levels above the 95th percentile in clinic or hospital, who is normotensive outside a clinical setting. Ambulatory BP monitoring (ABPM) or home monitoring of blood pressure is usually required to make this diagnosis.

5. Presentation of hypertension

Hypertension may present as an asymptomatic incidental finding, during screening in at risk groups or with clinical signs and symptoms including:

- Congestive cardiac failure
- Headache
- Cerebrovascular incident
- Hypertensive encephalopathy
- Facial nerve palsy
- Failure to thrive

The history and examination needs to seek out these features and also look for features of any secondary causes.

6. Causes and co-morbidities of hypertension

Hypertension can be primary (where no underlying cause can be found, formerly known as essential) or secondary to an underlying cause. In general, the younger the child and the higher the BP, the greater the likelihood that hypertension is

secondary to an identifiable cause. A secondary cause of hypertension is most likely to be found before puberty; after puberty, hypertension is most often essential. This guideline is not intended to provide an exhaustive list of all the clinical features of the many causes of hypertension but in summary:

i. Primary hypertension

Primary hypertension is identifiable in children and adolescents. However, hypertension in children and adolescents should be investigated with primary hypertension being a diagnosis of exclusion.

Primary hypertension is often mild (Stage I) and associated with family history of hypertension or cardiovascular disease. Affected individuals are frequently overweight and may have some degree of insulin resistance. In addition, high triglycerides and low high density lipoprotein cholesterol may also be found as other components of the metabolic syndrome. Sleep disturbance and disordered breathing may be associated with primary hypertension, particularly in those that are overweight.

ii. Secondary hypertension

An underlying disorder or cause should be considered in all who have elevated blood pressure. This list is not exhaustive but causes include:

- i. Renal parenchymal or renovascular abnormality – accounts for the vast majority of secondary causes in childhood and can be acute or chronic conditions
- ii. Cardiovascular abnormalities – eg coarctation of the aorta
- iii. Excess corticosteroid production - eg Cushing's syndrome
- iv. Excess mineralocorticoid production – eg congenital adrenal hyperplasia, primary hyperaldosteronism
- v. Excess catecholamine production eg neuroblastoma, pheochromocytoma
- vi. Thyrotoxicosis
- vii. Related to nervous system – eg raised intracranial pressure, autonomic dysfunction
- viii. Drugs – many may be responsible but would include especially corticosteroids, calcineurin inhibitors, sympathomimetics, methylphenidate and related drugs, contraceptive pill, clonidine
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iii Common causes of hypertension by age of presentation:

Newborn – 1 year	1-5 years	5-10 years	10-20 years
<ul style="list-style-type: none"> • Renal artery stenosis • Renal vein or artery thrombosis • Congenital renal disease (ARPKD, dysplasia etc) • Aortic coarctation • Neuroblastoma • Wilm's tumour • Bronchopulmonary dysplasia • Patent ductus • Intraventricular haemorrhage • Hydrocephalus • Drugs 	<ul style="list-style-type: none"> • Renal artery stenosis • Middle aortic syndrome • Glomerulonephritis • Renal vein thrombosis • Phaeochromocytoma • Neuroblastoma • Cystic kidney disease • Corticosteroids • Monogenic hypertension (e.g. Liddle's syndrome) • Wilm's tumour • Brain tumour 	<ul style="list-style-type: none"> • Reflux nephropathy • Glomerulonephritis • Cystic renal disease • Renal artery stenosis • Middle aortic syndrome • Endocrine tumours • Wilm's tumour • Other parenchymal renal disease e.g. nephronphthisis • Primary hypertension • Brain tumour 	<ul style="list-style-type: none"> • Primary Hypertension • Reflux nephropathy • Glomerulonephritis • Renal artery stenosis • Endocrine tumours • Monogenic hypertension • Pregnancy • Drugs inc oral contraceptive pill • Brain tumour • Intracerebral bleed

7. Assessment and Investigation of Hypertension

The initial assessment is a thorough clinical history and examination (including palpation of femoral pulses at all ages) to look for evidence of underlying causes as outlined above, co-morbidity, family history of relevance, past medical history and drug history (including over the counter and recreational).

Investigations are aimed at identifying the cause of hypertension (if this is not already known), assessing the presence of any co-morbidities and identifying any end-organ damage. Investigations will be directed by age, clinical findings, severity of hypertension and presence or absence of symptoms but below is a suggested scheme.

NB If possible, blood and urine samples should be taken prior to commencing treatment. However, treatment should not be delayed unnecessarily.

i All Children with Stage I or II hypertension

- **To identify a cause – the necessity for all these investigations depends on if the cause is known and if previous investigations have been undertaken:**

- Full blood count
- U&Es, creatinine, bone profile
- Thyroid function tests
- Plasma renin and aldosterone
- Urinalysis for protein / blood / infection
- Urine HVA/VMA, catecholamines
- Renal ultrasound (with renal vessel doppler if available)
- Cardiac ultrasound scan

Also consider depending on if cause known and clinical circumstances:

- Urine pregnancy test
 - Urine toxicology screen
 - Plasma cortisol, ACTH
 - Urine steroid profile
-
- **To identify co-morbidities where appropriate, particularly where thought to be primary hypertension:**
 - Fasting lipids
 - Fasting glucose, insulin
 - Consider HbA1c
 - Liver function tests
 - Consider ultrasound scan of liver
-
- **To assess for end-organ damage:**
 - ECG
 - Echocardiogram (to look for presence of left ventricular hypertrophy but may also identify a cause eg. coarctation of aorta)
 - Retinal examination (in those with severe or long standing hypertension)
 - U&Es and urinalysis - also part of the end-organ assessment

ii Further investigation may be required depending on initial results and clinical circumstances:

- Eg DMSA scan, MR or formal angiography, renal biopsy
- Renovascular disease should be considered in children if peripheral renin/aldosterone is elevated or basic renal imaging is suggestive. It should also be considered if hypertension remains difficult to control despite the use of two agents, even if other investigations are normal.

8 Management of hypertension**i Goals of Management**

1. To reduce blood pressure to <95th percentile
2. To reduce blood pressure to <90th percentile in those with co-morbidities
3. To consider aggressive blood pressure control (<50th percentile) in some patient groups (e.g. those with chronic kidney disease)

ii Lifestyle advice

This may be all that is required in pre or primary hypertension and should be given to all children with hypertension:

- Dietary advice regarding healthy eating (including reducing salt intake). Ideally all children with hypertension and pre-hypertension should be referred to a dietician or local community programme for lifestyle advice regarding eating and exercise depending on circumstances.
- Regular physical activity (30-60 minutes/day)
- Weight reduction if overweight or obese
- Assessment and interventions to improve sleep if sleep apnoea identified.
- Advice regarding alcohol, caffeine and drugs

iii Pharmacological Intervention

Indications depend on clinical circumstances and stage.

Prehypertension - drug therapy is not usually indicated unless compelling indications such as chronic kidney disease (CKD), diabetes mellitus, heart failure or left ventricular hypertrophy.

Stage I hypertension – drug therapy indicated if compelling reasons as outlined above or indications as outlined below.

Stage II hypertension – drug therapy usually indicated especially if any indications as outlined below.

Indications for antihypertensive drug treatment:

- Symptomatic hypertension
- Secondary hypertension (together with specific management of underlying cause where possible, NB if raised intracranial hypertension is possible do NOT lower blood pressure)
- Hypertensive target-organ damage
- Diabetes mellitus (Type 1 and 2)
- Persistent hypertension despite non-pharmacological measures

iv Initial Antihypertensive Medication

Selection of an appropriate anti-hypertensive depends upon the age of the patient, the clinical scenario and the presence of any contraindications. This guidance intends to highlight some important points about each drug class but is not intended to replace a full clinical assessment or the advice contained within the BNFC.

a General Principles

- Once daily dosing regimes are preferable when possible to aid compliance
- Younger children (<1 yr) may need multiple daily dosing to increase dose flexibility e.g. propranolol rather than atenolol or captopril rather than enalapril.
- Doses should be commenced at the starting dose in the BNFC and then gradually titrated until the desired blood pressure is achieved (see goals of therapy).
- In infants or those with impaired cardiac function it may be necessary to initiate antihypertensive medication in hospital with BP monitoring – these patients should be discussed with a paediatrician experienced in this area or a paediatric nephrologist.

b Commonly used drugs

i Calcium Channel Blockers (eg. nifedipine, amlodipine)

- Can be used as first or second line agents in most cases of hypertension if not contraindicated (eg. diabetes mellitus (nifedipine))
- Amlodipine tablets can be dispersed in a known volume of water and a proportion taken. This avoids the need to order expensive special medications which also have a short shelf life.
- Nifedipine has a short half-life and so can lead to relatively large fluctuations in BP. Amlodipine is therefore preferable for long term treatment, though modified

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release preparations of nifedipine are an acceptable alternative in patients able to swallow tablets.

- Patients under 6 years of age may have an increased ability to clear amlodipine. Dividing the daily dose into two divided doses in this age group may therefore improve efficacy, though this has not been robustly demonstrated to be beneficial.

ii Beta Blockers (eg propranolol, atenolol)

- Can be used as first or second line agent in most cases of hypertension if not contraindicated (eg. asthma, portal hypertension)
- NB Cases of phaeochromocytoma need concurrent alpha-blockade

iii ACE Inhibitors (eg.captopril, enalapril, lisinopril)

- Good first line agent in cases of chronic kidney disease providing renal artery stenosis has been excluded.
- Electrolytes and creatinine must be checked 7 – 10 days after initiating or increasing an ACE inhibitor dose because of the risk of renal impairment and hyperkalaemia
- Counsel teenage girls regarding the contraindication in pregnancy
- Counsel regarding the importance of stopping medication whilst unwell with diarrhoeal or vomiting illnesses
- Enalapril and lisinopril tablets can be crushed and made into a suspension. This removes the need for expensive Special Preparations.
- Angiotensin 2 receptor blockers (eg. Losartan) may provide an alternative in those who are unable to tolerate ACE inhibitors or can be used in addition.

iv Diuretics (eg.furosemide)

- May be the most appropriate treatment for hypertension in the context of fluid overload – for example, acute glomerulonephritis.
- Counsel regarding the importance of stopping medication whilst unwell with diarrhoeal or vomiting illnesses

9. Guidelines for management of specific categories of hypertensive child**i Hypertensive crisis**

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IE Where there are convulsions, encephalopathy or cardiac failure secondary to hypertension.

These children will require admission to HDU or PICU setting for close blood pressure monitoring and intravenous anti-hypertensives – consider labetalol or sodium nitroprusside. Hydralazine may also be used, particularly in neonates and infants. Discuss with paediatric nephrology.

Intra-arterial blood pressure monitoring should be considered and frequent neurological observations should be undertaken as well as pulse rate and blood pressure.

Special considerations

1. Consider intracerebral pathology which might be causing raised intracranial pressure – if suspected, investigate and DO NOT aim to lower blood pressure until this cause has been excluded.
2. If proven or suspected pheochromocytoma consideration should be given to beta and alpha-blockade and patients should be managed in conjunction with paediatric oncologist.

Reduction of blood pressure

Reduce blood pressure to “safe” levels. Use iv treatment to reduce BP SLOWLY and titrate drug infusion to aim to reduce BP by:

- First 1/3 of total BP reduction over first 12 hours
- Next 1/3 of total BP reduction over second 12 hours
- Final 1/3 of total BP reduction over subsequent 24 hours

Do not decrease BP by more than 25% in first 8 hours.
If blood pressure drops suddenly, then treat with iv fluid bolus.
Ultimately, convert to oral treatment when BP is under good control and when clinical condition allows.

ii Symptomatic hypertension and/or acute severe hypertension

Symptomatic hypertension eg headaches, facial nerve palsy or acute severe hypertension (Stage II hypertension) ie average SBP and / or DBP >5 mmHg above the 99th percentile.

1 Admit to a ward able to monitor blood pressure frequently and discuss management with a paediatrician or nephrologist experienced in the management of acute severe hypertension.

Requirement to admit if asymptomatic and chronic depends on clinical situation and decision should be taken on an individual basis.

2 Ensure hypertension NOT secondary to intracerebral pathology in which case lowering BP could be dangerous

3 Consider cause of hypertension and initiate appropriate management

4 Control BP

- Consider **fluid overload** as the cause of acute hypertension in which case a diuretic and appropriate management of fluid balance may be the most appropriate treatment
- Otherwise use Nifedipine up to 250 micrograms/kg/dose (maximum dose: 5 mg) if not contraindicated* or need to use with extreme caution ** (nb frequent small doses are safest)
- Aim to **reduce blood pressure slowly** (1/3 of the total BP reduction over the first 12 hours of treatment, next 1/3 of total BP reduction over next 12 hours of treatment and final 1/3 over next 24 hours of treatment). Total reduction to "safe" levels in first instance but depends on clinical circumstances and response. Slower than the above may be reasonable depending on circumstances.
- Ensure immediate medical review if the blood pressure drops markedly or the patient becomes symptomatic
- **Set a BP threshold** for PRN treatment appropriate for the patient e.g. 10 mm Hg above 95th percentile on 2 occasions 15 mins apart, re-check BP every 30 minutes and consider second dose of nifedipine if BP remains raised above threshold
- **Discuss with paediatrician experienced in management of hypertension or paediatric nephrologist if unable to control BP**
- Once BP improving convert to a long acting anti-hypertensive (see below)
- Investigations as above

*Contraindications for use of Nifedipine:

- Shock
- Advanced aortic stenosis
- Encephalopathy / cranial hypertension

**Use Nifedipine with caution:

- Impaired cardiac function
- Diabetes (may affect blood sugars)

iii Asymptomatic/chronic hypertension

IE: Stage I hypertension with average SBP and/or DBP greater or equal to the 95th percentile but less than 5 mm over the 99th percentile for age, sex and height on three or more occasions.

Can usually be managed as an outpatient. Counsel re:lifestyle advice as outlined above. Consider drug therapy in line with indications and any compelling reasons to treat as outlined above.

Stage II hypertension, if asymptomatic and chronic, may be managed as outpatient depending on severity and clinical circumstances but will require frequent outpatient review.

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Blood pressure centiles by sex, age and height centile

TABLE 3. BP Levels for Boys by Age and Height Percentile

Age, y	BP Percentile	SBP, mm Hg								DBP, mm Hg							
		Percentile of Height								Percentile of Height							
		5th	10th	25th	50th	75th	90th	95th	9th	10th	25th	50th	75th	90th	95th		
1	50th	80	81	83	85	87	88	89	34	35	36	37	38	39	39		
	90th	94	95	97	99	100	102	103	49	50	51	52	53	53	54		
	95th	98	99	101	103	104	106	106	54	54	55	56	57	58	58		
	99th	105	106	108	110	112	113	114	61	62	63	64	65	66	66		
2	50th	84	85	87	88	90	92	93	39	40	41	42	43	44	44		
	90th	97	99	100	102	104	105	106	54	55	56	57	58	58	59		
	95th	101	102	104	106	108	109	110	59	59	60	61	62	63	63		
	99th	109	110	111	113	115	117	117	66	67	68	69	70	71	71		
3	50th	86	87	89	91	93	94	95	44	44	45	46	47	48	48		
	90th	100	101	103	105	107	108	109	59	59	60	61	62	63	63		
	95th	104	105	107	109	110	112	113	63	63	64	65	66	67	67		
	99th	111	112	114	116	118	119	120	71	71	72	73	74	75	75		
4	50th	88	89	91	93	95	96	97	47	48	49	50	51	51	52		
	90th	102	103	105	107	109	110	111	62	63	64	65	66	66	67		
	95th	106	107	109	111	112	114	115	66	67	68	69	70	71	71		
	99th	113	114	116	118	120	121	122	74	75	76	77	78	78	79		
5	50th	90	91	93	95	96	98	98	50	51	52	53	54	55	55		
	90th	104	105	106	108	110	111	112	65	66	67	68	69	69	70		
	95th	108	109	110	112	114	115	116	69	70	71	72	73	74	74		
	99th	115	116	118	120	121	123	123	77	78	79	80	81	81	82		
6	50th	91	92	94	96	98	99	100	53	53	54	55	56	57	57		
	90th	105	106	108	110	111	113	113	68	68	69	70	71	72	72		
	95th	109	110	112	114	115	117	117	72	72	73	74	75	76	76		
	99th	116	117	119	121	123	124	125	80	80	81	82	83	84	84		
7	50th	92	94	95	97	99	100	101	55	55	56	57	58	59	59		
	90th	106	107	109	111	113	114	115	70	70	71	72	73	74	74		
	95th	110	111	113	115	117	118	119	74	74	75	76	77	78	78		
	99th	117	118	120	122	124	125	126	82	82	83	84	85	86	86		
8	50th	94	95	97	99	100	102	102	56	57	58	59	60	60	61		
	90th	107	109	110	112	114	115	116	71	72	73	74	75	76	76		
	95th	111	112	114	116	118	119	120	75	76	77	78	79	79	80		
	99th	119	120	122	123	125	127	127	83	84	85	86	87	87	88		
9	50th	95	96	98	100	102	103	104	57	58	59	60	61	61	62		
	90th	109	110	112	114	115	117	118	72	73	74	75	76	76	77		
	95th	113	114	116	118	119	121	121	76	77	78	79	80	81	81		
	99th	120	121	123	125	127	128	129	84	85	86	87	88	88	89		
10	50th	97	98	100	102	103	105	106	58	59	60	61	61	62	63		
	90th	111	112	114	115	117	119	119	73	73	74	75	76	77	78		
	95th	115	116	117	119	121	122	123	77	78	79	80	81	81	82		
	99th	122	123	125	127	128	130	130	85	86	86	88	88	89	90		
11	50th	99	100	102	104	105	107	107	59	59	60	61	62	63	63		
	90th	113	114	115	117	119	120	121	74	74	75	76	77	78	78		
	95th	117	118	119	121	123	124	125	78	78	79	80	81	82	82		
	99th	124	125	127	129	130	132	132	86	86	87	88	89	90	90		
12	50th	101	102	104	106	108	109	110	59	60	61	62	63	63	64		
	90th	115	116	118	120	121	123	123	74	75	75	76	77	78	79		
	95th	119	120	122	123	125	127	127	78	79	80	81	82	82	83		
	99th	126	127	129	131	133	134	135	86	87	88	89	90	90	91		
13	50th	104	105	106	108	110	111	112	60	60	61	62	63	64	64		
	90th	117	118	120	122	124	125	126	75	75	76	77	78	79	79		
	95th	121	122	124	126	128	129	130	79	79	80	81	82	83	83		
	99th	128	130	131	133	135	136	137	87	87	88	89	90	91	91		
14	50th	106	107	109	111	113	114	115	60	61	62	63	64	65	65		
	90th	120	121	123	125	126	128	128	75	76	77	78	79	79	80		
	95th	124	125	127	128	130	132	132	80	80	81	82	83	84	84		
	99th	131	132	134	136	138	139	140	87	88	89	90	91	92	92		
15	50th	109	110	112	113	115	117	117	61	62	63	64	65	66	66		
	90th	122	124	125	127	129	130	131	76	77	78	79	80	80	81		
	95th	126	127	129	131	133	134	135	81	81	82	83	84	85	85		
	99th	134	135	136	138	140	142	142	88	89	90	91	92	93	93		
16	50th	111	112	114	116	118	119	120	63	63	64	65	66	67	67		
	90th	125	126	128	130	131	133	134	78	78	79	80	81	82	82		
	95th	129	130	132	134	135	137	137	82	83	83	84	85	86	87		
	99th	136	137	139	141	143	144	145	90	90	91	92	93	94	94		
17	50th	114	115	116	118	120	121	122	65	66	66	67	68	69	70		
	90th	127	128	130	132	134	135	136	80	80	81	82	83	84	84		
	95th	131	132	134	136	138	139	140	84	85	86	87	87	88	89		
	99th	139	140	141	143	145	146	147	92	93	93	94	95	96	97		

The 90th percentile is 1.28 SD, the 95th percentile is 1.645 SD, and the 99th percentile is 2.326 SD over the mean. For research purposes, the SDs in Table B1 allow one to compute BP Z scores and percentiles for boys with height percentiles given in Table 3 (ie, the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles). These height percentiles must be converted to height Z scores given by: 5% -1.645; 10% -1.28; 25% -0.68; 50% 0; 75% 0.68; 90% 1.28; and 95% 1.645, and then computed according to the methodology in steps 2 through 4 described in Appendix B. For children with height percentiles other than these, follow steps 1 through 4 as described in Appendix B.

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Blood Pressure and Hypertension

TABLE 4 BP Levels for Girls by Age and Height Percentile

Age, y	BP Percentile	SBP, mm Hg								DBP, mm Hg							
		Percentile of Height								Percentile of Height							
		5th	10th	25th	50th	75th	90th	95th	99th	5th	10th	25th	50th	75th	90th	95th	
1	50th	83	84	85	86	88	89	90	38	39	39	40	41	41	42		
	90th	97	97	98	100	101	102	103	52	53	53	54	55	55	56		
	95th	100	101	102	104	105	106	107	56	57	57	58	59	59	60		
	99th	108	108	109	111	112	113	114	64	64	65	65	66	67	67		
2	50th	85	85	87	88	89	91	91	43	44	44	45	46	46	47		
	90th	98	99	100	101	103	104	105	57	58	58	59	60	61	61		
	95th	102	103	104	105	107	108	109	61	62	62	63	64	65	65		
	99th	109	110	111	112	114	115	116	69	69	70	70	71	72	72		
3	50th	86	87	88	89	91	92	93	47	48	48	49	50	50	51		
	90th	100	100	102	103	104	106	106	61	62	62	63	64	64	65		
	95th	104	104	105	107	108	109	110	65	66	66	67	68	68	69		
	99th	111	111	113	114	115	116	117	73	73	74	74	75	76	76		
4	50th	88	88	90	91	92	94	94	50	50	51	52	52	53	54		
	90th	101	102	103	104	106	107	108	64	64	65	66	67	67	68		
	95th	105	106	107	108	110	111	112	68	68	69	70	71	71	72		
	99th	112	113	114	115	117	118	119	76	76	76	77	78	79	79		
5	50th	89	90	91	93	94	95	96	52	53	53	54	55	55	56		
	90th	103	103	105	106	107	109	109	66	67	67	68	69	69	70		
	95th	107	107	108	110	111	112	113	70	71	71	72	73	73	74		
	99th	114	114	116	117	118	120	120	78	78	79	79	80	81	81		
6	50th	91	92	93	94	96	97	98	54	54	55	56	56	57	58		
	90th	104	105	106	108	109	110	111	68	68	69	70	70	71	72		
	95th	108	109	110	111	113	114	115	72	72	73	74	74	75	76		
	99th	115	116	117	119	120	121	122	80	80	80	81	82	83	83		
7	50th	93	93	95	96	97	99	99	55	56	56	57	58	58	59		
	90th	106	107	108	109	111	112	113	69	70	70	71	72	72	73		
	95th	110	111	112	113	115	116	116	73	74	74	75	76	76	77		
	99th	117	118	119	120	122	123	124	81	81	82	82	83	84	84		
8	50th	95	95	96	98	99	100	101	57	57	57	58	59	60	60		
	90th	108	109	110	111	113	114	114	71	71	71	72	73	74	74		
	95th	112	112	114	115	116	118	118	75	75	75	76	77	78	78		
	99th	119	120	121	122	123	125	125	82	82	83	83	84	85	86		
9	50th	96	97	98	100	101	102	103	58	58	58	59	60	61	61		
	90th	110	110	112	113	114	116	116	72	72	72	73	74	75	75		
	95th	114	114	115	117	118	119	120	76	76	76	77	78	79	79		
	99th	121	121	123	124	125	127	127	83	83	84	84	85	86	87		
10	50th	98	99	100	102	103	104	105	59	59	59	60	61	62	62		
	90th	112	112	114	115	116	118	118	73	73	73	74	75	76	76		
	95th	116	116	117	119	120	121	122	77	77	77	78	79	80	80		
	99th	123	123	125	126	127	129	129	84	84	85	86	86	87	88		
11	50th	100	101	102	103	105	106	107	60	60	60	61	62	63	63		
	90th	114	114	116	117	118	119	120	74	74	74	75	76	77	77		
	95th	118	118	119	121	122	123	124	78	78	78	79	80	81	81		
	99th	125	125	126	128	129	130	131	85	85	86	87	87	88	89		
12	50th	102	103	104	105	107	108	109	61	61	61	62	63	64	64		
	90th	116	116	117	119	120	121	122	75	75	75	76	77	78	78		
	95th	119	120	121	123	124	125	126	79	79	79	80	81	82	82		
	99th	127	127	128	130	131	132	133	86	86	87	88	88	89	90		
13	50th	104	105	106	107	109	110	110	62	62	62	63	64	65	65		
	90th	117	118	119	121	122	123	124	76	76	76	77	78	79	79		
	95th	121	122	123	124	126	127	128	80	80	80	81	82	83	83		
	99th	128	129	130	132	133	134	135	87	87	88	89	89	90	91		
14	50th	106	106	107	109	110	111	112	63	63	63	64	65	66	66		
	90th	119	120	121	122	124	125	125	77	77	77	78	79	80	80		
	95th	123	123	125	126	127	129	129	81	81	81	82	83	84	84		
	99th	130	131	132	133	135	136	136	88	88	89	90	90	91	92		
15	50th	107	108	109	110	111	113	113	64	64	64	65	66	67	67		
	90th	120	121	122	123	125	126	127	78	78	78	79	80	81	81		
	95th	124	125	126	127	129	130	131	82	82	82	83	84	85	85		
	99th	131	132	133	134	136	137	138	89	89	90	91	91	92	93		
16	50th	108	108	110	111	112	114	114	64	64	65	66	66	67	68		
	90th	121	122	123	124	126	127	128	78	78	79	80	81	81	82		
	95th	125	126	127	128	130	131	132	82	82	83	84	85	85	86		
	99th	132	133	134	135	137	138	139	90	90	90	91	92	93	93		
17	50th	108	109	110	111	113	114	115	64	65	65	66	67	67	68		
	90th	122	122	123	125	126	127	128	78	79	79	80	81	81	82		
	95th	125	126	127	129	130	131	132	82	83	83	84	85	85	86		
	99th	133	133	134	136	137	138	139	90	90	91	91	92	93	93		

* The 90th percentile is 1.28 SD, the 95th percentile is 1.645 SD, and the 99th percentile is 2.326 SD over the mean. For research purposes, the SDs in Table B1 allow one to compute BP Z scores and percentiles for girls with height percentiles given in Table 4 (ie, the 5th, 10th, 25th, 50th, 75th, 90th, and 99th percentiles). These height percentiles must be converted to height Z scores given by: 5% -1.645; 10% -1.28; 25% -0.68; 50% 0; 75% 0.68; 90% 1.28; and 95% 1.645 and then computed according to the methodology in steps 2 through 4 described in Appendix B. For children with height percentiles other than these, follow steps 1 through 4 as described in Appendix B.

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Neonatal blood pressure centiles

Blood Pressure and Hypertension

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

This table provides estimated values for blood pressures after two weeks of age in infants from 26 to 44 weeks post conceptual age. The 95th and 99th percentile values are intended to serve as a reference to identify infants with persistent hypertension that may require treatment.

SBP: systolic blood pressure; DBP: diastolic blood pressure; MAP: mean arterial pressure.

Reproduced from: Dionne JM, Abitbol CL, Flynn JT. Hypertension in infancy: diagnosis, management, and outcome. *Pediatr Nephrol*

Blood Pressure and Hypertension

Ambulatory Blood Pressure centiles by sex and height

Appendix 3 90th and 95th percentiles of mean day- and night-time systolic and diastolic BP, stratified according to gender and height

BOYS Height (cm)	Systolic BP				Diastolic BP			
	Day		Night		Day		Night	
	90th pct	95th pct	90th pct	95th pct	90th pct	95th pct	90th pct	95th pct
120	120.6	123.5	103.7	106.4	79.1	81.2	61.9	64.1
125	121.0	124.0	104.9	107.8	79.3	81.3	62.2	64.3
130	121.6	124.6	106.3	109.5	79.3	81.4	62.4	64.5
135	122.2	125.2	107.7	111.3	79.3	81.3	62.7	64.8
140	123.0	126.0	109.3	113.1	79.2	81.2	62.9	65.0
145	124.0	127.0	110.7	114.7	79.1	81.1	63.1	65.2
150	125.4	128.5	111.9	115.9	79.1	81.0	63.3	65.4
155	127.2	130.2	113.1	117.0	79.2	81.1	63.4	65.6
160	129.2	132.3	114.3	118.0	79.3	81.3	63.6	65.7
165	131.3	134.5	115.5	119.1	79.7	81.7	63.7	65.8
170	133.5	136.7	116.8	120.2	80.1	82.2	63.8	65.9
175	135.6	138.8	118.1	121.2	80.6	82.8	63.8	65.9
180	137.7	140.9	119.2	122.1	81.1	83.4	63.8	65.8
185	139.8	143.0	120.3	123.0	81.7	84.1	63.8	65.8

GIRLS Height (cm)	Systolic BP				Diastolic BP			
	Day		Night		Day		Night	
	90th pct	95th pct	90th pct	95th pct	90th pct	95th pct	90th pct	95th pct
120	118.5	121.1	105.7	109.0	79.7	81.8	64.0	66.4
125	119.5	122.1	106.4	109.8	79.7	81.8	63.8	66.2
130	120.4	123.1	107.2	110.6	79.7	81.8	63.6	66.0
135	121.4	124.1	107.9	111.3	79.7	81.8	63.4	65.8
140	122.3	125.1	108.4	111.9	79.8	81.8	63.2	65.7
145	123.4	126.3	109.1	112.5	79.8	81.8	63.0	65.6
150	124.6	127.5	109.9	113.1	79.9	81.9	63.0	65.5
155	125.7	128.5	110.6	113.8	79.9	81.9	62.9	65.5
160	126.6	129.3	111.1	114.0	79.9	81.9	62.8	65.4
165	127.2	129.8	111.2	114.0	79.9	81.9	62.7	65.2
170	127.5	130.0	111.2	114.0	79.9	81.8	62.5	65.0
175	127.6	129.9	111.2	114.0	79.8	81.7	62.3	64.7

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