

Hypertension in children and adolescents



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1

Objectives

1. ทราบคำจำกัดความของภาวะความดันโลหิตสูงในเด็ก
2. สามารถวินิจฉัยภาวะความดันโลหิตสูงในเด็กได้
3. ทราบสาเหตุของความดันโลหิตสูงในเด็กแต่ละกลุ่มอายุ
4. สามารถส่งตรวจเพิ่มเติมทางห้องปฏิบัติการเพื่อหาสาเหตุได้
5. สามารถให้การรักษาภาวะความดันโลหิตสูงในเด็กได้

2

How to measure BP in children?

1. The child should be seated in quiet room for **3–5 min before measurement**, with back supported & feet uncrossed on the floor.
2. BP should be measured in **right arm**. The arm should be at **heart level**, supported, and uncovered above the cuff.



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Pediatrics. 2017;140(3):e20171904

3

3

How to measure BP in children?

3. The correct cuff size should be used. The bladder **length should be 80–100%** of the circumference of the arm, and the **width should be at least 40%**.



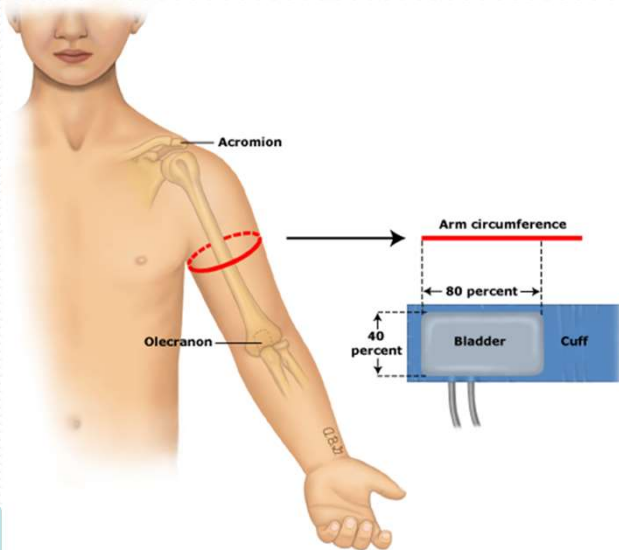
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4

4

How to measure BP in children?



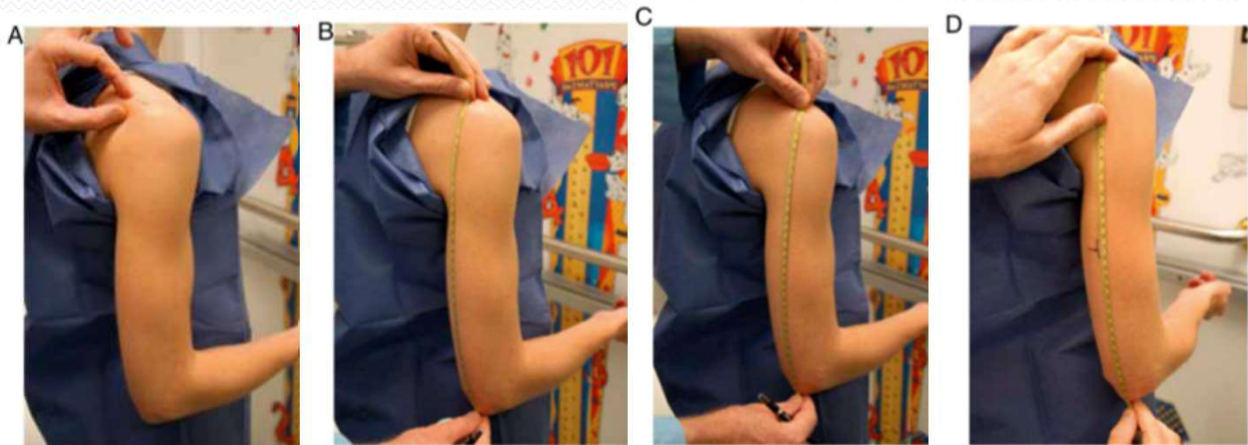
The bladder length should be 80–100% of the circumference of the arm, and the width should be at least 40%.

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5

5

Mid-arm circumference



✓ Correct

✗ Incorrect

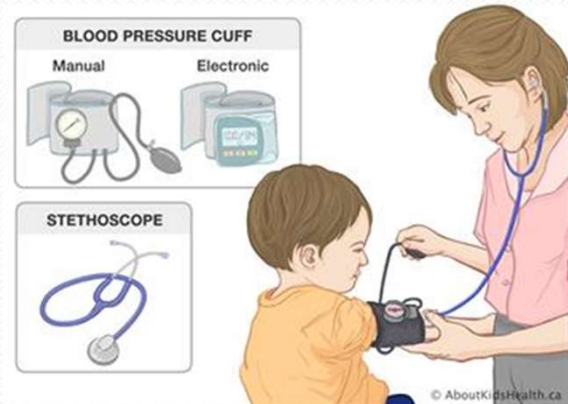
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6

How to measure BP in children?

4. For an auscultatory BP, the bell of stethoscope placed over **brachial artery**. The cuff should be deflated at a rate of 2–3 mmHg/sec. The first (phase I Korotkoff) and last (phase V Korotkoff) audible sounds should be taken as SBP and DBP.



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7

7

How to measure BP in children?

5. To measure BP in the legs, prone position, if possible. A cuff should be placed midthigh and stethoscope placed over popliteal artery. The SBP in legs is usually 10%–20% higher than brachial artery.



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8

8

How to measure blood pressure?

1. Sphygmomanometers for Clinical Use

- Manual devices: Mercury/Non-mercury sphygmomanometers
- Automated devices for clinical use



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9

9

How to measure blood pressure?

2. Sphygmomanometers for self-measurement of Blood Pressure (SBPM)

- Upper arm devices for self-measurement of Blood Pressure
- Wrist devices for self-measurement of Blood Pressure



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10

10

How to measure blood pressure?

3. Sphygmomanometers for Ambulatory Blood Pressure Measurement



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11

11

Updated Definitions of BP Categories and Stages

For Children Aged 1 - <13 y	For Children Aged ≥ 13 y
• Normal BP: <90th percentile	• Normal BP: <120/<80 mm Hg
• Elevated BP: ≥ 90th percentile to <95th percentile or 120/80 mmHg to <95th percentile (whichever is lower)	• Elevated BP: 120/< 80 to 129/<80 mmHg
• Stage 1 HTN: ≥ 95th percentile to <95th percentile + 12 mmHg, or 130/80 to 139/89 mmHg (whichever is lower)	• Stage 1 HTN: 130/80 to 139/89 mmHg
• Stage 2 HTN: ≥ 95th percentile + 12 mm Hg, or $\geq 140/90$ mm Hg (whichever is lower)	• Stage 2 HTN: $\geq 140/90$ mmHg

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12

12

New normative BP table for boys

TABLE 4 BP Levels for Boys by Age and Height Percentile

Pediatrics. 2017;140(3):e20171904

Age (y)	BP Percentile	SBP (mmHg)								DBP (mmHg)							
		Height Percentile or Measured Height								Height Percentile or Measured Height							
		5%	10%	25%	50%	75%	90%	95%	99%	5%	10%	25%	50%	75%	90%	95%	99%
1	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	41	41	41	42	42		
	90th	98	99	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		
2	95th + 12 mm Hg	114	114	115	115	116	117	117	66	66	67	67	68	69	69		
	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		
3	95th	104	105	105	106	107	108	108	57	58	58	59	59	60	61		
	95th + 12 mm Hg	116	117	117	118	119	119	120	69	70	71	71	72	73	73		
	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		
4	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 + 12 mm Hg	118	118	119	119	120	121	121	72	73	73	74	75	76	76		
	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		
5	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 + 12 mm Hg	119	119	120	120	121	122	122	75	76	77	78	79	79	80		
	Height (in)	41.1	41.8	43.0	44.3	45.5	46.7	47.4	41.1	41.8	43.0	44.3	45.5	46.7	47.4		
6	Height (cm)	104.4	106.2	108.1	112.4	115.7	118.8	120.3	104.4	106.2	108.1	112.4	115.7	118.8	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 + 12 mm Hg	119	120	121	121	122	123	124	78	79	80	81	82	82	83		
7	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	108	110	110	66	66	67	68	69	69	70		
	95th	108	108	110	111	112	113	114	69	70	71	72	73	74	74		

13

13

New normative BP table for girls

TABLE 5 BP Levels for Girls by Age and Height Percentile

Pediatrics. 2017;140(3):e20171904

Age (y)	BP Percentile	SBP (mmHg)								DBP (mmHg)							
		Height Percentile or Measured Height								Height Percentile or Measured Height							
		5%	10%	25%	50%	75%	90%	95%	99%	5%	10%	25%	50%	75%	90%	95%	99%
1	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	45		
	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		
2	95th + 12 mm Hg	113	114	114	115	116	117	117	71	71	72	72	73	74	74		
	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	59	59	60	61	62	62	62		
3	95th	104	105	106	106	107	108	108	62	63	63	64	65	66	66		
	95th + 12 mm Hg	116	117	118	118	119	120	121	74	75	75	76	77	78	78		
	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	88	89	90	91	92	93	48	48	49	50	51	52	52		
4	90th	102	103	104	104	105	106	107	60	61	61	62	63	64	64		
	95th	106	106	107	108	109	110	110	64	65	65	66	67	68	69		
	95th + 12 mm Hg	118	118	119	120	121	122	122	76	77	77	78	79	80	81		
	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		
5	50th	89	90	91	92	93	94	94	50	51	51	52	53	54	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 + 12 mm Hg	119	120	121	121	122	123	124	78	79	80	81	82	82	83		
	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		
6	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	53	54	55	56		
	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 + 12 mm Hg	120	121	121	122	123	124	125	80	81	82	83	84	85	85		
7	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	58		
	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		
8	95th + 12 mm Hg	121	121	122	123	124	125	126	82	83	84	84	85	86	86		

14

14

A 6-year-old girl with BP 118/78 mmHg

TABLE 5 BP Levels for Girls by Age and Height Percentile

Age (y)	BP Percentile	SBP (mmHg)								DBP (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%		
6	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 + 12 mmHg	121	121	122	123	124	125	126	82	83	84	84	85	86	86		



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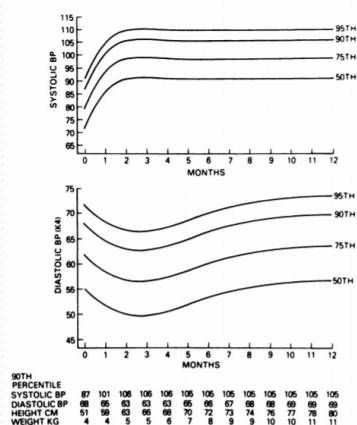
Hypertension?

1. Measure height → 115 cm
2. Check BP from the table → BP percentile 95th = 110/72 mmHg, BP percentile 95th + 12 mmHg = 122/84 mmHg
3. Diagnosis → Hypertension stage 1

15

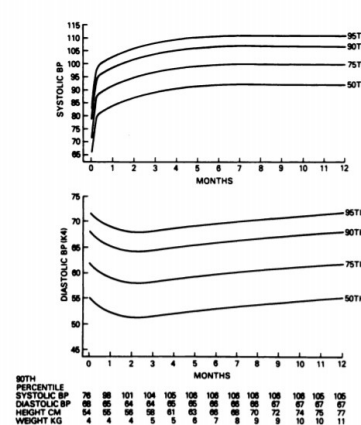
15

Blood pressure in neonate and infant



Age-specific percentiles of BP measurements in boys-birth to 12 months of age

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Age-specific percentiles of BP measurements in girls-birth to 12 months of age

Pediatrics. 1987 Jan;79(1):1-25.

16

16

If elevated BP is detected...

- **Auscultatory confirmed BP readings $\geq$ 95th percentile at 3 different visits**
- **Oscillometric devices may be used for BP screening. If elevated BP, confirmatory measurements should be obtained by auscultation.**



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17

17

Ambulatory BP monitoring (ABPM)

- **ABPM “gold standard” technology for blood pressure measurement**
- **24 hours monitoring**, at 15-30 min during waking times and every 20-60 min during sleep



Should confirm blood pressure by ABMP before diagnosis

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18

18

What is ABPM?

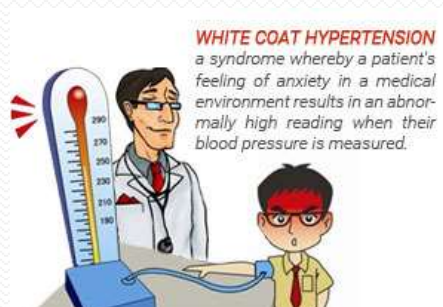


19

19

Masked HTN & White coat HTN

- **White coat HTN:** BP $\geq$ 95th percentile in the office/clinical setting but < 95th percentile outside the office
- **Masked HTN:** normal office BP but elevated BP on ABPM



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Pediatrics. 2017;140(3):e20171904 20

20

Causes of hypertension by age group

Newborn

- Renal artery thrombosis or embolus
- Renal vein thrombosis (RVT)
- Congenital renal malformations
- Coarctation of aorta (CoA)
- Renal artery stenosis (RAS)
- Bronchopulmonary dysplasia (BPD)

Infancy – 6 years

- Renal parenchymal disease
- Renal artery stenosis (RAS)
- Coarctation of the aorta (CoA)
- Med (steroids, albuterol, pseudoephedrine)
- Endocrine causes: CAH, Hyperaldosterone
- Wilms tumor, Neuroblastoma

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21

21

Causes of hypertension by age group

7-12 years

- Renal parenchymal disease
- Renal artery stenosis (RAS)
- Primary (essential) hypertension
- Endocrine causes: CAH, Cushing syndrome, pheochromocytoma, hyperthyroidism, hyperaldosteronism

Adolescence

- Primary (essential) hypertension
- White coat hypertension
- Renal parenchymal disease
- Substance abuse (cocaine, amphetamines, caffeine, phencyclidine, methylphenidate)
- Endocrine causes

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22

22

History for HTN

- **Perinatal history:** preterm, oligohydramnios, small for gestational age, birth weight, umbilical catheter placement
- **Appropriate nutritional history:** high fat-foods, high sodium intake, poor weight gain
- **Sleep history:** snoring
- **Family history:** HTN, obesity, renal disease
- **Genetic syndromes associated with HTN:** neurofibromatosis, Turner syndrome, Williams syndrome, coarctation of the aorta
- **Surgical history:** repaired aortic coarctation
- **Drugs:** steroids, caffeine, amphetamines
- **Symptoms:** headache, palpitation, blurred vision, breathlessness, oliguria

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Pediatrics. 2017;140(3):e20171904 23

23

Physical examination

- | | |
|--|---|
| • Pulse volume and BP in 4 extremities | • Abdominal mass and bruit |
| • Length/height, BMI | • Ambiguous genitalia |
| • Retinal examination | • Skin lesions |
| • Thyroid gland | • Peripheral edema, joint swelling |
| • Cardiovascular /pulmonary examination | • Neurological examination |
| • Signs of congestive heart failure | |

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24

24

Physical Examination Findings (1)

Tachycardia	Decreased lower extremity pulses, Heart murmur	Obesity(high BMI) Moon facies Acne, hirsutism, striae	Retinal changes
Adenotonsillar hypertrophy	Growth retardation Anemia	Proptosis Goiter Palpitation	Truncal obesity Acanthosis nigricans

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25

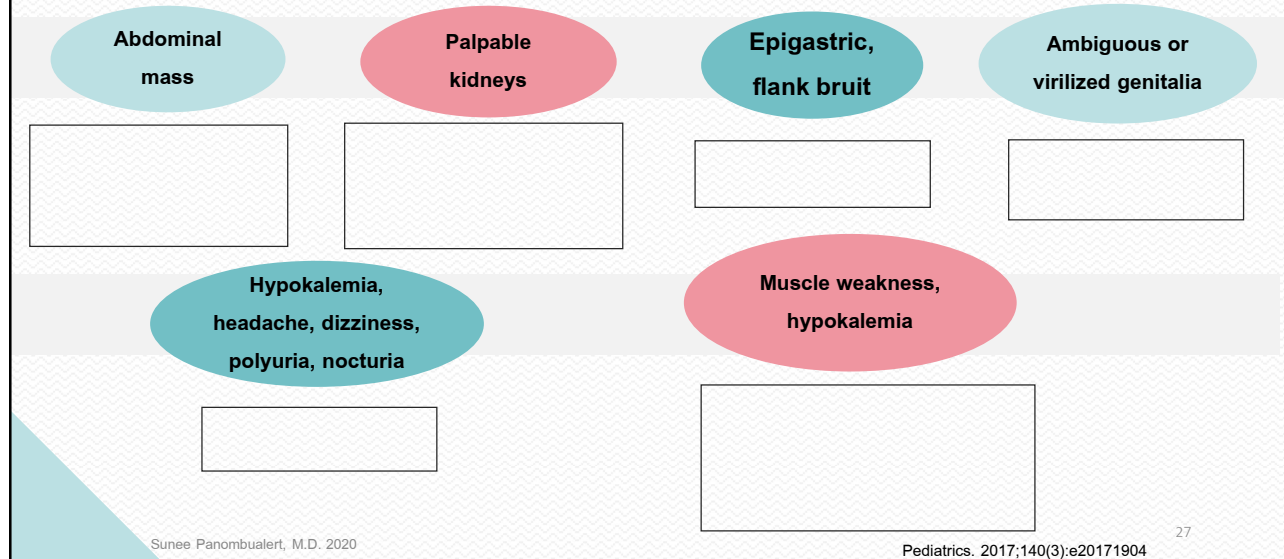
Physical Examination Findings (2)

Elfin facies	Webbed neck Widely spaced nipples	Café-au-lait spots	Adenoma sebaceum
Chest pain Palpitations Exertional dyspnea	Pallor, flushing, diaphoresis	Apical heave	Malar/discoid rash Alopecia, oral ulcer

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26

Physical Examination Findings (3)



27

Laboratory evaluation for causes

Initial tests : CBC, BUN, creatinine, electrolytes, UA

Additional evaluation as indicated:

- UTI: urine culture, renal ultrasound, DMSA scan(renal scar)
- RAS: renovascular imaging (Doppler U/S KUB, CTA, MRA, angiography)
- Plasma renin activity, aldosterone (preferably obtained 8:00-10:00 AM)
- Thyroid function
- Fractionated plasma and/or urine metanephrines and normetanephrines
- Polysomnography
- Drug screening

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Pediatrics. 2017;140(3):e20171904 28

28

Laboratory evaluation for target organ damage and comorbidity

Chest X-ray

EKG

Echocardiography for LVH

Retinal exam

Fasting lipids panel and glucose, HbA1C

Urine microalbuminuria

Uric acid

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Pediatrics. 2017;140(3):e20171904 29

29

Treatment target

Goals for treatment:

- Reduce risk for target organ damage
- Reduce risk for HTN and related cardiovascular disease in adulthood

Treatment goal with nonpharmacologic and pharmacologic therapy:

SBP and DBP <90th percentile and <130/80 mmHg in adolescents $\geq$ 13 years old, whichever is lower

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Pediatrics. 2017;140(3):e20171904 30

30

Lifestyle and Non-pharmacologic interventions

- Consume more fresh vegetables & fruits, low-fat dairy products, whole grains, fish, nuts, lean red meats
- Reduce Na intake < 2.3 g/day
- Exercise/limit TV and other sedentary activities: 3-5 days/week
- Weight reduction
- Avoid alcohol and smoking, limit caffeine
- Stress reduction

Follow up q 3-6 months

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Pediatrics. 2017;140(3):e20171904 31

31

Pharmacologic Treatment: Indications

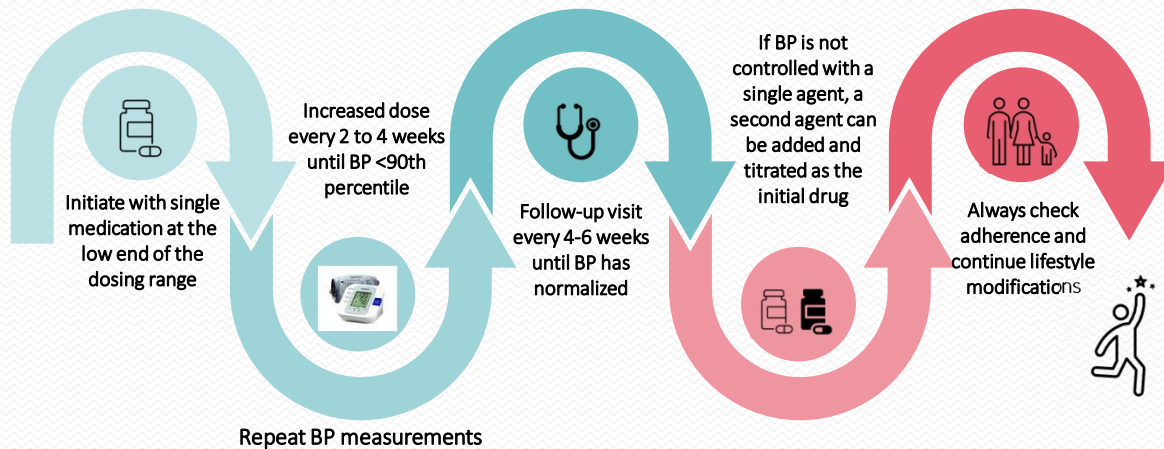
1. Stage 1 hypertension with unresponsive to changes in lifestyle
2. Stage 2 hypertension without clearly modifiable factor (e.g. obesity)
3. Symptomatic hypertension
4. Secondary hypertension
5. Any stage of HTN associated with DM, CKD
6. Evidence end target organ damage
(LVH or ↑ left ventricular mass index, hypertensive retinopathy)

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Pediatrics. 2017;140(3):e20171904
Pediatrics. 2004;114: 555-576. 32

32

Medication therapy guide



Pediatrics. 2017;140(3):e20171904 33

33

Pharmacologic Treatment: Choice of Agent

- Initiate with ACEI, ARB, long-acting calcium channel blocker, thiazide diuretic
- HTN in proteinuria, or DM: ACEI or ARB
- Renovascular HTN: single side ACEI or ARB
- Acute glomerulonephritis: furosemide, calcium channel blocker
- HTN in CKD: ACEI or ARB (stage 1,2), calcium channel blocker (stage 3-5)
- Pheochromocytoma, neuroblastoma: alpha-adrenergic blockers, phentolamine, nicardipine
- Acute intracranial bleeding/ischemic stroke: Nicardipine, labetalol
- Acute renal failure: Nicardipine
- Acute aortic dissection: Esmolol

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34

34

Dosing recommendations for initial prescription of antihypertensive drugs

Drug	Age	Initial dose	Maximum dose	Dosing interval
ACEI				
Contraindications: pregnancy, angioedema S/E: Hyper K, AKI, angioedema, cough, dizziness, fetal toxicity				
Captopril	Infants	0.05 mg/kg/ dose	6 mg/kg/day	OD-q 6 hr
	Children	0.5 mg/kg/ dose	6 mg/kg/day	Q 8 hr
Enalapril	≥ 1 mo	0.08 mg/kg/day (5)	0.6 mg/kg/day (40)	OD-BID
Lisinopril	≥ 6 yr	0.07 mg/kg/day (5)	0.6 mg/kg/day (40)	OD
ARBs				
Contraindications: pregnancy S/E: Hyper K, AKI, cough, headache, dizziness, fetal toxicity				
Candesartan	1-5 yr	0.2 mg/kg/day (4)	0.4 mg/kg/day (16)	OD-BID
	≥ 6 yr	4 mg/day(<50 kg)	16 mg/day(<50 kg)	
		8 mg/day(≥50 kg)	32 mg/day(≥50 kg)	
Losartan	≥ 6 yr	0.7 mg/kg (50)	1.4 mg/kg (100)	OD
Valsartan	≥ 6 yr	1.3 mg/kg (40)	2.7 mg/kg (160)	OD

Sunee Panombualert, M.D. 2020

Pediatrics. 2017;140(3):e20171904 35

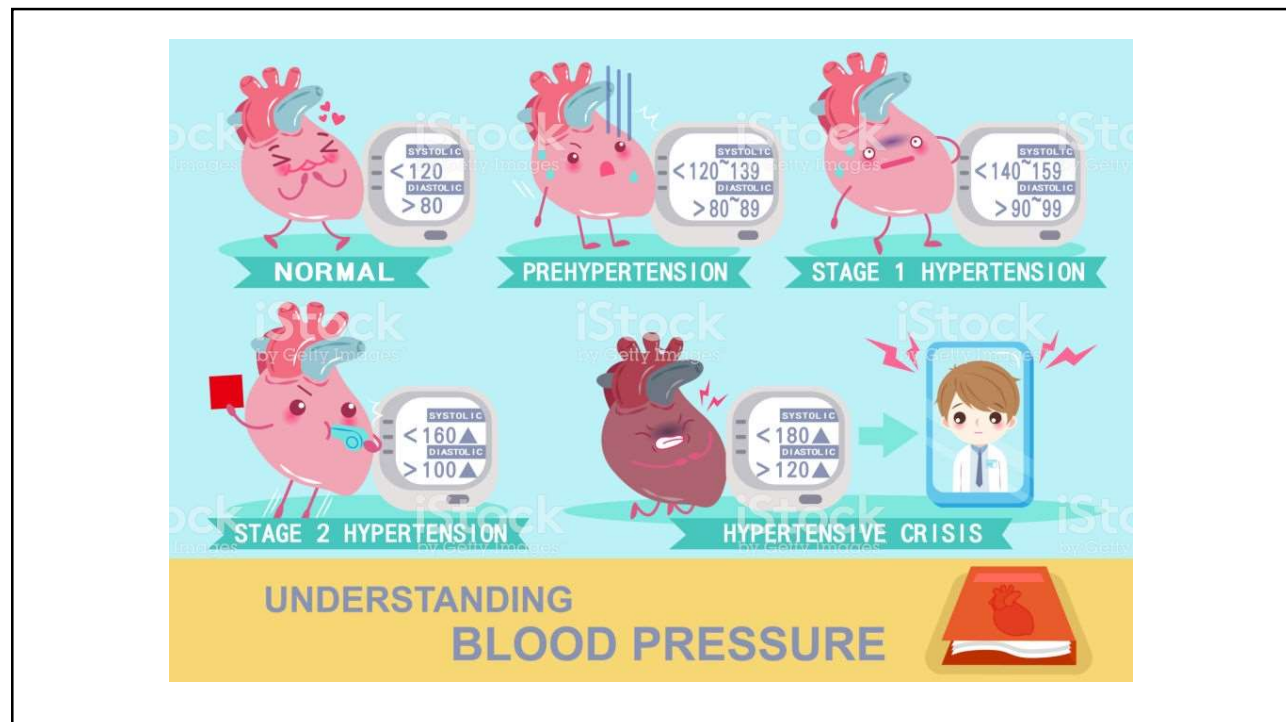
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Dosing recommendations for initial prescription of antihypertensive drugs

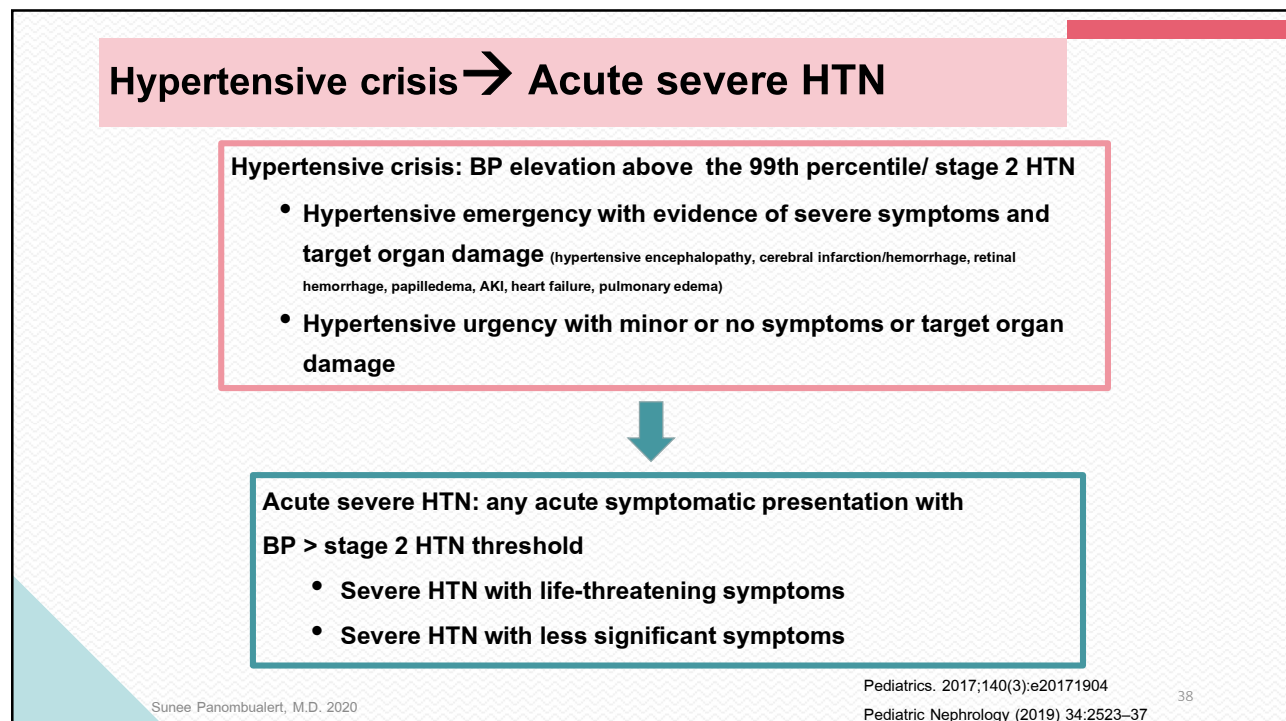
Drug	Age	Initial dose	Maximum dose	Dosing interval
Calcium channel blockers				
Contraindications: hypersensitivity S/E: flushing, peripheral edema, dizziness, angioedema				
Amlodipine	1-5 yr	0.1 mg/kg/ dose	0.6 mg/kg(5)	OD
	≥ 6 yr	2.5 mg	10 mg	
Felodipine	≥ 6 yr	2.5 mg	10 mg	OD
Isradipine	Child	0.05-0.1 mg/kg	0.6 mg/kg/day (10)	BID-TID
Nifedipine extended release	Child	0.2-0.5 mg/kg/day	3 mg/kg/day (120)	OD-BID
Thiazide diuretics				
Contraindications: anuria S/E: dizziness, hypo K ,cardiac dysrhythmias, cholestatic jaundice, new onset diabetes mellitus, pancreatitis				
Chlorothiazide	Child	10 mg/kg/day	20 mg/kg/day (375)	OD-BID
Hydrochlorothiazide	Child	1 mg/kg /day	2 mg/kg (37.5)	OD-BID

Pediatrics. 2017;140(3):e20171904 36

36



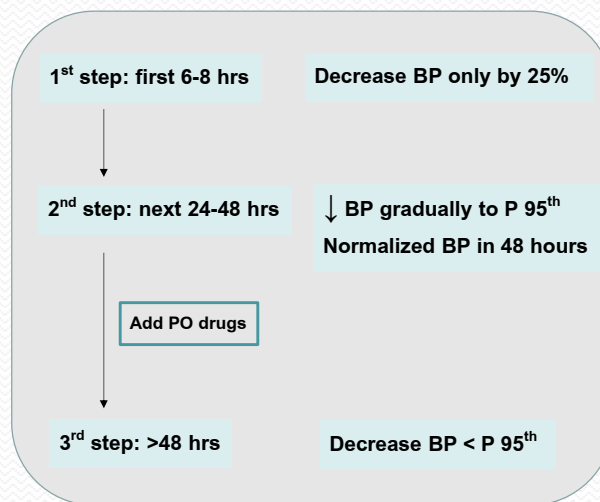
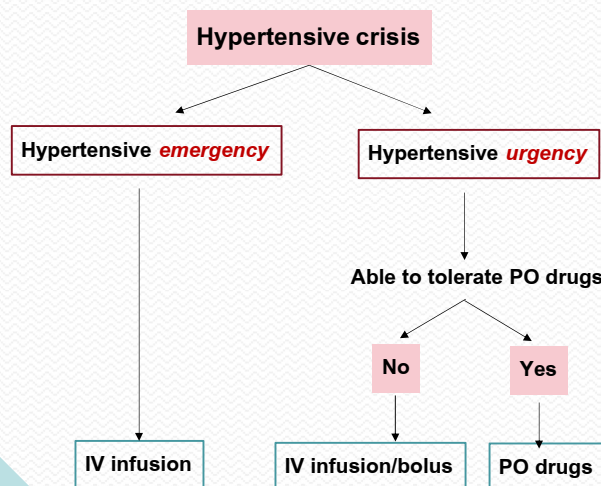
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38

38

Treatment of acute severe HTN



Sunee Panombualert, M.D. 2020

Pediatrics. 2017;140(3):e20171904

Pediatric Nephrology (2019) 34:2523–37

39

39

IV antihypertensive medications for acute severe HTN

Drug	Class	Dose	Route
Nicardipine	Calcium channel blocker	Bolus: 30 mcg/kg up to 2 mg/dose Infusion: 0.5–4 mcg/kg/min	Intravenous bolus or infusion
Hydralazine	Direct vasodilator	0.1–0.2 mg/kg/dose up to 0.4 mg/kg/dose	Intravenous, intramuscular
Labetalol	α- and β-adrenergic blocker	Bolus: 0.20–1.0 mg/kg/dose up to 40 mg/dose Infusion: 0.25–3.0 mg/kg/hr	Intravenous bolus or infusion
Esmolol	β-adrenergic blocker	100–500 mcg/kg/min	Intravenous infusion
Sodium nitroprusside	Direct vasodilator	Starting: 0–3 mcg/kg/min Maximum: 10 mcg/kg/min	Intravenous infusion

Sunee Panombualert, M.D. 2020

Pediatrics. 2017;140(3):e20171904

40

40

Oral antihypertensive medications for acute severe HTN

Drug	Class	Dose	Route
Hydralazine	Direct vasodilator	0.25 mg/kg/dose up to 25 mg/dose q 6–8 hr	Oral
Minoxidil	Direct vasodilator	0.1–0.2 mg/kg/dose up to 10 mg/dose q 8–12 hr	Oral
Isradipine	Calcium channel blocker	0.05–0.1 mg/kg/dose up to 5 mg/dose q 6–8 hr	Oral
Clonidine	Central α -agonist	2–5 mcg/kg/dose up to 10 mcg/kg/dose q 6–8 hr	Oral
Nifedipine	Calcium channel blocker	0.1 – 0.25 mg/kg/dose (max 5 mg) q 4-6 hr	Oral

Sunee Panombualert, M.D. 2020

Pediatrics. 2017;140(3):e20171904 41

41

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Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents

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42

42