Evaluation of hypertension in children and adolescents

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EVALUATION OF HYPERTENSION IN CHILDREN AND ADOLESCENTS

It has become clear that hypertension *(HTN) begins in childhood and adolescence, and that it contributes to the early development of cardiovascular disease* (CVD).

Objectives

- How to measure the blood pressure?
- When to measure B/P?
- What is the definition of hypertension ?
- what is the approach to a child with hypertension?

How to measure the blood pressure?

We should consider 4main items when measuring the child blood pressure

1– the circumstances

2– the child

3– the sphygmomanometer

4– the procedure it self

1- the circumstances

- The child should take a 5 minutes rest before measuring the blood pressure ,trying to calm down the child, for two reasons

- 1– to avoid stress hypertension
- 2– to build a lovely , kindly circumstances to avoid crying and anger which may interfere with the measuring process..

2– the child

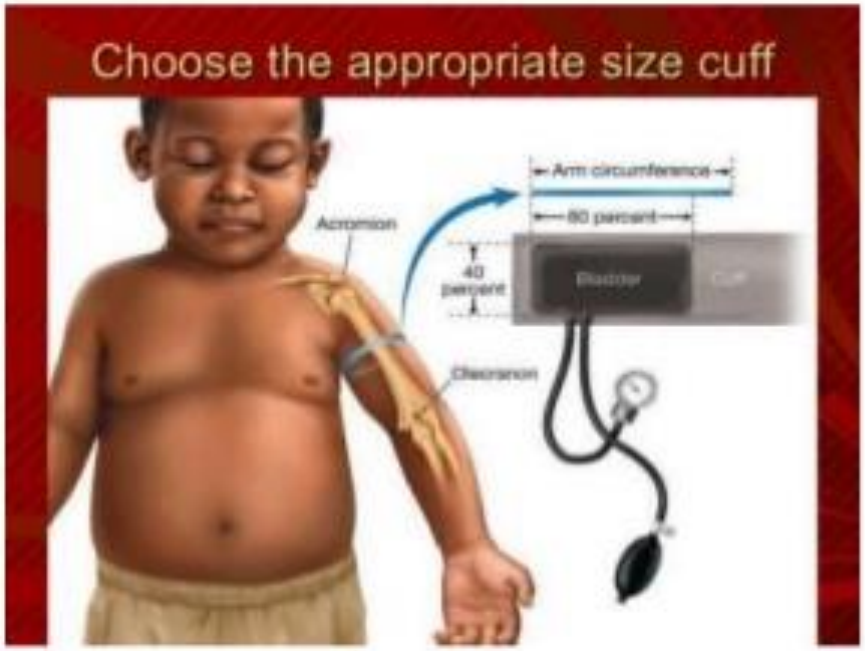
the child should be in sitting position better supported back with feet reaching the floor and the cubital fossa supported at the heart level

3– the sphygmomanometer

**Choose the appropriate size of the cuff

It should cover at least 70% of the distance between the acromion and the olecranon..

**the bladder length should be > 80 of the arm circumference , and width should be > 40 % of the arm circumference..



Recommended Dimensions for Blood Pressure Cuff Bladders

Maximum Arm Circumference (cm)*	Length (cm)	Width (cm)	Age Range
10	8	4	Newborn
15	12	6	Infant
22	18	9	Child
26	24	10	Small adult
34	30	13	Adult
44	38	16	Large adult
52	42	20	Thigh

*Calculated so that the largest arm would still allow the bladder to encircle the arm by at least 80 percent.

4– the procedure

** try to inflate and deflate slowly..

** try to feel the systolic blood pressure by pulse ..

POINTS TO BE REMEMBERED

**BP should be recorded in all 4 limbs.

**Cuff should not be applied two tight (low Bp recording) or too loose (high BP recording).

**BP monitoring subsequently should be taken in the same limb and position.

**Normally the BP is 10-20mm Hg higher in lower limbs compared to the upper limbs.

Objectives

- How to measure the blood pressure? accomplished
- When to measure B/P?
- What is the definition of hypertension ?
- what is the approach to a child with hypertension?

When to measure the B/P

** children above 3 years

_____

Children older than 3 years who are seen in medical care settings should have their BP measured at least once during every health care episode..

Children under 3 years

**History of prematurity, very low birth weight, or other neonatal complication requiring intensive care

**Congenital heart disease (repaired or nonrepaired)
**Recurrent urinary tract infections, hematuria, or proteinuria
**Known renal disease or urologic malformations
Family history of congenital renal disease Solid organ transplant
**Malignancy or bone marrow transplant
**Treatment with drugs known to raise BP
**Other systemic illnesses associated with hypertension (eg, neurofibromatosis, tuberous sclerosis)
**Evidence of elevated intracranial pressure

Objectives

- How to measure the blood pressure? accomplished
- When to measure B/P? accomplished
- What is the definition and causes of hypertension ?
- what is the approach to a child with hypertension?

definition

- Hypertension is defined as average SBP and/or diastolic BP that is $\geq$ 95th percentile for gender , age and height on 3 or more occasions

CLASSIFICATION OF HYPERTENSION

Normal = less than 90 th percentile for age sex and height

Pre-hypertension = >90th percentile but <95th percentile.
‡120/80 Or As with adults, adolescents with BP levels mmhg.

Stage 1 hypertension = 95^{th} to 99^{th} percentile + 5 mmhg.

Stage 2 hypertension = > 99^{th} percentile + 5 mmhg.

White-coat hypertension

A patient with BP levels above the 95thpercentile in a physician's office or clinic who is normotensive outside a clinical setting. (Ambulatory BP monitoring is usually required to make this diagnosis.)

ETIOLOGY

COMMONEST CAUSES

Newborn	Umbilical artery catheterization and Renal artery thrombosis.
Childhood	Renal disease, COA, endocrine disorders or medications.
Adolescents.	Essential hypertension becomes increasingly common.

CAUSES OF HYPERTENSION IN PEDIATRIC POPULATION

Renal Causes	Renal Parenchymal diseases (78%)
	Renal vascular diseases (12%)
Cardiovascular	CoA(2%)
	Condition with large stroke volume (PDA, AV fistula)
Endocrine	Hyperthyroidism
	Excessive Catecholamine levels (Pheochromocytoma)
	Adrenal dysfunction (CAH 11β, 17 α hydroxylase deficiency)
	Hyperaldosteronism (Conn's Syndrome, Renin Producing Tumors)
	Hyperparathyroidism
Neurogenic	Raised ICT, Poliomyelitis, LGB.
Drugs and Chemical	Sympathomimetic drugs , Amphetamines, Steroids, OCP, Heavy matal poising (Hg, Lead), Cocaine, Cyclosporine
Miscellaneous	Hypercalcemia, After Coarctation repair, Pre eclampsia etc.

CLINICAL MANIFESTATION OF HYPERTENSION

Many children with mild hypertension are asymptomatic and hypertension is diagnosed as a result of routine BP measurement.

Severe hypertension may be symptomatic like headache, dizziness, nausea, vomiting, irritability, personality changes..

Occasionally with complications like neurological, CHF, Renal dysfunction, Stroke.

Clinical approach to a child with hypertension

When we make a diagnosis of hypertension careful and professional approach should be followed so as to reach a final diagnosis which me be if treated clear the hypertension state

In such approach we should begin with history , then clinical examination followed by laboratory investigations and imaging studies

HISTORY

Present and Past History

Neonatal

- prematurity, BPD, umbilical artery catheterization .

Cardiovascular

History of CoA or surgery for it, history of palpitation , Headache, excessive - sweating (excessive catecholamine levels).

Renal- -

History of obstructive uropathy, UTI, radiation, trauma or surgery to kidney area.

Endocrine-

weakness, fiushing, weight loss, muscle cramps (hyperaldosteronism). Constipation

Medication/Drugs

- Corticosteroids, amphetamines, cold medications, antiasthamatic drugs, OCP, cyclosporine/tacrolimus, cocaine.NSAIDs Stimulant medications (eg, dexedrine, methylphenidate) Beta-adrenergic agonists (eg, theophylline) ,Erythropoietin, Tricyclic antidepressants, Recent abrupt discontinuation of antihypertensives

PHYSICAL EXAMINATION

Accurate measurement of BP in all limbs.

Complete physical examination.

Delayed growth/short stature (renal disease)

Bounding peripheral pulses (PDA, AR)

Weak or absent femoral pulses or BP differential between arms and legs (CoA)

Abdominal bruits (Renal Vascular Disease)

Abdominal mass(Wilms tumor, neuroblastoma, pheochromocytoma)

Palpable kidneys (Polycystic kidney disease, hydronephrosis, multicystic dysplastic kidney, mass)

Skin lesions (café au lait spots, neurofibromas, adenoma sebaceum, striae, hirsutism, butterfly rash, Acanthrosis nigricans palpable purpura)

Tenderness over kidney .....(renal infection).

Ambiguous genitalia .....(CAH).

Moon facies, truncal obesity, buffalo hump

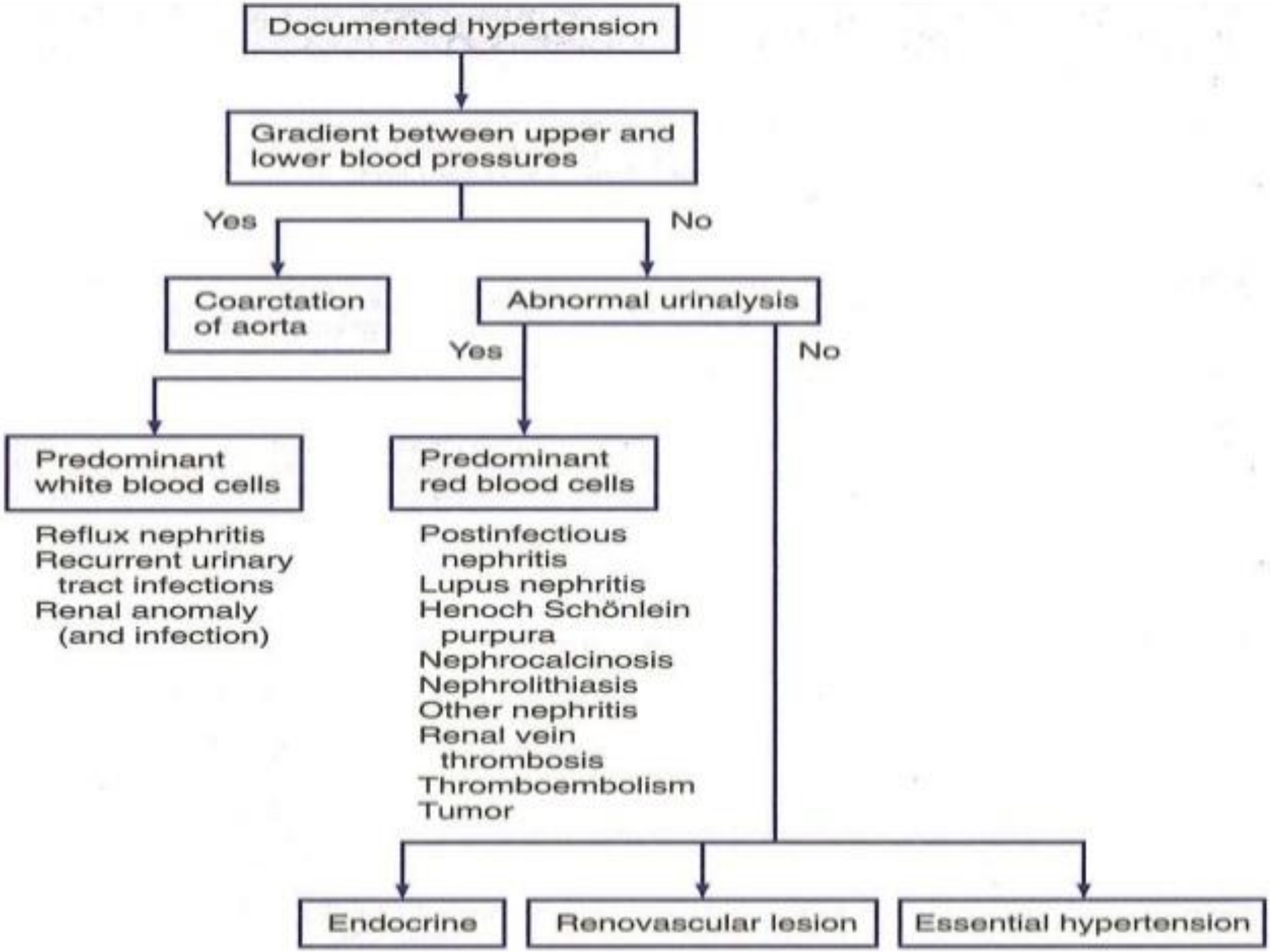
Thyromegaly, Proptosis, hyperdynamic circulation..... (Hyperthyroidism)

Signs of meningeal irritation,..... CNS Infections.

Widely spaced nipples, Webbed neck .....(turner's)

Routine and Special Laboratory Tests and Their Significance

Laboratory Test	Significance
Urinalysis, urine culture, blood urea nitrogen, creatinine, uric acid	Renal parenchymal disease
Serum electrolytes (hypokalemia)	Hyperaldosteronism (primary or secondary) Adrenogenital syndrome Renin-producing tumors
ECG, chest x-ray studies	Cardiac cause of hypertension; also baseline function
Intravenous pyelogram (or ultrasonography, radionuclide studies, computed tomography, or magnetic resonance imaging of the kidneys)	Renal parenchymal disease Renovascular hypertension Tumors (neuroblastoma, Wilms' tumor)
Plasma renin activity (peripheral)	High-renin hypertension (renovascular hypertension, renin-producing tumors, some Cushing's syndrome, some essential hypertension) Low-renin hypertension (adrenogenital syndrome, primary hyperaldosteronism)
24-hr urine collection for 17-ketosteroid and 17-hydroxycorticosteroids	Cushing's syndrome Adrenogenital syndrome
24-hr urine collection for catecholamine levels and vanillylmandelic acid	Pheochromocytoma Neuroblastoma
Aldosterone	Hyperaldosteronism (primary or secondary) Renovascular hypertension Renin-producing tumors
Renal vein plasma renin activity	Unilateral renal parenchymal disease Renovascular hypertension
Abdominal aortogram	Renovascular hypertension Abdominal coarctation of the aorta Unilateral renal parenchymal disease Pheochromocytoma
Intra-arterial digital subtraction angiography	Renovascular hypertension


Documented hypertension
Gradient between upper and lower blood pressures
Yes
No
Coarctation of aorta
Abnormal urinalysis
Yes
No
Predominant white blood cells
Predominant red blood cells
Reflux nephritis
Recurrent urinary tract infections
Renal anomaly (and infection)
Postinfectious nephritis
Lupus nephritis
Henoch Schönlein purpura
Nephrocalcinosis
Nephrolithiasis
Other nephritis
Renal vein thrombosis
Thromboembolism
Tumor
Endocrine
Renovascular lesion
Essential hypertension

CONCLUSIONS

Hypertension is a silent killer. All children >3 years of age attending OPDs should have their BP recorded (Special circumstances in children < 3 years).

Thorough history and physical examination followed by relevant investigations can clinch the cause of hypertension.

Hypertension is a curable disease.

DEFINITION

For children in the United States, the 2017 American Academy of Pediatrics (AAP) guidelines for screening and managing high blood pressure for children and adolescents definitions are used to categorize blood pressure for two different age groups (table 1) .

BP percentiles are based upon gender, age, and height .

- **Primary HTN – No identifiable cause is found.**
- **Secondary HTN – An underlying cause is identified.**

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2017 American Academy of Pediatrics updated definitions for pediatric blood pressure categories

	For children aged 1 to 13 years	For children aged ≥13 years
Normal BP	Systolic and diastolic BP <90th percentile	Systolic BP <120 and diastolic BP <80 mmHg
Elevated BP	Systolic and diastolic BP ≥90th percentile to <95th percentile, or 120/80 mmHg to <95th percentile (whichever is lower)	Systolic BP 120 to 129 and diastolic BP <80 mmHg
Stage 1 HTN	Systolic and diastolic BP ≥95th percentile to <95th percentile + 12 mmHg, or 130/80 to 139/89 mmHg (whichever is lower)	130/80 to 139/89 mmHg
Stage 2 HTN	Systolic and diastolic BP ≥95th percentile + 12 mmHg, or ≥140/90 mmHg (whichever is lower)	≥140/90 mmHg

BP: blood pressure; HTN: hypertension.

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OVERVIEW

Rationale

There is good evidence that identifying children with HTN and successfully treating their primary HTN has an important impact on long-term outcomes of CVD.

Children with primary HTN are likely to continue to have elevated BP as adults, and multiple randomized trials in adults have shown that reduction of BP by antihypertensive therapy reduces CV morbidity and mortality

The magnitude of the benefit increases with the severity of the HTN.

In patients with secondary HTN, clinical outcomes vary depending on the underlying etiology and whether the underlying cause is amenable to treatment.

Thus, ***one of the most important components of the successful management of childhood HTN is distinguishing between primary and secondary HTN, and if the latter determining whether there is an underlying cause that is amenable to treatment*****.**

Goals

The *goals of the evaluation of the hypertensive child or adolescent* are to:

- **Distinguish between primary and secondary HTN (table 4).**

- **For children with secondary HTN, identify secondary HTN (ie, an underlying cause of hypertension), which may be cured, thereby avoiding the need for prolonged drug therapy (table 5).**

●Identify other comorbid risk factors (eg, obesity and dyslipidemia) for cardiovascular disease (CVD) or diseases associated with an increased risk for CVD (eg, diabetes mellitus) (table 6). CVD risk factors often occur concurrently, which further increases the likelihood of premature atherosclerosis and CVD.

The presence of another CVD risk factor or disease associated with a high risk of CVD impacts the timing and choice of intervention for high BP.

●Identify children who should be treated with antihypertensive drug therapy. Indications for pharmacologic therapy are discussed separately.

Most hypertensive children, particularly those who are likely to have secondary HTN, should be referred to a pediatric nephrologist or other clinician with experience in childhood HTN.

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Distinguishing clinical features between primary (essential) and secondary pediatric hypertension

Clinical features	Primary HTN	Secondary HTN
Age:		
Prepubertal		Secondary HTN is more likely in younger children, especially those less than six years of age.
Postpubertal	Older children and adolescents are more likely to have primary HTN.	
Diastolic HTN*		Diastolic HTN is more likely to be associated with secondary HTN.
Nocturnal HTN*		Nocturnal HTN is more likely to be associated with secondary HTN.
Overweight/obesity	Overweight or obese children/adolescents are more likely to have primary HTN.	
Family history of HTN	Children with a positive family history of primary HTN are more likely to have primary HTN.	Family history may be positive in some cases of secondary HTN due to a monogenic cause (eg, autosomal dominant polycystic kidney disease).
Symptoms of underlying disorder	Patients with primary HTN are typically asymptomatic.	Patients with secondary HTN often have other symptoms related to the underlying cause (eg, headache, sweating, and tachycardia due to catecholamine excess in patients with pheochromocytoma).

HTN: hypertension; ABPM: ambulatory blood pressure monitoring.

* Nocturnal and diastolic hypertension are usually detected by ABPM.

Causes of secondary hypertension in children and adolescents

Renal disease
Pyelonephritis
Renal parenchymal disease
Congenital anomalies
Reflux nephropathy
Acute glomerulonephritis
Henoch-Schönlein purpura
Renal trauma
Hydronephrosis
Hemolytic uremic syndrome
Renal stones
Nephrotic syndrome
Wilm's tumor
Hypoplastic kidney
Polycystic kidney disease
Endocrine disease
Hyperthyroidism
Congenital adrenal hyperplasia
Cushing syndrome
Primary aldosteronism
Primary hyperparathyroidism
Diabetes mellitus
Hypercalcemia
Pheochromocytoma
Neurologic causes
Increased intracranial pressure
Guillain-Barré syndrome

Psychologic causes
Mental stress
Anxiety
Pharmacologic causes
Sympathomimetics
Corticosteroids
Stimulants
Oral contraceptives
Anabolic steroids
Cocaine
Phencyclidine (PCP)
Licorice
Nicotine
Caffeine
Vascular disease
Renal artery abnormalities
Renal vein thrombosis
Coarctation of the aorta
Patent ductus arteriosus
Arteriovenous fistula
Other causes
Neuroblastoma
Heavy metal poisoning
Acute pain
Collagen vascular diseases
Neurofibromatosis
Tuberous sclerosis

Data from:

1. Tennessen WW, Roberts KB. *Hypertension. In: Signs and Symptoms in Pediatrics, 2nd ed*, Lippincott, Williams & Wilkins, Philadelphia 1998. p.413.
2. Pappoulis SL, Somers MJ. *Hypertension in adolescence: a review of diagnosis and management. Curr Opin Pediatr* 2003; 15:370.

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INITIAL EVALUATION

The initial evaluation of the child with HTN includes history, physical examination, laboratory tests, and imaging procedures. It is, as discussed above, primarily focused upon the following [1]:

- **Differentiate primary from secondary HTN by looking for signs and symptoms that are associated with specific underlying etiologies for HTN (table 7 and table 8).**

- Identify comorbid cardiovascular disease (CVD) risk factors or diseases associated with a risk of CVD.

- Identify patients with stage 2 HTN or with evidence of end-organ injury so that pharmacologic therapy can be initiated

History in the child or adolescent with elevated blood pressure

History	Possible cause of hypertension
CNS: Head trauma, headache, visual disturbance, lethargy, seizures, tremors, morning vomiting	Elevated intracranial pressure
Hearing: Hearing loss	Renal disease (ie, Alport syndrome)
	Lead poisoning
Cardiovascular: Palpitations, irregular pulse	Catecholamine excess
Renal: Edema, history of UTI or unexplained fever, abnormal urine color, enuresis, flank pain, dysuria	Reflux nephropathy
Skin: Rash, sweating, pallor	Catecholamine excess
	Thyroid dysfunction
	Renal vasculitis
Recent medical history: Recent pharyngitis or impetigo, exposure to sources of enterohemorrhagic *E. coli*	Post-infectious glomerulonephritis
	Hemolytic uremic syndrome
Medications: Sympathomimetics, oral contraceptives, corticosteroids	Side effect of medication
Substance use: Cocaine, amphetamines, anabolic steroids, phencyclidine, ephedra-containing alternative medications, caffeine	Drug-mediated effects
Family history: Hypertension, early MI, diabetes, stroke	Essential hypertension
Sexual history: Postmenarchal female actively engaged in sexual intercourse	Preeclampsia
Neonatal history: Use of umbilical artery catheters	Renovascular hypertension
Growth history: Excessive weight gain or loss, change in growth percentiles	Obesity, thyroid dysfunction
Dietary history: Types and amount of food ingested; salt craving	Obesity, essential hypertension
Social history: Stress factors at home and school	Stress

CNS: central nervous system; UTI: urinary tract infection; MI: myocardial infarction.

Physical examination findings associated with possible etiology of hypertension in children and adolescents [1-3]

Physical examination finding	Possible etiology
General	
Obesity	Essential hypertension
Truncal obesity	Cushing syndrome, corticosteroid therapy
Growth retardation	Chronic kidney disease
Vital signs	
Tachycardia	Catecholamine excess (PCC or neuroblastoma) or hyperthyroidism
BP differences in extremities	If upper extremity BP > lower extremity BP, coarctation of aorta
Head and neck	
Elfin facies	Williams syndrome
Moon facies	Cushing syndrome, corticosteroid therapy
Thyroid enlargement or goiter	Hyperthyroidism
Webbed neck	Turner syndrome
Tonsillar hypertrophy	Sleep-disordered breathing, sleep apnea
Eye	
Retinal changes	Suggest severe hypertension and secondary etiology
Papilledema	Increase intracranial pressure
Skin	
Pallor, flushing	Catecholamine excess (PCC and neuroblastoma)
Acne, hirsutism, striae	Cushing syndrome, corticosteroid therapy
Café-au-lait spots and/or neurofibromas	Neurofibromatosis
Ash leaf spots and/or adenoma sebaceum	Tuberous sclerosis
Rash	Lupus nephritis, Henoch-Schönlein purpura (IgA vasculitis)

Skin	
Pallor, flushing	Catecholamine excess (PCC and neuroblastoma)
Acne, hirsutism, striae	Cushing syndrome, corticosteroid therapy
Café-au-lait spots and/or neurofibromas	Neurofibromatosis
Ash leaf spots and/or adenoma sebaceum	Tuberous sclerosis
Rash	Lupus nephritis, Henoch-Schönlein purpura (IgA vasculitis)
Acanthosis nigricans	Type 2 diabetes
Chest	
Widely spaced nipples	Turner syndrome
Murmur	Coarctation of the aorta
Apical heave	Left ventricular hypertrophy
Abdomen	
Abdominal bruit	Renovascular disease
Mass	Hydronephrosis, polycystic kidney disease, renal tumors, neuroblastoma
Extremities	
Traction/casts	Orthopedic manipulation
Asymmetry of limbs	Beckwith-Wiedemann syndrome
Arthritis	Henoch-Schönlein purpura (IgA vasculitis), collagen vascular disease (systemic lupus erythematous)
Neurologic	
Muscle weakness	Liddle syndrome, hyperaldosteronism
Diminished pain response	Familial dysautonomia
Genitalia	
Ambiguous/virilization	Adrenal hyperplasia
Advanced puberty	Intracranial tumors

Symptomatic hypertension

Symptoms consistent with hypertensive emergencies include *headache, seizures, changes in mental status, vomiting, focal neurologic complaints, visual disturbances, and cardiovascular (CV) complaints indicative of heart failure (such as chest pain, palpitations, cough, or shortness of breath*).

Children with hypertensive emergency require pharmacologic therapy without delay and hospitalization for evaluation and ongoing care.

Secondary versus primary hypertension

Secondary HTN should be suspected in children with one or more of the following findings

- **Prepubertal, particularly younger than six years of age.**

- **A thin child with a negative family history for HTN.**
- **An acute rise in blood pressure (BP) above a previously stable baseline.**

- **Specific ambulatory BP patterns, such as sustained diastolic HTN, nocturnal HTN, and/or blunted nocturnal dipping.**

- **Past history of the following suggests renal disease as an underlying etiology:**

- **Urinary tract infection, especially pyelonephritis**

- **Congenital kidney or urologic anomalies**

- **Perinatal history of neonatal umbilical arterial catheterization, oligohydramnios, or perinatal anoxia**

- **History of snoring, daytime sleepiness (in adolescents), or hyperactivity (in younger children) are associated with obstructive sleep apnea.**

- **Family history of chronic or congenital renal disease (such as polycystic kidney disease), or other genetic conditions that are associated with HTN, such as neurofibromatosis or tuberous sclerosis.**

- **History of drugs known to increase BP including glucocorticoids, central nervous system stimulants, decongestants with pseudoephedrine, or oral contraceptives. Recreational drugs, including anabolic steroids and stimulants (eg, cocaine and amphetamine).**

- **Physical finding(s) suggestive of systemic disease or a specific secondary etiology of HTN include (table 8):**

- **Cutaneous findings associated with tuberous sclerosis (ash leaf spots or adenoma sebaceum) or neurofibromatosis (café-au-lait spots and neurofibromas).**

- **Ambiguous genitalia may be suggestive of congenital adrenal hyperplasia with excess endogenous secretion of androgens and mineralocorticoids. Children with mineralocorticoid excess may develop hypokalemia**
- **Edema and hematuria may be indicative of renal parenchymal disease.**

- **Clinical findings of arthritis or rash may be suggestive of glomerulonephritis due to systemic disorders, such as immunoglobulin A vasculitis (IgAV; Henoch-Schönleinpurpura [HSP]) or systemic lupus erythematosus (SLE). Abdominal pain may also be present in patients with IgAV (HSP).**

- **The presence of an abdominal bruit raises the possibility of renovascular disease, but its absence does not exclude the diagnosis.**

- **Coarctation of the aorta is suggested by findings of hypertension in the upper extremities and low or unobtainable blood pressure in the lower extremities, significant difference between right and left arm BP, and diminished or delayed femoral pulses.**

- Symptoms suggestive of catecholamine excess in addition to elevated BP include headache, sweating, and tachycardia.

Possible etiologies include pheochromocytoma, neuroblastoma, or use of sympathomimetic drugs including phenylpropanolamine (over-the-counter decongestant), cocaine, amphetamines, phencyclidine, epinephrine, phenylephrine, and terbutaline, and the combination of a monoamine oxidase (MAO) inhibitor plus ingestion of tyramine-containing foods.

- Findings suggestive of hyperthyroidism include tachycardia, proptosis, or enlarged thyroid or goiter. Of note, HTN, particularly diastolic HTN, is associated with hypothyroidism.

Clinical symptoms of hypothyroidism in children include weight gain, exercise intolerance, constipation, fatigue, and cold intolerance.

Risk factors for CVD and hypertension

The history and physical examination should assess for risk factors that contribute to high BP and other cardiovascular disease (CVD) risk factors or diseases associated with CVD [1] (table 6).

- **Family history of premature CVD and/or strokes.**

Obesity
Hypertension
Dyslipidemia
Family history of premature coronary artery disease*
Smoke exposure

Special-risk conditions
- High-risk conditions:
  - Diabetes mellitus
  - Chronic kidney disease
  - Cardiac transplantation
  - Kawasaki disease with current coronary artery aneurysms
- Moderate-risk conditions:
  - Chronic inflammatory diseases (eg, SLE)
  - HIV infection
  - Nephrotic syndrome
  - Kawasaki disease with regressed coronary artery aneurysms
  - Depressive and bipolar disorders

- Identify overweight and obese children by calculating body mass index (BMI) (table 9 and figure 1 and figure 2).

BMI is defined as the weight in kg divided by height in m2.

- History of smoking or exposure to tobacco.

- **History of type 1 or 2 diabetes mellitus, chronic kidney disease (CKD), organ transplantation, cardiac disease, Kawasaki disease, autoimmune disease, familial hypercholesterolemia, and cancer.**

- **History of sleep disorders or symptoms related to obstructive sleep (loud snoring, daytime sleepiness, or history of apnea) .**

- **History of physical activity to identify sedentary children in whom increased physical activity will improve BP and help in weight reduction in children who are overweight or obese (BMI >85th percentile).**

- **Dietary history may identify dietary contributors to HTN (excess salt intake) and contributors to CVD (consumption of high-fat foods) and identify interventions that may decrease BP.**

Physical findings of end-organ damage

The physical examination should include a retinal examination to detect any retinal vascular changes due to HTN (image 1)

Cardiac heave or laterally displaced point of maximal impulse (PMI) may indicate left ventricular hypertrophy (LVH).

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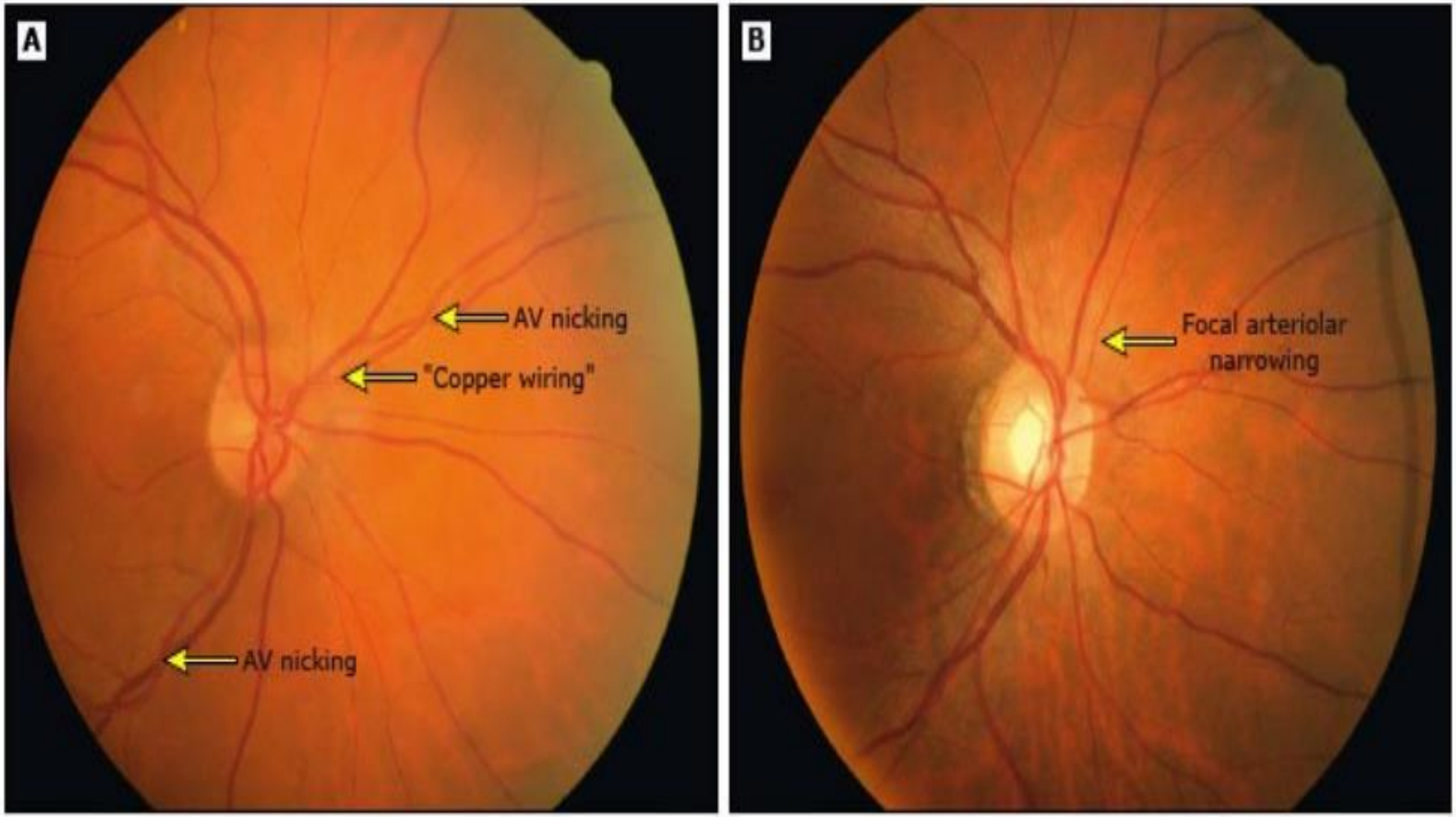
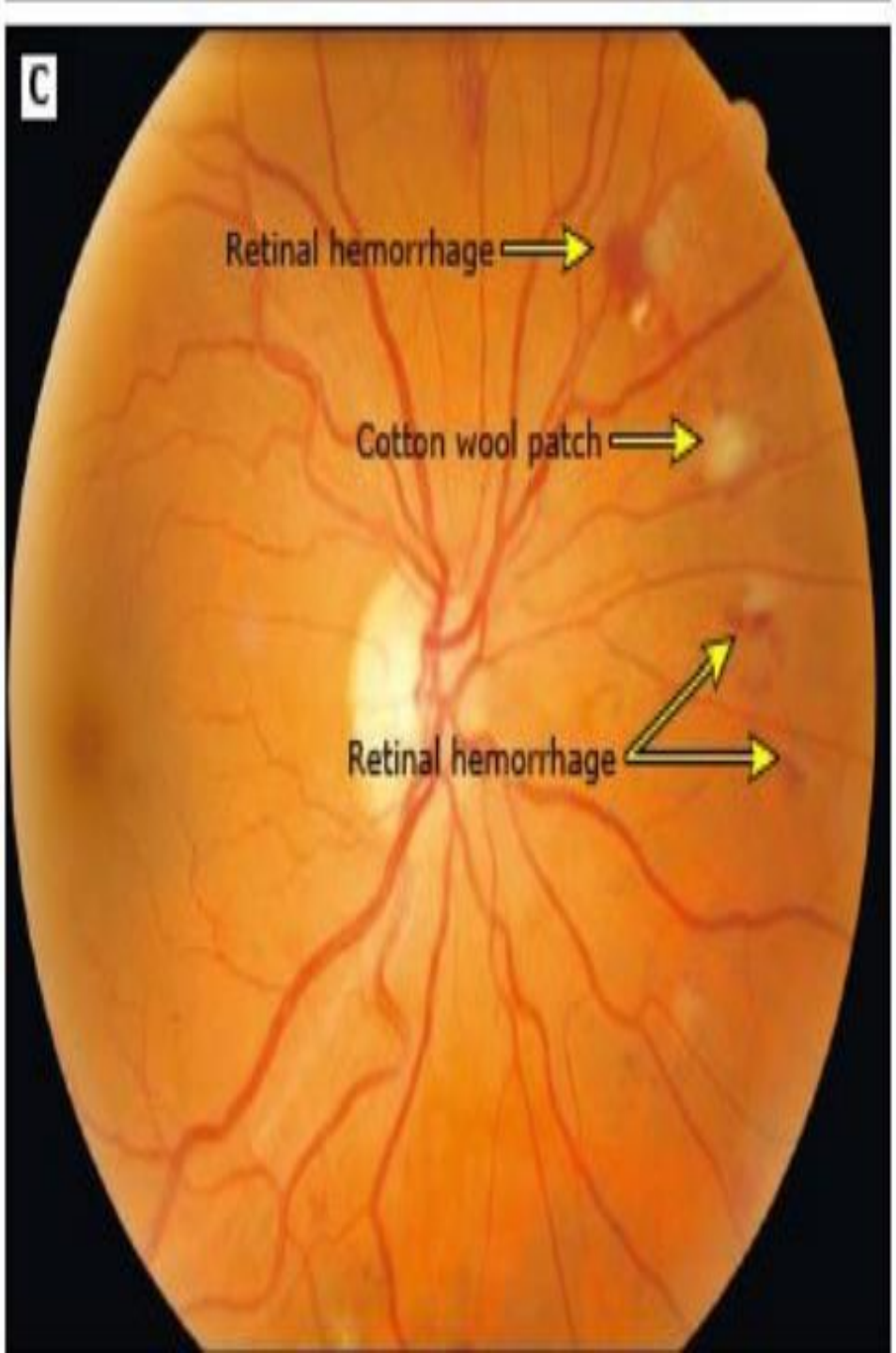
Retinal fundus photographs of hypertensive retinopathy

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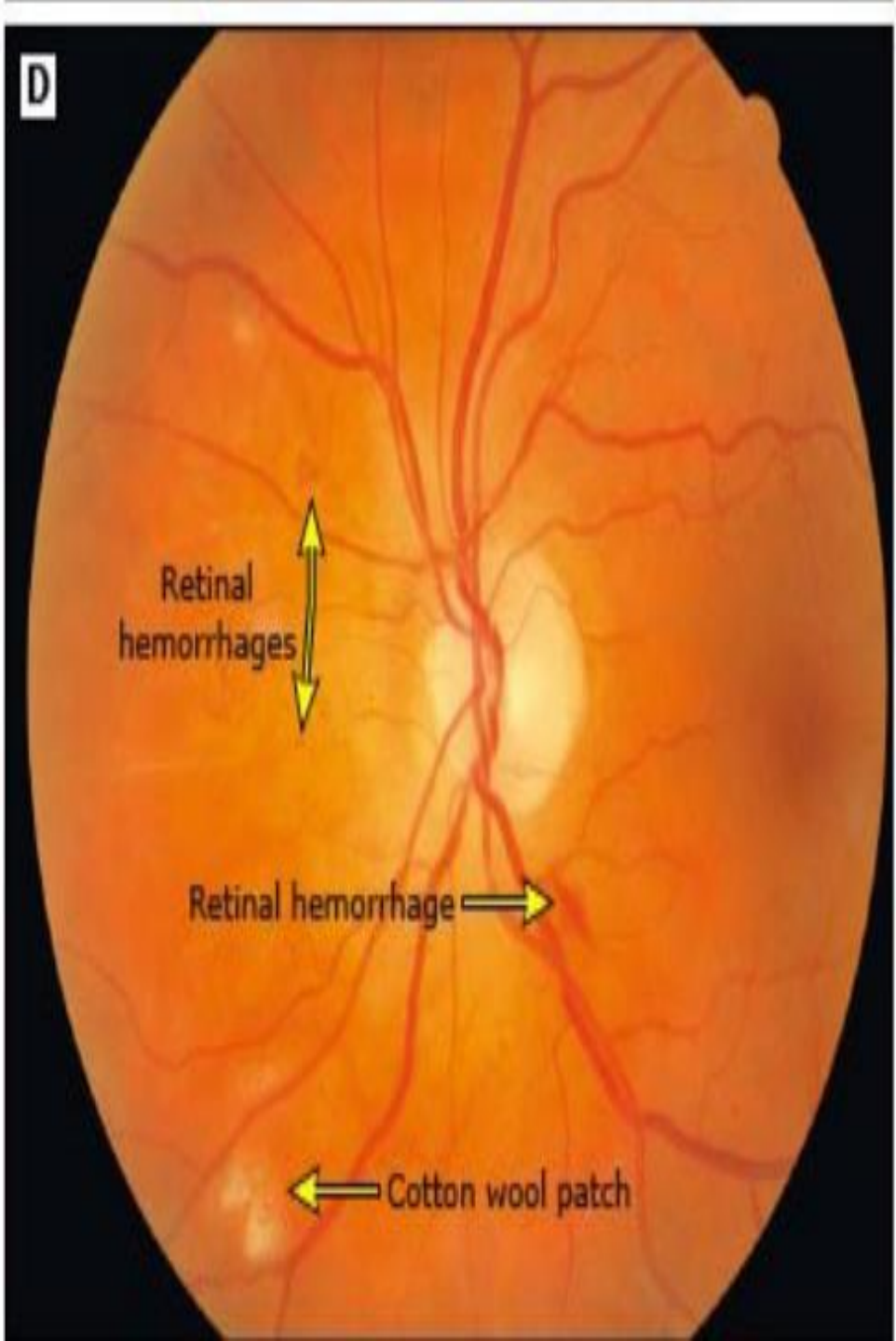
Retinal hemorrhage
Cotton wool patch
Retinal hemorrhage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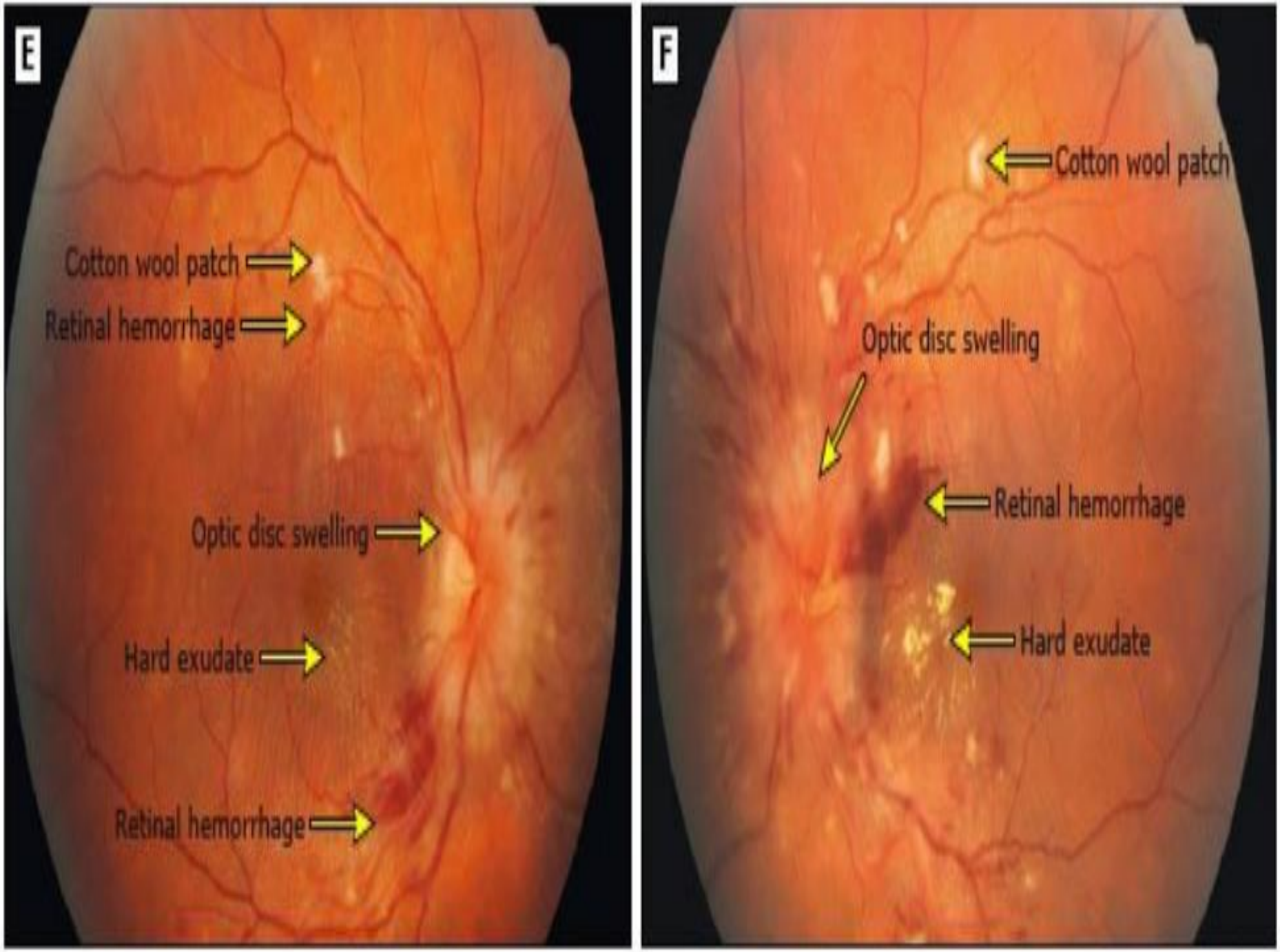
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Cotton wool patch
Retinal hemorrhage
Optic disc swelling
Hard exudate
Retinal hemorrhage
F
Cotton wool patch
Optic disc swelling
Retinal hemorrhage
Hard exudate

Laboratory evaluation and renal imaging

Initial laboratory evaluation in all children with persistent HTN is directed at determining the etiology of HTN and identifying other CVD risk factors, especially in obese children We concur with the following initial evaluation for all children with HTN recommended by the 2017 American Academy of Pediatrics (AAP) **guidelines for high BP :**

- **Measurement of serum blood urea nitrogen (BUN), creatinine, and electrolytes and urinalysis.**

These tests permit quick assessment of renal function and abnormalities in potassium homeostasis or acid-base status (eg, CKD or congenital adrenal hyperplasia, Liddle syndrome).

An abnormal urinalysis (eg, hematuria or proteinuria) and/or an elevation in serum creatinine are suggestive of underlying renal disease.

Glycosuria may be an indication of diabetes mellitus.

- **Measurement of lipid profile to identify children with dyslipidemia, another CVD risk factor.**

- **Renal ultrasound for children less than six years of age or those with abnormal urinalysis or renal function, regardless of age. Of note, for children who are referred to our center for evaluation of HTN, an initial renal ultrasound is performed.**

Obese children

— Additional tests are recommended for children who are obese [1]:

- Hemoglobin A1c (screen for diabetes mellitus).

- Aspartate transaminase and alanine transaminase (screen for fatty liver).

- Fasting lipid profile (additional screen for dyslipidemia). (See "Dyslipidemia in children: Definition, screening, and diagnosis".)

- In our practice, we also will obtain a fasting serum glucose, especially if the urinalysis detects glycosuria.

FURTHER EVALUATION

Further evaluation is performed to assess for end-organ damage, specifically left ventricular hypertrophy (LVH), to establish whether the HTN is primary or secondary, and in patients with secondary HTN, to identify a potentially reversible cause of secondary HTN (table 4).

Detection of end-organ damage

LV hypertrophy and echocardiography

Left ventricular hypertrophy (LVH) is the most prominent manifestation of end-organ damage from HTN.

LVH is associated with adverse cardiovascular disease (CVD) outcomes, and a significant number of children and adolescents with HTN have LVH

Echocardiography is the recommended modality to detect LVH due to pediatric HTN.

The 2017 American Association of Pediatrics (AAP) high blood pressure (BP) guidelines recommends echocardiography to assess for target-organ cardiac damage be performed at the time when pharmacologic therapy is being considered [1].

LVH is defined as LV mass >51 g/m for children and adolescents older than eight years or LV mass >115 g/body surface area (BSA) for boys, and LV mass >95 g/BSA for girls.

The recommended interval for subsequent echocardiographic assessment is based on the results of the initial study [1]:

- **For children without evidence of LV target organ damage, echocardiography to monitor for subsequent end-organ damage is *repeated in one year for patients with stage 2 HTN, secondary HTN, or in patients with stage 1 HTN whose BP is not well controlled despite intervention with pharmacologic and nonpharmacologic therapy.***

- **For children with evidence of LV target organ damage, echocardiography is *performed at six months to monitor for improvement or progression of damage.***

The results of the study are used to determine the scheduling of future studies.

Electrocardiography should not be performed to assess for end-organ cardiac damage, as the study is not sensitive enough to reliably identify pediatric patients with LVH [1].

Primary hypertension

Hypertensive children who fit the primary HTN profile need no further laboratory evaluation beyond the initial testing cited above (table 4)

Secondary hypertension

Further evaluation of patients with findings suggestive of secondary HTN is directed towards identifying the underlying causeThe following diagnostic studies may be performed in hypertensive children with a high degree of suspicion that an underlying disorder is present .

Plasma renin and aldosterone activity

Evaluation of plasma renin and aldosterone activity (PRA) may be useful in patients in the following uncommon conditions:

- Excess mineralocorticoids (eg, aldosterone) secretion – Patients with mineralocorticoid excess usually present with hypokalemia and metabolic alkalosis and their PRA is low and often unmeasurable.

- Congenital adrenal hyperplasia is a common cause of excess mineralocorticoid secretion in children.

Affected patients may present as a neonate with ambiguous genitalia due to the excess secretion of androgens.

- Aldosterone-secreting tumors, which are rare in children.

- **Primary hypersecretion of aldosterone may result from familial hyperaldosteronism, a group of rare genetic disorders, including glucocorticoid-remediable hyperaldosteronism (GRA).**

GRA should be considered in a hypertensive child with a family history of early HTN (before age 21 years) and evidence of metabolic alkalosis even in the absence of hypokalemia.

- **Suppressed mineralocorticoids – Rare genetic disorders with low levels of aldosterone and renin, despite presenting with symptoms suggestive of mineralocorticoid excess, include Liddle syndrome, pseudohypoaldosteronism type 2 (also referred to as Gordon syndrome) and syndrome of apparent mineralocorticoid excess**

- **Renin-secreting tumor – Renin-secreting tumors are rare both in children and adults. Patients generally present with severe HTN, hypokalemia, metabolic alkalosis, and markedly elevated renin levels [14].**

- **Renovascular disease – The plasma renin activity may be elevated in children with renovascular HTN, but, as is true in adults, it is a relatively insensitive test. Approximately 15 percent of children with arteriographically evident renal artery stenosis have normal plasma renin activity [15,16].**

Plasma and urine catecholamines

Patients with HTN due to disorders with catecholamine excess such as pheochromocytoma and neuroblastoma will have elevated levels of both *plasma and urine catecholamines and metabolites.*

In addition to HTN, affected patients may present with headache, sweating, and tachycardia.

In patients with symptoms of catecholamine excess and elevated plasma and urine catecholamines, further evaluation is required.

Renal imaging

As discussed previously, the 2017 AAP high BP guidelines recommend **a renal ultrasound initially for children less than six years of age, or those (regardless of age) with abnormal urinalysis or renal function .**

Renal **ultrasonography is useful to determine the presence of both kidneys, presence of any congenital anomaly, or disparate renal size, which may suggest renal scarring**. In our tertiary center, we obtain an ultrasound for all patients referred for hypertension evaluation.

In patients with a strong suspicion for renal scarring based on history (eg, recurrent febrile urinary tract infections) or with a suggestive but indeterminant finding on renal ultrasound, a 99mTc–dimercaptosuccinic acid (DMSA) renal scan can be performed, since it is a more sensitive study to detect renal cortical loss and scarring [17].

Renovascular imaging

In our practice, renovascular imaging is considered when infants and children have known predisposing factors or findings associated with renal artery stenosis such as prior umbilical artery catheter placements, family history or findings for neurofibromatosis, an abdominal bruit, or a significant size discrepancy on renal ultrasonography.

In addition, we consider renovascular imaging in younger children with HTN, who are less likely to have primary HTN, and in patients with stage 2 HTN when no other cause has been identified.

Standard digital subtraction angiography (DSA), previously called renal angiography, is the current gold standard for evaluating renovascular disease in children.

Although noninvasive tests such as magnetic resonance angiography (MRA) and computed tomographic angiography (CTA) can be used to screen for renovascular diseases, they are not as reliable as DSA in detecting renovascular disease

We **do not** recommend routine duplex Doppler ultrasonography for evaluation of renovascular hypertension in otherwise healthy children because of its low sensitivity/specificity for diagnosis of renal artery stenosis.

Considerations that must be taken into account in the use of these modalities to screen for renovascular disease in children include:

- When performing MRA, the need for conscious sedation or general anesthesia for small children and infants.

- The need to modify computed tomographic (CT) dosing to minimize unnecessary radiation exposures.

- The poorer sensitivity of Doppler ultrasonography compared with other imaging modalities in detecting renal vascular hypertension, especially in patients who have segmental artery lesions . As a result, Doppler ultrasound should not be used to diagnosis renal artery stenosis.

Sleep study evaluation

Evaluation of obstructive sleep apnea (OSA), including polysomnography is considered for children with history of snoring, daytime sleepiness (in adolescents), or hyperactivity (in younger children), especially if they are obese

Drug screening

— If HTN is suspected due to cocaine or amphetamine use, drug testing should be initiated.