

Diagnosis and Management of Acute Renal Failure

I. Definition

Acute renal failure (ARF), also known as acute kidney injury, means decreased kidney function (reduced glomerular filtration rate) over a relatively short period of time. This can occur in the setting of previously normal kidney function or as an acute-on-chronic phenomenon.

Manifestations of ARF may include:

- Rising BUN and serum creatinine
- Oliguria
- Volume overload
- Hypertension
- Electrolyte abnormalities

Patients may present with signs and symptoms of renal failure, or with hematuria, or with flank/abdominal pain, or with no symptoms at all. A high index of suspicion is often required.

II. Etiology

Normal kidney function requires the following steps:

1. Flow of blood to the glomeruli in the kidney
2. Formation of a filtrate across the glomeruli that flows into the tubules
3. Water and electrolyte manipulation along the length of the tubule
4. Passage of the final urine out of tubules, through the renal collecting system and ureters to the bladder and subsequent excretion through the urethra

ARF will occur when parts of this system are disrupted.

- A. "Pre-renal" conditions: poor flow of blood to the glomeruli. Usually related to
 - a. Volume depletion
 - b. Relative hypotension

Possible etiologies include hemorrhage, volume loss from stool or urine, heart failure, shock

- B. Renal conditions: Injury to the kidney itself that interrupts glomerular and/or tubular function.
 - a. Glomerular disease (e.g., acute glomerulonephritis)
 - b. Tubulointerstitial disease (e.g., interstitial nephritis, acute tubular necrosis)
 - c. Vascular disease (e.g., vasculitis)
- C. Post-renal conditions: Obstruction of the drainage system distal to the renal tubules. This could be at any point along the urinary tract but is frequently seen at the bladder outlet. ARF usually requires bilateral obstruction, or obstruction of the one functioning kidney. Causes include:
 - a. Kidney stones
 - b. Congenital obstructions (UPJ obstruction, posterior urethral valves)
 - c. Tumor
 - d. Strictures

III. Evaluation

- A. Thorough history and physical examination. Pay attention to time course, systemic complaints, drugs or exposures, family history, urinary symptoms, blood pressure, fluid balance.

- B. Check and follow the serum creatinine. Consider the appropriate level for the size/age of the patient. A rising creatinine suggests ARF.
- C. Check the urine. Look for evidence of blood, protein and casts in the urine. A bland urine with little or no findings might be seen in interstitial nephritis. Urinary indices (e.g., fractional excretion of sodium (FE_{Na})) can sometimes be useful.
- D. Evaluate the volume/perfusion status. Determine if the patient is volume overloaded or volume deplete. Assess the perfusion of vital organs.
- E. Consider imaging studies. Renal ultrasound is often a good test to look for hydronephrosis (suggestive of obstruction) or intrinsic renal structural abnormalities.
- F. Consider additional tests. Blood tests can point to some causes of ARF (HUS, acute glomerulonephritis, vasculitis). Sometimes a kidney biopsy is needed.

IV. Management

Management depends on the etiology and severity of the ARF.

- A. “Pre-renal” ARF: Improve renal blood flow by replacing lost volume and/or optimizing perfusion. Be *very careful* about using potassium in this setting!
- B. Post-renal ARF: Relieve the identified obstruction. This may require placement of a Foley catheter or a percutaneous nephrostomy, removal of a stone, etc. Following relief of obstruction, there may be a very brisk post-obstructive diuresis with very high urine output and electrolyte loss, putting your patient at risk for pre-renal ARF. Be prepared!
- C. Renal causes of ARF: Specific therapy depends on the diagnosis.

For any patient with persistent ARF, it is important to maintain fluid and electrolyte balance:

- Consider giving fluids to patient as insensible losses plus replacement of all measured losses. This will keep the patient in balance. Calculate insensible losses as $\sim 300 - 500 \text{ ml/m}^2/\text{day}$ (adjust up or down depending on situations that have an effect on losses, such as fever, coma, ventilator, etc.)
- Use diuretics, such as furosemide, to help get more fluid out of your patient and assist in maintaining balance.
- If oliguric, carefully adjust and limit input of potentially problematical electrolytes (sodium, potassium, phosphorus).
- Adjust medications for decreased clearance in the setting of ARF.
- Consider dialysis or hemofiltration if:
 - Volume overload unresponsive to diuretic
 - Hyperkalemia
 - Severe acidosis
 - Other electrolyte abnormalities
 - Uremic symptoms
 - Unable to provide adequate nutrition in the setting of fluid restriction
 - Overall clinical picture is consistent with a condition where renal failure will persist for more than 24 – 48 hours and the patient is a risk for any of the conditions listed

Renal Replacement Therapy for Hospitalized Patients

1. Introduction

Members of the Nephrology Division coordinate all forms of renal replacement therapy. Some concepts should be understood by the medical team in order to facilitate the patient's overall care.

A patient may require renal replacement therapy temporarily for an acute indication or chronically if renal function is permanently lost.

2. Goals of Renal Replacement Therapy:

- Correct fluid overload
- Balance input/output
- Maintain electrolyte and acid/base homeostasis
- Remove toxic substances normally excreted by the kidney

3. Renal Replacement Therapy Modalities

All forms of renal replacement therapy involve the movement of particles and/or water out of the patient across a semipermeable membrane. The various modalities (hemodialysis, peritoneal dialysis, CRRT/hemofiltration) differ in the type of semipermeable membrane used, the method of access to the vascular compartment, the efficiency of water/particle removal and the usual length of the therapy session.

a. Hemodialysis

Membrane:	Artificial
Access:	Dialysis catheter, arteriovenous fistula, subcutaneous dialysis graft
Efficiency:	High
Session length:	Usually one to four hours; daily, every other day, or 3x/week

How it works: During hemodialysis, blood leaves the patient via a vascular access and passes through a dialyzer, or "artificial kidney", with a semipermeable membrane. Dialysate passes on the other side of the membrane. Dialysate generally contains sodium, chloride, calcium, bicarbonate, magnesium and dextrose in serum concentrations. Undesirable solutes (urea, potassium, etc.) are absent from the dialysate or present in very low concentrations. Therefore, they leave the blood through the membrane by diffusion, moving down concentration gradients. Volume (water, dissolved electrolytes) can also be removed by applying negative pressure on the dialysate side of membrane. Blood cells and protein do not cross the membrane due to their size. After filtration, the blood returns to the patient through the vascular access.

Advantages of Hemodialysis	Disadvantages of Hemodialysis
Very efficient; removes large amounts of solute or volume in short period of time Modality of choice when rapid correction needed: <ul style="list-style-type: none"> • Severe hyperkalemia • Pulmonary edema • Toxic ingestion Good for chronic dialysis	Rapid removal may be inappropriate for critically ill, hospitalized patients; patient must be stable enough to tolerate large fluid/electrolyte shifts in a relatively short session Risks of bleeding, hypertension, hypotension, rare allergic reactions Requires vascular access

b. Peritoneal Dialysis

Membrane:	Patient's peritoneum
Access:	Peritoneal dialysis catheter
Efficiency:	Low
Session length:	10 - 24 hours/day; every day

How it works: Peritoneal dialysate, a sterile solution typically containing sodium, chloride, calcium, magnesium, dextrose and lactate, is instilled into the patient's abdomen through a peritoneal dialysis

catheter and allowed to dwell in the peritoneal cavity for a period of time usually between 15 minutes and two hours. The patient's own peritoneum acts as the semipermeable membrane; particles move down concentration gradients, out of the bloodstream and into the peritoneum. After the dwell time is complete, the fluid is drained from the peritoneal cavity and fresh dialysate is instilled, repeating the process. Volume can be removed by increasing the osmotic gradient within the dialysate with higher concentrations of dextrose. Peritoneal fluid can be exchanged manually or with the use of an automated system ("cycler").

Advantages of Peritoneal Dialysis	Disadvantages of Peritoneal Dialysis
Does not require vascular access; therefore often useful for infants and small children Slow, steady removal of particles and volume can be better for unstable patients Good for chronic dialysis; can be performed in the home, often overnight while patient is asleep	Low efficiency makes it a poor choice for rapid correction of serious abnormalities Risks of peritonitis, fluid leakage, protein loss, pulmonary compromise due to abdominal fluid Some patients do not have a functional peritoneum, making PD difficult or impossible

c. Continuous Renal Replacement Therapy (Hemofiltration)

Membrane:	Artificial
Access:	Dialysis catheter
Efficiency:	Low/Moderate
Session length:	Continuously, 24 hours/day

How it works: For CRRT, blood leaves the patient, usually via a hemodialysis catheter and passes through a hemofilter with a semipermeable membrane. Negative pressure applied to the semipermeable membrane causes water and dissolved particles to leave the blood by convection. To increase the loss of particles by convection, the rate of filtration can be increased; if this exceeds the amount of fluid the patient needs to have removed, replacement fluids must be given to the patient to balance input and output. Dialysate can be added to the system on the opposite side of the semipermeable membrane; in that case, particles also leave the blood by diffusion, down concentration gradients (like hemodialysis). The system runs much more slowly than hemodialysis, making it less efficient, but that efficiency is balanced by the continuous nature of the therapy.

Advantages of CRRT	Disadvantages of CRRT
Slow, continuous therapy makes it an ideal choice for unstable patients in the ICU setting Avoids some problems of hemodialysis: <ul style="list-style-type: none"> • Fewer episodes of hypotension • Less rapid electrolyte shifts • More even metabolic balance 	Requires vascular access Risks of bleeding, as in hemodialysis, now extended to 24 hrs/day Greater risks of infection associated with temporary catheter placement in critically ill patients Large daily losses of electrolytes must be balanced

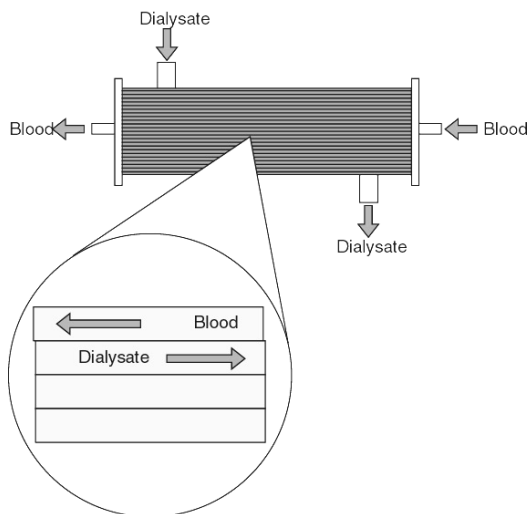
4. Indications for Renal Replacement Therapy

Indications for renal replacement therapy include the following:

- Volume overload unresponsive to diuretics
- Severe hyperkalemia
- Refractory acidosis
- Uremic symptoms
- Toxic ingestions or endogenous toxicities

In addition, dialysis is also started in those patients who have diminished kidney function (e.g., Cr clearance <10ml/min/1.73m²), are unlikely to improve rapidly and cannot be managed conservatively.

Renal replacement therapy may also be considered earlier in some critically ill patients with multi-system organ dysfunction or in those patients with slightly diminished renal capacity who require very large amounts of daily fluid (meds, nutrition, etc.). Renal replacement therapy can help maintain fluid balance in these patients.



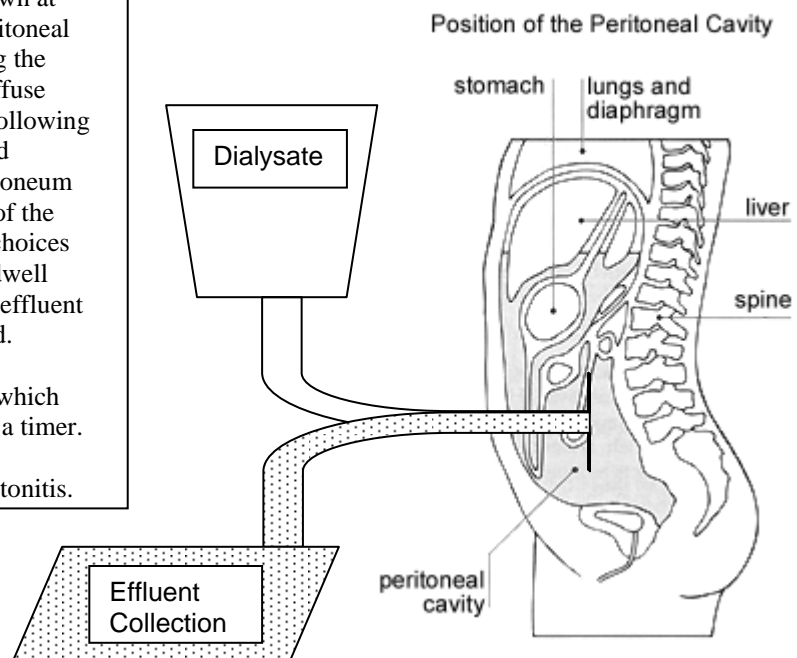
Schematic of a dialyzer, or “artificial kidney”, shown at left. This type of device would be used for hemodialysis or for hemofiltration. Blood enters the dialyzer and flows through thousands of hollow fibers, each of which acts as a semipermeable membrane. Dialysate can be run through the system as indicated; it will pass on the opposite side of the membrane from the blood, allowing substances to filter across the membrane due to concentration gradients.

Volume (water and dissolved electrolytes) is removed from the blood by pressure gradients across the membrane. Negative pressure can be applied at the dialysate outlet port to achieve this.

Schematic for peritoneal dialysis setup, shown at right. Dialysate flows into the patient’s peritoneal cavity through a peritoneal catheter. During the dwell period within the patient, particles diffuse through the peritoneum into the dialysate, following concentration gradients. Volume (water and dissolved particles) passes through the peritoneum into the dialysate due to the osmotic effect of the dialysate dextrose concentration (standard choices 1.5%, 2.5%, 4.25%). After the prescribed dwell time, the fluid is permitted to drain into the effluent collection bag. The process is then repeated.

PD can be done manually or with a cycler, which automatically instills and drains fluid using a timer.

Sterile technique is *essential* to prevent peritonitis.



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Diagnosis and Management of Pediatric Hypertension

Many of the recommendations in this outline are based on the 4th Report on Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents. The Report was published in *Pediatrics* in 2004 (*Pediatrics* 2004; 114(2):555-576).

Definition of Hypertension in Pediatric Patients

Normotensive	Average systolic and diastolic BP <90% for age, sex and height
Prehypertensive	Average systolic or average diastolic BP ≥ 90 and <95% for age, sex and height OR $\geq 120/80$
Hypertensive	Average systolic or average diastolic BP $\geq 95\%$ for age, sex and height <i>on ≥ 3 occasions</i>

Measurement of Blood Pressure

- Measure BP in any child >3 years old
- Auscultation is the preferred method
- Must use an appropriately-sized cuff
- High readings obtained by oscillometric device should be rechecked by auscultation
- Elevated BP should be confirmed on repeated visits

Blood Pressure Screening in Pediatrics

Pediatric patients should be screened for high blood pressure. After taking the patient's BP, you must evaluate and stage the findings:

- Determine appropriate percentile using current BP charts
 - <90% is normal
 - >90%: repeat and take average BP
 - Persistently high values need further evaluation
- **Prehypertension:** BP ≥ 90 and <95% for age, sex and height **OR** $\geq 120/80$
- **Hypertension:** BP $\geq 95\%$ for age, sex and height
 - **Stage 1 HTN:** 95% to 99% + 5mmHg
 - **Stage 2 HTN:** >99% + 5mmHg

Follow-up from Blood Pressure Screening

	When to Recheck BP?	Intervention
Normal	Next regular visit	Encourage healthy diet
PreHTN	6 months	TLC*; meds if comorbidities
Stage 1 HTN	1-2 wks; sooner if Sx	TLC*; meds if indicated; complete evaluation
Stage 2 HTN	Eval/refer within 1 wk; immediately if Sx	TLC*; meds; complete evaluation

*TLC: Therapeutic Lifestyle Changes

Diagnostic Evaluation of Pediatric Hypertension

With younger child or higher BP, it is more likely that HTN has a secondary cause. Staged evaluation, including multiple readings of BP, will determine if HTN is sustained and if therapy is warranted. In severe HTN, more aggressive investigation is indicated, and therapy may be necessary before the cause of the hypertension is certain. Essential, or primary hypertension, is a growing problem in pediatrics.

Causes of Hypertension in Children

- Secondary hypertension
 - Renal or urological disease
 - Renovascular disease
 - Endocrinological abnormalities
 - Rare genetic abnormalities
- Primary (essential) hypertension

Primary (Essential) Hypertension in Childhood

- Primary hypertension is seen in children
- Strong association between hypertension and overweight
- Increasing prevalence of overweight children

Specific Evaluation for the Hypertensive Child

History

- General history
- Family history
- Risk factors
- Diet
- Habits (tobacco, alcohol)
- Sleep history

Physical Examination

- Height, weight, BMI
- Four-extremity BP
- Skin manifestations, aberrant sexual characteristics, abdominal bruits, pulses
- Funduscopic examination
- Consider any unifying syndromes

Studies

a. Initial Studies:

Some of the studies listed below should be considered depending on the history and presentation. For example, polysomnography might be indicated with a history of snoring and sleep apnea.

- | | |
|--|-----------------------|
| ▪ Urinalysis, including microscopic exam | ▪ Fasting lipid panel |
| ▪ Urine culture | ▪ Fasting glucose |
| ▪ Serum chemistries | ▪ Drug screen |
| ▪ CBC | ▪ Polysomnography |
| ▪ Renal ultrasound | ▪ Echocardiogram |

b. Secondary Studies

Depending on level of hypertension and clinical suspicion, may also include the following as part of initial studies):

- Ambulatory BP monitoring
- Renin/aldosterone levels
- Renovascular imaging
- Catecholamine levels

Therapy for Pediatric Hypertension

Non-pharmacological methods

Therapeutic lifestyle changes (TLC) should always be considered in hypertensive children and adolescents, including:

- Weight management counseling
- Physical activity
- Diet management
- Risk factor modification

Pharmacological methods

Indications for medications in the setting of hypertension include the following:

- Symptomatic hypertension
- Secondary hypertension
- Hypertensive target-organ damage
- Diabetes (types 1 and 2)
- Persistent hypertension despite non-pharmacologic measures

In choosing pharmacological agents to treat pediatric HTN, consider the following:

- Level of HTN and the speed with which control must be achieved
- Source of HTN in the individual patient
- Which drugs are available
- Age of the child and form of the drug
- Potential interactions and complications

Categories of Antihypertensive Agents				
<i>Class of Drugs</i>	<i>General Properties</i>	<i>Advantages</i>	<i>Disadvantages</i>	<i>Examples</i>
Vasodilators	Diminish vascular resistance by vasodilatation	Act directly, quickly	Sodium retention Limited pediatric forms	•Hydralazine •Minoxidil •Nitroprusside •Diazoxide •Ca channel blockers (many kinds)
Calcium Channel Blockers	Inhibit Ca ⁺⁺ entry into smooth muscle cells	Pediatric experience Long-acting preparations	Dosing limitations Problems in adults	•Amlodipine •Isradipine •Nifedipine •Nicardipine •Diltiazem •Verapamil
ACE Inhibitors	Block conversion of A-I to A-II; increase bradykinins	Usually well tolerated “Renal protective”	Can effect Cr, K ⁺ , Hct, ANC Dry cough in some patients Can't use in pregnancy	•Captopril •Enalapril •Enalaprilat •Lisinopril •Quinapril •Ramipril •Benazepril
<i>beta</i> -Blockers	Effects on cardiac output, vascular resistance and renin production	Experience	Limited pediatric forms beta-2 reactivity Unpleasant side effects	•Propranolol •Atenolol •Labetalol •Esmolol
Diuretics	Block solute reabsorption	Long history Well tolerated Inexpensive	Must check chemistries	•Chlorothiazide •Hydrochlorothiazide •Furosemide •Bumetanide •Metolazone •Spironolactone •Amiloride
<i>alpha</i> -Blockers	Inhibit vasoconstriction by blocking alpha adrenergic receptors	Useful in special cases or in refractory HTN	Limited experience in pediatrics	•Prazosin •Phenoxybenzamine •Phentolamine
Centrally-Acting Sympathetic Inhibitors	Stimulate alpha-2 adrenergic receptors to inhibit sympathetic flow	Some preparations make compliance better (patch)	Unpleasant side effects Risk of rebound HTN	•Clonidine
Angiotensin II Receptor Blockers (ARBs)	Block A-II receptors	“Renal protective”	Can affect creatinine Limited peds experience	•Losartan •Valsartan •Irbesartan •Candesartan

Which drug should I choose?

- No data in pediatrics showing a long-term advantage to any particular class of drugs
- Choice left to the clinician
- Start low, increase to max, then add 2nd agent
- Consider physiology
 - Renal disease/proteinuria: ACEI, ARB
 - Migraine: β -blocker, Ca⁺⁺ channel blocker

Algorithm for Blood Pressure Monitoring and Intervention for Pediatric Patients

(from the 4th Report on Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents, *Pediatrics* 2004; 114(2):555-576)

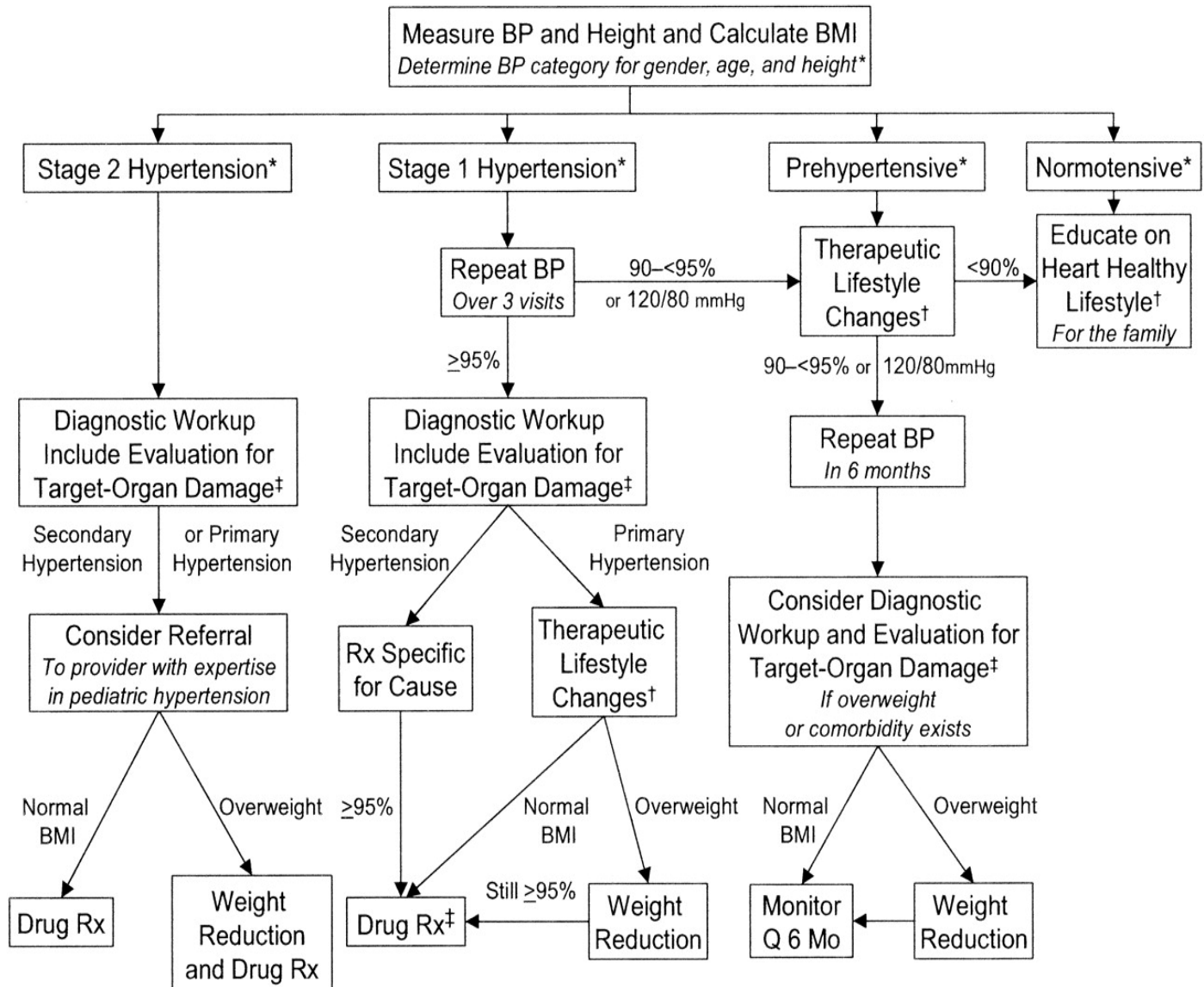


TABLE 3. BP Levels for Boys by Age and Height Percentile

Age, y	BP Percentile	SBP, mm Hg							DBP, mm Hg						
		Percentile of Height							Percentile of Height						
		5th	10th	25th	50th	75th	90th	95th	5th	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	92	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	72	73	74	75	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

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TABLE 4. BP Levels for Girls by Age and Height Percentile

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	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

(from the 4th Report on Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents, *Pediatrics* 2004; 114(2):555-576)

Hypertensive urgencies and emergencies (“Severe Hypertension”)

Definitions

In a *hypertensive emergency*, the patient has end-organ injury related to very high blood pressure (e.g., encephalopathy, pulmonary edema, cerebral hemorrhage). They usually have symptoms associated with high BP (e.g., blurred vision, headache, nausea). The blood pressure needs to be reduced quickly to a safer level.

In a *hypertensive urgency*, the blood pressure may be rising or elevated but there is no evidence of end-organ involvement. The patient may have symptoms similar to those seen in a hypertensive emergency or may be asymptomatic. The blood pressure needs to be reduced to prevent it from continuing to rise or causing later injury (i.e., becoming a hypertensive emergency); often, the goal is to normalize BP within 24 hours.

These two groups are sometimes lumped together as *hypertensive crises*.

Due to confusion regarding this nomenclature, some clinicians prefer the term *severe hypertension* and then comment on the presence or absence of end-organ injury.

Therapy

Hypertensive emergencies require quick, controlled reduction of the blood pressure. IV medications are indicated.

Hypertensive urgencies can often be treated with oral medications but sometimes IV medications will give better control.

FOR EITHER FORM OF HYPERTENSIVE CRISIS one would wish to avoid dropping the blood pressure too quickly to the normal level if the blood pressure has been high for a long (or indeterminate) period of time, given the possibility of cerebral hypoperfusion with a suddenly “normal” BP. It may be better first to target a safe, asymptomatic blood pressure, then adjust therapy to reduce BP by 10-15mmHg every 24hrs until in the normal range.