
بسم الله الرحمن الرحیم
به‌نام خدای بخشاینده مهربان
In the name of Allah, the Beneficent, the Merciful.

Kidney Replacement Therapy (Hemodialysis)

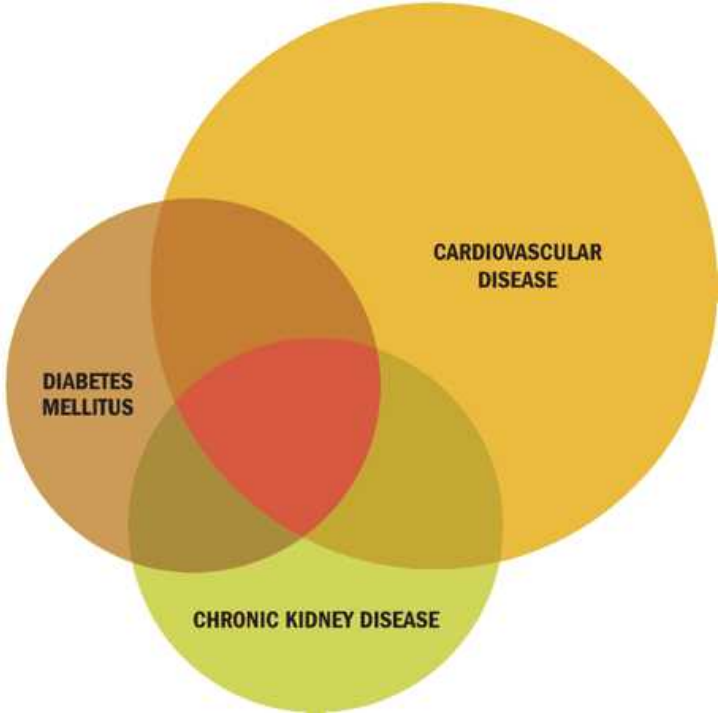
M.R.abbasi MD

Nephrologist

TUMS

1403

CKD-CVD-Diabetes Link: CKD is a Disease Multiplier



Criteria for CKD

- Abnormalities of kidney structure or function, present for >3 months, with implications for health
- Either of the following must be present for >3 months:
  - ACR >30 mg/g
  - Markers of kidney damage (one or more*)
  - GFR <60 mL/min/1.73 m2

*Markers of kidney damage can include nephrotic syndrome, nephritic syndrome, tubular syndromes, urinary tract symptoms, asymptomatic urinalysis abnormalities, asymptomatic radiologic abnormalities, hypertension due to kidney disease.m^2

Screening Tools: eGFR

- Considered the best overall index of kidney function.
- Normal GFR varies according to age, sex, and body size, and declines with age.
- The NKF recommends using the CKD-EPI Creatinine Equation (2009) to estimate GFR. Other useful calculators related to kidney disease include MDRD and Cockroft Gault.
- GFR calculators are available online at www.kidney.org/GFR.

Summary of the MDRD Study and CKD-EPI Estimating Equations:
https://www.kidney.org/sites/default/files/docs/mdrd-study-and-ckd-epi-gfr-estimating-equations-summary-ta.pdf

Screening Tools: ACR

- Urinary albumin-to-creatinine ratio (ACR) is calculated by dividing albumin concentration in milligrams by creatinine concentration in grams.
- Creatinine assists in adjusting albumin levels for varying urine concentrations, which allows for more accurate results versus albumin alone.
- Spot urine albumin-to-creatinine ratio for quantification of proteinuria
  - New guidelines classify albuminuria as mild, moderately or severely increased
- First morning void preferable
- 24hr urine test rarely necessary

Old Classification of CKD as Defined by Kidney Disease Outcomes Quality Initiative (KDOQI) Modified and Endorsed by KDIGO

Stage	Description	Classification by Severity	Classification by Treatment
1	Kidney damage with normal or increased GFR	GFR ≥ 90	
2	Kidney damage with mild decrease in GFR	GFR of 60-89	T if kidney transplant
3	Moderate decrease in GFR	GFR of 30-59	recipient
4	Severe decrease in GFR	GFR of 15-29	D if dialysis
5	Kidney failure	GFR < 15	D if dialysis

Note: GFR is given in mL/min/1.732 m^2

National Kidney Foundation. KDOQI Clinical Practice Guidelines for Chronic Kidney Disease: Evaluation, Classification, and Stratification. Am J Kidney Dis 2002;39(suppl 1):S1-S266

KDIGO, Kidney Disease: Increasing Global Outcomes

Classification of CKD Based on GFR and Albuminuria Categories:

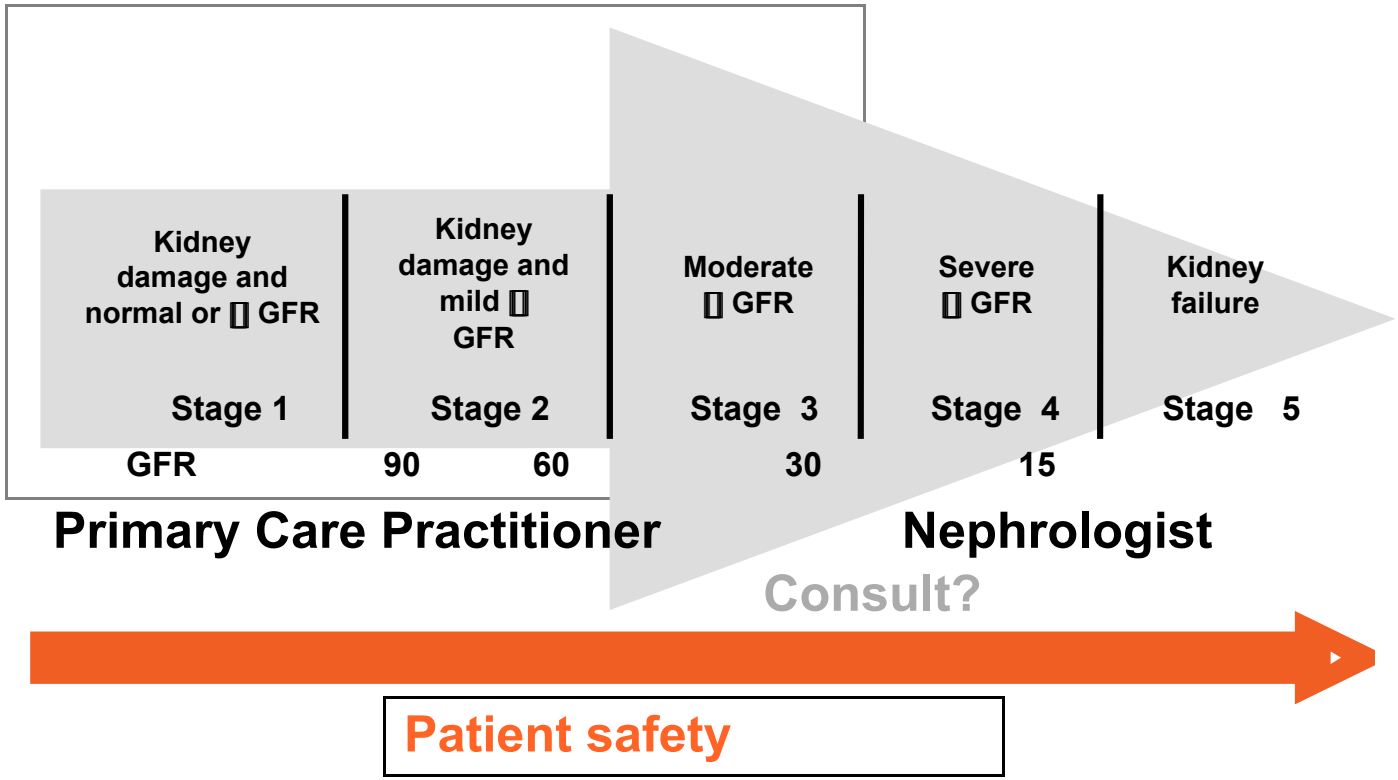
Prognosis of CKD by GFR and Albuminuria Categories

GFR categories (ml/min/1.73 m²) Description and range				Albuminuria categories Description and range		
				A1	**A2**	**A3**
				Normal to mildly increased	Moderately increased	Severely increased
				<30 mg/g <3 mg/mmol	30-299 mg/g 3-29 mg/mmol	≥300 mg/g ≥30 mg/mmol
	G1	Normal or high	≥90			
	G2	Mildly decreased	60-90			
	G3a	Mildly to moderately decreased	45-59			
	G3b	Moderately to severely decreased	30-44			
	G4	Severely decreased	15-29			
	G5	Kidney failure	<15			

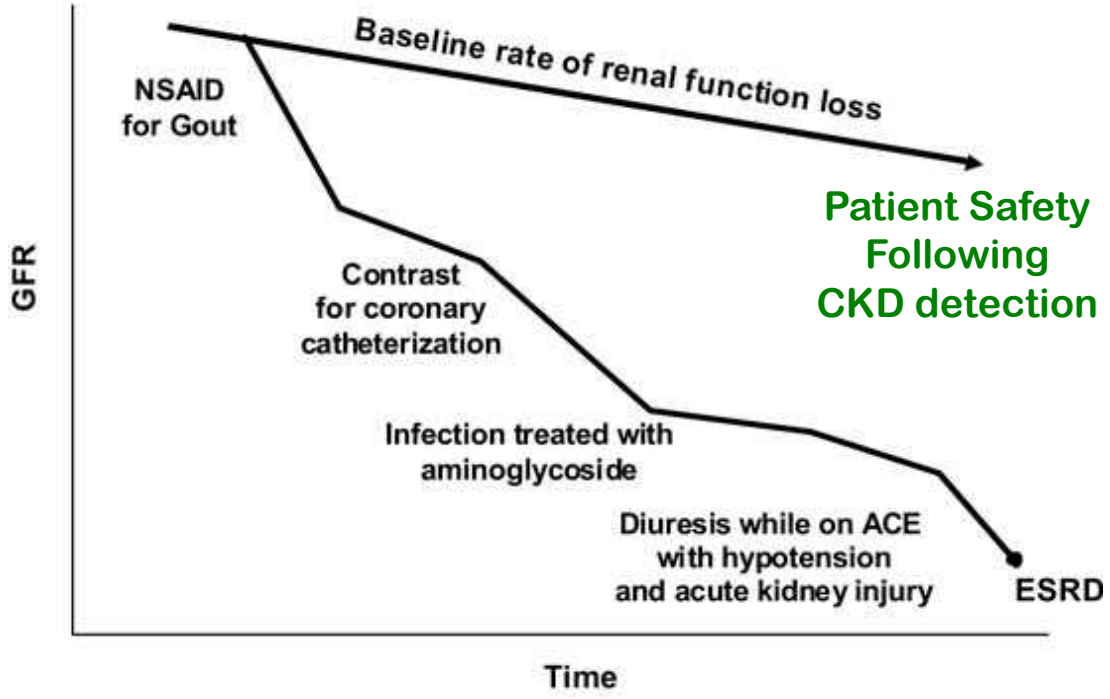
Green: low risk (if no other markers of kidney disease, no CKD); Yellow: moderately increased risk; Orange: high risk; Red, very high risk.
KDIGO 2012

Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. *Kidney Int Suppls*. 2013;3:1-150.

Who Should be Involved in the Patient Safety Approach to CKD?



Impact of primary care CKD detection with a patient safety approach



Improved diagnosis creates opportunity for strategic preservation of kidney function

Fink et al. *Am J Kidney Dis*. 2009,53:681-

Indications for Referral to Specialist Kidney Care Services for People with CKD

- Acute kidney injury or abrupt sustained fall in GFR
- GFR <30 ml/min/1.73m2 (GFR

*Significant albuminuria is defined as ACR ≥300 mg/g (≥30 mg/mmol) or AER ≥300 mg/24 hours, approximately equivalent to PCR ≥500 mg/g (≥50 mg/mmol) or PER ≥500 mg/24 hours

**Progression of CKD is defined as one or more of the following: 1) A decline in GFR category accompanied by a 25% or greater drop in eGFR from baseline; and/or 2) rapid progression of CKD defined as a sustained decline in eGFR of more than 5ml/min/1.73m2/year. KDOQI US Commentary on the 2012 KDIGO Evaluation and Management of CKD

Observational Studies of Early vs. Late Nephrology Consultation

Table 36 | Outcomes of early versus late referral

Variable	Early referral mean (SD)	Late referral mean (SD)	P value
Overall mortality, %	11 (3)	23 (4)	<0.0001
1-year mortality, %	13 (4)	29 (5)	0.028
Hospital length of stay, days	13.5 (2.2)	25.3 (3.8)	0.0007
Serum albumin at RRT start, g/dl [g/l]	3.62 (0.05) [36.2 (0.5)]	3.40 (0.03) [34.0 (0.3)]	0.001
Hematocrit at RRT start, %	30.54 (0.18)	29.71 (0.10)	0.013

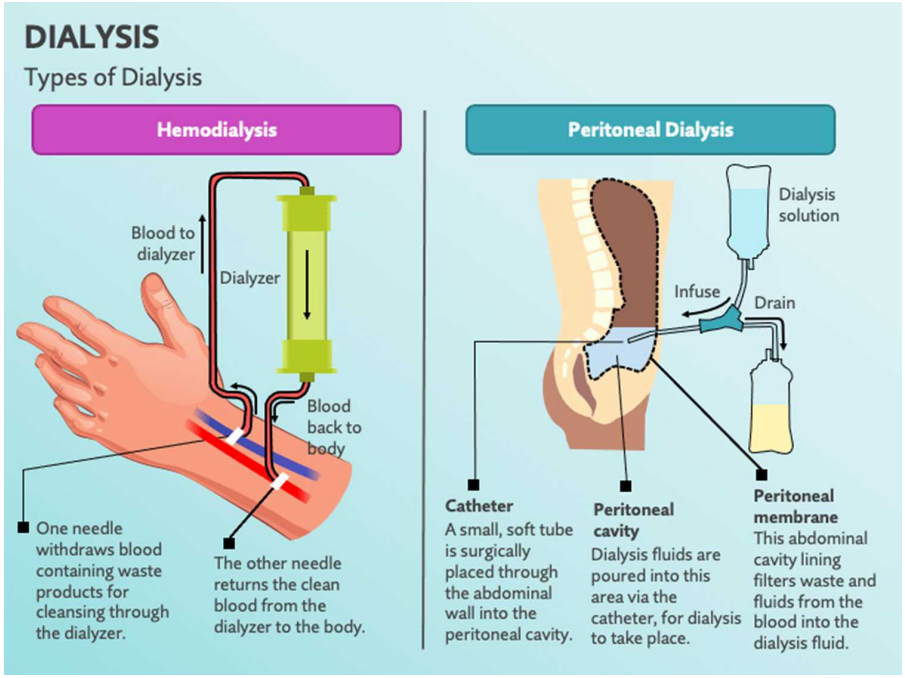
Abbreviation: RRT, renal replacement therapy.

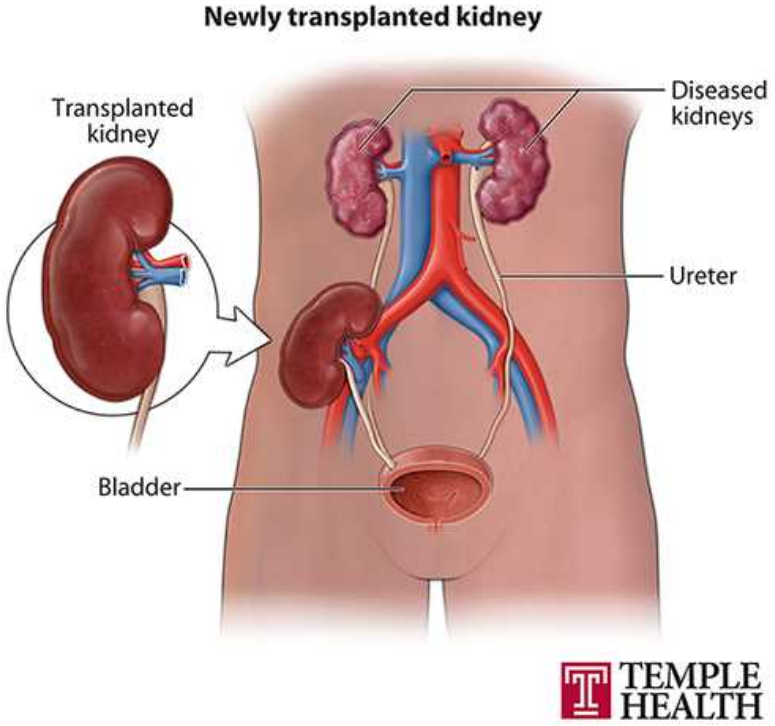
Adapted from Am J Med, Chan MR, Dall AT, Fletcher KE, *et al*[673] Outcomes in patients with chronic kidney disease referred late to nephrologists: a meta-analysis. 120: 1063-1070, 2007, with permission from Elsevier; accessed http://download.journals.elsevierhealth.com/pdfs/journals/0002-9343/PIIS000293430700664X.pdf

Chan M, et al. *Am J Med*. 2007;120:1063-1070.
http://download.journals.elsevierhealth.com/pdfs/journals/0002-9343/PIIS000293430700664X.pdf
KDIGO CKD Work Group. *Kidney Int Suppls*. 2013;3:1-150.

Treatment of ESKD

- Kidney transplantation
- KRT: HD, PD





Indications of KRT

- Acute
- Chronic

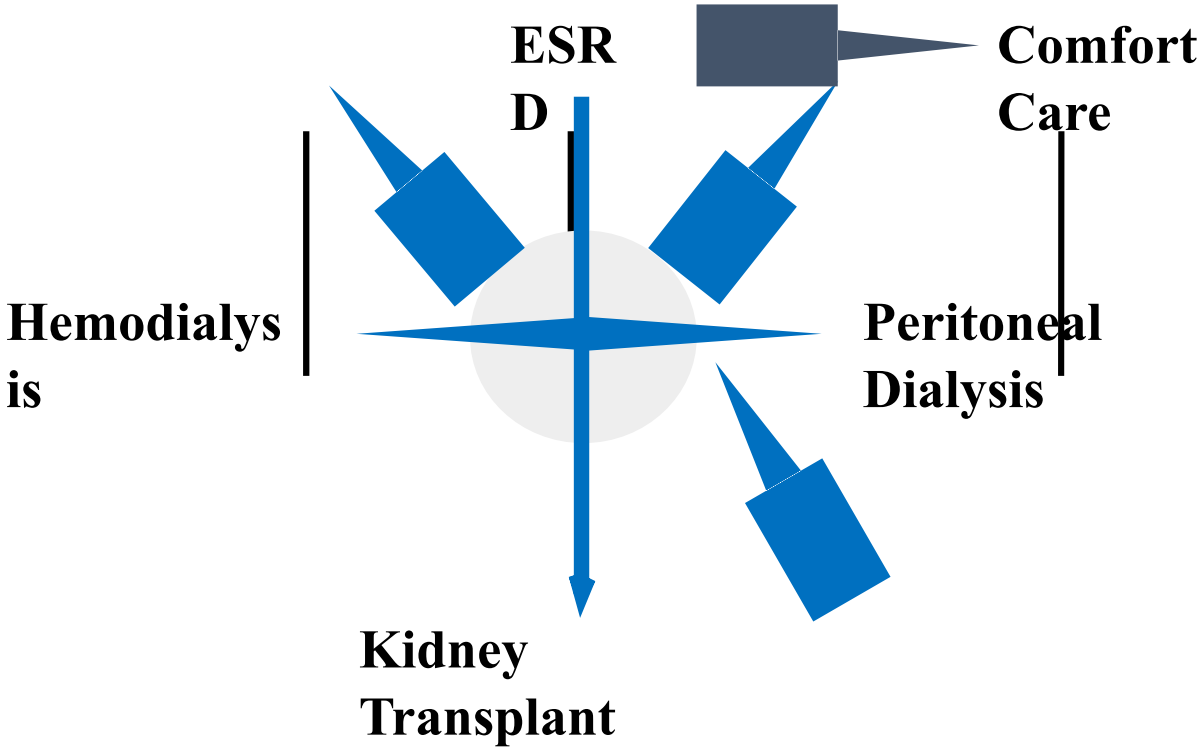
Indications for Renal Replacement Therapy(urgent)

- Hyperkalemia
- Metabolic acidosis
- Fluid overload (recurrent CHF admissions)
- Uremic pericarditis (rub)
- Altered consciousness
- Severe nausea and vomiting

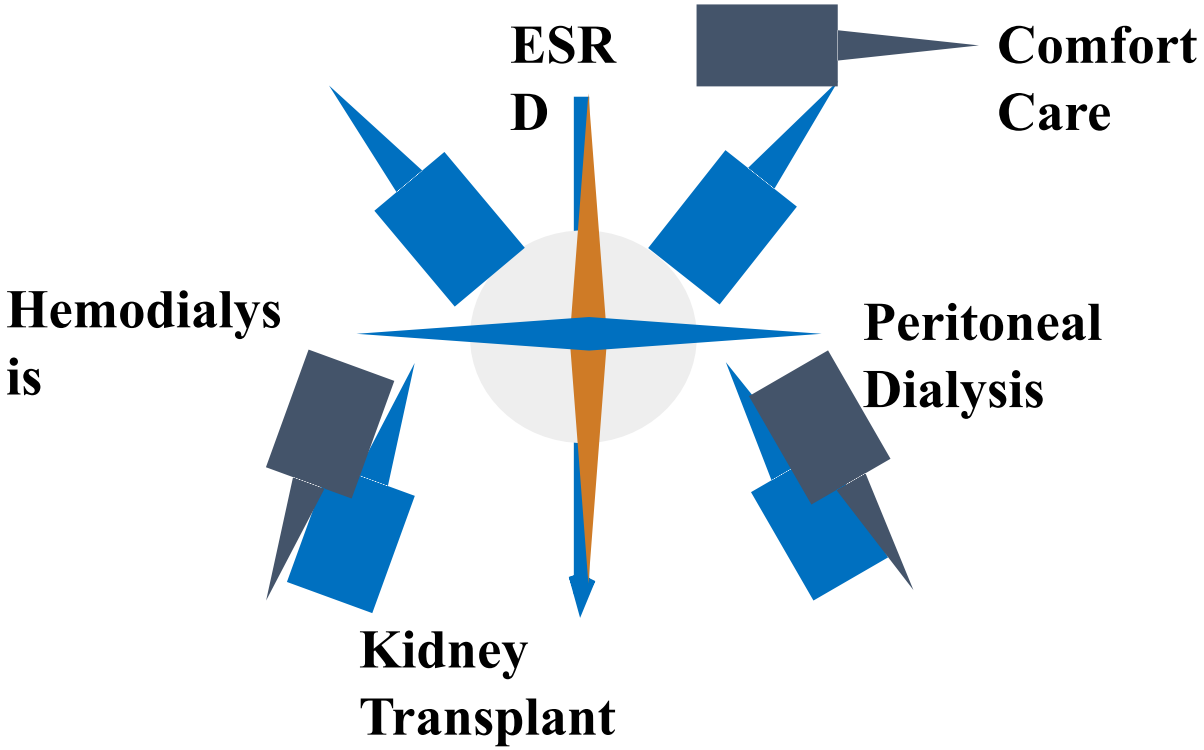
KDIGO 2024

- **Initiate dialysis based on a composite**
- **assessment of a person's symptoms, signs, QoL, preferences, level of GFR, and laboratory abnormalities.**
- **Symptoms or signs attributable to kidney failure(GFR 5-10 ml/min):**
- neurological signs and symptoms attributable to uremia
- Pericarditis
- Anorexia
- medically resistant acid-based or electrolyte abnormalities
- intractable pruritus, serositis

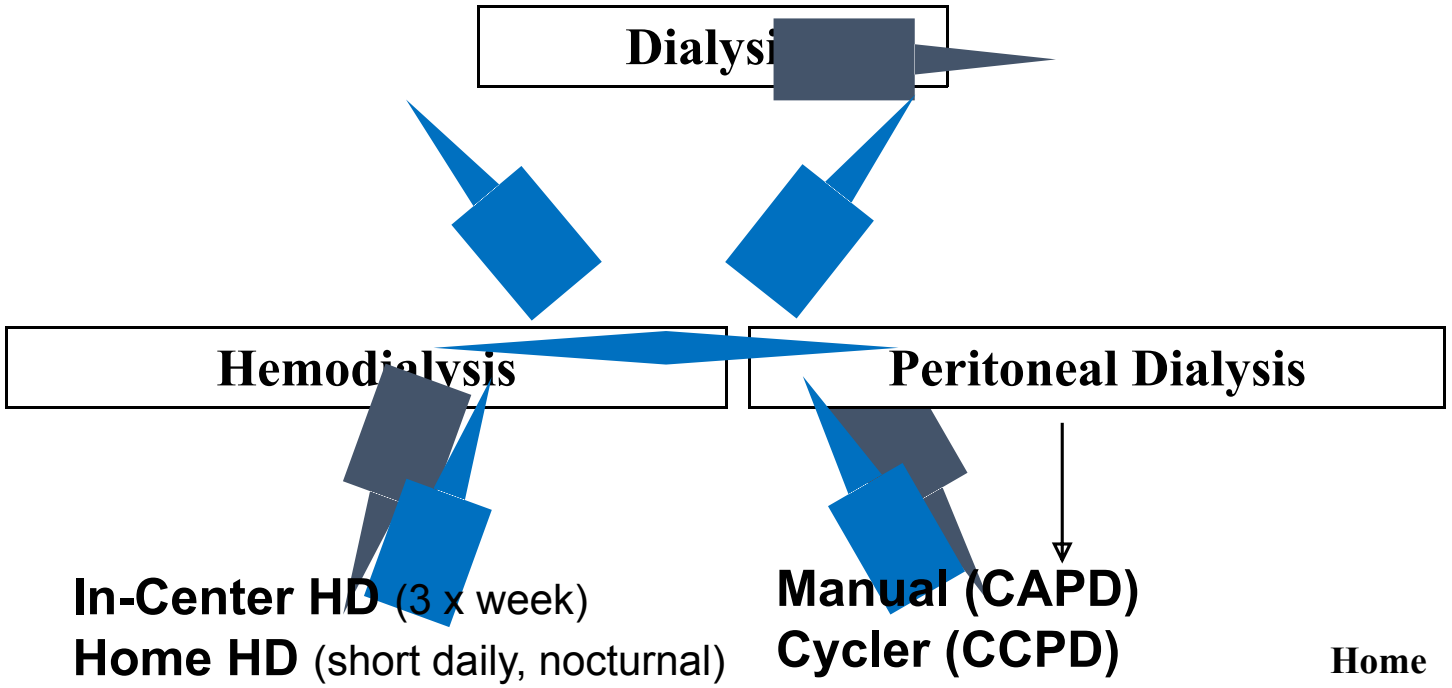
Treatment Options for Renal Replacement Therapy



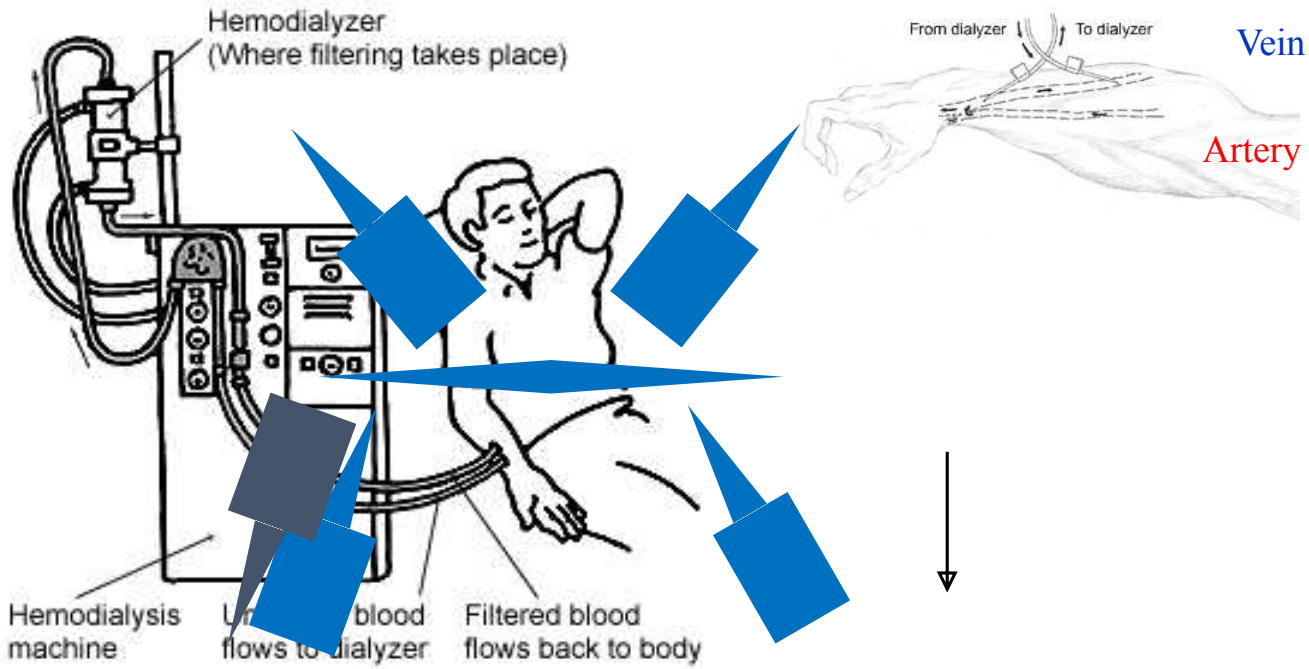
Treatment Options for Renal Replacement Therapy

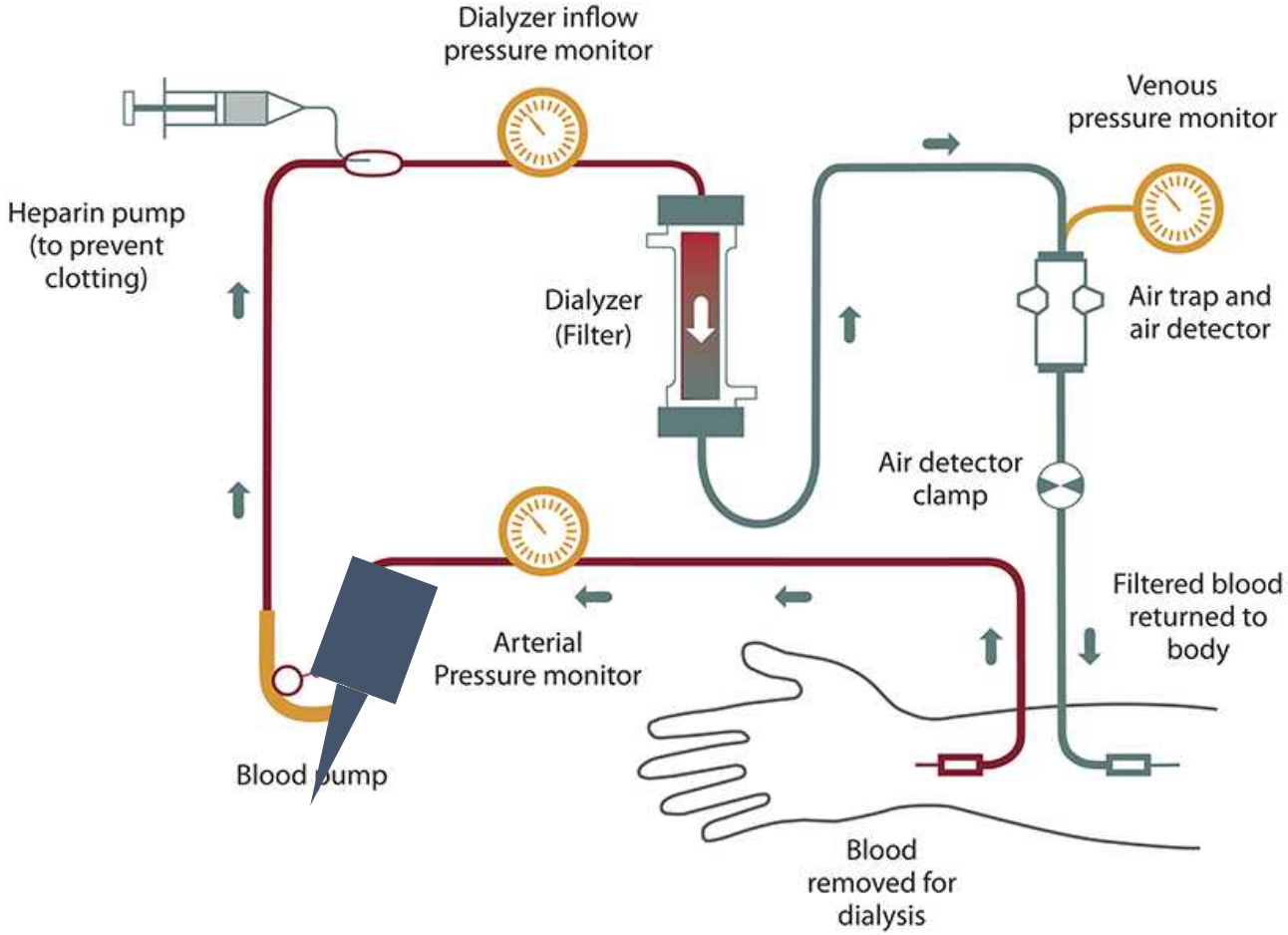


Dialysis Options



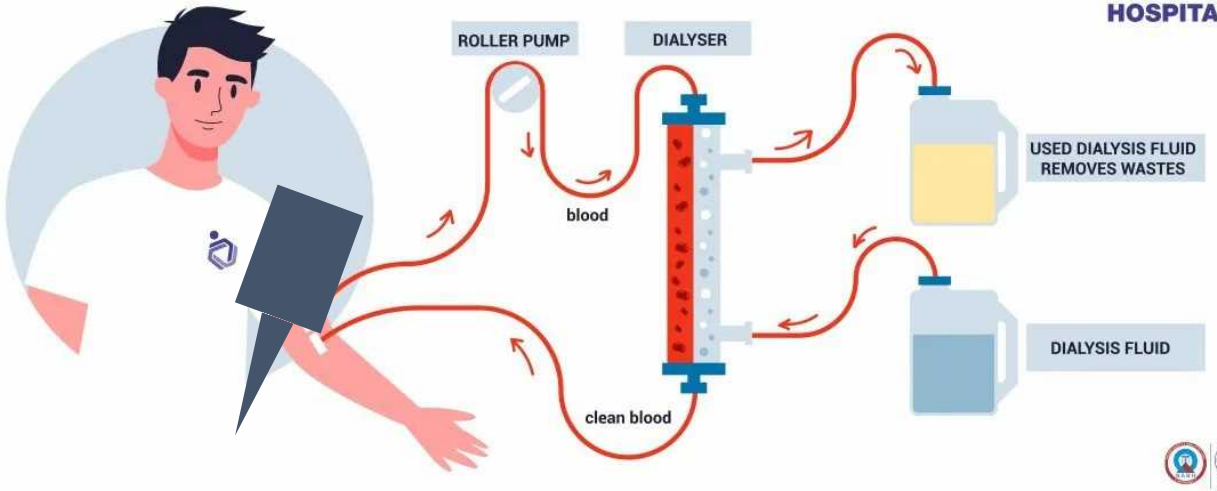
Principle of Hemodialysis




Dialyzer inflow
pressure monitor
Venous
pressure monitor
Heparin pump
(to prevent
clotting)
Dialyzer
(Filter)
Air trap and
air detector
Air detector
clamp
Filtered blood
returned to
body
Arterial
Pressure monitor
Blood pump
Blood
removed for
dialysis

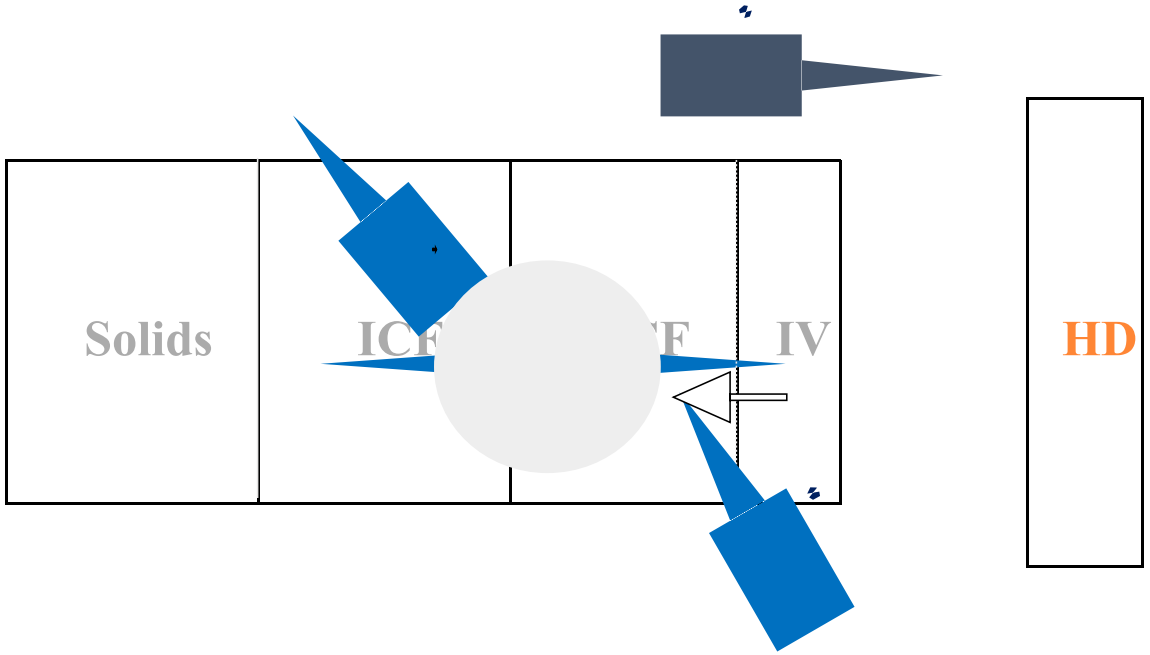
Hemodialysis Procedure

PACE HOSPITALS



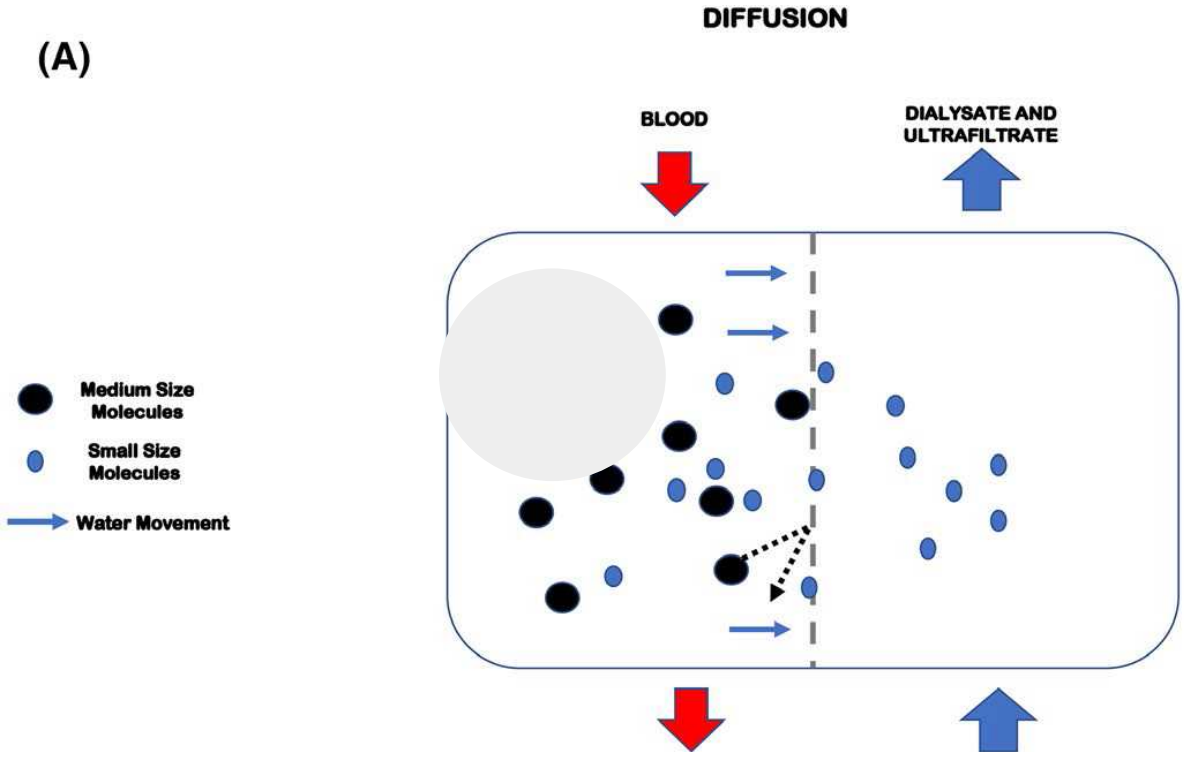
Hyderabad, Telangana, India 040 4848 6868 pacehospital.com @pacehospitals

Urea Mass Transfer During Hemodialysis

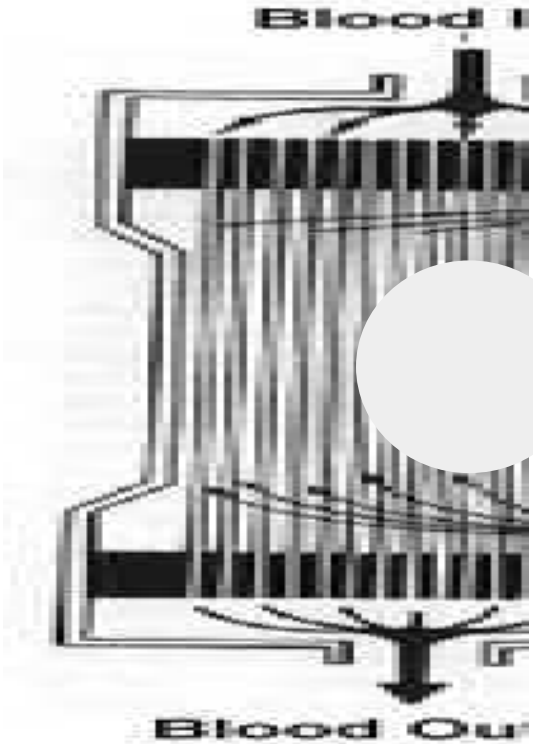


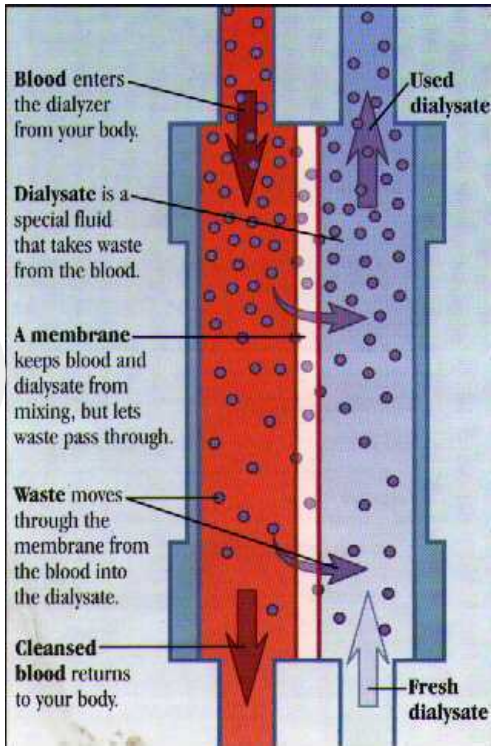
Harmon W, Jabs K: Hemodialysis (chap 77) in Pediatric Nephrology, 4th ed
Barratt, Avner, Harmon (ed) Lippincott, 1999

(A)


DIFFUSION
BLOOD
DIALYSATE AND ULTRAFILTRATE
Medium Size Molecules
Small Size Molecules
Water Movement

Hemodialysis Filter (Dialyzer)

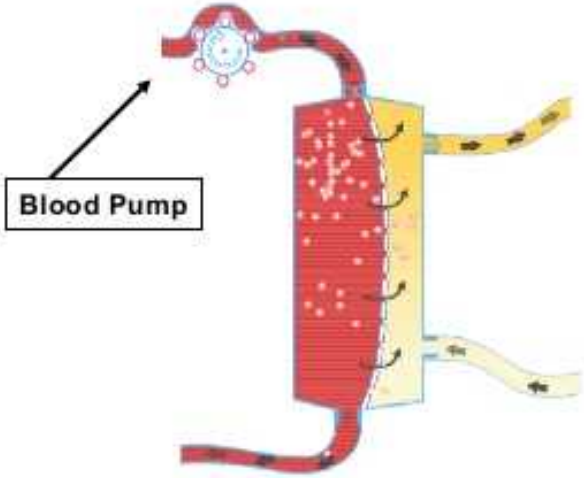




Dialyzer

Diffusion

Movement of solutes from an area of higher to lower solute concentration.



Factors affecting diffusion :

Concentration gradient

Blood flow rate (QB)

fluid flow rate (QD)

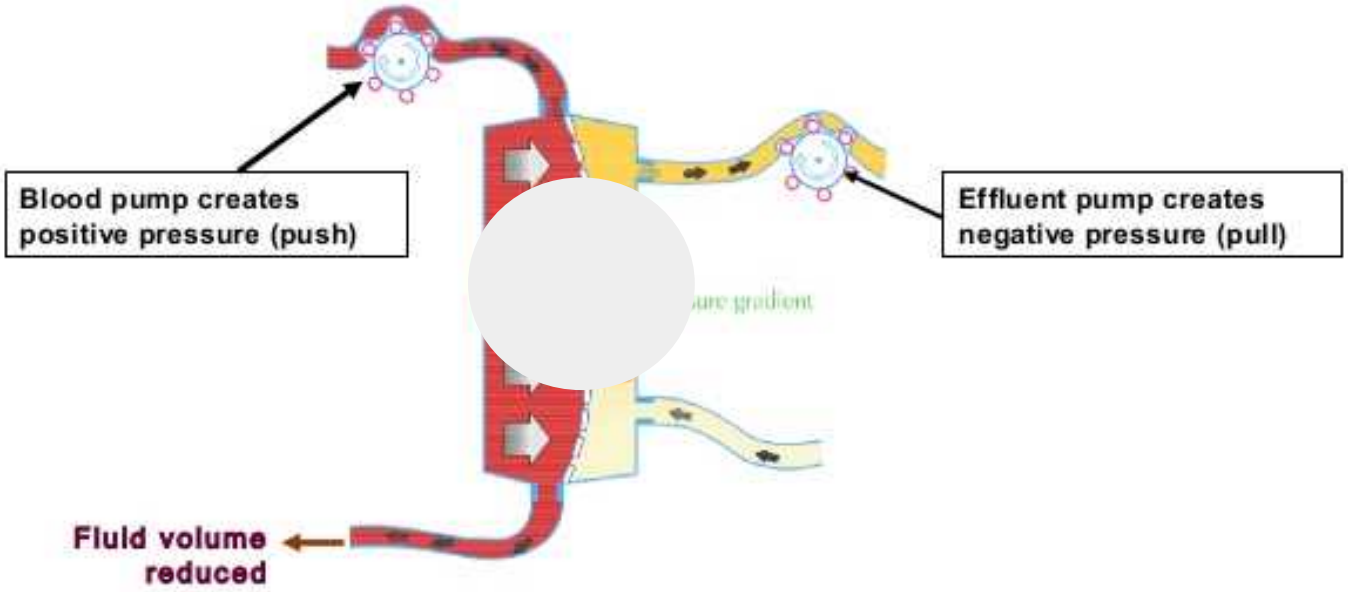
r size

racteristics

brane type- thickness, surface area

Ultrafiltration

The movement of fluid through a semi-permeable membrane driven by a pressure gradient.



The creation of a pressure gradient forces plasma water across the semi-permeable membrane.

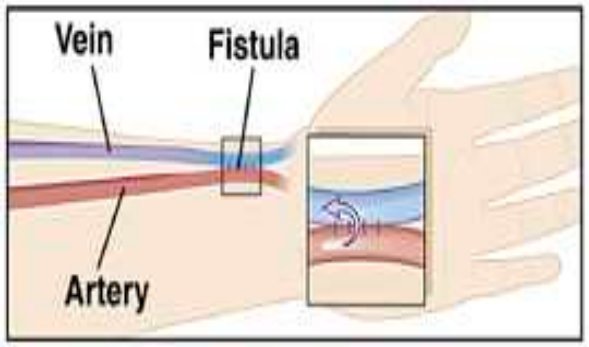
Dialysate

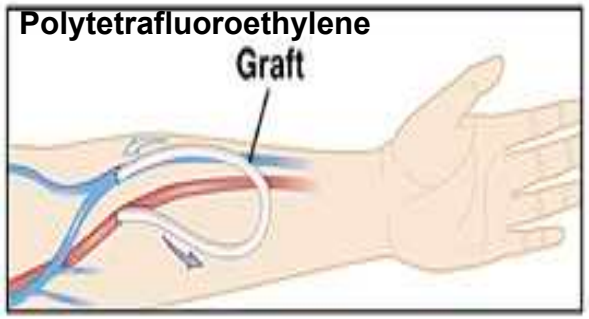
Concentration of Dialysate Components used in Hemodialysis

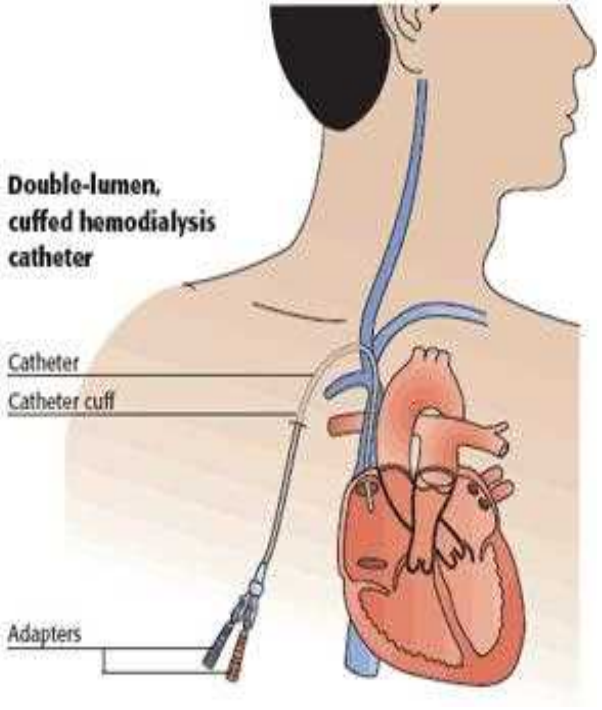
S.N.	Electrolytes	In Dialysate	In Plasma
1	Natrium	130 – 145 mmol/l	135 – 145 mmol/l
2	Potassium	1 – 4 mmol/l	3.5 – 5.5 mmol/l
3	Calcium	1.0 – 1.75 mmol/l	2.2 – 2.7 mmol/l (1.1 – 1.4 mmol/l : ionized)
4	Magnesium	0.25 – 0.75 mmol/l	0.7 – 1.1 mmol/l
5	Chloride	100 – 115 mmol/l	96 – 106 mmol/l
6	Glucose	0 – 2 g/l	1 g/l
7	Bicarbonate	30 – 36 mmol/l	24 mmol/l

Composition				
Formula	Concentrated Solution (g/l)		Diluted Solution (35 times) (g/L)	
Sodium chloride	216.812		6.194	
Potassium chloride	5.218		0.149	
Calcium chloride, $2H_2O$	6.431		0.183	
Magnesium chloride, $6H_2O$	3.557		0.101	
Acetic acid (glacial)	7.356		0.210	
Dextrose,H_2O	70.000		2.000	
Electrolytes	**mmol/l**	**mEq/l**	**mmol/l**	**mEq/l**
Na^+	3710	3710	106.00	106.00
K^+	70	70	2.00	2.00
Ca^{++}	43.75	87.50	1.25	2.50
Mg^{++}	17.50	35	0.50	1.00
CH_3COO^-	122.50	122.50	3.50	3.50
Cl^-	3902.50	3902.50	111.50	111.50

Hemodialysis Vascular Access



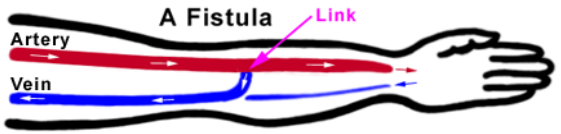




Arteriovenous (AV) Fistula

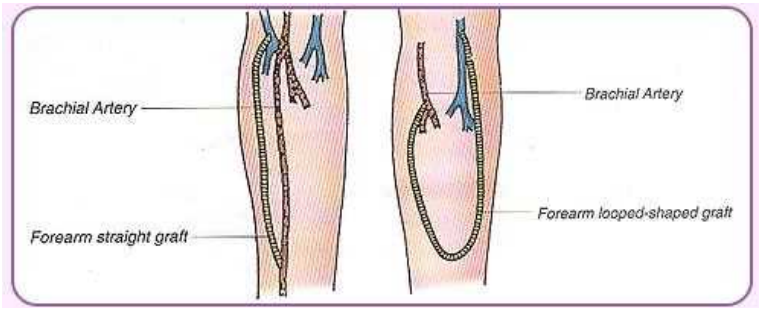
Dialysis Access

- AV Fistula
  - Vein cross-cut, attached end-to-side to artery
  - High-pressure flow dilates and thickens vein
  - Best alternative:
    - Lowest infectious risk
    - Longest lasting with least thromboses
  - Drawbacks
    - Takes 2-4 months to mature
    - Only about 50% ever mature
  - Goal for all dialysis patients



Dialysis Access

- AV Graft
  - Tube made of biocompatible material (gortex) attached end-to-side to artery and vein
  - Often required in patients with vascular disease, occluded distal veins
  - Advantages
    - Ready to use when swelling resolves (~2 weeks)
    - Able to use in most patients
  - Disadvantages
    - High stenosis/thrombosis
    - Moderate infectious risk



Dialysis Access

- Catheter (IJ most common)
  - Tunnelled under skin to reduce communication from skin flora with blood
  - Advantages
    - Ready for use immediately
  - Disadvantages
    - High infectious risk
    - High thrombosis risk
    - A/W increased mortality
      - Can be a sign of poor pre-dialysis care or extensive vascular disease

Vascular Access Guidelines

- **Arm veins suitable for placement of vascular access should be preserved, regardless of arm dominance.** Arm veins, particularly the cephalic veins of the non-dominant arm should not be used.
  - **Avoid PICC lines**
- **Dorsum of the hand** could be used for IV.
- A Medic Alert bracelet should be worn to inform hospital staff to avoid IV cannulation of essential veins.
- **Subclavian vein catheterization should be avoided** for temporary access in all patients with CKD (stenosis preclude use of ipsilateral arm for vascular access)

Goal of HD

Whenever dialysis is indicated,

the patient should receive ADEQUATE DIALYSIS *for*

GOAL

- **Survival**
- **Minimizing morbidity**
- **Quality of life**

Goals of Dialysis

- Solute clearance
  - Diffusive transport (based on countercurrent flow of blood and dialysate)
  - Convective transport (solvent drag with ultrafiltration)
- Fluid removal

Dialysis dose

- Urea Reduction Ratio(URR) at least 65%, preferably 70%
- KT/V = 1.2 – 1.4

KT/V TARGETS

- **1.2 is the minimum acceptable**
- **1.4 is the desirable target**

Based on Sp KT/V and 3x/wk schedule

KT/V: HD Clearance Concept

KT/V (urea) is the fractional urea clearance per session

- **KT= volume of blood cleared during session**
- **V= total volume of distribution of urea (=TBW)**
- **UREA: easily diffusible, easily measurable, evenly distributed over TBW**

Urea Reduction Ratio

URR

$$URR = \frac{C_o - C_t}{C_o} \times 100\%$$

Pre dialsis Urea=100

Post dialysis Urea= 30

URR= 70%

How KT/V is calculated

- **From URR**

KT/v= -In(1-URR)

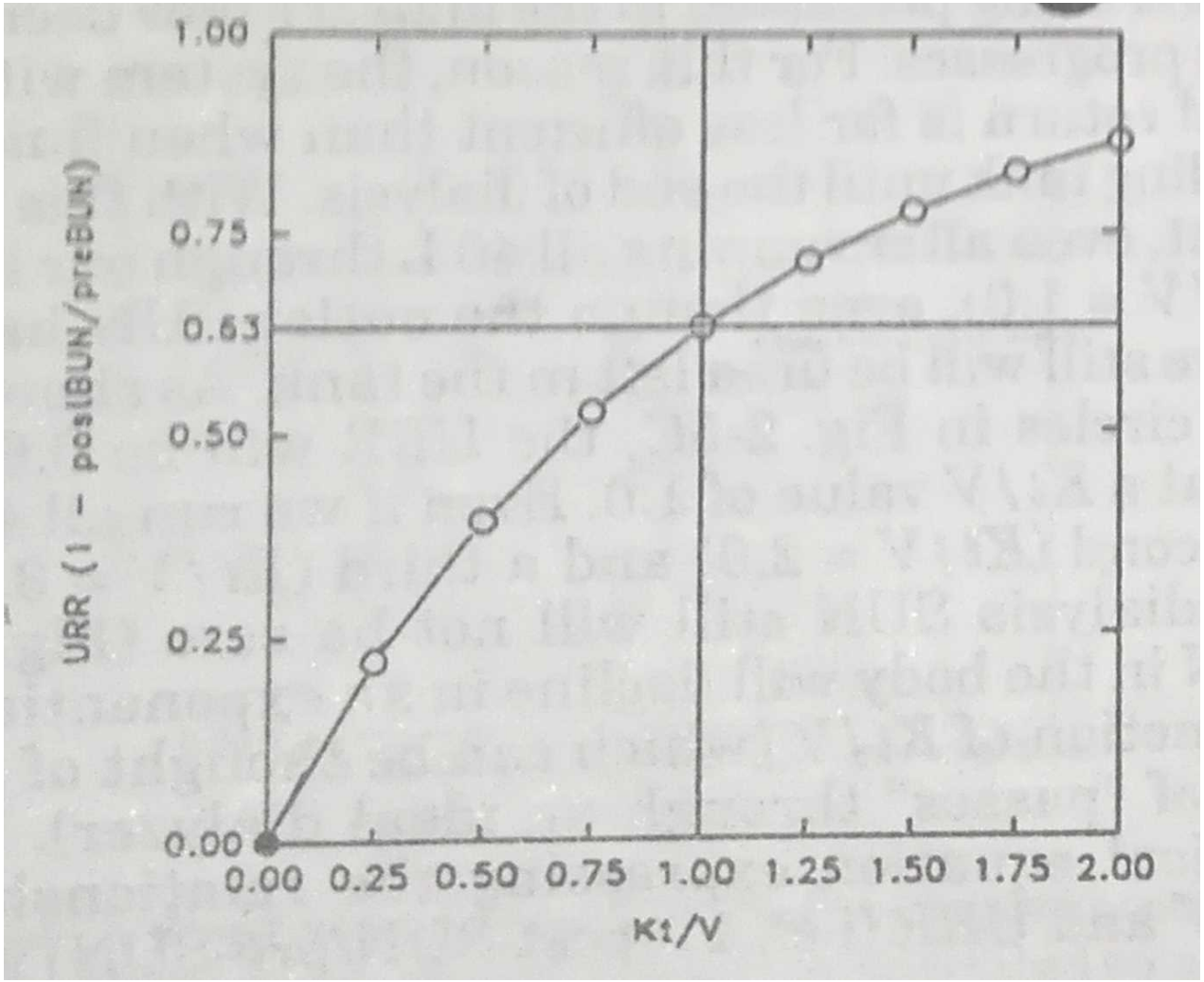
- **Corrected for uF & Urea generation**

Daugirdas (1995) natural logarithm formula

KT/v= -In(R-0.008xt)+(4-3.5xR)x0.55UF/V

Where R=1-URR or post/pre urea

- **The machine can do it !!!!**


1.00
0.75
0.63
0.50
0.25
0.00
URR (1 - postBUN/preBUN)
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Kt/V

The ‘very’ basic concept

- **Plasma solute concentration decreases fairly rapidly during dialysis**
- **Because dialysed blood is returned to patient !!!**

So KT/V of 1.00 removes only 63% of solute

The ‘very’ basic concept

- **Blood passing through the dialyser is cleared**
- **So blood flow x time is the amount cleared**
- **KT/V =1 is when that volume equals patient TBW**

65 Kg; V=36000 mL

Cl 150 mL/min x 240 min = 36000 mL; KT/V=1

Delivered KT/V

Pre dialysis BUN=150

Post dialysis BUN=50

Post dialysis wt 58 kg

UF=2 kg

Dialysis time = 4 hrs

Calculate KT/V

Pre-dialysis BUN	150	mg/dl
Post-dialysis BUN	50	mg/dl
Duration of dialysis	4	hrs
Volume of removed ultrafiltrate	2.0	liters
Post-dialysis weight	58	kg
Kt/V	1.30	
URR	66.67	%

Kt/V Calculator Daugirdas

Created by Łucja Zaborowska, MD, PhD candidate

Reviewed by Steven Wooding

Based on research by Daugirdas J. T. *"Simplified equations for monitoring Kt/V, PCRn, eKt/V, and ePCRn"* Advances in renal replacement therapy (October 1995)

See 2 more sources

Last updated: Nov 16, 2022

Acute Complications of Dialysis:

- Hypotension (25-55%)
- Cramps (5-20%)
- Nausea and vomiting (5-15%)
- Headache (5%)
- Chest pain (2-5%)
- Back pain (2-5%)
- Itching (5%)
- Fever and chills (<1%)
- Disequilibrium syndrome
- Dialyser reaction
- Hemolysis
- Air embolism
- Arrythmia
- hypoxemia

Intradialytic hypotension

- Definition: A decrease in systolic BP ≥20 mm Hg or a decrease in MAP ≥ 10 mm Hg associated with symptoms(abdominal discomfort,yawing,nausea,vomiting,muscle cramp,restlessness,dizziness,fainting, anxiety).

- Complication:ischemic(cardiac or neurologic event), cardiac arrhythmias, vascular access thrombosis, mesenteric venous infarction.
- precludes the delivery of an adequate dialysis dose
- Long term effects:volume overload due to suboptimal UF and use of fluid boluses, LVH with increase in mortality and intradialytic HTN.

K-DOQI guildline

Intradialytic Hypotension

1. Acute (episodic) hypotension Sudden SBP drop<90 mmHg OR at least 20 mmHg drop with symptoms

2. Recurrent acute hypotension Occurs in at least 50% of HD sessions

3. Chronic persistent hypotension Interdialytic BP is <100 mmHg

Kidney Int 2001; 59: 1175–1181

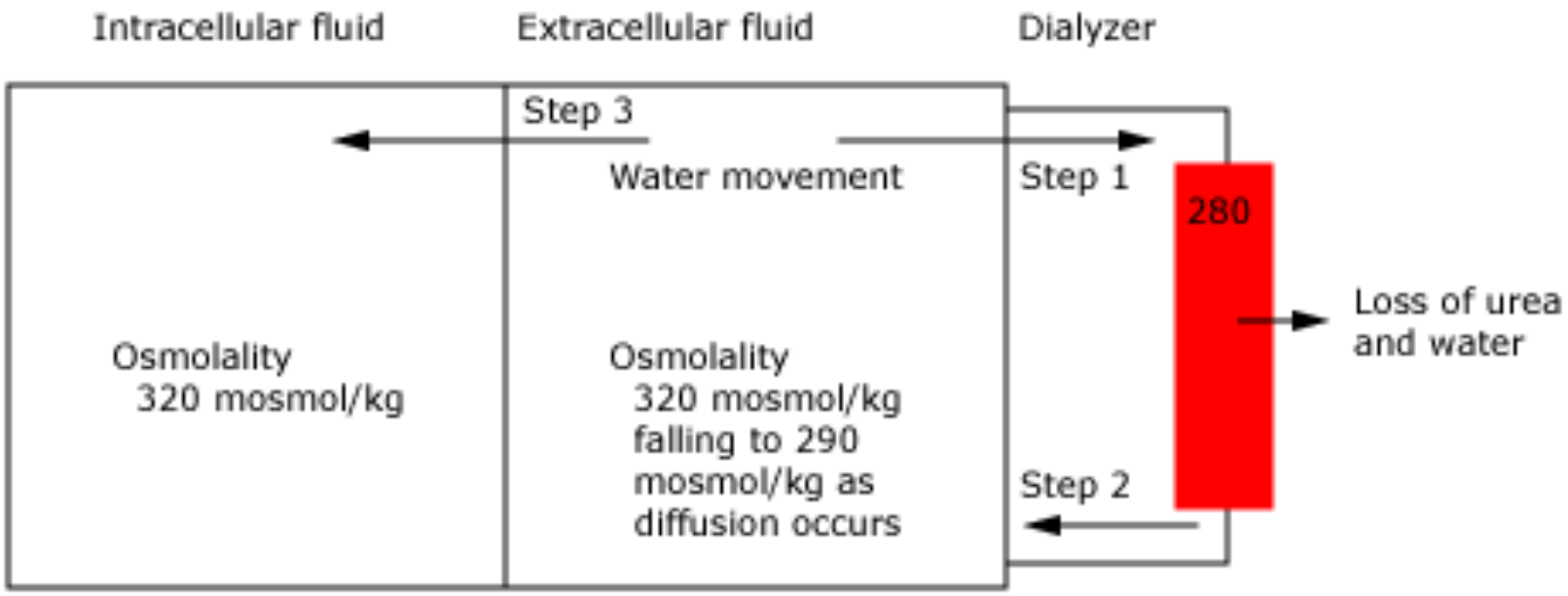
Risk Factors of Dialysis Hypotension

- 15-50% of dialysis patients
- Diabetic pts
- Low body mass index
- Poor nutritional status and hypoalbuminemia
- Severe anemia
- Advanced age (Age > 65 years old)
- Cardiovascular disease
- Large interdialysis weight gain
- Low blood pressure (predialysis systolic BP <100 mm

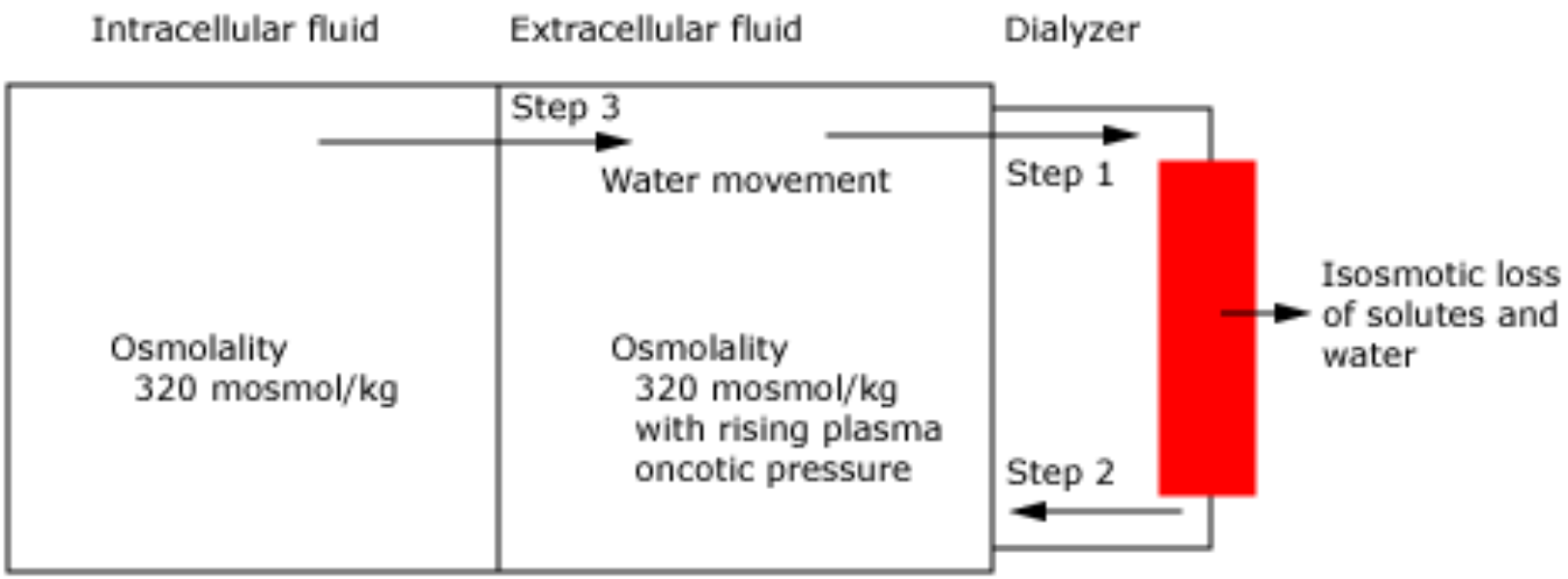
Hypotension

- ***Rapid reduction in plasma osmolality***
- ***Rapid fluid removal***
- ***Inaccurate determination of true "dry weight"***
- ***Autonomic neuropathy***
- ***Diminished cardiac reserve***
- ***antihypertensive medications***
- ***lower sodium concentration in the dialysate***
- ***adenosine release during organ ischemia***
- ***Ingestion of a meal***
- ***Arrhythmias, MI***
- ***pericardial effusion with tamponade***
- ***Reactions to the dialyzer membrane***
- ***Increased synthesis of endogenous vasodilators (nitric oxide)***
- ***High magnesium concentrations in the dialysate***
- ***Failure to increase plasma vasopressin levels***
- ***Use of acetate rather than bicarbonate as a dialysate buffer***
- ***High dialysate temperature***
- ***Occult bleeding***
- ***Septicemia***

Water shift in hemodialysis



Water shift in isolated UF



Plasma Refilling Rate

- Direct relationship with size of interstitial compartment
- Still very variable between patients of similar interstitial compartment size
- Higher risk of hypotension if low proteins or high ureas (oncotic & osmotic forces)
- Hypotensive episodes are common when extra/intravascular fluid shift occurs at a rate of <4 ml/mm Hg/min

Treatment

- UF shoud stopped or the rate decreased
- Pt shoud be placed in trendelenburg position
- The blood flow shoud be reduced(not with bicarbonate buffer)
- Intravenous infusion of saline, albumin or mannitol

Prevention

- *Accurate setting of the "dry weight"*
- *Steady, constant ultrafiltration*
- *sodium modeling*
- *UF modeling*
- *Sequential ultrafiltration and isovolemic dialysis*
- *Bicarbonate dialysate buffer*
- *Temperature control (cool dialysate)*
- *Improvement in cardiovascular performance*
- *Midodrine*
- *Carnitine*
- *Avoidance of food*
- *Adenosine release(caffein)*
- *Vasopressin infusion*
- *Serteraline*

Target weight

"The lowest [post-dialysis] weight a patient can tolerate without intradialytic symptoms and/or hypotension and in the absence of overt fluid overload" *Henderson KI 17: 571-576; 1980*

" The post-dialysis weight at which the patient is and remains normotensive until the next dialysis in spite of interdialytic fluid retention and without antihypertensive medication"
Charra 1996

Objective Determination of EDW

- Blood vol. monitoring
- US assesment of IVC diameter
- BNP, ANP, N-terminal of pro-BNP level
- Bioimpedance method
- Extravascular lung water index

Prevention

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The Best type of Kidney Replacement Therapy is Tra