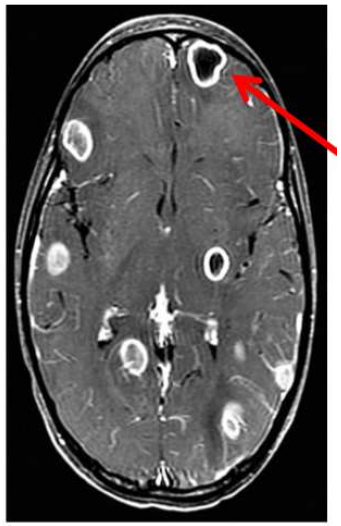
Solute Transfer During Hemodialysis

SKC In-service Dec 2015

Housekeeping

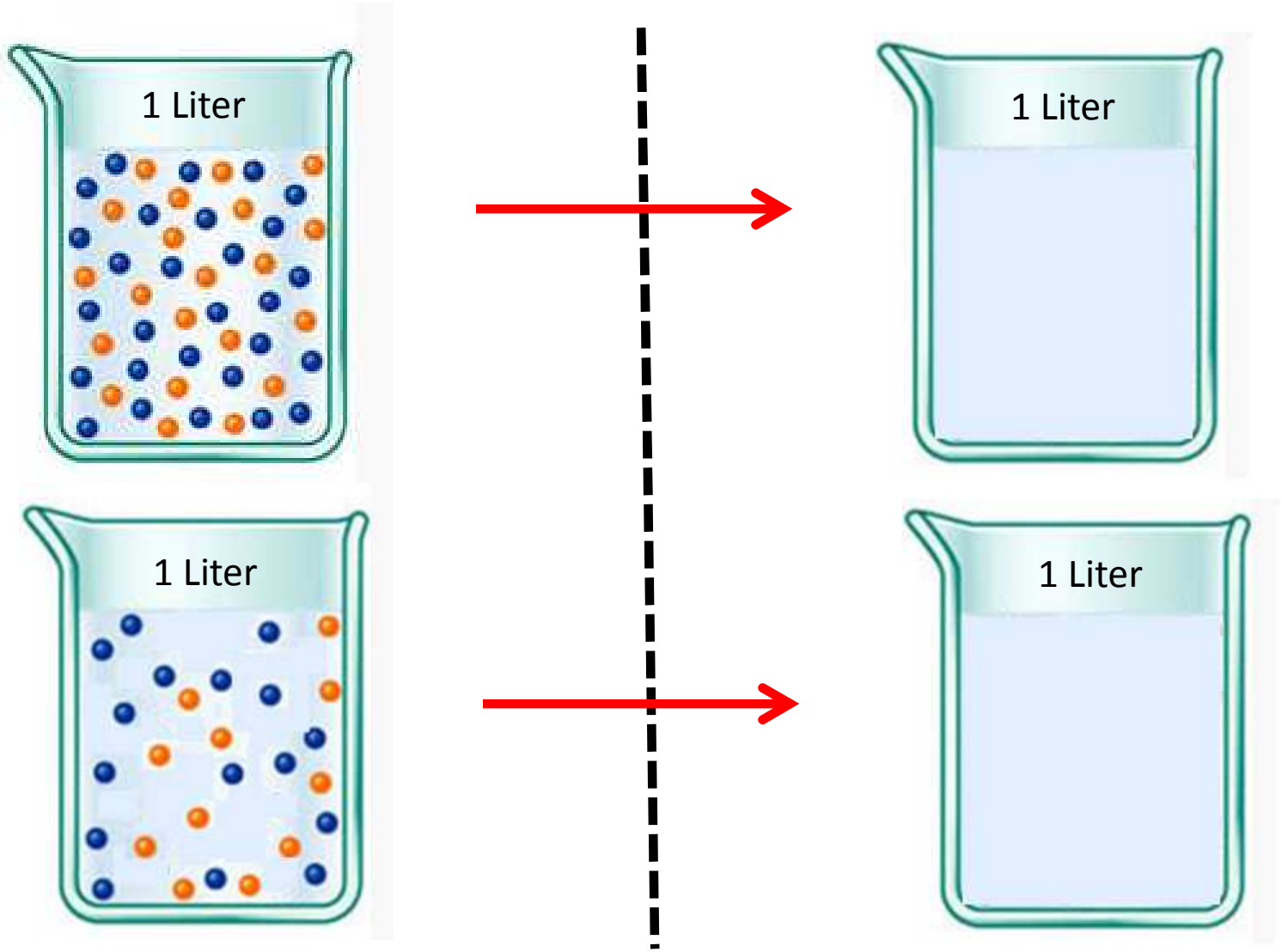


- Don’t forget about sterile technique
  - Wait for prep to dry
  - Do not touch cannulation area after prep
  - Do not use touch contaminated needles, tubing, filters, etc.
- All patients need to wash access with soap and water before sitting down in chair
- Hand hygiene / gloves at all times when interacting with patient or machine
- Lidocaine should be discouraged, Emla cream is alternative
- Buttonholes are not allowed except under special circumstances (short segment / difficult fistula)

Clearance Concept

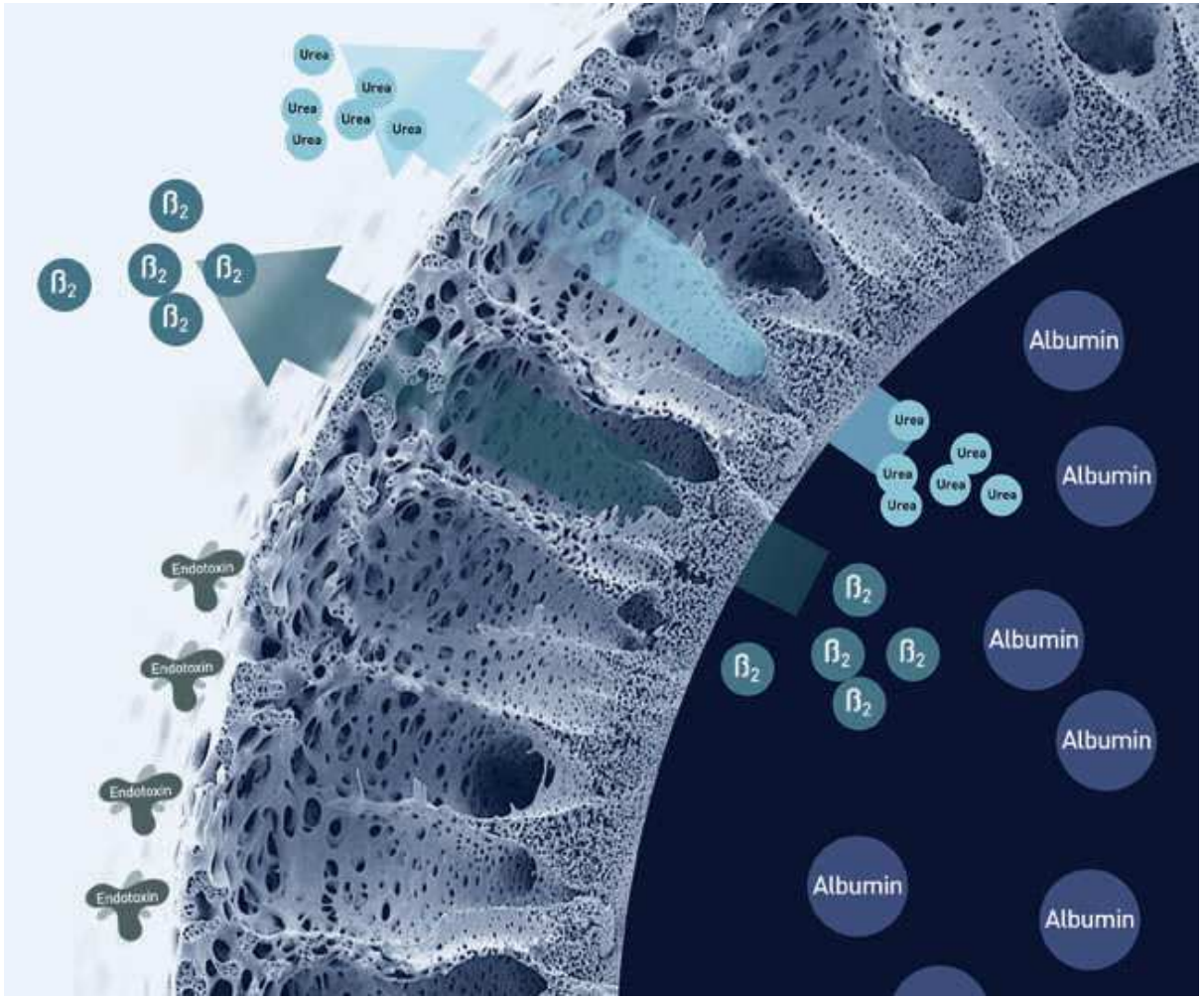
- Clearance is the volume from which a substance has been completely removed
- Clearance is usually described per unit time (e.g. ml/min)
- Clearance does not describe the mass or amount of a substance removed
- Kt/V is a way to reference clearance to the volume of distribution of urea (total body water) and thus is a dimensionless variable.
- For the purposes of simplification, Kt/V urea can be thought of as equivalent to the number of times the total body water has been cleared of urea

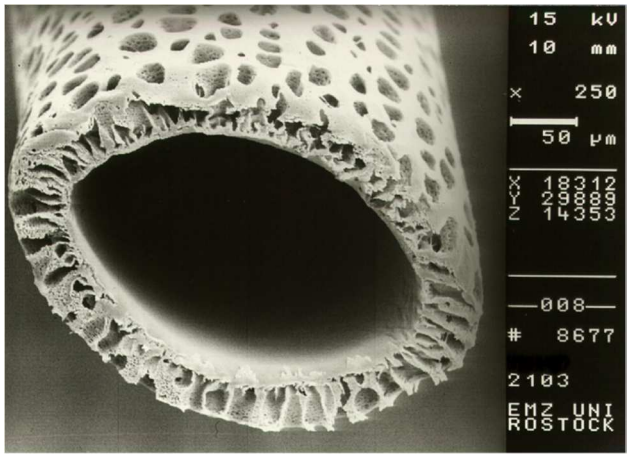
Clearance Concept

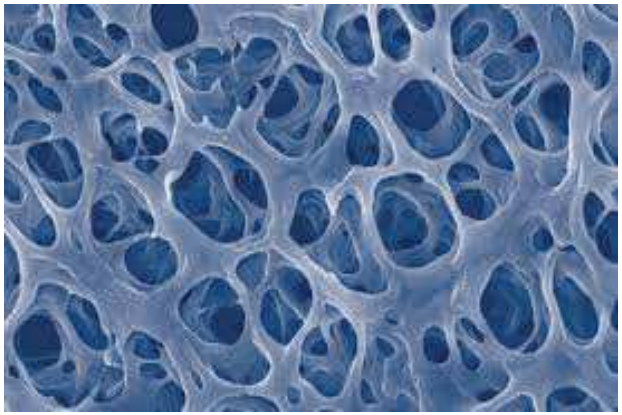


Clearance of both beakers is equal. Amount of solute removed from solution is different.

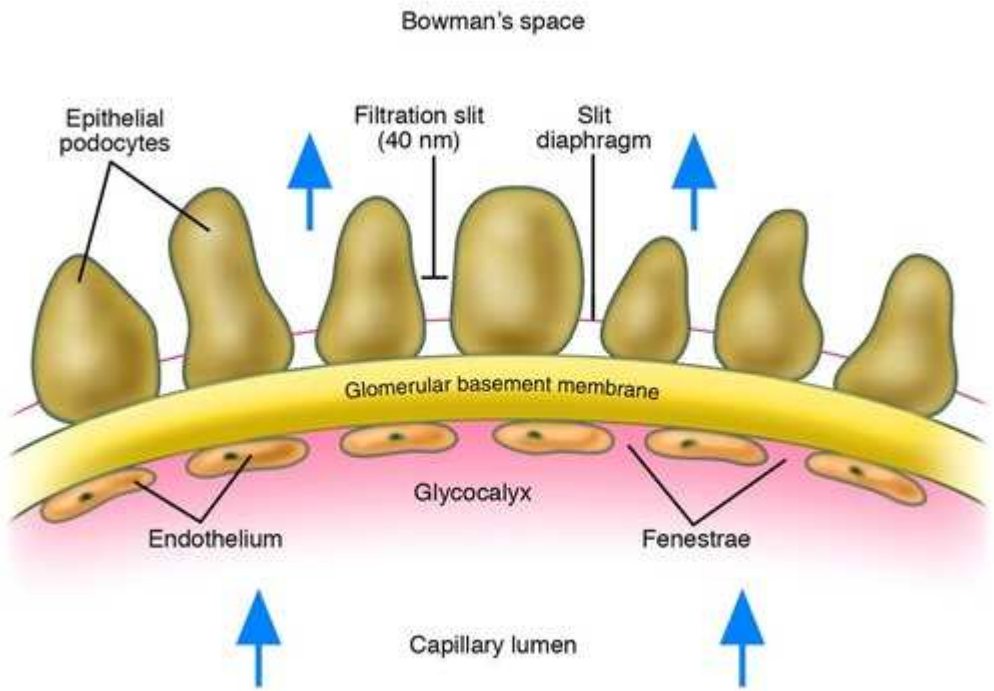
Hollow fiber capillary: site of clearance

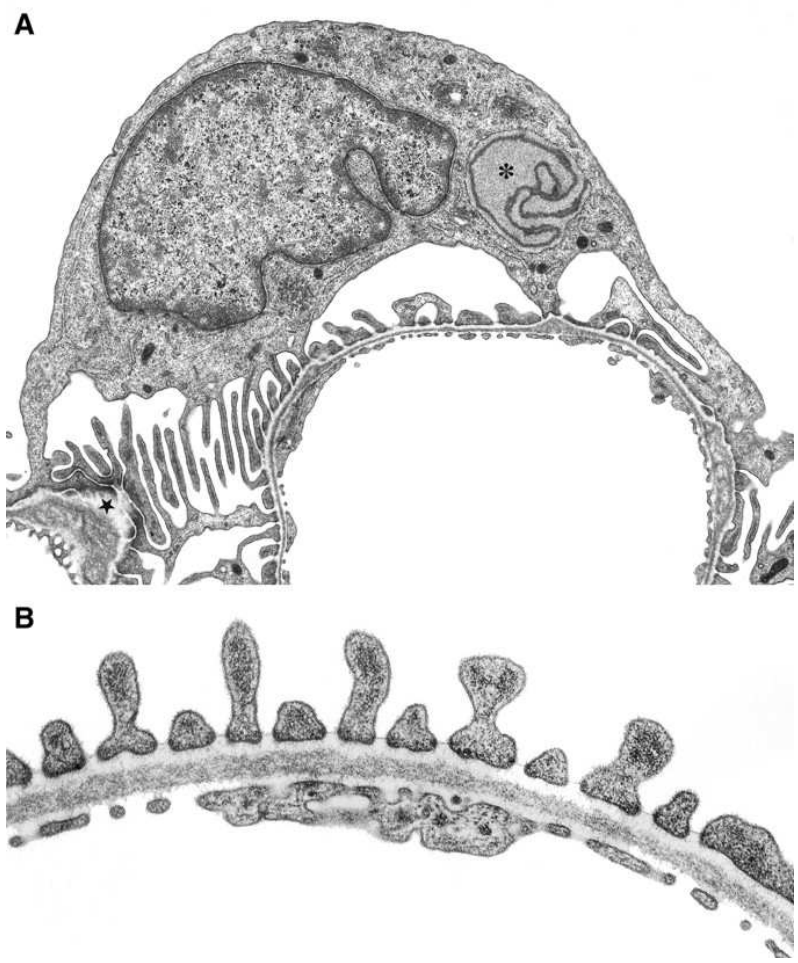






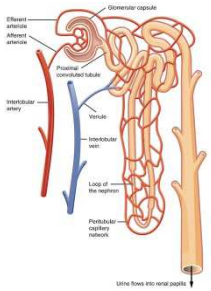
Similar to glomerular capillary?





Recall in the nephron clearance is dependent upon filtration tubular secretion and reabsorption.

Forces of clearance



Nephron

- GFR = Kf[(Pc-Pbs) + (πbs – πc)
- Kf coefficient described by surface area provided by capillary network, properties of endothelial fenestrae, podocytes
- Convective clearance
- Tubular secretion / reabsorption contribute and make the clearance relatively selective

Hollow fiber capillary

- UFR = Kuf (TMP)
- Kuf describes the surface area of the membrane, the pore characteristics (higher flux = higher kuf)
- Diffusion is predominant source of clearance in traditional hemodialysis
- Process is only selective by size, no refinement of the filtrate

Clearance Measured

Kidney Clearance

- UV/P
- Divide by 1440 and described as 24 hour clearance
- Relatively easy to collect urine for 24hrs
- Rate of clearance is proportional to blood concentration
- Rate of clearance is relatively constant with passage of time

Dialysance

- Dialysance = DV/P
- Where D ialysate co ntration, V dialy ume, P con zer
- Impra would require 0-190 L of dialysate on of solute is often rge volume that r ult
- Nat cle ld not be acc d for
- Steady state assumptions are violated (P is changing during dialysis)

Therefore, dialysis clearance cannot be described as a continuous clearance akin to kidney clearance. The intermittent nature of dialysis treatment obligates a per treatment clearance

Deriving the clearance equation

For Intermittent dialysis you cannot get past this point because concentration and volume are changing over time. Thus the need for an alternate way to describe clearance for intermittent dialysis

stribution

Re-written as a derivative:

$$V(dC)/dt + C(dV)/dt = G - K * C$$

Note that in steady state the entire left side of the equation is equal to zero because the concentration and volume are not changing over time.
Rearranging with the steady state assumption:

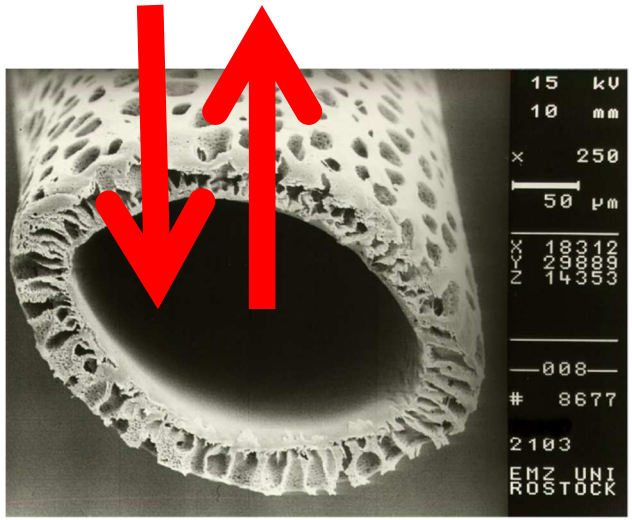
$$K = G / C$$

For creatinine clearance what you generate is what you put out, steady state is satisfied, thus

$$\text{Volume cleared} = UV / P$$

Ways that uremic solutes leave the blood during dialysis

- Diffusion
- Convection
- Absorption to membrane



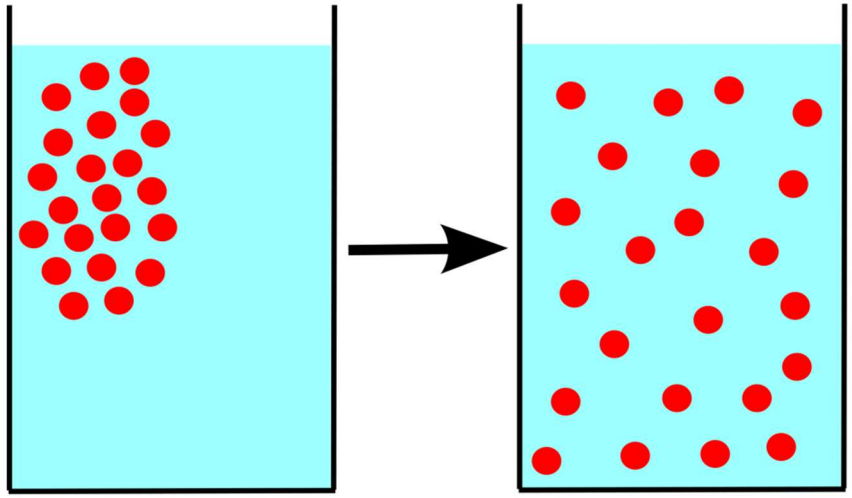
Note these forces are not always unidirectional from blood to dialysate!

Hollow Fiber Capillary

- Solute movement
  - Diffusion = Dialysis
  - Convection = Filtration = Hemofiltration = UF
  - Diffusion is driven by diffusive pressure between blood and dialysate
  - Convection is driven by transmembrane pressure (TMP)

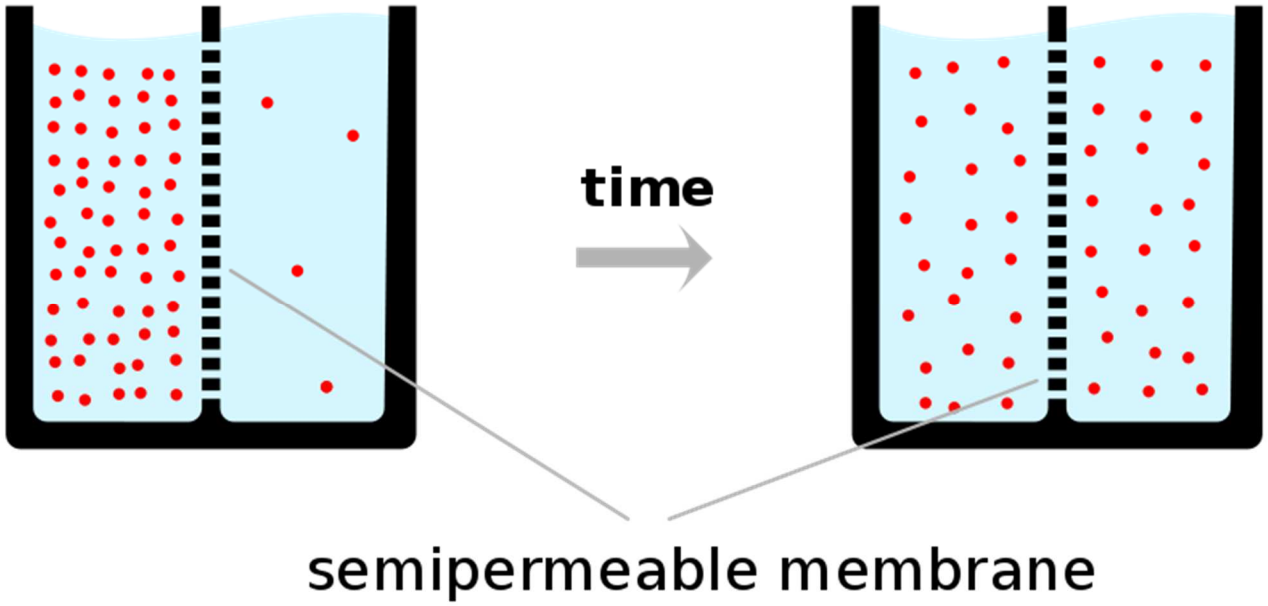
- Solvent movement
  - Fluid moves across the membrane through convection
  - Forces of oncotic pressure, osmotic pressure are negligible relative to the TMP

Diffusion



The movement of solute from an area of high concentration to low concentration. Over time solute concentration will equilibrate

Clearance with diffusion is difficult to describe or predict with an equation because concentration is constantly changing

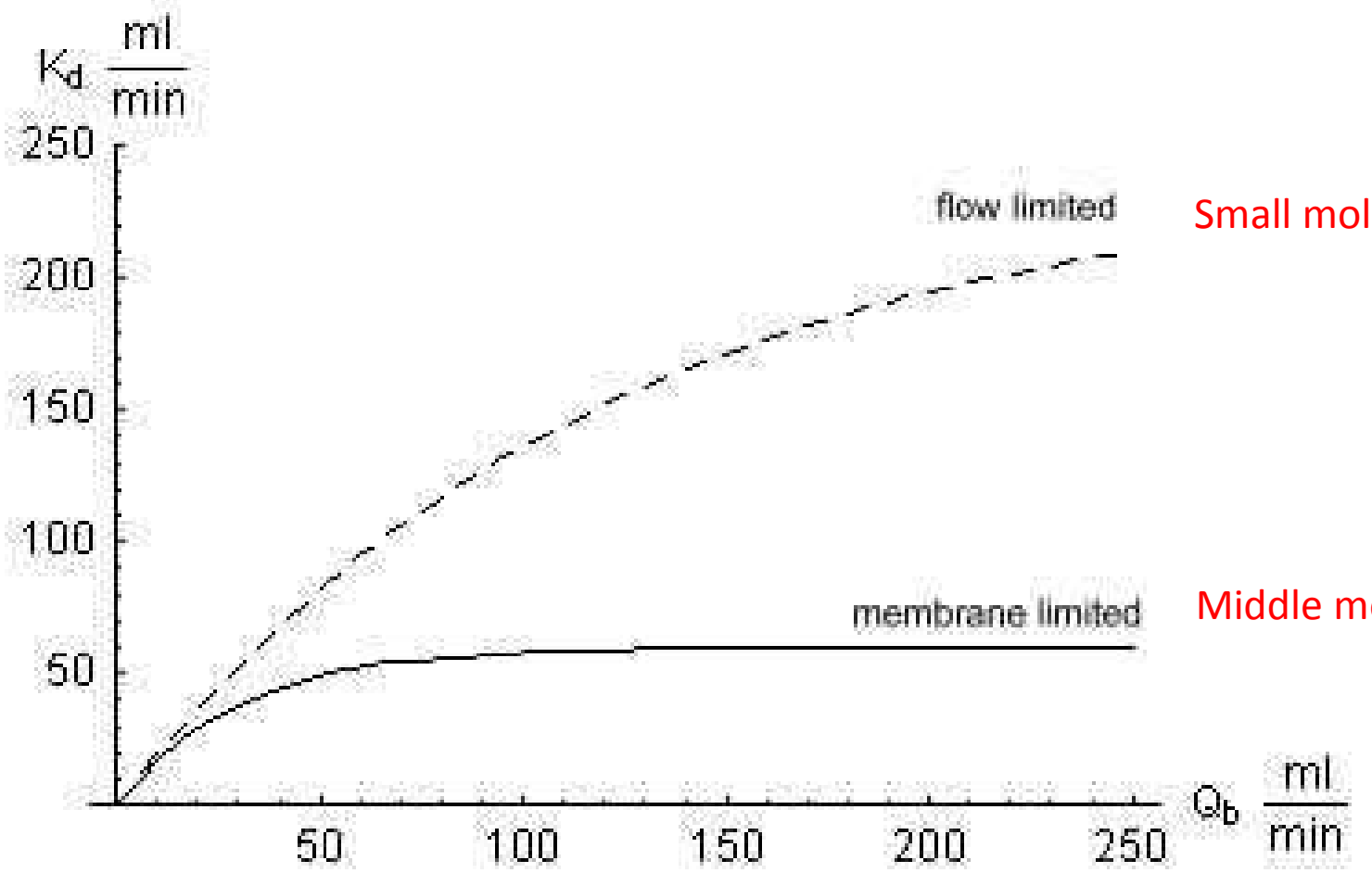


Diffusion During Dialysis

- To increase diffusive clearance:
  - Increase the solute gradient across the membrane
    - Increase blood concentration of solute by delivering more blood to the filter (increasing Qb)
    - Decrease dialysate concentration of solute by delivering more fresh dialysate to the filter (increasing Qd)
  - Increase the surface area of the membrane, i.e. increase the efficiency of the membrane

Note: Solute bigger than the filter pore size or solute bound to albumin will not diffuse well

Relationship of clearance to blood flow

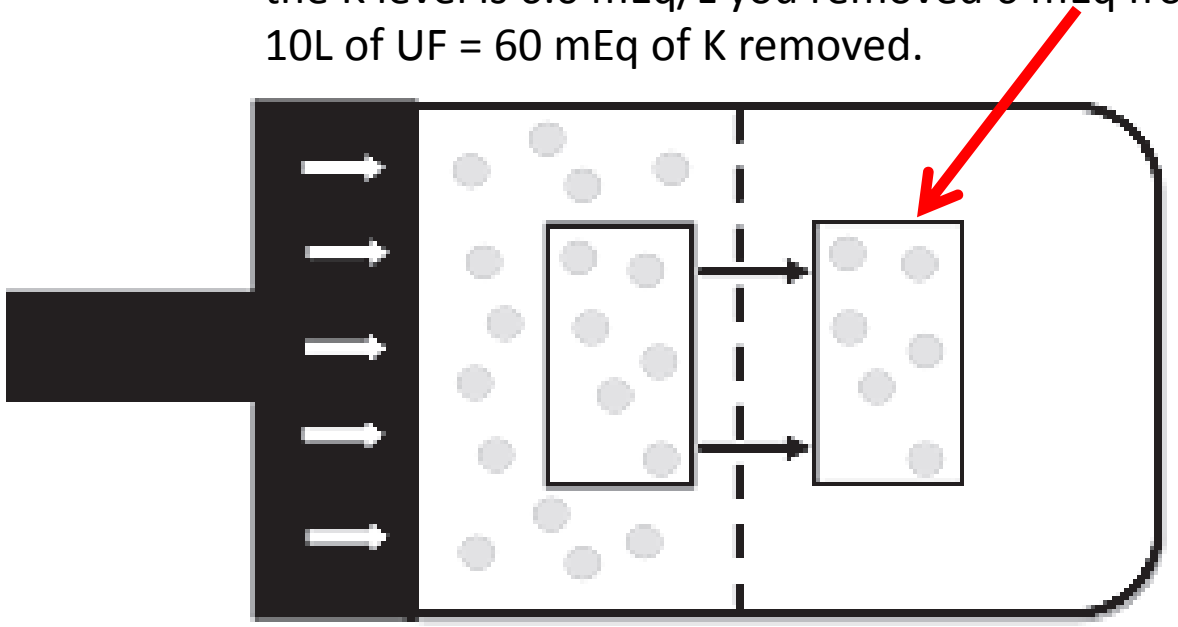


Small molecules

Middle molecules

Convection

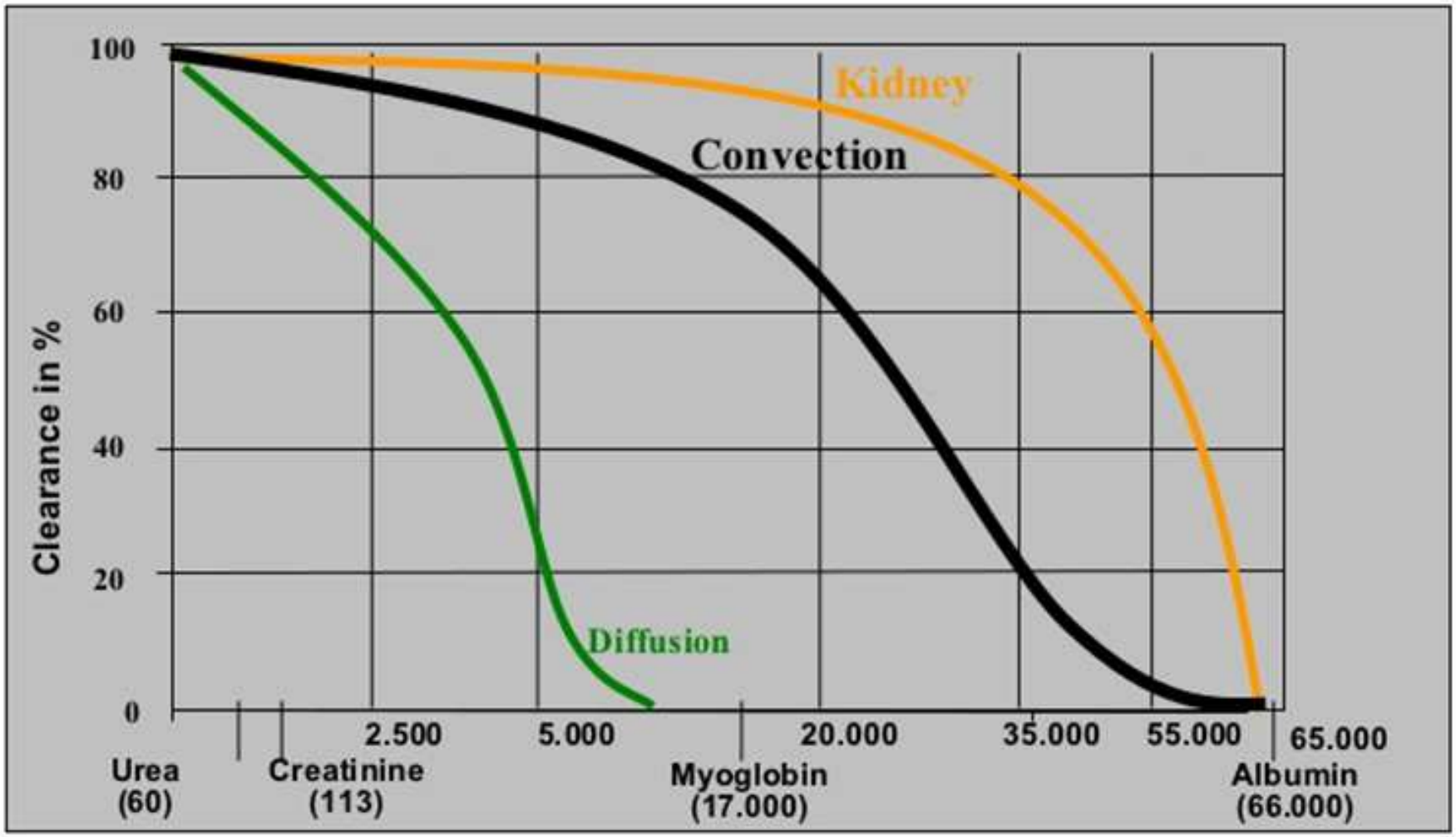
Clearance depends upon the volume of this box, more volume filtered = greater clearance. For example if you did 1 L of UF and the K level is 6.0 mEq/L you removed 6 mEq from the plasma. 10L of UF = 60 mEq of K removed.



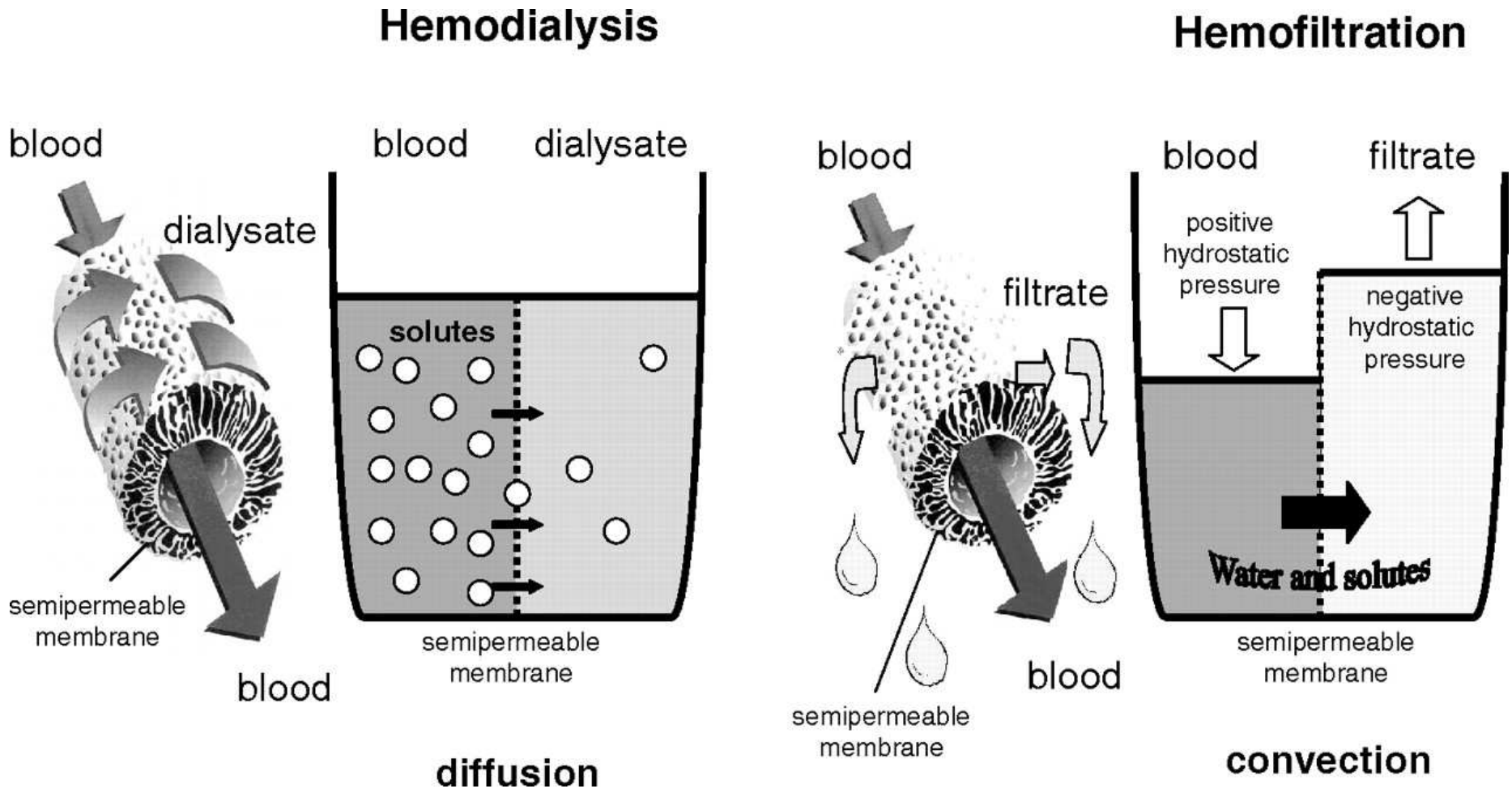
Pressure applied to a membrane will force a given volume of fluid through the membrane. If the solute is small enough to pass through the pores on the membrane it will be dragged along with the solvent and cleared from the blood.

Hemofiltration = Ultrafiltration = Convection

Convection


100
80
60
40
20
0
Clearance in %
Kidney
Convection
Diffusion
2.500
5.000
20.000
35.000
55.000
65.000
Urea
(60)
Creatinine
(113)
Myoglobin
(17.000)
Albumin
(66.000)

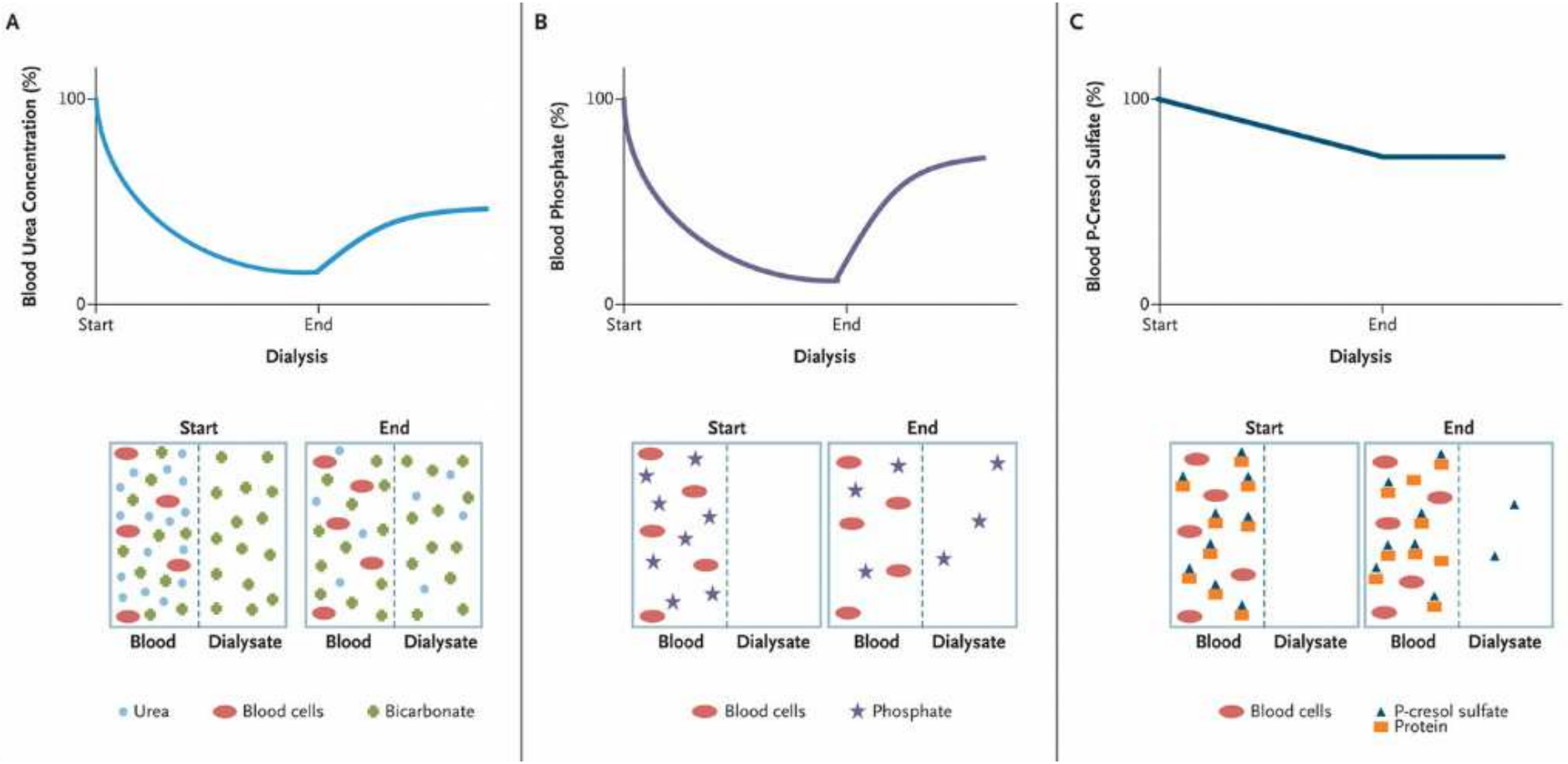
Summary: Diffusion vs Convection



Membrane Absorption

- Certain uremic retention solutes can get stuck in or bound to the dialysis membrane
- Thought to be more relevant with larger middle molecules
- Likely to account for a minimal amount of removal with contemporary dialyzers currently in use
- More absorption occurs with larger membrane surface area, higher flux
- Less absorption occurs later in the run or with reuse dialyzers on subsequent uses

Patterns of solute removal



Himmelfarb N Engl J Med. 2010 Nov 4;363(19):1833-45.

Take Home Points

- Clearance is the volume from which a substance has been completely removed, usually described per unit time
- Molecules are removed from the plasma during dialysis via diffusion, convection and absorption
- Molecules of different size, shape, charge, protein binding and volume of distribution will be removed at different rates during dialysis
- Current dialysis technology is inadequate, dose not mimic native kidney function and cannot correct the clearance lost from native kidney function

Keep up the good work and thank you for working so hard on behalf of our patients!