ADEQUACY OF HAEMODIALYSIS

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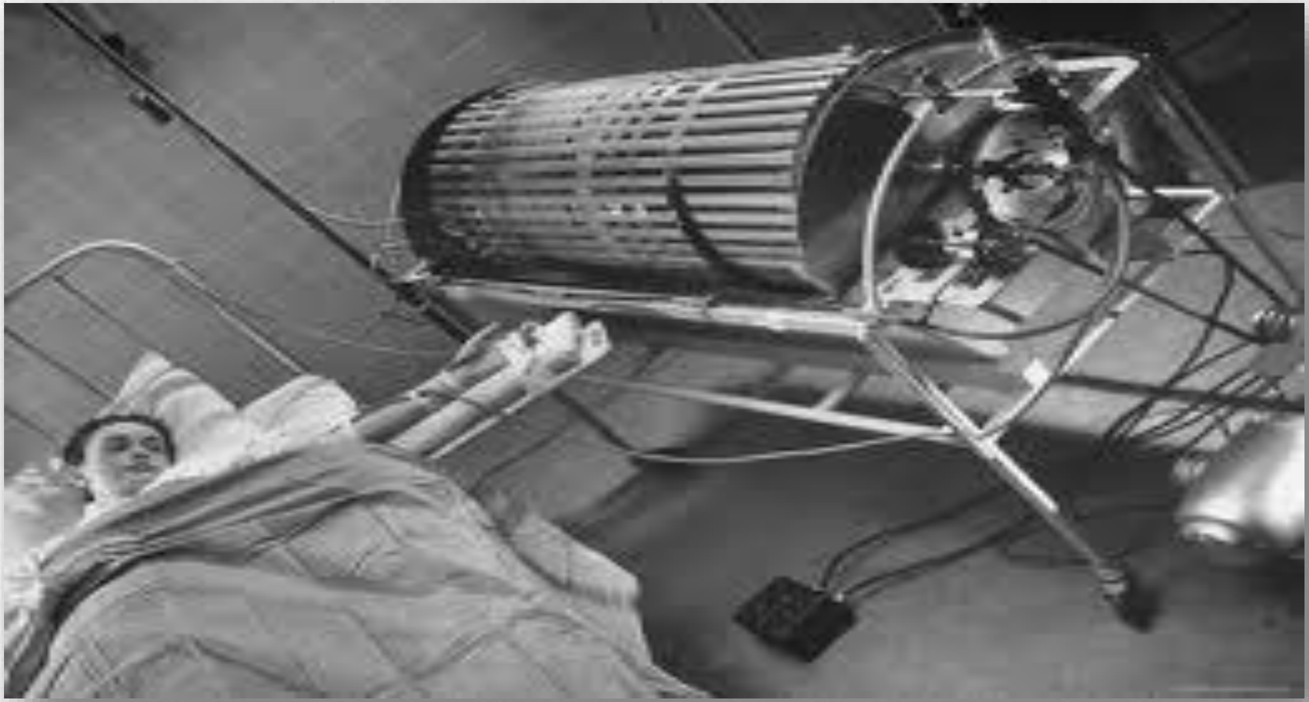
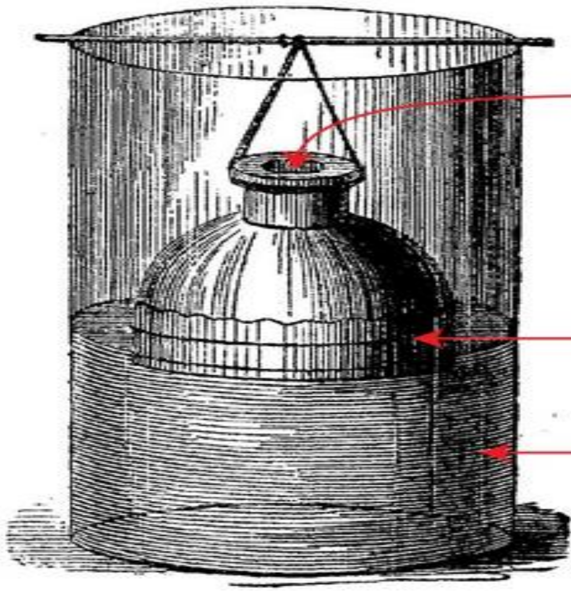
It was surprising to early investigators that a complex organ like the kidney could be replaced by simple diffusive removal of solute from the blood.



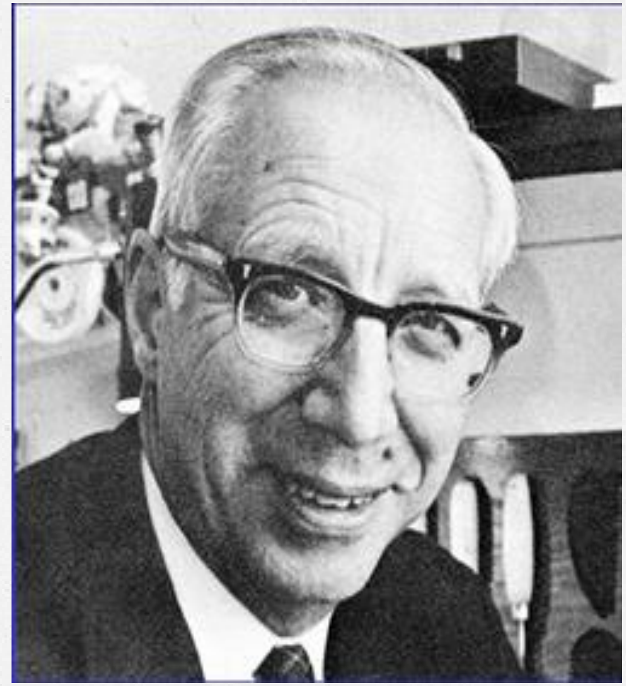
In 1854, Thomas Graham first presented the principles of solute transport across a semi-permeable membrane.



The wide open end of the bell was covered by a membrane created from an ox-bladder. He filled the bell-shaped vessel with urine and suspended it inside a larger container, filled with distilled water.

In 1913, the first artificial kidney was constructed

Kolff Rotating Drum, *ca.* 1943



In 1943, William Kolff constructed the first working dialyzer

At that time

Hemodialysis allowed life to continue and patients to prosper even after total loss of the kidneys

Nowadays


12 hours per week
on dialysis
7%
93%
156 hours per week
not on dialysis
Total hours in a week: 168

Total kidney replacement requires more than just dialysis, but a minimum amount of dialysis is still required to optimize both the duration and the quality of life

NCDS (National Cooperative Dialysis Study in 1981 suggested that a minimal dose of dialysis is required.

So the era of adequacy started.

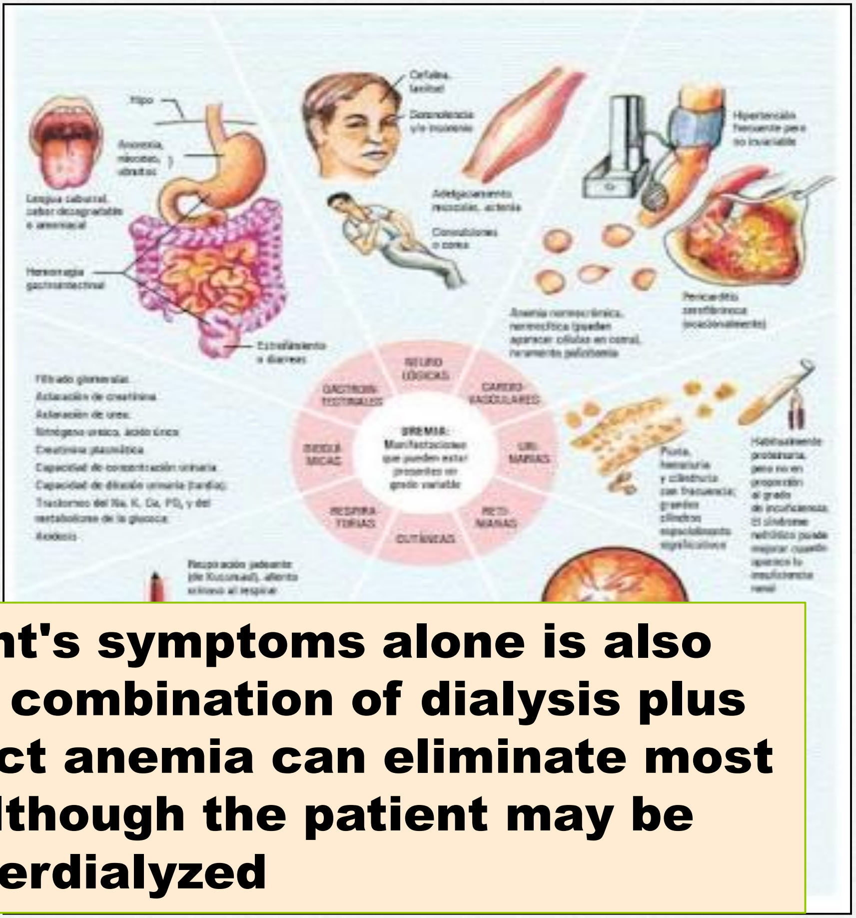
Kt/V came to life depending on urea clearance in 1985

Adequacy is a measure of how well the dialysis is working

How to evaluate adequacy of dialysis?

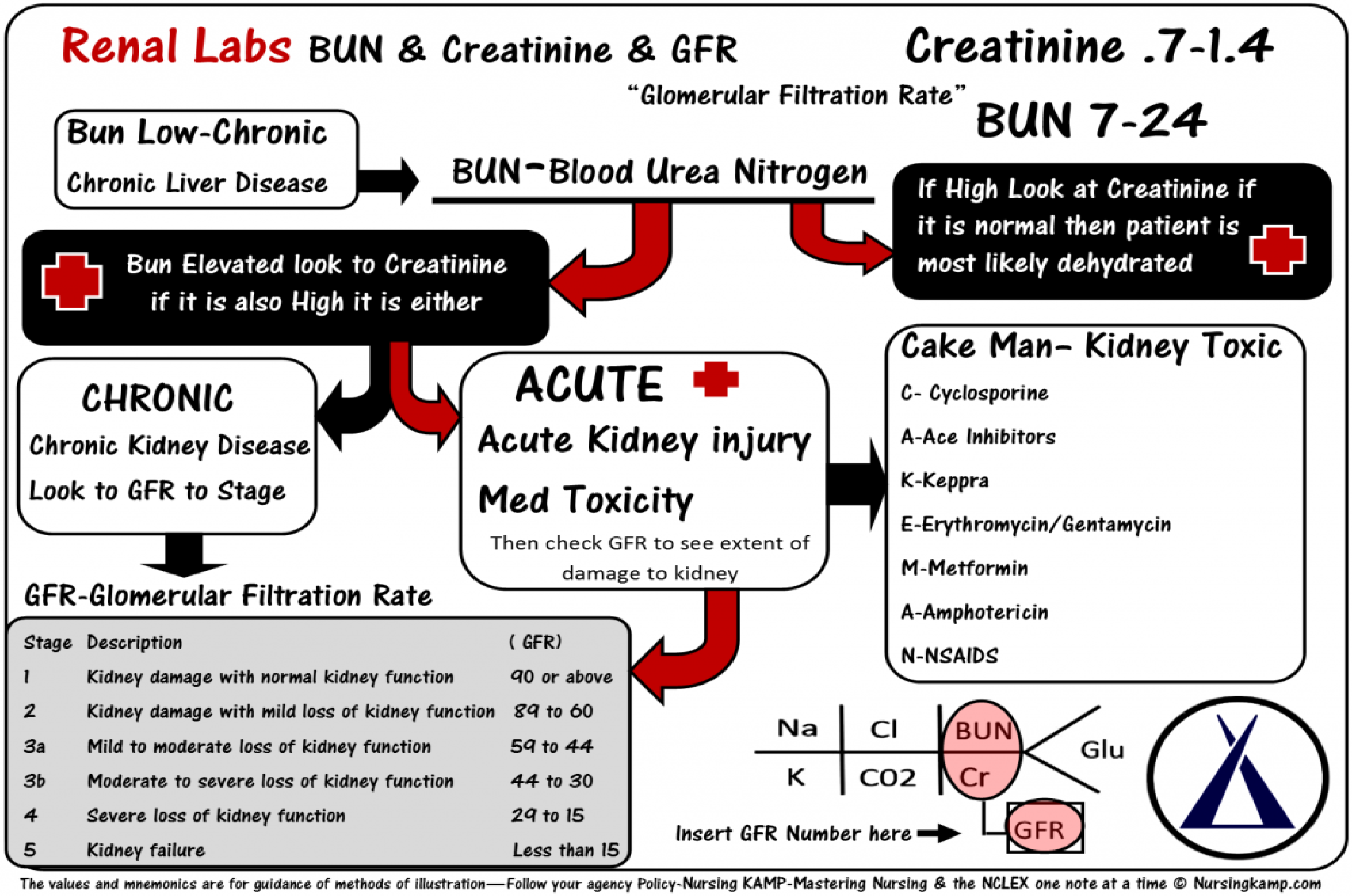
Improved signs and symptoms of uremia

- Tiredness, weakness
- Nausea or poor appetite
- Losing body weight
- Malnutrition
- Anemia



Monitoring the patient's symptoms alone is also insufficient, since the combination of dialysis plus erythropoietin to correct anemia can eliminate most uremic symptoms although the patient may be underdialyzed

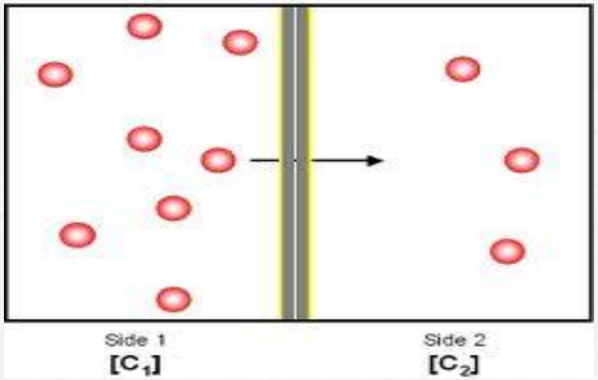
Laboratory evaluation



To see whether dialysis is removing enough urea,

- Two methods are generally used to assess dialysis adequacy:
- Either URR OR Kt/v
- Both depends upon urea clearance
- —normally once a month—

Why UREA?

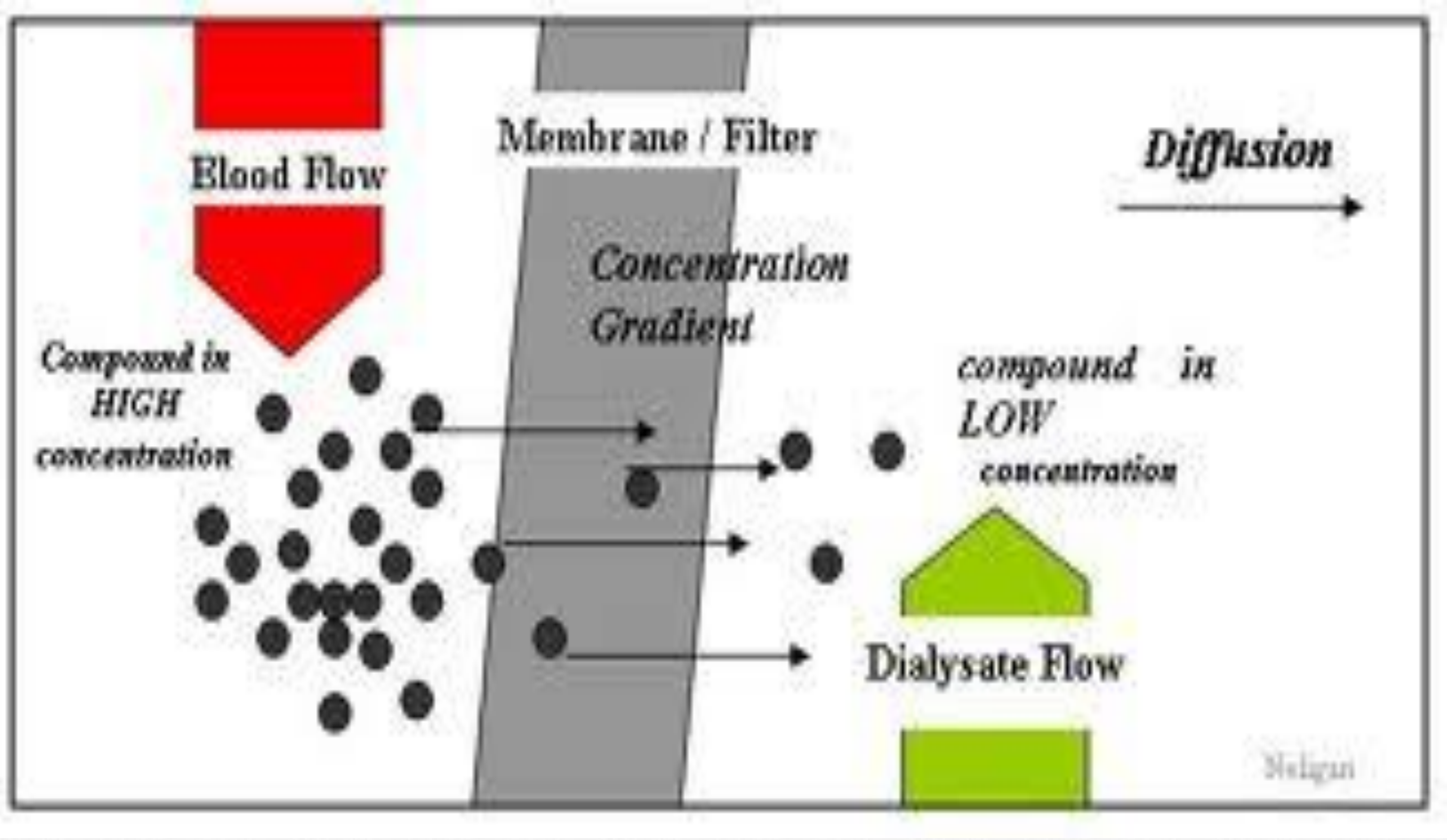


An ideal clearance marker

- Accumulates in uremia;
- Is easily measured; and
- Is easily removed by the dialyzer.

Clearance

The ratio of removal rate to blood concentration of certain solute (K is the sympol of clearance)



As the dialyzer blood and dialysate flow rates increase, solute clearance increases, but at a diminishing rate.

URR

- URR stands for urea reduction ratio.
- The URR is one measure of how effectively a dialysis treatment removed waste products from the body
- expressed as a percentage.
- Blood is sampled at the start of dialysis and at the end. The levels of urea in the two blood samples are then compared.

$$URR = (C_0 - C)/C_0$$

Example:

- If the initial, or predialysis, urea level was 50 (mg/dL)
- the postdialysis urea level was 15 mg/dL
- The amount of urea removed was:50 mg/dL - 15 mg/dL = 35 mg/dL
- The amount of urea removed (35 mg/dL) is expressed as a percentage of the predialysis urea level (50 mg/dL).
- 35/50 = 70/100 = 70%

only once every 12 to 14 treatments, which is once a month.

What percentage is optimal?

- Although no fixed percentage can be said to represent an adequate dialysis, patients generally live longer and have fewer hospitalizations if the URR is at least 60 percent.
- Experts recommend a minimum URR of 65 percent.

The URR may vary considerably from treatment to treatment. Therefore, a single value below 65 percent should not be of great concern, but a patient's average URR should exceed 65 percent.

Kt/V

- Gotch later used a mechanistic analysis of these data and showed that the Kt/V of urea was an important measure of clinical outcome
- The Kt/V is mathematically related to the URR and is in fact derived from it, except that the Kt/V also takes into account extra urea removed during dialysis along with excess fluid so the Kt/V is more accurate than the URR , primarily because the Kt/V also considers the amount of urea removed with excess fluid.
- The correction of total urea removal for volume of distribution is important because, in a large patient, a given degree of urea loss represents a lower rate of removal of the total body burden of urea (and presumably of other small uremic toxins).

Kt/V

Consider two patients with the same URR and the same postdialysis weight, one with a weight loss of 1 kg during the treatment and the other with a weight loss of 3 kg. compare URR to Kt/v

The patient who loses 3 kg will have a higher Kt/V, even though both have the same UR

Delivered KT/V:

- Using one of the following formulas:

  (a) 2.2-3.3 x (R-0.3-UF/W) [bedside].

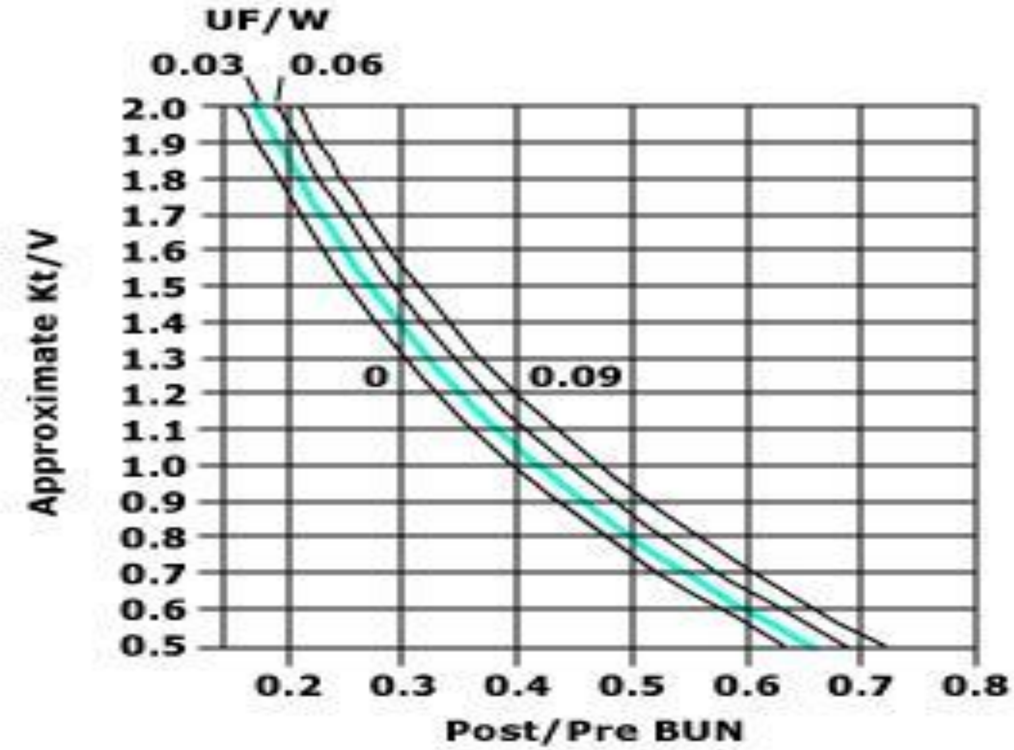
  (b) **kt/v= -In (R -0.008*t)+[(4 - 3.5 R)x (UF/ W)]** .

- R= BUN before – BUN after.
- UF/W= wt removed during Dx /post Dx weight.

K depend on:

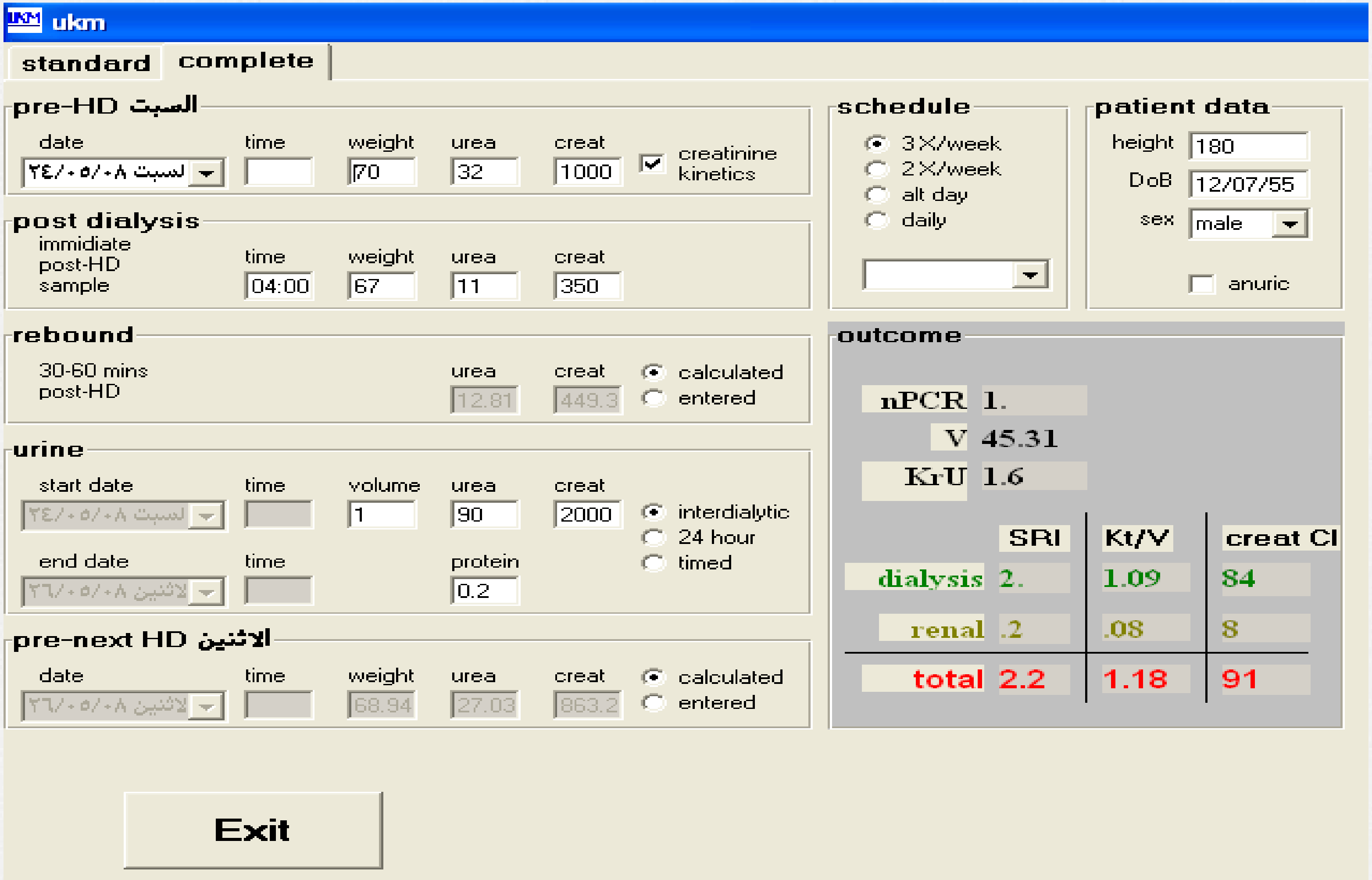
- **Membrane specification including (pore size , Surface area).**
- **- Blood flow**

Estimation of Kt/V



Nomogram to estimate Kt/V from the ratio (R) of the postdialysis to predialysis BUN and the fraction of body weight removed by ultrafiltration (UF/W), ranging from 0 to 0.09 (0 to 9 percent). Drawing the postdialysis blood sample should be delayed for 30 minutes after short-duration, high-efficiency hemodialysis to permit reequilibration with intracellular stores (see text for details). *Data from Daugirdas, JT, J Am Soc Nephrol 1993; 4:1205.*

Computer model



Example:

If the dialyzer's clearance is 300 mL/min and a dialysis session lasts for 180 minutes (3 hours) in a 70 kg patient. What is his Kt/V?

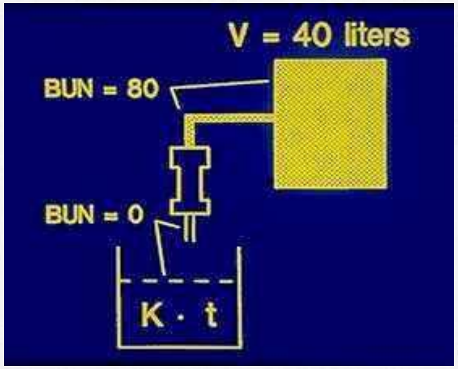
Kt = 300 mL/min multiplied by 180 minutes
Kt = 54,000 mL = 54 liters
The body is about 60 percent water by weight.
If a patient weighs 70 kilograms (kg), or 154 pounds (lbs), V will be 42 liters.
V = 70 kg multiplied by .60 = 42 liters.
Kt/V = 54/42 = 1.3

The Kidney Disease Outcomes Quality Initiative (KDOQI) group has adopted the Kt/V of 1.2 as the standard for dialysis adequacy.

A single low value is not always of concern, the average Kt/ should be at 1.2 (based on single pool dialysis model)

What can patients do to improve their Kt/V?

If a patient's average Kt/V—usually the average of three measurements—is consistently below 1.2, the patient and the nephrologist need to discuss ways to improve it. What would you suggest?



UREA KINETIC MODELLING

- Urea kinetic modeling is a method for verifying that the amount of dialysis prescribed (the prescribed Kt/V) equals the amount of dialysis delivered (the effective Kt/V).

- It allows for variations in dialysis time, use of larger, high efficiency, high-flux dialyzers, and optimization of dietary protein needs.

Increase Blood Flow through the Dialyzer

- Increasing K depends primarily on the rate of blood flow through the dialyzer.
- In many patients, a good rate is difficult to achieve because of vascular access problems.

If a patient's blood flow rate is good, further improvements in clearance can be obtained by:

- Increasing the flow rate for dialysis solution from the usual 500 mL/min to 600 or 800 mL/min.
- Using a big dialyzer
- A few centers are even using two dialyzers at the same time to increase K in larger than average patients

Increase Time on Dialysis

The other way to improve the Kt in Kt/V is to increase t by dialyzing for a longer period.

Example

If the Kt/V is 0.9 and the goal is 1.2, K is not changed in a 3 hourly session. how much time you need to add to achieve the goal

- **1.2/0.9 = 1.33,**
- **so 1.33 times more Kt is needed.**
- **this means the length of the session needs to increase by 33 percent. If the inadequate sessions lasted 3 hours, they should be increased to 4 hours.**

Drawing Samples for Measuring Urea Clearance

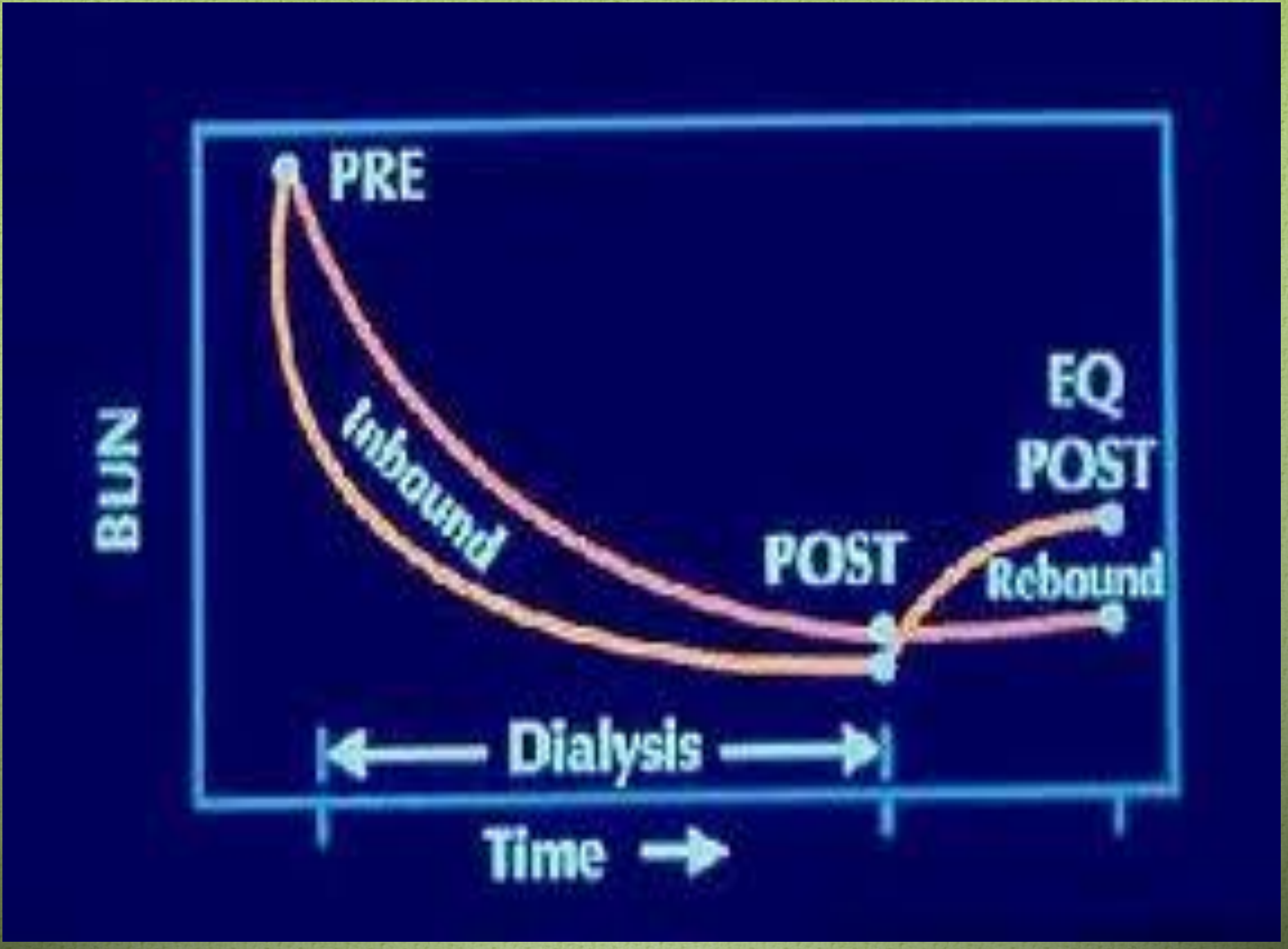
- Predialysis and postdialysis samples must be drawn at the same dialysis session.
- Draw predialysis blood from the arterial needle before administering any saline or heparin.
- With central lines: if heparin and/or saline is used, withdraw at least 10 cc of blood before drawing the blood sample. The blood withdrawn may then be returned to the patient.
- The postdialysis [urea] blood sample must not be diluted by either recirculation or saline.

Conventional methods of measuring recirculation in HD access include a three site method performed during dialysis, and a two site technique at the end of a HD treatment. (BUN) is measured in these samples, and the results entered into the formula to calculate the percent recirculation.

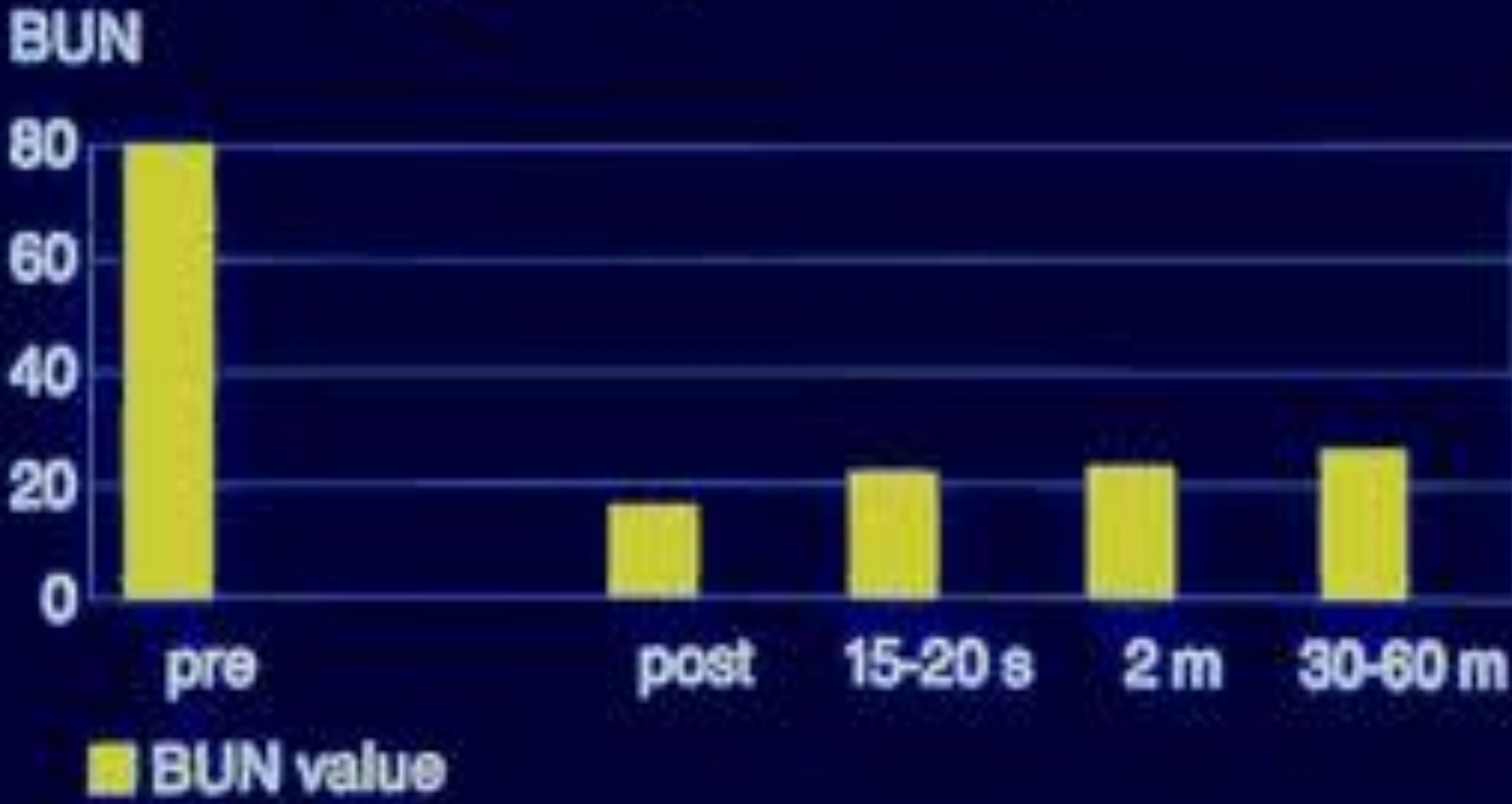
Significant recirculation should be suspected when there is an inadequate reduction in the postdialysis (BUN), which should be less than 40 percent of the predialysis value

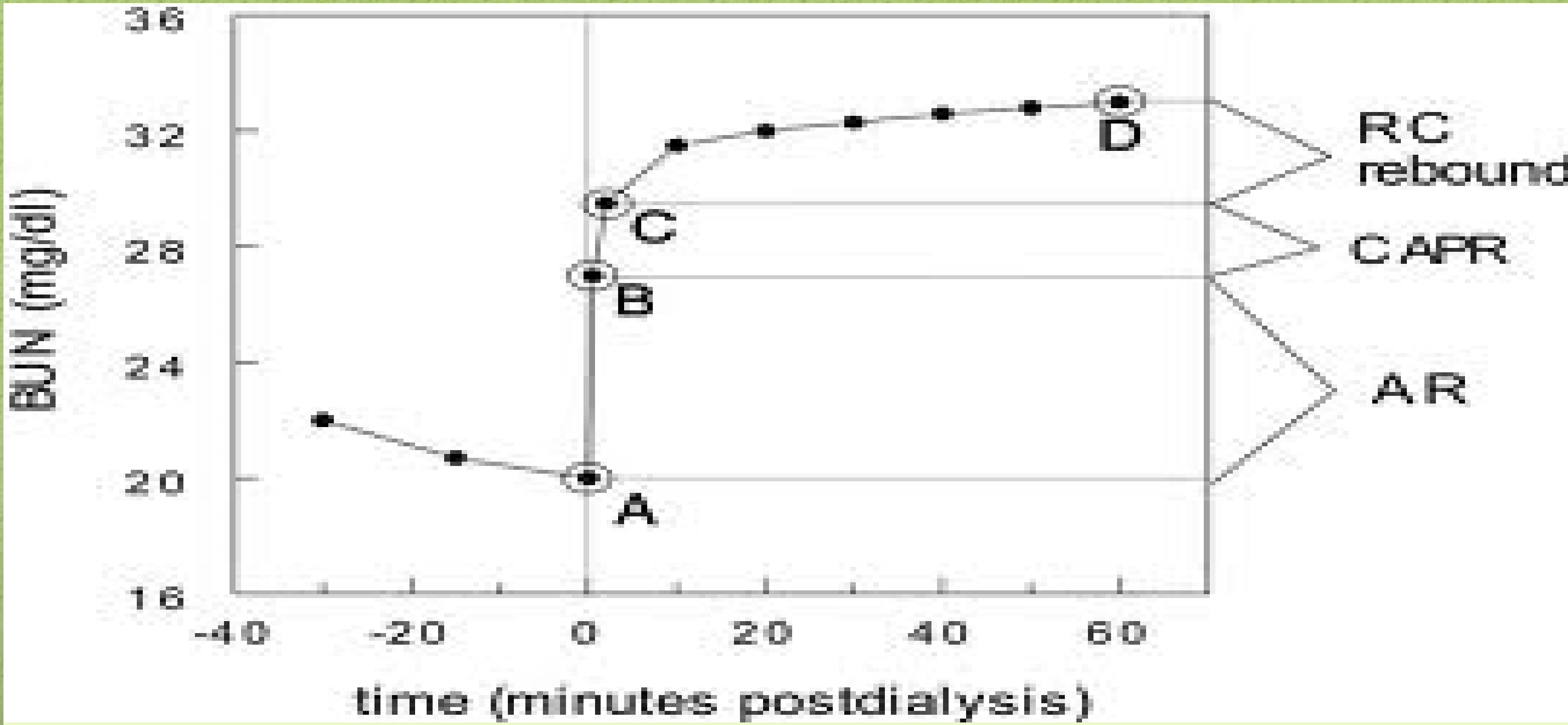
It is important to measure hemodialysis access recirculation for two reasons:

1. The efficiency of dialysis is reduced. High degrees of recirculation can lead to a significant discrepancy between the amount of HD prescribed (prescribed Kt/V urea) and the amount of HD delivered (delivered Kt/V).
2. High degrees of access recirculation indicate the presence of access stenoses, the most common cause of access thrombosis.


PRE
BUN
Inbound
EQ
POST
POST
Rebound
Dialysis
Time

Drawing the postdialysis BUN





A The immediate postdialysis BUN in a patient with significant access recirculation.
B The immediate postdialysis BUN after taking precautions to wash out the recirculated blood
C Rebounded BUN 2 min after stopping the blood pump. When dialysis ceases, reequilibration (mixing) of the blood compartment causes a rapid increase in the BUN, beginning as early as 10 s after stopping dialysis.
D After 60 min, all compartments are equilibrated and the BUN reflects uniform urea concentrations throughout the body.

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Table 6. Slow-Blood-Flow Method for Obtaining the Postdialysis Sample

A. Drawing the sample from the blood line sampling port

1. At the completion of HD, turn off the dialysate flow and decrease the UFR to 50 mL/hr, to the lowest TMP/UFR setting, or off. If the dialysis machine does not allow for turning off the dialysate flow, or if doing so violates clinic policy, decrease the dialysate flow to its minimum setting.
2. Decrease the blood flow to 100 mL/min for 15 s (longer if the bloodline volume to the sampling port exceeds 15 mL). To prevent pump shut-off as the blood flow rate is reduced, it may be necessary to manually adjust the venous pressure limits downward. At this point, proceed to obtain your sample. You can either shut off the blood pump before sampling, or leave it running at 100 mL/min while the sample is being drawn.
3. After the sample has been obtained, stop the blood pump (if not already stopped) and complete the patient disconnection procedure as per dialysis clinic protocol.

B. Method that avoids use of an exposed needle: Drawing the sample from the arterial needle tubing using a syringe or vacutainer device.

1. Proceed with steps (1) and (2) as per A above.
2. After the 15 s slow-flow period (a slow-flow period is still required to clear the small volume in the arterial needle tubing of recirculated blood), stop the blood pump. Clamp the arterial and venous blood lines. Clamp the arterial needle tubing. Disconnect the blood line tubing from the inlet bloodline, and attach either a syringe or a Vacutainer with a Luer-Lok type connection to the arterial needle tubing (or arterial port of the venous catheter). Release the clamp on the arterial needle tubing and obtain the blood sample.
3. Proceed with step (3) as in section A above.

TMP: Transmembrane pressure; UFR: Ultrafiltration rate

Table 5. Recommended Predialysis Blood-Drawing Procedure

A. When using an AV fistula or graft

1. Obtain the blood specimen from the arterial needle prior to connecting the arterial blood tubing or flushing the needle. Be sure that no saline and/or heparin is in the arterial needle and tubing prior to drawing the sample for BUN measurement.
2. Do not draw a sample for use as a predialysis measure of BUN if HD has been initiated.

B. When using a venous catheter

1. Using sterile technique, using a 5 mL syringe, withdraw any heparin and saline from the arterial port of the catheter, along with blood, to a total volume of 5 mL.[87,88] Discard the contents of this syringe.
2. Connect a new syringe or collection device and draw the sample for BUN measurement.
3. Complete initiation of HD per dialysis clinic protocol.

Table 7. Stop-Dialysate-Flow Method of Obtaining the Postdialysis Sample

1. At the completion of HD, turn off the dialysate flow (or put it into bypass) and decrease the UFR to 50 mL/hr, to the lowest TMP/UFR setting, or off.
2. Wait 3 min. Do NOT reduce the blood flow rate during this 3-min period.
3. Obtain the blood sample, either from the sampling port on the inlet bloodline, or from the arterial needle tubing or from the arterial port of the venous catheter if using the needle-free method as described in Table 6, part B. If sampling from the inlet bloodline, it does not matter if you stop or do not stop the blood flow while this sample is being taken. It probably is best to stop the blood pump prior to sampling. In the stop-dialysate-flow method, slowing the blood flow prior to sampling should not be done.
4. After the sample has been obtained, return the patient's blood in the bloodlines and dialyzer per protocol.

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SAMPLING OF KT/V &URR

- Pre-sample: After insertion of the needle.
- Post sample :

A. To prevent rebound ; sequestration of urea from other tissues into blood to reach equilibrium less than 2 min after ending,

B. To prevent recirculation ; blood pump is slowed to 30 ml/min for one minute and a sample is taken from art. line.

Protein catabolic rate (PCR) in maintenance dialysis

- PCR, is the parameter used in most HD units to assess dietary protein intake in patients who are in a steady state.
- It is a function of protein catabolism.
- Determined by measuring interdialytic appearance of urea in body fluids plus any urea lost in urine in patients with residual renal function.
- In a patient with little or no urine output,

  PCR = dialysis + stool losses of {urea, protein, and A.A.}.

Residual renal function(Kr)

- Has insignificant effect on urea clearance during HD. with Kr needs less kt/v.
- Reducing dose of Dx is not a good idea:
- But has a significant effect on lowering predialysis BUN.
- Every 1 ml/min of Kr offers a kt/v of 0.13.
- Consequently patients

  Residual kidney functions deteriorates after HD.

  Consider the Kr a BOUNDS for the patient.

Calculation of Kr

- Interdialytic urine collection.
- BUN after and just before next Dx.
- Kr = $\frac{\text{urine volume}}{\text{Id time/min}} \times \frac{\text{urine urea nitrogen.}}{\text{mean BUN}}$

TOTAL Kt/V = Kt/V + $\frac{\text{Kr x 5.5}}{\text{v}}$

Recommendations

All hemodialysis patients should have regular global assessments of dialysis adequacy. (Grade D, opinion) Assessment of hemodialysis adequacy should include urea clearance, volume control, blood pressure, mineral metabolism, and clinical symptoms. (Grade C)

Hemodialysis centers should consider offering a range of options, including more frequent or sustained treatment times, for those patients with dialysis inadequacy. (Grade D, opinion)

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The minimum acceptable target for urea clearance during hemodialysis is a single-pool Kt/V of 1.2 or percent reduction of urea (PRU) of 65% three times per week. (Grade C)

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Survival curves for high and standard dialysis doses

Urea clearance as assessed by Kt/V .Although practice guidelines have traditionally emphasized the role of urea clearance, this parameter is only one component of dialysis adequacy.

A well-designed, randomized study found no benefit of a single-pool Kt/V target of 1.65 compared with 1.25


Thank You