Dialysis Dose

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Introduction

This article will introduce the student to the concepts of dialysis dose and adequacy of dialysis. The student will focus on a single issue, dialysis dose, and the factors that influence the outcome of the hemodialysis procedure. A basic understanding of the risk factors that contribute to the morbidity and mortality rates of the End Stage Renal Disease (ESRD) patient is necessary to improve patient survival.

Objectives

1. Identify two (2) assessment tools being used today to determine the dialysis dose.
2. Calculate the URR for a dialysis patient with a pre-dialysis BUN of 100 mg/dL and a post-dialysis BUN of 25 mg/dL; converting the results to a percentage.
3. Identify four (4) different methods of post-dialysis blood sampling that can yield inaccurate test results that influence the formulas of URR and Kt/V.
4. Identify the meaning of the formula Kt/V.
5. Identify four (4) problems with the use of the formula Kt/V as an individual assessment tool.
6. Define the term half-life, also called t-½.
7. Define the term adequacy of dialysis.
8. Identify four (4) parameters to assess when using the multiple criteria approach to adequacy of dialysis.

Dialysis dose can be defined –in general terms– as the amount of hemodialysis time received per dialysis and the dialysis frequency per week. Any specific definition of dialysis dose *must* include the frequency per week of dialysis. Though not mandatory, the dialysis dose definition should also include the *length* of time of each dialysis. There are many formulas for dialysis dose.

The most important dialysis dose, in terms of American Medi-Care reimbursement, is the urea reduction ratio (URR). Partial or full Medi-Care reimbursement for hemodialysis covers almost ninety percent (90%) of United States of America (American) dialysis reimbursement. Dialysis facilities who care for Americans covered by Medi-Care reimbursement are required by Health Care Financing Administration (HCFA) to submit a dialysis dose estimation on all Medi-Care bills.

Urea Reduction Ratio (URR)

HCFA has mandated that the URR[1], as the dialysis dose, be reported on each patient's bill. Failure to include a URR on a Medi-Care bill will result in non-payment. HCFA personnel have also implied and intimated that some time into the future a *low* URR value on the Medi-Care bill will result in non-payment of said bill. There is precedent for this proposed action. Medi-Care bills which contain hematocrit (Hct) values greater than 37.5% are reviewed and often are rejected for payment of the erythropoietic drug epoetin. Thus, like the patient's Hct values, the URR is a very important formula and value to know and understand for all ESRD personnel.

The URR is a formula which calculates an *estimate* of the amount of urea removed during *one* dialysis. No dialysis dose definition is complete without knowing the frequency per week of dialysis when a dialysis dose is calculated. Dialysis frequency is *not* part of the formula in determining the URR, making this dialysis dose value subject to various false interpretations.

The URR value, without knowing the frequency of dialysis per week, is a useless number. The URR describes the amount of urea removed during a single dialysis by measuring the blood urea nitrogen (BUN). The length of time of that dialysis can *not* be inferred from the result of the URR. A high URR will result if a small patient is dialyzed a short period of time. A low URR occurs in a large patient dialyzed a longer period of time than the small dialysis patient. The formula for URR is:

$$\text{URR} = (\text{Pre BUN} - \text{Post BUN}) / \text{Pre BUN}$$

The resulting fraction is often converted to a percentage by multiplying the result by 100. This latter formula is:

$$\text{URR} = (\text{Pre BUN} - \text{Post BUN}) / \text{Pre BUN} * 100$$

To obtain a URR, blood is drawn from the patient pre-dialysis, let's assume a BUN (PreBUN) is determined by the laboratory to be 100 mg/dL. If at the end of that *same dialysis* a **correctly drawn post-dialysis BUN** of 25 mg/dL is determined, then the URR can be calculated as:

$$\text{URR} = (100 - 25) / 100$$

This is a URR of .75, a very high value. The URR can be converted to a percentage by multiplying the result by one-hundred yields a URR of seventy-five percent (75%).

Post-Dialysis Blood Drawing

Though simple in concept and simple to calculate, the URR is fraught with error because it depends on a post dialysis blood sample. In our experience, the URR results may be *inverse* to the quality of the education of the dialysis personnel drawing these blood samples. That would mean that the better trained and knowledgeable nursing staff who draws these blood samples, will result in *lower* URRs in that dialysis facility. The less well trained nursing staff who performs careless, sloppy, and indifferent blood drawing will have URR results that are much *higher*.

Using Blood Drawn From Different Dialysis Days

We are aware of dialysis facilities which use, or at least have used, the pre-dialysis BUN from the *first* dialysis of the week and the post-dialysis of the *last* dialysis of that week. This will result in a URR which is both false and very high. This error invalidates the use of the URR as a estimate of an honest dialysis dose but is useful in guaranteeing payment of those Medi-Care bills with such URR results.

Recirculation, Rinsing, and Rebound [2]

Recirculation

Most dialysis patients have A-V fistulas or catheters for semi-permanent access to their blood. Both of these access devices have some degree of recirculation between arterial and venous blood. Unless the post dialysis blood is drawn deftly and with careful attention to recirculation of blood, the post dialysis BUN may be *higher* due to mixture with arterial blood.

Rinsing With Saline Post dialysis

If the post dialysis blood sample is drawn without care to avoid saline contamination, the post dialysis BUN may be *lower* due to the presence of that diluting saline solution.

Priming the Artificial Kidney

All dialyzers and blood lines are primed with normal saline prior to patient use. The pre-dialysis blood samples should be drawn directly from the patient's arterial access prior to initiating the dialysis treatment to avoid a pre-dialysis blood sample that may contain the priming solution. If blood is drawn from the arterial line when dialysis is being initiated, the pre-dialysis BUN will be *lower* due to the presence of saline as a diluent in the blood sample.

Urea Rebound Post-dialysis

Present day artificial kidneys are capable of removing urea and other substances from the blood more rapidly than these substances can be transferred from their intra-cellular spaces. Potassium like urea is artificially low post-dialysis and is probably a much more important solute to assess. Unfortunately, most of the research has focused on post-dialysis urea rebound and not solutes like potassium, bicarbonate, and phosphate.

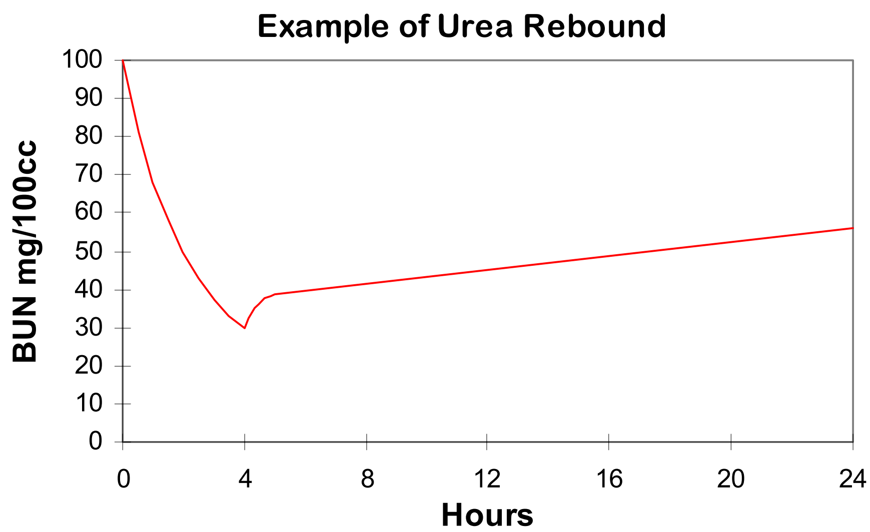

Figure 1 - Idealized Urea Rebound

Figure 1 is a graph depicting an idealized example of post-dialysis urea rebound following a hemodialysis treatment. The pre-dialysis BUN is 100 mg/dL. The length of dialysis is four (4) hours. The immediate post-dialysis BUN is 30 mg/dL. The BUN is lowest immediately post-dialysis. The BUN value then rises sharply for about an hour, in this instance, to about 38 mg/dL. This latter BUN is the urea rebound value. The rapid increase in post-dialysis BUN is believed to be due to intra-cellular urea transfer into the blood compartment.

Much medical literature has been devoted to this problem, primarily because the URR result is dependent on the post-dialysis blood sample's accuracy. Some studies have reported sequential blood samples from patients post-dialysis and concluded that it may take an hour before a true post-dialysis blood urea may be determined. Depending on the nursing staff, the post-dialysis urea rebound may be more artifactual than real. In our experience the un-predictability of the post-dialysis urea concentration is often due to the careless technique of the dialysis staff coupled with the issues of:

1. recirculation of blood between arterial and venous needles,

2. saline rinsing post-dialysis,

and not due to slow urea flow from intra-cellular to blood compartment.

Kt/V As a Measure of Dialysis Dose

All the blood drawing errors associated with determining the URR are also associated with the more complex formula called Kt/V[3] used in urea kinetic modeling. The Kt/V[4] has additional errors which are built into the formulas used for Kt/V. The "V" is an estimate of total body water of the patient. The "K" is the "Klearance" (clearance) of that particular artificial kidney and the "t" is the time of actual dialysis. Of these three (3) variables, the easiest one to assess, control and verify, is "t" or time on dialysis.

Time on Dialysis

Unfortunately the time on dialysis, the simplest of the three (3) variables, is commonly subject to improper recording in the patient's treatment log. Even in the very best dialysis facilities there are employees who will write in the total treatment time *prior* to placing the patient on dialysis! Thus, the simplest variable "t" is subject to inaccurate fluctuations due to human error. If "t" is often erroneous, one may assume that the more complex variables of "V" and "K" are also imperfectly estimated.

How to Estimate Actual Time on Dialysis

Time on dialysis, by itself means little or nothing if the blood and dialysate flows are not maximal and optimal. Time on dialysis, without use of the correct type of dialyzer for that individual patient: ie using a small surface area dialyzer for a large patient and visa versa, is fraught with error and peril. If one logs the beginning dialysis time as that when blood lines are connected and the blood pump begins to turn, that is incorrect. If one logs as the end dialysis time the after the rinse saline occurs, and post dialysis blood samples are taken, that is incorrect.

The correct beginning time on dialysis is that time when the blood flow is maximized. The correct end dialysis time is that time when the saline rinse begins.

Basic Kt/V Formula & Natural Logarithms

The basic formula for Kt/V looks remarkably like the URR formula. The major difference is that the Kt/V formula relies on conversion of real numbers into logarithms of those real numbers. The common logarithm of base 10 is not used in calculating removal of drugs and other substances from the body. For those calculations, the natural logarithm base number 2.718… is used.

A logarithm of a real number is the *power* that the base logarithm number is raised. The formula for *natural* logarithms is:

$$\mathrm{Log(e)}\ a = x$$

Let *e* be the natural logarithm base number. The natural logarithm is the number 2.718…. Let *a* be the real number you wish to convert to a natural logarithm. Let *x* be the *power* that *e* must be raised to achieve *a*. Thus, the natural logarithm of a real number is *x*, the exponent, the power, of the natural logarithm. Written another way, this formula is:

$$e^{X} = a$$

Medical and other researchers commonly use logarithmic transformation of numbers either in calculus or in statistics. Often they may not be able to check that these mathematical transformations are correct because of the complexity of understanding logarithmic formulas and anti-log functions. The author[5] developed a small computer program which provides examples of logarithmic transformations and anti-log functions which reverse the process. This program is published as part of useful code examples in a major Excel book.

Natural Logarithm and Excel

The symbol commonly used in equations and formulas to denote the natural logarithm base number of 2.718… is *e*, or Ln. LN is also the *name* of the function used in the Microsoft software Excel to calculate the natural logarithm (log). If one uses Excel, it is a trivial matter to calculate Kt/V. Type into any cell of an Excel worksheet: =LN(100/25) and press {Enter}.[6] The result will be approximately 1.4. In the Excel formula, the expression "100/25" stands for a pre dialysis BUN of 100 divided by a post dialysis BUN of 25. Prior to the HEMO[7] study, the author published computer programs[8] in QuickBASIC[9] called "Pretty Good Urea Modeling" and as an Excel 5.0c VBA program which calculated Kt/V and URR.

The basic formula for Kt/V is:

$$Kt / V = LN\,(\text{Pre BUN} \;/\; \text{Post BUN})$$

Using the same pre and post dialysis BUNs used to calculate the URR of 75%, the Kt/V for that URR is approximately 1.4. All more complex (and thus more confusing formulas) for Kt/V use the above basic formula for Kt/V. By the author's 1995 evaluation of all available more complex Kt/V formulas, the above basic, simple Kt/V over a wide range of values, is within five percent (5%) of the gold standard proposed for the HEMO study which began that year.

Pharmacokinetic Formulas

All formulas for Kt/V are modifications of formulas used for many decades to determine how injected drugs are removed from the body by the liver, kidney and –to a minor degree– by other organs.

These pharmacokinetic formulas are used to calculate half-life (t-½), or how long does it take in minutes or hours to remove one-half of the injected drug. These formulas use the natural logarithm to calculate half-life.

Kt/V is a Pharmacokinetic Formula

The Kt/V formulas are not specially derived nor unique to the ESRD patient. They are simple pharmacokinetic formulas which use urea as the measured substance and the artificial kidney as the method of removal of this substance. The initial use of Kt/V formulas was to propose a *theory* of what is adequate dialysis and not to describe urea t-½ which is a much more useful and direct estimation of urea removal by a dialysis session.

Half-Life of BUN

Since Kt/V is a simple pharmacokinetic formula, we can calculate the half-life[10] of blood urea that is removed by a dialysis procedure. We have used pre and post dialysis BUNs that give a high URR and Kt/V. In simple pharmacokinetic formulas, it takes seven (7) half-lives to remove almost all of the studied drug, in this case, urea, measured in the blood as blood urea nitrogen (BUN). Let us use a Kt/V of 1.4 and a t-½ of 1.5 and draw the graph for these values of BUN. You will note it takes seven (7) half-lives of BUN to almost completely remove that substance from the blood. See Figure 2 - Half-Lifes BUN**.**

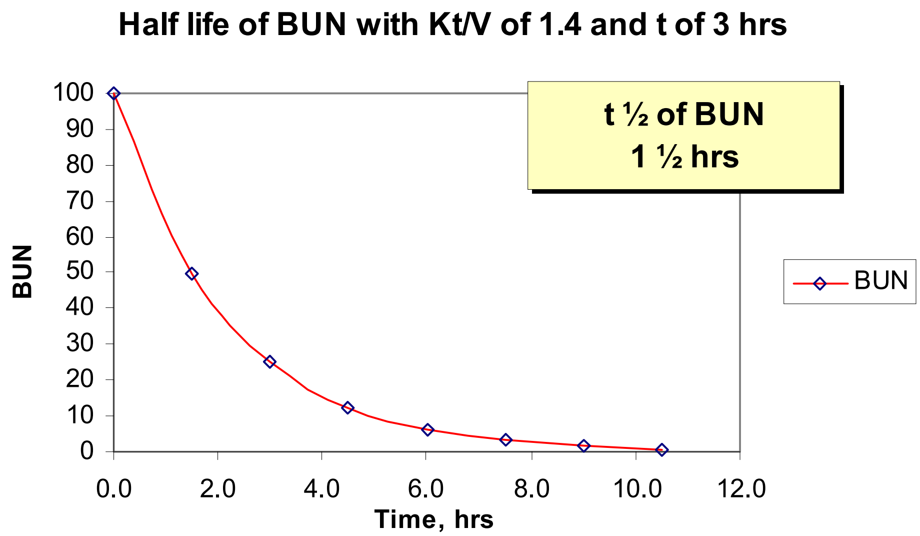

Figure 2 - Half-Lifes BUN

The authors[11] of the Kt/V concepts have repeatedly indicated that a Kt/V of one (1) removes *almost all* of the urea from the total body water.

Calculate the Half-Life, the t-½ of Urea

The t-½ of urea for any patient, for any dialysis situation, can be calculated by first determining the drug elimination rate constant or Kd:

$$Kd = LN(Pre\ BUN / Post\ BUN) / t$$

Note that the Kd, is nothing more than the basic formula for Kt/V divided by "t" or time. In calculating the half-life, the number two (2) is used in the numerator. Since we are using natural logarithms, 2 is converted to its natural logarithm 0.693….

$$T\ 1/2 = 0.693 / Kd$$

We know that the t-½ of urea given a URR of 75%, a Kt/V of 1.4 and a dialysis time of 3 hours is exactly 1.5 hours; See, Figure 2**.** To remove almost all of the total body water's urea by dialysis will take seven (7) half-lives or ten and one-half (10.5) hours.

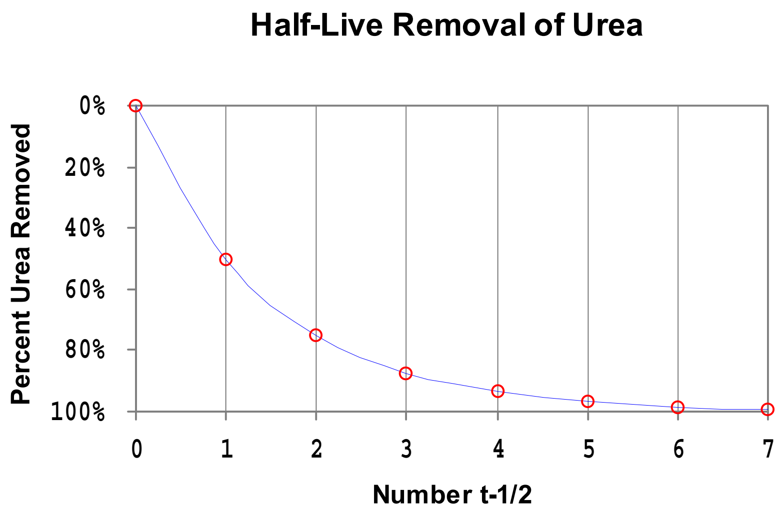

Figure 3 - Urea Removal

What if the dialysis treatment prescription is still 3 hours and yields a Kt/V of 1.0? Then the t-½ is 2.1 hours and to remove *almost all* (seven t-½s) of the urea from that patient's total body water is 14.7 hours of dialysis! The first t-½ time removes 50% of the urea, the second 25%, the third 12.5%, the fourth 6.25%. Being less doctrinaire, four t-½s remove a total of 93.75% of urea, which would still require 8.4 hours of dialysis! See Figure 3 - Urea Removal.

The student is now armed with the ability to calculate from the pre and post dialysis BUN levels what the t-½ of urea is for any dialysis session. The student –hopefully– now also understands that Kt/V is a simple pharmacokinetic formula and may conclude rather quickly that the numeric values returned by Kt/V calculations has little meaning or value as far as urea removal by the artificial kidney.

The National Cooperative Dialysis Study (NCDS)

The National Cooperative Study of twenty-five (25) years ago, was funded by the federal government to determine what mortality was caused by very short dialysis and secondly to determine if a longer dialysis was better. The senior author of that seminal study was Doctor Edmund G Lowrie, MD.

The NCDS was a six (6) month study to determine patient mortality with very short dialysis and to possibly determine if longer dialysis would remove unknown middle molecules which were thought to be the cause of dialysis mortality. The data from that study was used by co-authors Doctors Gotch and Sargent to develop *unproven* mathematical models using urea as a surrogate of these yet unknown uremic toxins. Doctor Lowrie was not involved in developing those mathematical models. The formulas developed advanced the *still unproven* concept that urea removal, that small molecule dialysis dose, determines dialysis adequacy.

Kt/V as Dialysis Dose is An Unproved Theory

The senior author of the NCDS Edmund G Lowrie, has published several articles because his statistical analyses of dialysis patient mortality versus URR and Kt/V do not validate the original theory proposed by Doctors Gotch and Sargent.

In his most recent paper, in the opening paragraph, Doctor Lowrie[12] writes, “The question before us for the purpose of this discussion is, 'Is Kt/Vi the best dialysis dose parameter?' The clear answer is, 'No', if clinicians believe that the dose parameter must be associated with medical outcome (e.g. mortality, morbidity, or medical well-being) rather than simply a BUN concentration. The answer applies equally well to Kt/V, spKt/V, eKt/V, (Kt/V)dp (single-pool, effective and double-pool Kt/V, respectively), and all past, present and future permutations of the general quantity we call Kt/V. Indeed, the following will show that the urea kinetic construct, from which the Kt/V derives, is not an appropriate construct for developing an outcome-based measure of dialysis dose.”

We agree with Doctor Lowrie and though the above quotation does not include URR, his later discourse makes use of URR data to disprove the use of that formula and all the Kt/V formulas as a valid marker of dialysis dose.

Doctor Lowrie further notes and indicates that the Kt/V mathematical models developed in the NCDS by Doctors Gotch and Sargent are invalid and false. Doctor Lowrie states, “Mathematical models that do not rest on valid premises are not valid models. Such systems are little more than mathematical fantasies useful for drawing equation-based pictures but little else. Arguing otherwise shifts discussion from the physical to the meta-physical and transforms medicine into theology.”

Again, we agree with Doctor Lowrie. It is time to separate religious belief in Kt/V from the hard science of patient morbidity and mortality and focus less on simple data and more on staff practice and patient care that predicts patient morbidity and mortality.

Doctor Lowrie further states, “No term for survival (eg. d Survival) appears in any urea kinetic model and there is no 'familiar mathematical recipe' that could accommodate such a construct.”

We agree. Any dialysis dose used as a marker of adequacy of dialysis must include and reflect patient survival data.

Pitfalls of Using Kt/V as Dialysis Dose

Though rarely stated explicitly by the authors of the Kt/V concept, Kt/V values assume a dialysis frequency of three dialyses per week. When the term “Kt/V” is used alone it means the dialysis dose for one dialysis and a weekly Kt/V of three (3) times that amount. Thus the standard Kt/V of one (1) means a weekly Kt/V of three (3).

Skipping Dialysis

Mentioned without much emphasis, USRDS data[13] indicates that in any month about five percent (5%) of American dialysis patients may skip a dialysis. If Kt/V and URR are markers of dialysis dose, where is the mathematical variable, or construct, which calculates this common and serious problem!? If a dialysis patient is on three times a week dialysis, then that patient should have one hundred and fifty-six dialyses (156) per year. Repeated analysis of pooled billing data[14] indicates that many American dialysis patients may have twenty (20) *less* dialyses per year than the commonly prescribed thrice weekly dialysis therapy.

Less Than Three Dialyses per Week

Unfortunately, authors of the Kt/V concept have rarely addressed the issue of the many dialysis facilities who dialyze patients once or twice a week and report high to very high Kt/V and URRs though they are actually under-dialyzing these patients.

Daily Dialysis Produces High Dialysis Dose

The inverse is also true. Those home patients who perform daily dialysis report a Kt/V of, say 0.6 (and its attendant low URR). We have been made aware of situations where the attending nephrologist has been horrified saying that HCFA will disallow reimbursement for this *substandard* Kt/V and URR. These physicians have demanded that these home dialysis patients return to a three time a week dialysis so that their Kt/V is higher for reporting to HCFA.

If a home dialysis patient dialyzes seven days a week and reports a Kt/V of 0.6, then his/her *weekly* Kt/V is 4.2. The standard *weekly* Kt/V for three times a week dialysis is 3.0 which is the single dialysis number multiplied by three. To convert this home dialysis patient's Kt/V of 4.2 to the same base, ie: thrice weekly dialysis, divide the weekly Kt/V by 3. This home dialysis patient has a Kt/V of 1.4. A Kt/V of 1.4 is equivalent to a URR of 75%, a very high value.

These physicians fear the federal government may withhold reimbursement for low URR or Kt/V values reported on the patient billing forms. These physicians, along with the physicians and other staff in HCFA, do not understand what Kt/V measures and how it should be reported.

At the very least, HCFA needs to amend their form. No Kt/V or URR should ever be reported without also stating the frequency of dialysis per week. Both of these formulas are based on a standard of thrice weekly dialysis. As a more prudent action HCFA should cease the requirement of reporting the URR on patient billing forms and require *audited, accurate* patient morbidity and mortality reports.

Errors In Calculating Kt/V

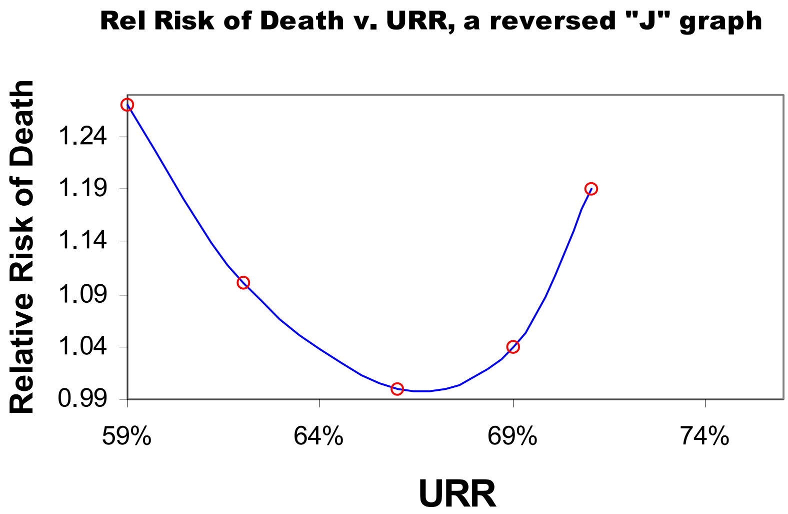

Figure 4 - Example of a Reversed 'J' Graph; Chertow's data[15]

Each of the three (3) elements or variables that make up the Kt/V formula: "K", "V" and "t" may induce errors in attempting their estimation.

The most disturbing and glaring error according to Doctor Edmund G Lowrie and others is the use of any number as an estimate for a patient's total body water. He and others have elegantly demonstrated that analysis of Kt/V graphed against patient mortality shows a "reversed J" curve.

A reversed "J" curve means that the patient mortality is high with a low Kt/V, drops to it's lowest level with a moderate Kt/V and the climbs upward to a higher mortality with increasing Kt/V. The graph thus appears like the letter "J" flipped vertically, or reversed. The same graphs are also true for URR. See, Figure 4 - Example of a Reversed "J" Graph which is plotted from data in Doctor Lowrie's article: "The Normalized Treatment Ratio (Kt/V) Is Not the Best Dialysis Dose Parameter."

If Kt/V is a valid measure of dialysis dose, these data indicate that toxic dialysis or over-dialysis occurs as the Kt/V increases. We know of no evidence that toxic dialysis or over-dialysis exists. We have been involved in hemodialysis treatment since 1966 and were the first to report on the superiority of daily dialysis[16] for the home hemodialysis patient versus the standard of thrice weekly hemodialysis.

We were also among the first[17] to present evidence that adequacy of dialysis[18] was a complex issue which included measurement of many parameters and analysis of many variables. The search for a single laboratory data test such as BUN to describe the problems of the uremic state is done in the belief that such a single test exists. It does not.

All evidence points that the more –proper– dialysis a patient receives, the better is the patient survival, strength, quality of life, blood and other protein manufacture, and blood pressure control. The longevity of **Hi**'s five-hundred and fifty (550) patients coupled with evidence based clinical outcomes support our medical and nursing care design.

How Much Dialysis is Enough?

HCFA, the large US government agency which oversees the ESRD program, wishes for a simple way to quantify dialysis and to justify the annual increase of ESRD expense to the American federal government of over a billion dollars per annum. Unfortunately, dialysis dose as measured by URR or Kt/V has been equated with adequacy of dialysis by HCFA, DOQI, and the HEMO study. By medical evidence, neither URR nor Kt/V measure adequacy of dialysis.

The most simple definition of adequacy of dialysis is as that amount of *dialysis care* which does not cause patient illness or death from the delivery of dialysis treatment. Dialysis care includes far more than reviewing the laboratory data of a dialysis patient once a month. It requires trained nursing staff to provide both skilled nursing but –as critical– an analysis for each and every dialysis of the patient's clinical state so that dialysate bath may be appropriately adjusted; the ultrafiltration tuned to the patient's dry weight and anti-hypertensive medications, and a visit by either a nephrologist or a designee <u>for</u> <u>each</u> <u>dialysis</u>.

If a supposed marker of adequacy of dialysis shows increased mortality as that marker improves, it is a false marker and should be discarded. If used at all, used because it is required by Medi-Care reimbursement policies. The URR is required on each Medi-Care bill; that fact does not translate or mean that the URR is a marker of adequacy of dialysis.

We will explore the variables which denote adequacy of dialysis in an article devoted just to that topic at a latter date. In order not to leave the student without some concept of what adequacy of dialysis is, we note the following incomplete list of markers of adequacy of dialysis. Adequacy of dialysis is that amount of dialysis care which allows that ESRD patient:

1 To maintain a hematocrit of equal or greater than 37.5% without the use of epoetin administration.

2 Enough dialysis in terms of frequency of treatment per week, time of each treatment not to cause complication due to too little or too infrequent dialysis.

3 Proper ultrafiltration to treat the majority of ESRD patients who have volume related hypertension. These patients should be on no anti-hypertensive medications.

4 Provision of a nutritious diet which gives the ESRD patient normal or near normal nutritional markers and prevents malnutrition.

Post Test

1. There are many different meanings for nephrologists regarding adequacy of dialysis. A very popular method used today is *urea kinetic modeling*, even though it is fraught with problems and inaccuracies. Which ***one*** of the following formulas/calculations is used to calculate this guide to hemodialysis therapy?
   a) Urea reduction ratio
   b) Creatinine clearance
   c) Creatinine/kilogram ratio
   d) Kt/V
   e) (P - A ÷ P - V) X 100

2. The calculated percentage of the URR for a patient with a pre-dialysis BUN of 90 mg/dL and a post-dialysis BUN of 20 mg/dL is?
   a) 65%
   b) 70%
   c) 75%
   d) 80%
   e) none of the above

3. Identify the marker currently required by HCFA on each Medi-Care bill for reimbursement of dialysis therapy.
   a) Urea reduction ratio
   b) Creatinine clearance
   c) Creatinine/kilogram ratio
   d) Kt/V
   e) (P - A ÷ P - V) X 100

4. Adequacy of dialysis is that amount of dialysis care which allows that ESRD patient:

   a) To make blood without the use of epoetin.

   b) Enough dialysis in terms of frequency of treatment per week, time of each treatment not to cause complication due to too little or too infrequent dialysis.

   c) Proper ultrafiltration to treat the majority of ESRD patients who have volume related hypertension. These patients should be on no anti-hypertensive medications.

   d) Provision of a nutritious diet which gives the ESRD patient normal or near normal nutritional markers and prevents malnutrition.

   e) All of the above.

5. URR and Kt/V may be fraught with inaccuracies due to the various methods in use to obtain the post-dialysis BUN blood sample. Which one of the following methods would not contribute to a falsely high or low BUN?

   a) Using pre and post BUN's from different dialysis days.

   b) Using a diluted blood sample with normal saline.

   c) Obtaining a blood sample from a patient's access with a high rate of recirculation.

   d) Obtaining the post dialysis blood sample before discontinuation of dialysis.

   e) Obtaining the post-dialysis blood sample after dialysis is completely discontinued and the patient is disconnected from the extracorporeal circuit, making sure that the blood sample is free of any normal saline.

6. Figure 5 is a graph that translates the pre-dialysis BUN to post-dialysis BUN ratio to Kt/V. The student will calculate the Pre/Post BUN ratio and plot the Kt/V from Figure 5. The first row of the table contains a completed example. The pre-dialysis BUN is 100 mg/dL, the post-dialysis BUN is 25 mg/dL. Dividing 100 by 25 (100/25) gives us 4, the ratio of pre to post Dialysis BUN. Using a ruler placed on the number 4 on the vertical axis and parallel to the horizontal axis of Figure 5, we determine that the Kt/V is about 1.4 for a ratio of 4.

   Calculate and write in the "Ratio" boxes the answers to the BUN data below. Then use a ruler to find the Kt/Vs for those values and write the answers in the "Kt/V" boxes:

Pre-dialysis BUN	Post-dialysis BUN	Ratio	Kt/V
100	25	4	1.4
100	33		
96	22		
120	67		
75	50		
50	25		

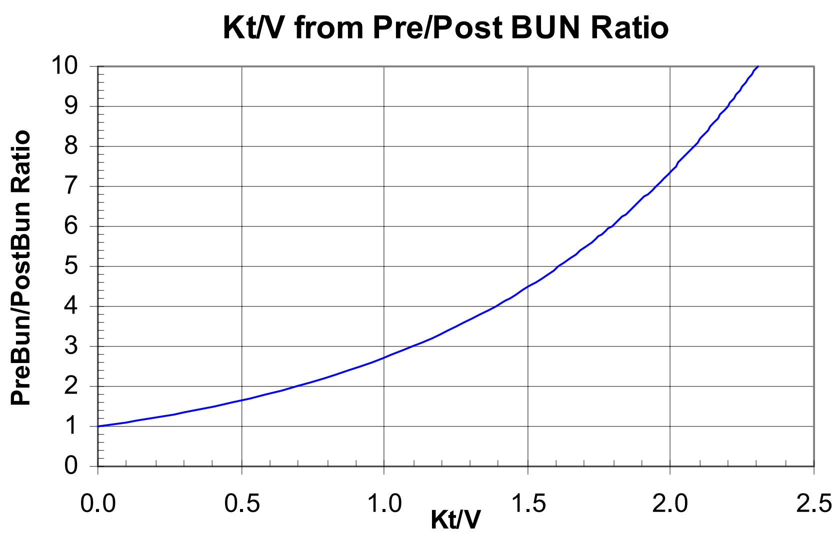

Figure 5 - Calculate Kt/V from Pre/Post BUN

6. The Kt/Vs found are:
   a) all greater than 1.2.
   b) all less than 1.0.
   c) all reflect adequate dialysis care.
   d) all reflect three times a week dialysis.
   e) none of the above.

7. T F Dialysis dose can be generally defined as the amount of hemodialysis given per time or per week. Any specific definition of dialysis dose must include both the frequency per week of dialysis and the length of time of each dialysis.

8. T F The URR is a formula which calculates an *estimate* of the amount of urea removed during one dialysis. No times are given nor frequency of dialysis per week are incorporated in determining the URR.

9. T F Obtaining the pre-dialysis BUN from the first dialysis of the week and the post-dialysis of the last dialysis of that week, will result in a URR which is both false and very high.

10. T F If the post dialysis blood sample is drawn without care to avoid saline contamination, the post dialysis BUN may be lower due to the presence of that diluting saline solution.

11. T F Figure 2 - Half-Lifes BUN shows that to remove almost all of the total body water's urea by dialysis will take seven (7) half-lives or ten and one-half (10.5) hours.

RETURN THIS POST TEST FORM TO:

Hemodialysis, Inc
1560 E Chevy Chase Drive, Suite 435
Glendale, CA 91206-4175
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State of Licensure ______________ Date______________________________

Post Test Answer Form - Circle the correct response

1. A B C D E
2. A B C D E
3. A B C D E
4. A B C D E
5. A B C D E
6. A B C D E
7. T F
8. T F
9. T F
10. T F
11. T F

Glossary

1 DOQI A four letter acronym. Pronounced by the faithful as "Dough-Key," meaning: **D**ialysis **O**utcomes **Q**uality **I**nitiative. Launched in 1995 by the National Kidney Foundation (NKF) with funds from Amgen. Using the NKF words, "A groundbreaking initiative undertaken to develop and implement treatment guidelines for patients with end-stage renal disease (ESRD)." Originally published as five (5) small books in 1998 containing about one-hundred and sixty eight (168) recommendations for dialysis care. The section on "Adequacy of Dialysis" contains a discussion for use of URR or Kt/V; nothing else. The authors of DOQI have declared that most to all of these 168 recommendations are evidence based. The DOQI study reviewed only a small fraction of the available literature on hemodialysis and drew conclusions from that small subset.

2 HEMO, the name for the research idea formerly known as the MMHD (Morbidity and Mortality in Hemodialysis) project. HEMO, a fifteen (15) center National Institute of Health (NIH) thirty-three million dollar ($33,000,000), five year study which began about 1995. It task is to determine if the small dialysis dose of a Kt/V of 1.0 is worse than a Kt/V dialysis dose of about six to ten percent (6 - 10%) higher. Patient mortality will be used as the gold standard to measure outcomes. There are nineteen (19) principal investigators, most are academic professors of medicine and nephrology. HEMO is the successor to the National Cooperative Dialysis Study (NCDS) done twenty-five years ago.

3 Irrational number, are numbers that can't be converted into a simple fraction. Examples of irrational numbers are: pi (π) or 3.1415…, the square root of two (2) 2.141…, the natural logarithm 2.718…. Irrational numbers may be denoted in print by the addition of ellipses (…) to the number.

4 Real numbers, numbers that exist. Real numbers are numbers that have a precise position on a ruler or measuring device. They may be whole numbers such as 1, 2, 3 or fractional numbers such as 3 ½ , 4 ¼; or decimal numbers such as 5.5. Though the number zero (0) exists on a ruler as the junction between negative real and positive real numbers, some textbooks state that zero is not a real number. Like everything else, knowing the definition is all important.

5 Imaginary numbers, numbers that don't exist. These numbers are used in higher mathematics to describe complex wave forms such as the sine wave of alternating electrical current. The best known example is *i*, the square root of minus one. By definition, squaring any number makes it a positive number thus there can be no such number as *i*. But it is commonly used, along with the natural logarithm to calculate wave forms.

6 Mathematics as a measure of the truth. Almost all (99.99%) health-care professionals believe that mathematical analysis of data using statistics will always provide the truth of a complex problem. Unfortunately they are wrong. Mathematics is a human construct. Made for and by humans; thus is fallible like the inventors of the art of mathematics. For those who believe this definition is false, please solve the following *simple* mathematical[19] problem:

The Problem

Three (3) academic nephrologists meet and greet each other and decide to share lunch. After lunch, the waiter states that the bill is thirty dollars ($30.00). Each physician gives the waiter a ten (10) dollar bill ($10.00). The waiter carries these three (3) ten dollar bills totaling thirty dollars ($30.00) to the cashier. The cashier states that the bill is really only twenty five dollars ($25.00) and tells the waiter to return the five ($5.00) to the three (3) doctors. On the way back to the dining room, the waiter ponders this and decides to pocket two (2) dollars and give each MD a one dollar bill ($1.00). He does so and walks away thinking, "Each doc paid 10 minus 1 for his lunch. That is 9 dollars each. I have two bucks in my back pocket. Where the hell is that other dollar!?"

The Reward

If you can solve this problem, the authors will send you a free copy of our newest monograph, "Blood & Uremia - 2000" which is a beautiful 226 page book containing thirty contact hour credits. The solution must be written simply and understandable by virtually anyone who reads the solution. The answer must include the math to explain where that dollar went!

Contact Hour (CH) Credits

This educational article is especially designed for two (2) contact hour (CH) credits for registered nurses (RNs), Patient Care Technicians (PCTs), and other direct care personnel who are licensed or certified by the Board of Registered Nursing (BRN) of California. Most (not all) American states recognize and accept the California BRN certified CHs. Thus, most American health-care personnel can receive CHs which are applicable for re-certification or re-licensure. It is the reader's responsibility to contact their state BRN or its equivalent prior to submitting the post test for CH credits to their state agency.

Other Values of These CHs

Other nursing organizations also recognize California BRN CHs. Again, it is the reader's responsibility to contact these organizations to verify that they accept California BRN CHs. We make no claim or representation that the earned CHs are applicable outside of California. Since 1998, Hemodialysis, Inc (**Hi**) has published nursing literature containing CHs. These educational instruments have been purchased by dialysis and other nursing personnel in most if not all of the fifty (50) American states as well as overseas and Canada. Letters from purchasers whose state or country does not have a BRN nor requirement for CHs have indicated that employers use and value these CHs for evaluation of the employee for promotion and salary enhancement. Thus, these CHs have substantial value even if they can not be applied towards re-certification or re-licensure.

Other Benefits From This Article

Understanding the content of this educational article is vital for the health-care professional who attempts to provide competent care for the ESRD patient. The authors know of no other single written or electronic file which clearly discusses and explains the concepts, formulas, and graphs in this article.

Hemodialysis, Inc (Hi), Provider of the Free CHs

The certifying agent for these CHs is **Hi**, a Southern California health-care corporation. **Hi** makes these CHs available as a free perquisite to the readers of this educational product. Arrangements are underway to have this educational product published by ESRD related magazines in order to make these CHs more widely available to the health-care community as a community service.

Conditions of Receiving CHs

Those health-care personnel who wish to receive a certificate for these two CHs are required to correctly answer and submit the eleven (11) question post test by mail to **Hi.** Please do not fax the post test; it will not be processed.

Must Submit Post Test with Stamped Envelope

A first-class affixed stamp to a self-addressed business envelope (9 x 4 ¼") ***must*** be enclosed with the eleven (11) question post test in the mailing to **Hi**. No request for CHs will be processed without this requirement.

Educational Article Content

Excellent medicine and nursing care is a moving target. The content of this educational article, the questions, and the graphics, are current, topical, and have been generated specifically for this article. The authors have chosen to present fresh data, opinion, and information not widely disseminated in the ESRD community but vitally important to excellent medical and nursing care.

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