Body Mass Index and Uremia

John R De Palma, MD, FACP

CEO – Hemodialysis, Inc (**Hi)**

℘

Joanne D Pittard MS, RN

Professor of Allied Health – Glendale Community College

Revision #: 176

Introduction

This educational article will instruct the student in the use of the body mass index (BMI) and its application in the treatment of the End Stage Renal Disease (ESRD) patients. The BMI is a centuries old formula, which is useful to estimate:

- malnutrition
- obesity
- lean body weight
- "dry" body weight
- total body water (TBW)
- hemodialysis ultrafiltration calculations
- dialysis dose
- incidence of diabetes mellitus type II
- epidemiologic correlations.

Objectives

1 Identify two (2) assessment tools being used today to determine obesity.
2 List five (5) disease states associated with BMI values of 30 or more in individuals without renal failure.
3 Calculate the BMI for yourself and your associates in your work place. Determine for each of you if any kind of dietary intervention is needed.
4 List four (4) reasons why body height is important as a measure of health and disease states.
5 Define anthropometric assessment.
6 List three (3) examples of methods of anthropometric assessment.

7   Define the term "gold standard."

8   Give three (3) examples of clinical gold standards useful in ESRD care.

9   Define the relationship any two (2) formulas which both use the variables of body height and weight. Will the results of these formulas be similar?

10   Define the term adequacy of dialysis as it relates to ESRD patients.

11   Identify at least two (2) parameters to assess when using the multiple criteria approach to adequacy of dialysis.

12   List twelve (12) types of different studies, which use BMI as a marker.

BMI, a Gold Standard?

A gold standard is that test or measure which serves as the best marker for a disease or condition. The hematocrit (Hct) is the clinical gold standard for red blood cell mass and indicator of anemia in the ESRD patient. Its surrogate, hemoglobin is the best measure for *payment* for epoetin by the American federal agency, the Centers for Medi-Care and Medi-Cal Services (CMS). The original meaning of gold standard was the measure of the quality of money used by a government. The gold standard for money in America is silver.

This series of educational articles targets simple, useful clinical tools for the healthcare worker who seeks to improve patient care of the ESRD patient. We will suggest and focus on the BMI as a possible gold standard for the *clinical* estimation of the ESRD patient's nutritional state. We choose the BMI with full knowledge that many have published that there are much more sophisticated, powerful, and accurate tests for blood fluid compartments and body fat. Once these values are obtained, formulas are used to derive an estimate of the body's nutritional state. Unfortunately, these tests are not simple, reproducible, in-expensive, nor easily available. If time and money are the currency of medical care, then the BMI may become be the gold standard for body habitus for ESRD patients.

The BMI Is A Clinical Tool

Many if not all of the tests for total body water (TBW), extra-cellular water (ECW), lean body weight (LBW) and other measures of body muscle mass or fluid compartments require knowledge of the patient's height and weight. These two variables, the patient's weight and height, decide --mathematically– a substantial or, in some formulas, the *majority* of the final value of these testing systems. These more exact tests invoke the use of: radio-isotopes, injection of compounds such as antipyrine, measurement of bioelectric impedance, conductance, or bioelectric impedance analysis (BIA).

BMI is Easy To Use

We have no quarrel with any and all of these sophisticated undertakings. The end result may be only somewhat better than measuring the patient's BMI. The BMI can be done on data that is (or should be) normally collected on all ESRD patients. That BMI can then be used as a starting point to determine body composition and nutritional analysis.

Figure 1 - Commemorative Belgium Stamp of Doctor Quetelet

The Quetelet Index

Doctor Adolphe Quetelet invented the BMI formula. Doctor Quetelet was born in 1796 in Ghent, Belgium. He received his first doctorate in mathematics in the city of Ghent. Over time, Doctor Quetelet received other doctoral degrees. He became a trained astronomer and social scientist. After studying the new theory of probability in Paris, France he used this knowledge to devise a formula to estimate the body habitus of his Belgian countrymen. Doctor Quetelet organized the first international conference on statistics in 1853.

He died in Brussels, Belgium in 1876. Figure 1, above is redrawn from a commemorative Belgium stamp issued in 1974 honoring Doctor Quetelet's many accomplishments. The stamp depicts Doctor Quetelet as a young man, dressed in the style of the day.

Quetelet Index, Not Used for Centuries

Doctor Quetelet's name is the eponym for "The Quetelet Index." Though known since the 1800's, the Quetelet Index lay fallow for over one hundred and fifty (150) years. Only in the last decade of the past millennium has this simple formula gained substantial use and common recognition. Before 1990, it was dimly referenced in medical physiology[1] as a possible measure of obesity.

The Original Quetelet Index Formula:

$$\text{Quetlet Index (QI)} = \frac{\text{Weight in Kilograms}}{\text{Height in Meters}^{\text{squared}}}$$

Equation 1 – Original Quetelet Index Formula

How to Remember the Units of Measure

The units of measure for the original formula is thus "kilograms per meter squared" (kg/m^2). As simple as this formula is, it is easy to reverse the height and weight numbers. An easy mnemonic and way to remember the units of measure of the BMI and which number is the numerator and which is the denominator is to associate the BMI to a "pressure." Consider the units of measure of air pressure such as in an automobile tire. That pressure is expressed in United States of America (America) as "PSI" which is "pounds per square inch" (pds/in^2 or $\#/in^2$). In metric terms, that pressure is: "kilograms per meter squared." For the rest of this discussion the BMI will be expressed as a number with no trailing units of measure unless the author of a quoted article has included those units of measure.

The BMI Formula Using "Pounds & Inches"

Many decades ago, Americans set the educational wheels in motion to convert the reporting of numbers from the English "pounds and inches" number system, to the metric system of "kilograms and meters." That goal has not happened. Most of us, young and old, still use the English system and struggle with conversion numbers. We struggle to convert the metric number standards, "kilograms and meters" to our beloved "pounds and inches." The formula for "pounds and inches" as variables for the BMI is:

$$\text{BMI} = \frac{\text{Weight in Pounds times 703}}{\text{Height in Inches squared}}$$

Equation 2 – BMI Using Pounds & Inches

Truncated Conversion Factors

Many of us have arrived –by different mathematical paths– at the BMI correction factor of "703…." to convert the original "kilogram and meters" variables to "pounds and inches." The ellipses (…) after the number 703 means we believe that number to be irrational. An irrational number is one that cannot be evenly divided by another number. The decimal fraction of an irrational number is composed of a non-repeating set of decimals. A common example of an irrational number is the number *pi. Pi* is 3.14159…. It is the ratio of the circumference to the diameter of any circle. *Pi* is probably the most common irrational number.

However, some medical texts use a *larger* number such 704.5 or 705. No less than The American College of Physicians, American Society of Internal Medicine (ACP-ASIM)[2] has published

a table using the a BMI conversion factor of 704.5 The same BMI conversion factor is used on their web site in a JavaScript™ formula to calculate BMI.. They published a table in 1998 for physicians of internal medicine showing the BMI for various heights and weights derived from the conversion factor of 704.5. We also published a BMI table about 1998.[3] Theirs and our tables or charts contain different values as we used the conversion factor of 703…. Our tables and charts match the European charts that use "kilogram and meters" and others, which use "pounds and inches," based on those European charts or tables.

A Tempest In A Teapot?

One might argue that this is a tempest in a teapot. The difference between the numbers 704.5 and 703…. is less than one percent. But, mathematics is –probably– the hardest science we have. If we can't agree on a relatively simple conversion of "kilograms and meters" to "pounds and inches," can we discourse on exponential formulas such as Kt/V or the half-life (t½) of heparin?

BMI Charts Are Everywhere

We need the patient's trust to correct their dietary indiscretions or to reduce their sodium and caloric intake. If we advise them that their BMI is too high or low, we need to then plot a course of action. Can the patient trust us if we can't calculate –accurately– a conversion factor? We know these patients find BMI tables and formulas in lay magazines, a nutritional manual[4], and newspaper inserts such as "Parade." These lay publications use BMI tables and formulas with the conversion factor of 703…. One nephrology textbook[5] uses a conversion factor for "pounds and inches" of 705.

The query is, "How did these medical publications arrive at the correction factor, 704.5 or higher?" The intuitive answer is that incorrect conversion factors for kilograms to pounds and meters to inches were used. We didn't, in 1998, know how to mathematically deduce a correction factor that contained a square of a number multiplied by another number. In writing the monograph, "Blood & Uremia,"[6] we used Microsoft's Excel 5.0c with an iterative formula to arrive at the number 703….

This year, we laboriously and formally determined the exact BMI correction factor for the American "pounds to inches" formula. We have deduced:

Kilogram Factor

$$\text{Weight in kilograms factor} = \frac{\text{Weight in Pounds}}{2.204623...}$$

Equation 3 - Kilogram factor for BMI

Height Factor

$$\text{Height in meters factor} = \frac{\text{Height in Inches}}{39.37001...}$$

Equation 4 - Meters factor for BMI

Expressed as a formula:

$$\text{BMI} = \frac{\text{Weight in Pounds}/2.204623...}{\text{Height in Inches}/39.37001...\ \text{squared}}$$

Equation 5 - BMI Factors

BMI Conversion Factor

Thus the final, single conversion factor is:

$$\text{BMI factor} = \frac{39.37001...^2}{2.204623...} = 703.07...$$

Equation 6 - Final BMI Factor

If the conversion factor for pounds to kilograms is set to be 2.2 (rather than the correct 2.204623[1]) and the height conversion factor for meters to inches set to be 39.37, one arrives at the conversion number of 704.5440…. We assume that those authors who use a number of 705 or higher decided to round up the number.

Anthropometry

Anthropometry (pronounced an.thro.**pom**$.e.try) is the science which deals with the measurement of the size, weight, and proportions of the human body. The prefix, "anthropo" is from the Greek word *anthrō pos* which means "man, human being." Some tasks or measurements associated with anthropometry are:

- body compartments (muscle mass, lean body mass…)
- body estimation of fat
- body fluid spaces (TBW, ECW, plasma water…)
- habitus (body habitus)
- height
- weight

to determine body composition in health and disease.

---

[1]   Kilogram definition in Dorland's Medical Dictionary, 1988, page 879.

Body Habitus

Habitus, is the physical and constitutional characteristics of an individual. In medicine and nursing habitus is important to assess and determine in health and disease states. The term body habitus is used for additional clarity though that two word term is partially redundant. Habitus means body shape and size. The definition of body habitus is a part, not the whole, of anthropometry. The attributes of the individual which are his/hers habitus can be determined by sight, without weighing or measuring the person. Body habitus is what you see. The classic beginning of a well written medical history and physical describes body habitus: "The patient is an alert, lean, well nourished, well developed, male who appears younger than his stated age."

The Burgeoning Use Of The BMI

There has been an explosive growth in number of articles that use the BMI since about 1990. These articles averaged about one-thousand (1,000) per year in the last decade of the last millennium. Prior to 1990, there were, at most, one or two articles per year that used the BMI as a variable or marker to tease out the association of body habitus with various illnesses and genetic entities.

Genetics And the BMI

As an example of how useful the BMI has become, a 1990 article in the New England Journal of Medicine addressed the relative importance of genetic versus environmental effects on the body habitus. Does environment or heredity determine obesity in later life? The authors, Stunkard[7] et alle, studied ninety-three (93) pairs of identical twins reared apart, and found that the majority had similar BMIs. The results indicated that genetic influences (heritability) were more important than childhood environment. Important and useful information easily gained by using a simple formula.

The World Health Organization

Part of the exponential growth in papers and reference articles that use the BMI is due to the World Health Organization (WHO)[8]. The WHO studies discuss a variety of important medical findings:

1   Increasing Obesity In Adolescents:
The Netherlands, the United Kingdom, and the USA are among the countries with recent reports of increased prevalence of obesity in children and adolescents. The evidence suggests that obesity rates are related more to a reduction in energy expenditure than to an increase in caloric intake. Prevention of obesity through the promotion of a healthy lifestyle is an important challenge for the new millennium, and should start in childhood.[9]

2   Underweight Increases Mortality in Non-Smokers:
The relation between body mass index (BMI) and mortality among the 20, 346 middle-aged (25-54 years) and older (55-84 years) non-Hispanic white members of the Adventist Health Study (California, 1976-1988 who had never smoked cigarettes and had no history

of coronary heart disease, cancer, or stroke) was examined in a 12-year prospective study. The findings identified adiposity as a risk factor among adults, and raised the possibility that very lean older women can experience an increased mortality risk that may be due to their lower levels of adipose tissue-derived estrogen.[10]

3   Diet and Hypertension:

The authors compared the differences in diet-related factors and their associations with blood pressure (BP) between Chinese and Japanese. A total of 1,151 Chinese and 1,681 Japanese were studied. This work was a constituent part of the World Health Organization (WHO) Cardiovascular Disease and Alimentary Comparison (CARDIAC) Study. Japanese men had a significantly higher mean systolic and diastolic BP. Japanese women had a significantly higher diastolic BP than the Chinese subjects. Japanese had significantly higher mean BMI, serum total cholesterol, sodium excretion, and lower mean magnesium excretion than Chinese.[11]

4   Epidemic of Type II Diabetes in Adolescents:

The common denominator in patients who develop adolescent-onset type II diabetes was extreme obesity with body mass index of 35-38 kg/m^2, accompanied by family obesity, a diet rich in fat and sedentary lifestyle. The current epidemic of type II diabetes among adolescents demonstrates that failure to prevent obesity at primary and secondary opportunities for intervention leads to the development of associated diseases with significant morbidity and potential mortality. Family education programs are needed to institute gradual, permanent changes in diet and activity.[12]

5   Diet Therapy, Too Little, Too Late:

Overweight and obesity are increasingly prevalent in the United States. The authors examined the percentage of individuals who reported being advised to lose weight by a health care practitioner. Participants were individuals in the 10 states participating in the 1996 Behavioral Risk Factor Surveillance System. The prevalence of reporting advice to lose weight was most strongly associated with body mass index (BMI). In individuals with a BMI of 25 to 27, only 5.6% of those with no co-morbidities and 13.6% of those with co-morbidities received advice. These rates were increased to 32.4% and 47.3%, in those with a BMI greater than 30. Advice to lose weight is uncommon and is given primarily to those who are already obese, are middle-aged, and have co-morbidities.[13]

6   Education and Obesity:

Twenty-six (26) different populations were sampled. Almost all populations showed the less education, the higher the BMI. Lower education was associated with higher BMI in about half of the male and in almost all of the female populations, and the differences in relative body weight between educational levels increased over the study period. Socio-economic inequality may increase obesity in many countries.[14]

BMI, a Measure Of Ideal Body Weight

Chen[15] and associates, in the year 2000, studied the body composition of hemodialysis patients and normal subjects. The results indicated that lean body mass (LBM) and the LBM/body weight ratio was not different between hemodialysis patients and normal subjects. The LBM of hemodialysis patients correlated with gender, height, and weight.

Slightly over a decade earlier, in 1991, Tokunaga and others reported that the ideal body weight could be estimated from the BMI.[16] They investigated the ideal body weight and BMI in respect to morbidity in 4565 Japanese men and women aged 30-59 years. The value of BMI associated with the lowest morbidity was 22.2 kg/m^2 in men and 21.9 kg/m^2 in women. They proposed that the ideal body weight is a BMI of 22.

A study by Kannel[17] using the data from the Framingham Heart Study and from other studies concluded that the degree of overweight is related to the rate of development of cardiovascular disease. They concluded that the optimal weight for avoidance of cardiovascular disease and prolonging life corresponds to a body mass index of 22.6 for men and 21.1 for women. Thus, both oriental and occidental data show that a BMI of about 22 can be a surrogate for ideal body weight.

Are Lean Body Weight and Ideal Body Weight The Same?

Is ideal BMI or ideal body weight the same as an estimate of an individual's lean body weight? In a word, no. But we believe that these three numbers:

- ideal BMI
- ideal body weight
- lean body weight

may be almost all the same. They are a close fit to one another. The lean body weight of a person is that body weight in a healthy normal that has a minimum amount of adipose tissue. There is some evidence that is a BMI of 22 can be an estimate of lean body weight.

Formula for TBW

Without access to a research center, one can estimate a patient's TBW with the time-honored formulas of Watson, Watson, and Batt. The authors' are/were PhDs in biochemistry or biophysics. They studied a small group of normal subjects of a "Western population" in New Zealand using an intravenous (IV) injection of the compound antipyrine. Antipyrine is not a radioisotope and disperses in the TBW. After a suitable period of time, knowing the exact total amount of antipyrine given IV, a blood sample is analyzed for the diluted antipyrine. The TBW can be easily and quickly calculated. These investigators analyzed the work of other, including the Hume and Weyers[18]. They incorporated these and other authors' findings into their formulas.

This historical review is important as many authors use both the Watson, Watson, Batt *and* the Hume and Weyers formulas. These authors may not be aware that the findings of the older study

of Hume and Weyers in 1971 are incorporated in the studies and formulas of Watson, Watson, and Batt reported in 1980. We think the *clinical* gold standard for an estimate of TBW is the Watson, Watson, and Batt formulas.[19]

For males:

$$TBW = 2.447 - 0.09516 \times \text{Age in years} + 0.1074 \times \text{Height in cm} + 0.3362 \times \text{Weight in Kg}$$

Equation 7 - TBW Formula for Males

For females, these investigators found that a correction for the age of the subject was unnecessary:

$$TBW = -2.097 - 1.069 \times \text{Height in cm} + 0.2466 \times \text{Weight in Kg}$$

Equation 8 - TBW Formula for Females, No Age Correction

Note that both formulas rely heavily on the variables "height and weight." All (as far as we have determined) anthropomorphic measures, which seek to determine body habitus and nutritional status, rely on the two parameters of height and weight. These two variables or parameters make up the BMI.

Estimating TBW From BMI

The Watson, Watson, Batt formulas make no correction for obesity. A person, who is morbidity obese, with a BMI of 30 or more, will have –incorrectly– a large TBW calculated by the Watson, Watson, and Batt formulas. How does the use of the BMI give a possibly better estimate of TBW?

Lean Body Weight and Total Body Water

We discussed total body water (TBW) and body weight as they relate to the ESRD patient in an earlier article.[20] The TBW is closely related to muscle mass. An estimate of lean body mass can be obtained if the TBW is actually *measured*. Measuring TBW accurately often means using an intravenously injected radioisotope or antipyrine. This test is neither a trivial nor a brief process. Muscle and tissue cells –the major components of lean body mass– are about seventy-three percent (73%) water. If the individual's TBW is measured as forty-two (42) liters then his/her lean body weight or mass of body muscle and non-fat cells is (42/73%) or 57.53 kilograms – see Equation 9 below:

$$\text{Lean Body Weight} = \frac{TBW}{.73}$$

Equation 9 - Lean Body Weight

Rearranging Equation 9 above, allows us to estimate percent excess body fat[21] as:

$$\text{Percent Excess Fat} = \frac{1 - \text{Percent TBW}}{.73}$$

Equation 10 - Excess Body Fat

If one calculates his/her BMI and applies the above equations to determine "Percent Excess Fat" almost all will be alarmed. Many will become despondent and feel the urge to increase their BMI with a box of high calorie sweets. Obesity –in the strictest sense– can be defined as a body fat greater than twenty percent (20%) of body weight in the adult male, somewhat higher for the adult female. By this stringent definition, almost all Americans over forty-five (45) years of age are obese.

The BMI is a more forgiving estimate of obesity, *See* Table 1- BMI Key to Body Habitus on page 14.

Can TBW Be Estimated For Dialysis Dose Without Body Height?

Many who use Kt/V[22] and other formulas to measure urea removal by a dialysis procedure do not correct their estimate of TBW for obesity. They use body weight and the fraction of 58% as the estimate of TBW. More improbable is that there is no mention of the equally important, necessary, and vital variable, body height. These investigators write that they use the human kidney's function as the gold standard for renal function. These authors state that estimating dialysis dose is intimately related to the human kidneys' amount of function.

Normal Kidney Function Estimation Uses Body Height

The most common of the human kidney's functions is expressed as a clearance, as glomerular filtration rate (GFR). This GFR is commonly expressed for the adult male as a GFR of 120 mL/min per 1.73 meters squared (m^2). That value can use a hypothetical adult male who weighs sixty-four and one-half (64.5) kilograms and is sixty-six (66) inches (1.68 meters) tall. His surface area is 1.73 m^2. His BMI is 22.85 {64.5/(1.68^2)}. Note the height and weight. It is not by chance we have chosen them. These values are close to the average height and weight of Americans on dialysis and *almost identical* to those of our patient population *See* Figure 7 on page 24.

Large individuals have more kidney function (GFR) than small. All formulas (that we are aware of) use body height to calculate body surface area in meters squared. How then can one leave out the absolutely vital variable, body height, in a formula to estimate TBW? In truth, one can't. If one does, one is led to impossible conclusions such as the real, not hypothetical, four hundred and eighty five (485) pound –220 kilogram– ESRD patient we have dialyzed with the impossible TBW of (220*58%) of 128 liters!

Body Surface Area and BMI

One cannot –truly– estimate TBW without factoring in body height. But… does body surface area, the gold standard of measure for many values of the body from cardiac index (cardiac output in liters per minute) to GFR relate mathematically to BMI?

That is a trick question. If two formulas use the same principal variables, they will be in almost perfect agreement. Plotted as a graph, these numbers will often form a straight line with the mathematical probability of one set of numbers agreeing with the second set of about one hundred percent. Both number sets may agree perfectly. The common statistical number used in these graphs is "R" or the coefficient of correlation. The square of that number is "R^2" and is the coefficient of determination, or how much variability of one number is due to the second number.
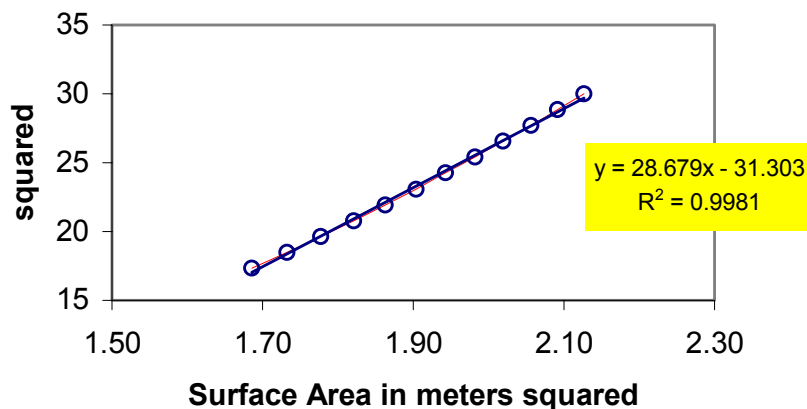
Compare Surface Area to BMI

Figure 2 - Comparison of Surface Area to BMI

Figure 2, above is a plot of various heights and weights using DuBois and DuBois[23] surface area formula and the BMI values for those heights and weights. These two formulas or calculations that use height and weight agree perfectly. For this, and other reasons, we feel fairly confident in using BMI as a surrogate for bioelectric impedance analysis (BIA) and other techniques that estimate body spaces or body fat and use body height and weight as substantial parts of their formulas.[24]

An Estimate of Body Fat From BMI

Unlike muscle, fat contains very little water, on the order of about ten percent (10%) of total weight. Fat, except in the massively obese, contribute only trivially to TBW. A lean adult male has a TBW is about sixty percent (60%) of body weight. A lean man with a TBW of 42 liters weighs 70 kilograms (42/60%). His svelte physique has a body fat of {(70-57.53)/70} eighteen (18%) percent. Our hypothetical average American whose height is five feet ten inches (5' 10") has a BMI of 22 {(153*703)/70^2}. The formulas for estimating a BMI of 22 is:

$$\text{Body Weight if BMI is 22} \ = \ \frac{\text{Weight in pounds}}{\text{Measured BMI}} \times 22$$

Equation 11 - Body Weight at a BMI of 22

Knowing the person's ideal body weight, that weight at a BMI of 22, allows one to estimate the TBW using sixty percent (60%) of that ideal body weight. Let's use a middle-aged male who is five foot ten inches tall (70 inches) and weighs two hundred and twenty pounds (220 pounds). Using Equation 2 on page 4, (220*703/70^2), we know his real BMI is 31.56. Using Equation 11 above, we find that his weight, if his BMI were 22, would be (220/31.56*22) or 153.36 pounds.

We estimate his TBW as sixty percent (60%) of his ideal body weight, giving us about forty-two (42) liters of TBW; the same number used to calculate the lean body weight above. At that weight his body fat would be about eighteen percent (18%). But what is his body fat at his real weight? If all the weight from 153.36 pounds to the 220 pounds is just fat, then his body fat may be forty-two percent (42%) {(220-(57.53*2.2))/220}. Does his TBW increase as his body weight increases? Only if he adds muscle and not fat.

Does Obesity Increase Muscle Mass?

Some have argued that obesity begets muscle to carry the increased weight. We are aware of obese weight lifters and obese football players who fit this model. We are aware of no ESRD patient… not one, that fits the body habitus of heavily muscled and obese athletes. We have dialyzed football players, boxers and the like. By the time we receive them, most of this hard-earned muscle has been cannibalized by their own body during periods of protein/caloric malnutrition.

Using body weights without regard to body fat estimate TBW may cause substantial errors in calculations of the TBW. Normalizing the person's weight to a BMI of 22 helps correct these errors due to obesity.

BMI and Body Fat Across Ethnic Groups

The above calculation of body fat and TBW from the BMI are *estimates*. Different ethnic groups have different amounts of body fat for the same BMI. We quote from an author who has written extensively on anthropomorphic measures, "The relationship between percent body fat and BMI differs in the ethnic groups were studied. For the same level of body fat, age and gender, American Blacks have a 1.3 kg/m^2 and Polynesians a 4.5 kg/m^2 lower BMI compared to Caucasians. By contrast, in Chinese, Ethiopians, Indonesians and Thai's BMIs are 1.9, 4.6, 3.2 and 2.9 kg/m^2 lower compared to Caucasians."[25]

BMI, a Lean Body Weight Surrogate

We have adopted the BMI formula[26] as an *estimate* of the lean body mass because –at the present time– there is no simple, easy, accurate, and inexpensive method of measuring TBW to determine lean body weight. The lean body weight is important to know. An estimate of the lean body weight allows the calculation of dosages of important IV medications such as heparin. The lean body weight allows the estimation of TBW.

Body Habitus and BMI

Used for what it is –an estimate of body habitus– the BMI is a good clinical tool. The BMI is much like the serum Na^+ and Hct, useful in the day-to-day management of ESRD patients. Table 1, below is a key to the range of BMI values for different body habitus. As we have indicated, an evaluation of current medical literature proofs out that lean body weight or mass, is a number close to a BMI of 22.

Body Habitus	Range
• Under-weight	16 through 18
• Normal	19 through 24
• Obese	25 through 29
• Morbidity Obese	over 30

Table 1- BMI Key to Body Habitus

Body Height, A Forgotten Measure

Body weight is a necessary pre and post-dialysis measure. Not so for the patient's height. If the patient's height is not taken and logged early in the treatment program, it is usually not done at all. The USRDS[27] report of 2000 indicates that the majority of new ESRD patients have a BMI calculated. That means that they must have had a body height at least *estimated*. We believe, based on our direct documentation that the data collected for height is nominally, normally, usually, and invariably basically by *asking* the patient how tall he or she is; not by direct measuring.

Since ESRD patients average about 62 years of age and since body height decreases with advancing age, we believe the actual height is substantially *less* than reported. Using the incorrect (estimated, not measured) *greater* height will *elevate* both the: calculated TBW and BMI.

In December 2001 and January 2002 we validated and measured heights of about five-hundred (500) of our patients. More often than not, the original heights logged on the charts appeared to from the memory of the patient or an estimate by the staff as they were different from the actual height measurement. We performed standing heights on all ambulatory patients. Patients who could not stand were measured with a cloth, non-elastic tape measure, *See Figure 3 - Tape Measure*, on page 15. For those who would like information about this excellent and inexpensive measuring device nominally used to measure US mail packages, please leave us a note on our web site.

We have no patients with missing limbs. If we did, we would have had to disregard these patients, as we have no formulas to measure BMI in patients with missing limbs.
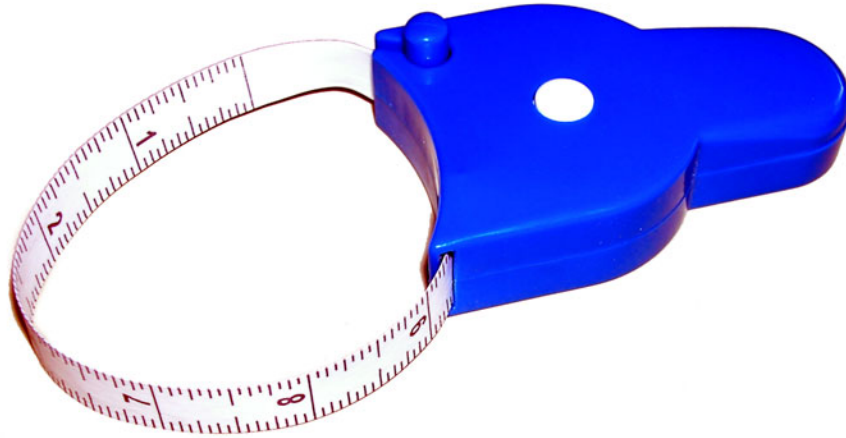
Figure 3 - Tape Measure

Limb Amputation And BMI Values

Only one ESRD author[28] has addressed limb amputation and BMI. This author states, "Amputation affects the relationship between weight and height independently of the degree of obesity. Corrections of both ideal body weight and BMI for amputation have been published, but a… computer nutrition program used in the authors' institution uses only the correction for ideal body weight…. Amputation without height loss decreases uncorrected BMI, while amputation with height loss increases, in general, uncorrected BMI.…"

Methods to Measure Body Fat

There are several methods of assessing body fat. They are:

- bioelectrical impedance (BIA)
- body specific gravity (hydro-densitometry)
- TBW by radio-isotope or antipyrine
- dual X-ray absorptiometry
- body part measurement (waist and forearm circumference, skin fold thickness, et cetera); the indirect anthropometric techniques and reference to charts
- BMI

all of which have advantages as well as limitations.

BMI&Uremia.doc

Bioelectrical Impedance Analysis (BIA)

Several authors[24] have reported successful use of BIA to measure first TBW then used to estimate other body compartments. BIA is a noninvasive estimation of body water; it could be a very useful technique for clinical monitoring and study of abnormalities of body water. Studies show that BIA is dominated by the arm (46%) and leg (44%) resistance (impedance). The trunk, which represents an average of 46% of the body weight, accounts for only 10% of the total impedance. The presence of:

- fever
- unilateral lymphedema (associated with an arterio-venous (AV) fistula
- supine or standing position
- AV fistula, central venous catheter, or vascular graft

all may result in measurement errors.

If and when CMS authorizes reimbursement for BIA for TBW, we will undertake a study to tease out these problems associated with BIA.[29] Until then, we believe that knowing the patient's height and weight, calculating the BMI and doing a *trend analysis* of the BMI values on each patient will have to suffice.

Is a BMI of 22 a fair measure of TBW?

If one calculates the TBW for a group of ESRD patients who are not obese, there is a fair correlation between the formulas of Watson, Watson, Batt and using a BMI corrected to 22. Since the Watson, Watson, Batt formulas are different for men and women and give a higher TBW for men, we elected to use sixty percent (60%) of the adjusted body weight for men and fifty-five percent (55%) for women in calculating the estimated TBW. Figure 4, below is a graph which compares the TBW for one-hundred and thirty-six (136) ESRD patients using the Watson, Watson, Batt formulas against a BMI of 22. The coefficient of determination (R^2) is 0.4696 and the correlation coefficient "R", is 0.685. Both values indicate that there is fair agreement between both formulas. This means there is a fair correlation between the two sets of numbers. The trend line drawn through the set of data points shows this relationship more graphically. If the association were perfect, the "R" would be 1.0 as it is the graph of body surface area and BMI (*See* Figure 2 - Comparison of Surface Area to BMI on page 12).

Compare TBW by Watson with BMI of 22

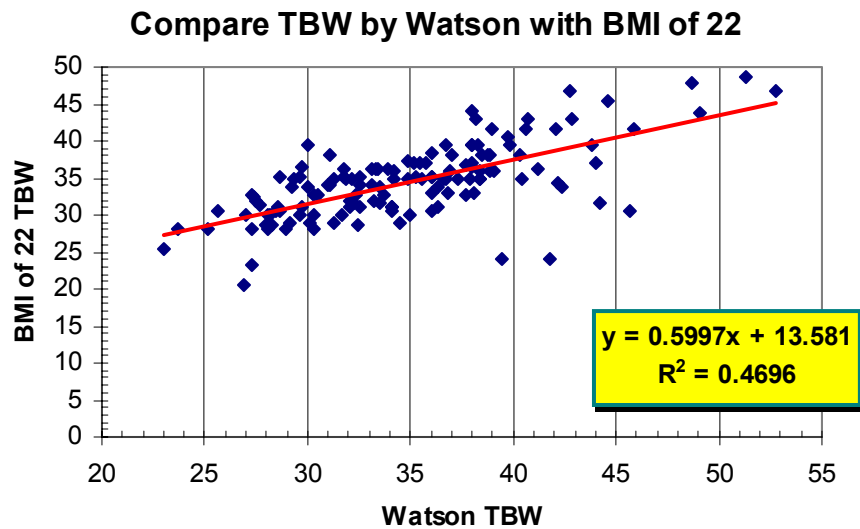$$y = 0.5997x + 13.581$$
$$R^2 = 0.4696$$

Figure 4 - Using BMI to Estimate TBW

What Are the Data for BMI in ESRD?

The reports and article about BMI at they relate to ESRD patients are unusual. Many of them indicate that obese ESRD patients do **not** confirm the literature of non-ESRD patients. In non-ESRD patients of many kinds, obesity is associated with increased morbidity (complications, hospitalizations, other diseases) and mortality (death).

High BMI Associated With Kidney Disease

In addition to a high BMI being associated with increased incidence of diabetes mellitus type II and hypertension, obesity is a primary marker for a form of kidney disease, which leads to progressive kidney failure.[30] These non-ESRD patients become ESRD patients.

The authors of this study wrote, "we assessed whether the presence of an elevated body mass index (BMI greater than 25 kg/m^2) at the time of the first renal biopsy correlated with clinical data, pathological data, and clinical progression to both arterial hypertension and chronic renal failure."

Their analyses indicated that the presence of an elevated BMI was associated with the severity of pathological renal lesions. Hypertension-free survival was less in overweight patients. Only elevated BMI and biopsy pathology were independent factors for the development of arterial hypertension. Biopsy pathology and BMI were both risk factors for ESRD. In IgA nephropathy, excessive BMI is a predictive factor for the development of arterial hypertension and, ultimately, ESRD.

BMI Studies in Non-ESRD Patients

There have been studies in Non-ESRD individuals who show that a BMI over about 22 (sic) is associated with increased:

1   Cancer

   a   Prostate

   b   Uterine

   c   Breast

   d   Colon

2   Coronary artery disease

3   Diabetes mellitus type II

4   High blood cholesterol or other dyslipidemias

5   Hypertension

6   Osteoarthritis

7   Sleep apnea

8   Stroke

BMI Data in ESRD Patients

We wrote about "Dialysis Dose" in the first article of this series. We wanted to inform the student that the urea removal studies championed by the United States Medi-Care program to define adequacy of dialysis did not truly define adequacy of dialysis. Just urea removal by dialysis probably has no direct role in patient survival. We noted that adequacy of dialysis care must include control of hypertension and provide adequate nutrition.

These markers of adequate dialysis care, control of hypertension and adequate nutrition, have been given short shrift by the Medi-Care program. A 1995 multi-million-dollar study involving almost all leading American academic institutions (dialysis outcomes quality initiatives (DOQI)) did not publish about nutritional issues initially. That information was published some years later.

In a large French study[31] of ESRD patients, nutrition and vascular disease were found to be the markers of survival, not urea removal. These authors wrote, "Nutritional factors and dialysis adequacy are associated with outcome in hemo dialyzed patients, but their relative contribution

remains controversial, particularly when dialysis adequacy complies with current recommendations (Kt/V >1.2). Survival, clinical, and nutritional data from 1,610 patients treated by hemodialysis in 20 centers in France, collected over a 2.5 year period, from January 1996 to July 1998."

These authors collected pre-dialysis and post-dialysis blood samples according to recommended procedures for dialysis quantification. Survival was significantly influenced by age, albumin level, prealbumin level, BMI, and diabetes, but not by sex, Kt/V, duration of dialysis, cholesterol level, hemoglobin level, or lean body mass.

Their patients had BMIs that averaged 23 ± 4.5 kg/m^2. Overall survival was $89.7\% \pm 0.8\%$ and $78.4\% \pm 1.1\%$ after 1 and 2 years. Note both the low average BMI and the survival data of about twelve percent (12%) per year in this study of ESRD patients. The survival is *twice as good as* the American survival rate for patients. The BMI values for these ESRD patients are also lower than the American experience.

These results indicate that nutritional protein concentrations are predictive of dialysis outcome. Dialysis adequacy (as measured by Kt/V or URR) had no influence on survival. Survival is dependent on age and nutritional status.

This trio of authors[32] also studied very aged ESRD patients and reported, "In a 30-month prospective study, we evaluated the role of nutrition on the outcome of 290 stable hemodialysis outpatients aged older than 75 years followed up in 20 French HD centers (167 men, 123 women; age, 79.8 +/- 4.2 years; previous time on dialysis, 41 +/-38 months)."

Again, cardiovascular mortality accounted for the majority of the patient deaths. They concluded that even in the very elderly HD patients, malnutrition influences overall survival despite adequate dialysis treatment.

Is Obesity Bad For ESRD Patients?

Surprising… it is not obesity with BMIs over 30, that is associated with increased mortality in ESRD patients, but a low BMI which is associated with malnutrition. It has been known for over a decade that black-Americans have better survival on dialysis than white-Americans. But what has not been noted is that black-Americans start dialysis an average of seven to eight (7 - 8) years earlier[27].

Years Of Potential Life Lost (YPLL)

The longer survival on dialysis of black-Americans does *not* make up for the "years of potential life lost (YPLL)" that they lose because they begin dialysis at an earlier age. The Centers of Disease Control and Prevention (CDC) had used YPLL to determine success of prevention/treatment of some therapies. We strongly urge and advocate that CMS and the USRDS begin to study YPLL for the ESRD population.

Yes, black Americans have more obesity. Yes, black Americans have more hypertension; and yes, they start dialysis earlier than white Americans. Because of obesity associated hypertension, black Americans require dialysis at a rate three to five (3-5) times than white Americans. Be-

cause they develop ESRD years earlier, they live *a shorter number of years* than white Americans.

The Hispanic Americans also have an increased incidence of obesity with an increase incidence of both hypertension and diabetes mellitus type II. This group has an incidence of renal failure of some three to five (3-5) times that of white-American, similar to the incidence of seen in black-Americans.

The Incidence Of ESRD Patients Doubled In The 1990's

We analyzed the United States Renal Disease System (USRDS) data some time ago. We determined that many physicians and nurses, unschooled in biostatistics, would be lost in the welter of "significant P values" and complex tables. We thought it would be nigh impossible to explain standardized mortality rates, gross mortality rates and other arcania with complex mathematics. We made this judgment while serving on the medical review board of Southern California ESRD Network #18.

We decided to write about what we discovered nestled deep in the hundreds-of-pages-long USRDS annual reports. We would present the data in an understandable manner, as a fairy tale.[33] The USRDS and the ESRD Network did not notice that the incidence (new cases each year) of Americans developing ESRD per year was increasing about nine percent (9%) per year.

We were seeing in a mature industry, one existing since the 1960's, an unprecedented, unexplained, and alarming growth in new patients per year. We knew that the number of new ESRD patients would increase one-hundred (100%) percent in just ten years.

We were pleased when the USRDS authors responded to our fable. Their rebuttal[34] added no new knowledge. They confirmed what we had discovered. We noted in describing this amazing increase in new ESRD patients, that we could not explain the cause of this increase. We further noted that there was no end in sight (*See* Figure 5 below).

ESRD Patient Incidence will double by 1999
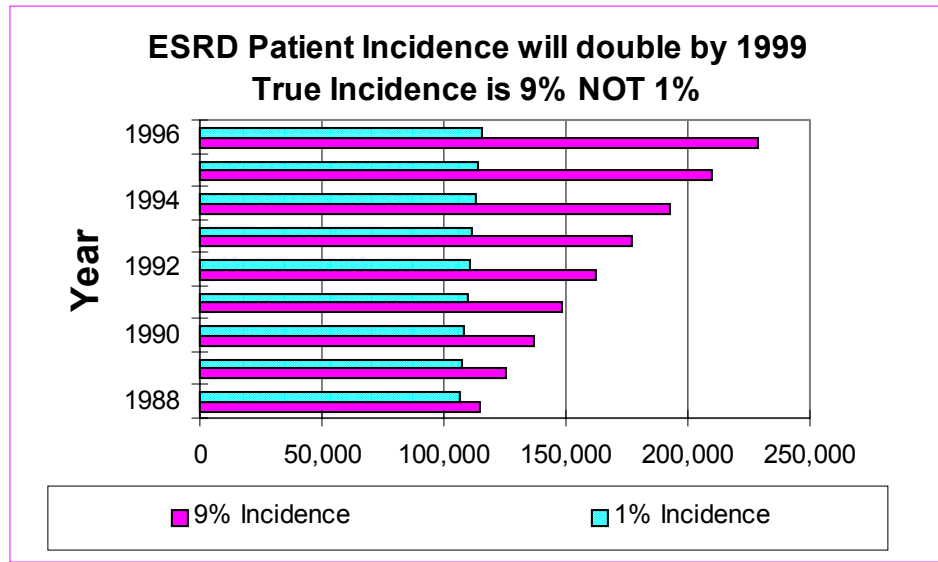**True Incidence is 9% NOT 1%**

Figure 5 - American ESRD Mortality in 1996

Why The ESRD Incidence Rate Is Doubling

The rising rate of new ESRD patients continues. Our prediction remains valid. The incidence of ESRD patients will double again in this decade. That means a *four-fold* increase of new patients each year in a span of less than twenty years!

What is driving this astounding escalation of new ESRD patients? What new disease is causing this explosion of renal failure? We joking –at a meeting in 1999– suggested that someone was putting a nephrotoxin such as gentamicin in all American water supplies. That joke had a grain of truth. It is not a direct nephrotoxin in the water supplies; it's an *indirect* nephrotoxin in our food supplies.

Obesity As An Indirect Nephrotoxin

Obesity *per se*, by itself, is not nephrotoxic. But obesity promotes hypertension not by an increase in peripheral resistance but possibly by producing a persistent increase in cardiac output. Obesity is also a predictor for developing diabetes mellitus type II. We noted the WHO data earlier in this article that found huge increases in adolescent diabetes mellitus type II. There are also large increases in diabetes mellitus type II in aging Americans as they become more obese.

We arrived at this too easy answer about 1999, a year before the millennium. This answer is hinted at in the text of the 2000 USRDS CD-ROM[35] as, "It is unclear why the rate of diabetes continues to increase –even when adjusted for age, gender, and race – while rates of non-diabetic incidence remain steady (table p.1). While low protein diets, blood pressure control, and ACE inhibitors have all been available for some time, they do not appear to have influenced the diabetic population. The dramatic rise in diabetes in the incident dialysis population may be related

to the advancing obesity, carbohydrate intolerance, and insulin resistance suggested by recent trends of increased weight and body mass index at initiation of therapy (fig 1.14)."

Our answer to the causation of the doubling and redoubling of the incidence of new ESRD patients is:

Rampant Obesity In Americans Of All Ages

Measurement of Body Fluid Volumes

There are several methods used to measure body volumes and spaces. This article may induce heated discussion by those who believe that complex studies using complex tests are to be preferred to simple estimates for clinical usage. In preparation for those queries we believe it is necessary for the student to have a working knowledge and understanding of the various tests used to measure body compartments or spaces. Table 2, below lists some of these tests.

#	Body Volume or Space	Measurement
1	TBW	Water containing heavy hydrogen as tritium (^3H_2O) or deuterium (^2H_2O), or antipyrine
2	Extracellular water (ECW)	Isotopic Na^+ as $^{22}Na^+$, ^{125}I-iothalamate, thiosulfate, insulin
3	Intracellular water	TBW - ECW
4	Plasma Volume	125I-albumin, Evans blue dye
5	Blood Volume	51Cr-labeled red blood cells (RBCs) or calculated as Blood Volume = Plasma Volume/(1-hematocrit (Hct))
6	Interstitial Volume	ECW - Plasma Volume
7	Body Fat	BMI, skin-fold thickness, bioelectric impedance analysis (BIA)

Table 2 - Tests to Measure Different Body Spaces

BMI And URR

We calculated the BMI and measured the urea reduction ratio (URR) in about five-hundred (500) ESRD patients. Figure 6, below is a regression graph of these variables. Note that the URR decreases as the BMI increases. If we plotted Kt/V against the BMI it would show the same negative slope. This means that larger ESRD patients receive less dialysis dose. We published this data on ours and other dialysis facilities in 1995. We believed then and still believe that patient mortality is not related to urea removal. Our patient survival is excellent, about twice the USA average for the past ten (10) years.
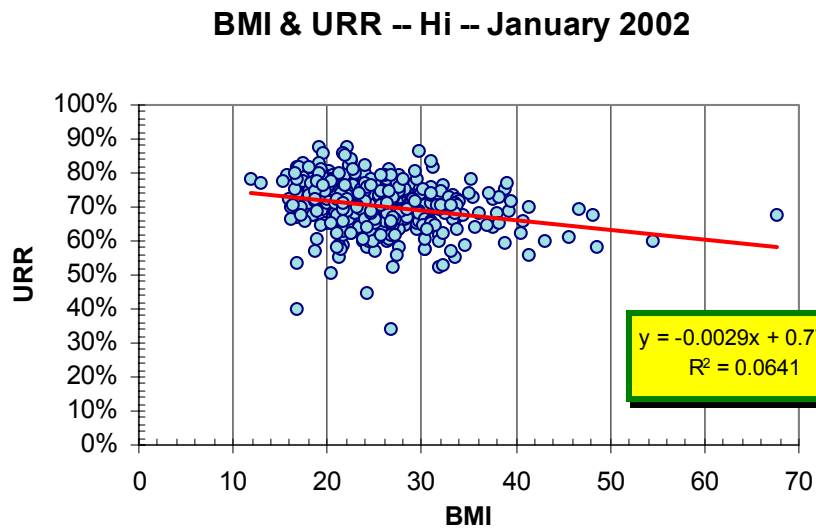
BMI & URR -- Hi -- January 2002

The chart shows URR (y-axis, 0% to 100%) versus BMI (x-axis, 0 to 70) with a scatter of data points and a red trend line. A yellow box shows:

y = -0.0029x + 0.7777
$R^2 = 0.0641$

Figure 6 - BMI and URR

In 1998, Doctors Ifudu and Friedman[36] published a similar graph as Figure 6, above using URR and body weight. Their data had a steeper negative slope. The authors wrote, "Our key findings are that hemodialysis prescription given with insufficient attention to individual variation in body mass increase the likelihood of inadequate hemodialysis…." We would demur, dialysis dose does not determine dialysis adequacy.

What is the Average BMI for ESRD Patients?

Our data is quite close to the USRDS's 2000 data for for average height, weight and BMI of ESRD patients. The USRDS CD-ROM data does not include standard deviations for these data sets so we can not compare their data exactly with ours.

Figure 7, below depicts the histogram of BMIs for about 500 ESRD patients and the idealized normal curve for that data. Note that the actual data is skewed towards the lower numbers with: a mean of 25.6, a median of 24.6, and a range of values for BMIs that encompasses 95% of all from a BMI of 13.8 to a BMI of 37.4.
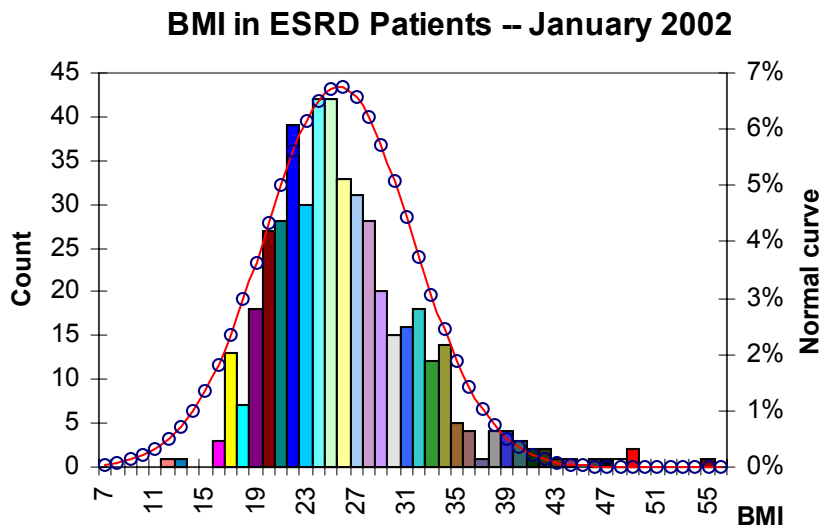
BMI in ESRD Patients -- January 2002

Figure 7 - Average BMI of ESRD Patients

The summary values for these ESRD patients expressed as median values rather than means (because the data are skewed[¥]) are:

Age in years	Height in inches	Weight in pounds	BMI	Albumin in gm/dL	URR
62.3	65.0	151.1	24.6	3.9	71%

But What Does This All Mean!?

"How does any of this stuff about BMI, obesity, hypertension, diabetes mellitus type II, malnutrition, and the numbers soup you two have thrown at us help me to better manage my hemodialysis patients!?" That is the ringing cry from the RNs who deal with the reality of hemodialysis units. A reality that includes: patients that gain too much weight between dialysis, too short dialysis time, no control of either obesity nor malnutrition, and too many patient medications that induce hypotension on dialysis!

We have heard you. And… we are here to help. We give you easy-to-use new clinical tools like the calculation of BMI to assess lean body weight, TBW, excess body fat, malnutrition and obesity. The tools needed to further assess and manage those serious and life-threatening problems will be presented in later articles. As always, we are continuing to search for answers to better the care of ESRD patients.

If all the health-care workers who work in dialysis units know is: "wring them out, we don't have time to do an assessment, we have get them out the door…" this article will give them pause. We hope what we write will help them to adjust the dialysis procedure to the patient… and not the reverse.

[¥]   Skewed, a statistical term that indicates that the normal curve's mean, median and mode are not all the same..

What To Do

1   Use the patient's post-dialysis weight to calculate the BMI, as that weight is closer to the "dry weight of the patient.

   a   If the BMI is less than **19**, check the most recent blood chemistries of that patient.

   b   If the patient's pre-dialysis dialysis BUN is less than **50** mg/dL and their serum albumin is less than **3.5** gm/dL, that patient probably has serious malnutrition. In our experience, that patient may have a life threatening incident within six months.

   c   Get help from the physician, social worker, family caregivers, and a registered dietitian (RD) who is a trained ESRD RD. Unfortunately, in Southern California, many of the dialysis unit RDs are not trained to handle sick or malnourished ESRD patients.

2   Estimate a "dry" weight prior to each and every dialysis to pick up a gradual decline in body weight.

3   Put yourself on a low-sodium diet and stick to it for a month before you ask a dialysis patient to do the same. Should be easy… eh?

4   Calculate the BMI for all patients in your dialysis unit. Note which patients are under 19 and which are over 30. Surprised?

5   An increasing pre-dialysis creatinine, such as **1** mg/dL in a month's time is either due to faulty dialysis or increasing muscle mass. The first condition requires longer or better dialysis; the second condition is associated with increasing true body weight (muscle weight).

Why We Have Stopped Using "True False" Questions

It has only been this year that we have determined that "True False" questions should never be used to test didactic competence. We found that students who guess can achieve nearly a passing score with alacrity and talent. We discovered that our 126 question exam which was expressed designed to determine the didactic competence of registered nurses (RNs) did not do so with purity and finality. Upon this discovery, we had clerical personnel take this test. Some came close to passing.

As a final test, one that would proof beyond doubt by the sternest critic of this scientific search for the truth, we decided to test a random subject who had no knowledge of ESRD what-so-ever. A single test subject whose score would once-and-for-all settle the issue of whether one should ever use "True False" type of questions.

We decided to test Suzy Q Cat, *felinus cattus magnum meowus*, by noting which answers she left her paw prints on as she strolled over the exam paper. Lest the reader think this is silly, be advised that this test carries with it the most honored and respected approach to statistics, Bernoulli trials, and use of the binomial formulas for random data. We used a random subject who could only *guess* and applied the binomial formulas to the results.

By taking her best score, Suzy scored 65 correct answers out of 126 questions. Without being able to read or write (that we know of) she had a test score of (65/126) or 52 %, answering correctly one-half of the questions! We then analyzed the test itself. Sixty-two (62) questions are multiple choice questions, with one of five (1 of 5) possible answers. That means that the probability of guessing the correct answer is one in five or 1/5 or 20% or 0.20. Since there were 62 questions multiple choice answers, the binomial formula for the mean of these questions is simply the number of questions times the probability of each question, that is 62*20% or an average of 12.4 questions can be answered correctly by random or by guessing or by walking over the exam papers.

The most some one can guess is probably two or at best three standard deviations above that number. The binomial formula to obtain the variance for this problem is the number of questions times the probability times the remaining probability or 62*20%*80% or 9.92. The square root of the variance is the standard deviation. The square root of 9.92 (9.92^.5) is 3.15. We add 3.15 times 3 to the average score of 12.4 and get {12.4+(3*3.15)}, rounding up to 22. Thus anyone, even Suzy, will get with 22 questions correct by guessing. They could score a (22/62) a maximum of 35% on the first part of the exam.

We analyzed the remaining 64 (126-62) questions which were all "True False." This time the probability for a correct answer is 50%. The average number of guessed answers (64*50%) is 32. The standard deviation is {(64*50%*50%)^.5} 4 and three (3) standard deviations above the mean is {32+(3*4)} is 44 correct answers. Adding both numbers together (44+22) is 66 correct answers out of 126 questions, a score of (66/126) a score of 52%. If all the questions were "True False" in type, then a good guesser could get a score of 65%.

The moral of this fable is, don't use "True False" questions to determine didactic competency.

Post Test

The following questions have only one correct answer. The probability of answering each question by guessing is: 1/7 or (14%). The inveterate guesser's will answer 1.4 (10*14%) questions correctly. True… the maximum that a lucky guesser can achieve is three (3) standard deviations above that. The standard deviation is: 1.097 {(10*14%*86%)^.5}. Three (3) standard deviations above the mean of 1.4 would a theoretical maximum of 4.7 {1.4+(3*1.097)} questions answered correctly by guessing. Suzy got one.

1   The BMI can be used to measure, directly or indirectly:

   A   TBW
   B   Lean body mass
   C   Body fat
   D   Kt/V
   E   A, B, and C
   F   D and E
   G   None of the above

2   The number of ESRD patients in America has doubled in the last ten years and will dou-
       ble again by the year 2010. Some of the factors that be causal, may underlie this surge in
       new patients is/are:

   A   Fad diets
   B   Lean body mass
   C   Body fat
   D   Kt/V
   E   A, B, and C
   F   D and E
   G   None of the above

3   A clinical gold standard is a useful test or procedure, which can be performed in almost,
       if not all ESRD settings. One or more gold standards are:

   A   BMI
   B   BMI of 30
   C   Hct
   D   Kt/V
   E   A and C
   F   D and E
   G   None of the above

4   Until the BMI surfaced as a useful clinical tool about 1990, the height of the ESRD pa-
       tient was either treated casually or not noted. Some of the following formulas use the pa-
       tient's height, they are:

   A   BMI
   B   Body Surface Area
   C   Watson, Watson, Batt formulas
   D   Kt/V
   E   A, B, and C
   F   D and E
   G   None of the above

5   The BMI in non-ESRD patients have been associated with serious illnesses. They are:

BMI&Uremia.doc

A   Cancer of the skin
B   Stoke
C   Hypertension
D   Low Kt/V
E   B and C
F   A, D, and E
G   None of the above

6   The units of measure of the BMI can be expressed in more than way because they can be in metric or other measuring units. A BMI can be expressed as:

A   PSI
B   Pounds per square inch
C   Kilograms per meter squared
D Kg/m^2
E $\#/in^2$
F   A, B, C, D, and E
G   Only A and B

7   Which of the following pre-dialysis laboratory studies would not be included when assessing protein/caloric malnutrition?

A   BMI < 19
B   Serum albumin < 3.5 g/dL
C   Pre-dialysis BUN < 50 at beginning of week
D   Phosphorous 1.0 mg/dL
E   Kt/ V
F   URR
G   E and F

8   The calculated BMI for an individual with a weight of 150 pounds and height of 65 inches is?

A   BMI 20.75
B   BMI 22.50
C   BMI 24.95
D   BMI 25.00
E   BMI 30.25
F   BMI 31
G   None of the above

9   The calculated BMI for a middle aged male weighing 220 pounds and a height of 70 inches is 31.56. Using Equation 11 on page 12, calculate this patient's estimated total body water (TBW).

A   TBW 25 liters
B   TBW 30 liters
C   TBW 35 liters
D   TBW 40 liters
E   TBW 42 liters
F   TBW 45 liters
G   None of the above

10   The World Health Organization (WHO) studies discuss a variety of important medical findings. Which one of the following would **not** apply?

A   The less education, the higher the BMI
B   Underweight increases mortality in non-smokers
C   Epidemic of type II diabetes among extremely obese adolescents
D   Increase in adolescent obesity
E   BMI studies are only helpful in the Western hemisphere
F   BMI studies are helpful world wide
G   None of the above

BMI&Uremia.doc

RETURN POST TEST FORM TO:

Hemodialysis, Inc
1560 E Chevy Chase Drive, Suite 435
Glendale, CA 91206-4175
Voice: 818-956-5357

Name (First and Last) _____

Street Address (Include Apt #) _____

City _____ State____ Zip Code_____

Home Phone (Include Area Code) _____

RN ❑ LVN ❑ PCT ❑ MD ❑ PhD ❑, Other:_____

License or Certificate No. _____

State of Licensure _____ Date_____

Post Test Answer Form - Circle the correct response

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

All Post Tests for this educational article must be received in **Hi**'s offices prior to:

Friday – May 28, 2004 – 5:00 PM

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, a number 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 log 2.718…. Irrational numbers are denoted 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.

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. 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 log 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 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 obtain a copy of the referenced book which contains many *simple* mathematical[37] problems.

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 nine (9) 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 ten (10) 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.

Download from Web site

This educational article with attached CHs will be available for download from **Hi**'s web site for a minimum of two (2) years prior to its expiration date. The address or universal resource locator (URL) for **Hi**'s web site is:

Http://www.Hemodialysis-Inc.Com

Expiration Date

All Post Tests for this educational article must be received in **Hi**'s offices prior to:

Friday – May 28, 2004 – 5:00 PM

May 2004

Sun	Mon	Tue	Wed	Thu	Fri	Sat
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	(28)	29
30	31					

Copyright ©

Doctor De Palma and Professor Pittard are the authors of this educational article. The content, graphics, tests, and all other intellectual property remain the property of the authors and **Hi**.

Chertow's TBW versus BMI of 22

We had hoped to publish in *BMI and Uremia* a graph comparing the TBW water calculated from a BMI corrected to 22 to that of a very extensive study published in *Kidney International*(KI) by Doctor Chertow[24] and his associates in 1997. That study used BIA to determine TBW in over a thousand ESRD patients. Formulas were developed to determine TBW. A major ESRD healthcare company advised their medical directors some time after the publication of this work to use the published formulas to determine TBW in their ESRD patients. This letter implied that the Watson, Watson, Batt formulas for TBW should be put out to pasture; the Chertow formulas were the new gold standard to clinically calculate the TBW.

The Chertow formulas uses ten (10) variables such as: age, sex, presence of diabetes et cetera. There are also five (5) combinations of these ten (10) variables, making a formula with fifteen (15) variables! After spending some hours with the Chertow formulas, we deduced that "height and weight" comprised about ninety percent (90%) of the mathematics. The formulas in the KI article were incorrect. No amount of Medline searching for *In Erratum* of KI back issues was successful (how to find errors in any printed medical article is another involved story that we may take up some time… but not now). The errors were "typos" made in the galley proofs; the original formulas were correct.

In the end, after *BMI and Uremia* was at the printers, we were able to obtain the correct formula from our colleague James H Shinaberger, MD, Professor of Medicine and Nephrology UCLA. The following is the correlation of Chertow's formulas and a BMI of 22 for about 500 ESRD patients. There is an ancient Chinese truth that a picture is worth a thousand words… we agree.
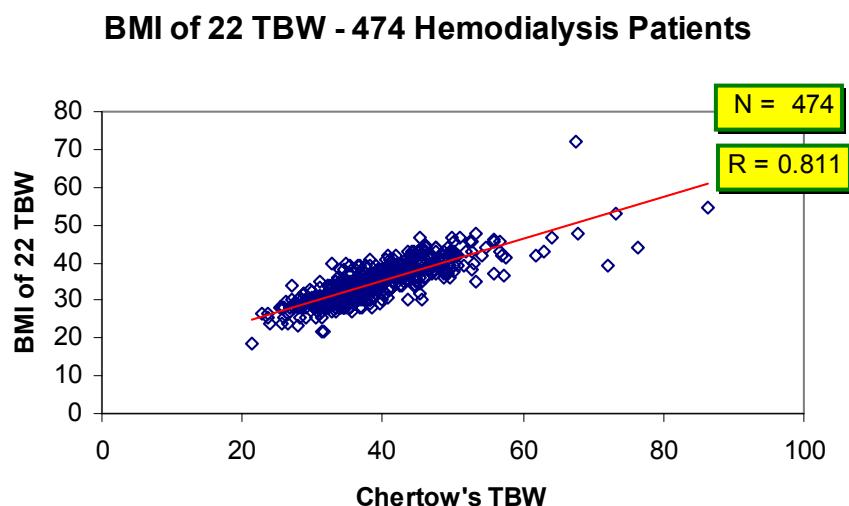
BMI of 22 TBW - 474 Hemodialysis Patients

N = 474

R = 0.811

Figure 8 - Chertow's Formula versus BMI of 22

References

[1] Ganong WJ. Review of Medical Physiology. 16th Edition. Publisher: Appleton & Lange. 1993. page 282.

[2] American College of Physicians. American Society of Internal Medicine. 190 N Independence Mall West Philadelphia, PA. 19106-1572. Voice: 800-523-1546 ext: 2600.

[3] Pittard, JD. Blood & Uremia – 2000, Hemodialysis Nursing. Book. Publisher; Hemodialysis, Inc. 2000. 1-223.

[4] Townsend, CE and Roth, RA. Nutrition & Diet Manual. 7th Edition. Book. Publisher; Delmar Publishers. 1999. page 268.

[5] Johnson, RJ & Feehally, J. Comprehensive Clinical Nephrology. Book. Publisher; Harcourt Publishers Limited. 2000. 7.44.7.

[6] Pittard, JD. Blood & Uremia – 2000, Hemodialysis Nursing. Book. Publisher; Hemodialysis, Inc. 2000. 1-223.

[7] Stunkard AJ, Harris JR, Pedersen NL, McClearn GE. The body-mass index of twins who have been reared apart [see comments]. N Engl J Med. 1990;322:1483-7.

[8] Maternal anthropometry for prediction of pregnancy outcomes: memorandum from a USAID/WHO/PAHO/MotherCare meeting. Bull World Health Organ. 1991;69:523-32.

[9] Seidell JC. Obesity: a growing problem. Acta Paediatr Suppl. 1999;88:46-50.

[10] Singh PN, Lindsted KD, Fraser GE. Body weight and mortality among adults who never smoked. Am J Epidemiol. 1999;150:1152-64.

[11] Liu L, Mizushima S, Ikeda K, et al. Comparative studies of diet-related factors and blood pressure among Chinese and Japanese: results from the China-Japan Cooperative Research of the WHO-CARDIAC Study. Cardiovascular Disease and Alimentary Comparison. Hypertens Res 2000 Sep;23(5):413-20. 2000;23:413-20.

[12] Pinhas-Hamiel O, Zeitler P. "Who is the wise man?--The one who foresees consequences:". Childhood obesity, new associated comorbidity and prevention. Prev Med 2000 Dec;31(6):702-5. 2000;31:702-5.

[13] Sciamanna CN, Tate DF, Lang W, Wing RR. Who reports receiving advice to lose weight? Results from a multi-state survey. Arch Intern Med 2000 Aug 14-28;160(15):2334-9. 2000;160:2334-9.

[14] Molarius A, Seidell JC, Sans S, Tuomilehto J, Kuulasmaa K. Educational level, relative body weight, and changes in their association over 10 years: an international perspective from the WHO MONICA Project. Am J Public Health 2000 Aug;90(8):1260-8. 2000;90:1260-8.

[15] Chen YC, Chen HH, Yeh JC, Chen SY. Body composition in hemodialysis patients--is it different from that of normal subjects? Clin Nephrol 2000 Apr;53(4):291-5. 2000;53:291-5.

[16] Tokunaga K, Matsuzawa Y, Kotani K, et al. Ideal body weight estimated from the body mass index with the lowest morbidity. Int J Obes. 1991;15:1-5.

[17] Kannel WB, D'Agostino RB, Cobb JL. Effect of weight on cardiovascular disease. Am J Clin Nutr. 1996;63:419S-22S.

[18] Hume R, Weyers E. Relationship between total body water and surface area in normal and obese subjects. J Clin Pathol. 1971;24:234-8.

[19] Watson PE, Watson ID, Batt RD. Total body water volumes for adult males and females estimated from simple anthropometric measurements. Am J Clin Nutr. 1980;33:27-39.

[20] De Palma, JR & Pittard, JD. Body Weight – Body Water, Parts I & II. Dialysis & Transplantation. 2001;30:717,700-705 and 2001;30:792,776-783.

[21] Pitts, RF. Physiology of the Kidney and Body Fluids. 2nd Edition. Book: Year Book Medical Publishers. 1963. page 27.

[22] De Palma, JR, Pittard, JD. Dialysis Dose, Parts I & II. Dialysis & Transplantation. 2001;30:266,252-265 and 2001;30:330,315-324.

[23] DuBois, D, DuBois, EF. A Formula to estimate the appropriate surface area if height and weight be known. Arch Int Med. 1916;17:863-71.

[24] Chertow GM, Lazarus JM, Lew NL, Ma L, Lowrie EG. Development of a population-specific regression equation to estimate total body water in hemodialysis patients. Kidney Int. 1997;51:1578-82.

[25] Deurenberg P, Yap M, van Staveren WA. Body mass index and percent body fat: a meta analysis among different ethnic groups. Int J Obes Relat Metab Disord. 1998;22:1164-71.

[26] Pittard, JD. Blood & Uremia – 2000, Hemodialysis Nursing. Book. Publisher; Hemodialysis, Inc. 2000. 1-223.

[27] USRDS 2000 ADR & Web site CD-ROM. USRDS Coordinating Center; 914 South 8th Street; Suite D-206; Minneapolis, Minnesota 55404. 2001.

[28] Tzamaloukas AH, Leger A, Hill J, Murata GH. Body mass index in patients with amputations on peritoneal dialysis: error of uncorrected estimates and proposed correction. Adv Perit Dial 2000;16:138-42. 2000;16:138-42.

[29] Di Iorio BR, Terracciano V, Bellizzi V. Bioelectrical impedance measurement: errors and artifacts. J Ren Nutr. 1999;9:192-7.

[30] Bonnet F, Deprele C, Sassolas A, et al. Excessive body weight as a new independent risk factor for clinical and pathological progression in primary IgA nephritis. Am J Kidney Dis 2001 Apr;37(4):720-7. 2001;37:720-7.

[31] Combe C, Chauveau P, Laville M, et al. Influence of nutritional factors and hemodialysis adequacy on the survival of 1,610 French patients. Am J Kidney Dis 2001 Jan;37(1 Suppl 2):S81-8. 2001;37:S81-8.

[32] Chauveau P, Combe C, Laville M, et al. Factors influencing survival in hemodialysis patients aged older than 75 years: 2.5-year outcome study. Am J Kidney Dis 2001 May;37(5):997-1003. 2001;37:997-1003.

[33] De Palma, JR. American ESRD Mortality or the Cruder the Better. Dialysis & Transplantation. 1996. May; 25:259,310-314.

[34] Port, FK, Wolfe, RA, Caitlin EC, Turenne, MN, Webb, RL, Held, PJ. Crude Mortality is Not the Best Outcomes Measure for Dialysis Patients. Dialysis & Transplantation. 1996. August; 25: 506,529-532. (Rebuttal to American ESRD Mortality).

[35] USRDS CD-ROM. 2000 Annual Data Report. 2000. page 38.

[36] Ifudu, O, Mayers, JD, Matthew, JJ, Friedman, EA. Standardized Hemodialysis Prescriptions Promote Inadequate Treatment in Patients with Large Body Mass. N Engl J Med. 1998;128:451-3.

[37] Northrop, EP. Riddles in Mathematics. Book, Penguin, Harmoundsworth. 1945. p 23.

c:\winword9\publications\bmi&uremia.doc

Body Mass Index

BMI

Height in Inches

Weight in Pounds

Male Female

Wt @ BMI of 22

1st:
===
Left mouse click drop-down boxes to enter numbers for height and weight.

2nd:
====
Left click Calculate button.

Http://www.Hemodialysis-Inc.Com