Summary

Adequate hemodialysis can be defined as the amount of dialysis required for optimal patient survival. Patient survival, morbidity and quality of life all have been linked to measures of dialysis adequacy. Thus, it is important to know what adequate hemodialysis means and to be able to prescribe it, deliver it, and monitor its influence on dialysis patient population.

Mortality is easily measured, but morbidity and quality of life are equally important outcomes (but difficult to quantities). Survival on dialysis has increased for all patient groups over the last decades, and is now predominantly determined by co-morbidity.

- Adequate dialysis maximizes well-being, minimizing morbidity, and helps a patient retain social independence.
- Adequate dialysis is not simply a dose of dialysis exceeding a given number, and should not be defined by solute clearance alone.
- Optimum dialysis is a method of delivering dialysis producing results that cannot be further improved.
- Dialysis prescription should be individualized, monitored, and reassessed regularly.

Assessment of adequacy should include:

- Patient well-being (physically, mentally, socially).
- Nutrition (lack of malnutrition)
- Small solute clearance
- Adequacy of UF
- Control of blood pressure
- Protein catabolic rate

- Clearance of medium sized and large molecules as β2-microglobulin.

Recent literature suggests that only one alternative method for calculating Kt/V (Kt/V natural logarithm formula) and one other measurement of the delivered dose of hemodialysis (URR) should be considered for routine use in adults

A number of factors contribute to UKM including:

- The size of the dialysis membrane, since larger surface area membranes can remove more urea per unit time.
- The blood flow rate to the dialyzer (Qb), since presenting new plasma with a high urea concentration maintains the favorable gradient for urea removal.

The dialysate flow rate (Qd), since delivering new fluid containing no urea also maintains the urea concentration gradient. The principal determinants of the blood water clearance during dialysis are the blood flow rate, the dialysis solution flow rate, and the efficiency of the dialyzer used

Some clinical researchers contend that the hemodialysis treatment time alone, independent of the Kt/V or URR, can be used as a measure of hemodialysis adequacy. Thus, longer hemodialysis times may enhance patient survival. However, other investigators have observed that when the dose of hemodialysis was controlled, no relationship was demonstrable between the prescribed duration of hemodialysis and patient outcomes. Most of these studies have examined the prescribed treatment time instead of the delivered dialysis time; this discrepancy needs to be considered.

The dialysate collection method is an alternative approach for quantifying the delivered hemodialysis dose. In this approach, the total dialysate that passes through the dialyzer during a hemodialysis treatment

is collected. The total mass of urea removed is then calculated as the product of the urea concentration and the volume of spent dialysate. This method has been considered by some investigators to be the gold standard for urea kinetic analysis. Advocates of this method emphasize the advantage of minimizing exposure of patients and staff to blood-borne pathogens. However, the HD Adequacy Work Group recognized that dialysate measurement techniques are not routinely available, are impractical to implement in most hemodialysis units, have not been examined in relation to patient outcomes, and may be associated with the exaggeration of systematic collection errors. For example, a 7% error in dialysate collection can result in a 20% error in the equilibrated Kt/V. Although, the HD Adequacy Work Group also recognizes that dialysate side urea kinetics are best characterized as an equilibrated model, the Work Group thought it was best to focus on single-pool models of urea removal. Therefore, the Work Group focused on blood-based measurements of urea removal.

Pre- and post- dialysis BUN measurement may not reflect the true systemic urea concentration at the time hemodialysis was initiated and terminated respectively due to errors in sampling procedure and or laboratory error. Reasons for errors in measurement of BUN concentration include:

- Dilution of predialysis BUN blood sample with saline. Drawing predialysis BUN blood sample after the start of dialysis.
- Laboratory error due to calibration or equipment problems. Drawing postdialysis BUN blood sample before the end of dialysis.
- Drawing postdialysis BUN blood sample more than 5 minutes after dialysis.

Obligatory dialysate protein losses are a feature of peritoneal dialysis and typically average 5-10 g daily, of which half is accounted for by albumin. These losses are probably the major cause of the lower serum albumin levels seen in peritoneal dialysis, as compared with hemodialysis, patients. Losses are greatest and serum albumin is lowest in high transporters. The losses or clearances of large molecular weight proteins such as albumin are relatively constant during the course of a dwell, but low molecular weight proteins such as lysozyme behave more like small solutes.

Both total weekly creatinine clearance normalized to 1.73 m^2 body surface area (BSA) and total weekly Kt/V_{urea} should be used to measure delivered PD doses.A valid and reproducible measure of PD dose is essential to assess the quantity of dialysis delivered to an individual patient. The quantity of dialysis is an important component of the quality of dialysis. Of the few available measures of PD dose, total weekly Kt/V_{urea} and total creatinine clearance normalized to 1.73 m^2 BSA are the best, because they are most strongly associated with mortality and morbidity. Additionally, when properly performed, these measures are reproducible enough to be useful in routine clinical practice

Residual kidney function (RKF), which can provide a significant component of total solute and water removal, should be assessed by measuring the renal component of Kt/V_{urea} (K_rt/V_{urea}) and estimating the patient's glomerular filtration rate (GFR) by calculating the mean of urea and creatinine clearances.

Twenty percent of PD patients report some noncompliance with their dialysis prescription. Preliminary data suggest that total daily creatinine excretion or appearance can be used as an indicator of compliance in CAPD. The premise for such use is that, in noncompliant patients who perform the proper number of exchanges only during the day of the

clearance measurement, the amount of creatinine excreted in 24 hours (equal to the daily amount of creatinine in the spent dialysate and urine plus an estimated amount of creatinine lost through other routes, primarily the gastrointestinal tract) will exceed the amount of creatinine produced daily. Essentially, noncompliance creates an unsteady state of recently accumulated creatinine. Thus, an increase in the daily excretion of creatinine in dialysate plus urine may indicate noncompliance just prior to the collection. Other potential causes of variation in the measured amount of creatinine excreted include changes in muscle mass, improper collection of dialysate or urine due to timing errors, and inaccurate urine or dialysate creatinine measurement by the laboratory. Finally, another potential cause of change in total creatinine excretion may be peritoneal membrane transport dysfunction.

Nutritional status of adult PD patients should be assessed on an ongoing basis in association with Kt/V_{urea} and C_{cr} measurements using the Protein equivalent of Nitrogen Appearance (PNA) and Subjective Global Assessment (SGA). There is strong indirect evidence linking survival on dialysis with nutritional status both at initiation of dialysis and during longitudinal follow-up. Better survival has been reported in PD patients with high normalized protein equivalent of nitrogen appearance (nPNA). Positive correlations between nPNA and clearance of urea or creatinine have been reported repeatedly in PD subjects. The correlation between nPNA and Kt/V_{urea} may indicate increased appetite and dietary protein intake as Kt/V_{urea} increases, but also may simply reflect the fact that nPNA and Kt/V_{urea} are mathematically linked. This mathematical linkage makes the correlation between nPNA and Kt/V_{urea} in cross-sectional studies of questionable clinical significance. However, nPNA tends to increase in the same subjects when Kt/V_{urea} and creatinine clearance (C_{Cr}) are increased by increasing the dose of PD, especially if the increase in

the dose of PD was prescribed because of inadequate clearances. In the latter instance, the association between Kt/V_{urea} and nPNA is not the result of a mathematical coupling. In addition, there is strong evidence suggesting that quality and quantity of dialysis influences nutrition. While the precise relationship between kidney function (or dialysis therapy) and nutrition is not yet adequately understood, it is the Work Group's opinion that adequate renal replacement therapy is necessary for normal appetite and metabolism. Thus, nutritional problems may reflect inadequate dialysis which, if corrected, may lead to subsequent improved outcomes

In current clinical practice, the peritoneal dialysis prescription is usually based on transport categorization using the peritoneal equilibration test (PET).With computerized UKM many possible PD regimens with variable exchange schedules and volumes can be tailored to be compatible with individual patient lifestyle preferences and to minimize total dialysate volume relative to required $K_{pr}t/V_{urea}$. A PD prescription can be quickly and rigorously evaluated mathematically using programs written for the personal computer. These programs all require baseline transport characterization using either the PET or peritoneal function test data

Quality of life (QOL) can be assessed with generic or disease-specific measures. Many quality of life measures have been used in dialysis patients. However, fewer measures have been used for peritoneal dialysis than for hemodialysis patients. Measures used in peritoneal dialysis patients and reported in the literature include:

- Medical Outcomes Study Short Form 36 (SF-36).
- Sickness Impact Profile (SIP).
- Index of Well Being, Index of Overall Life Satisfaction.
- Index of Psychological Affect.
- General Health Questionnaire.

- Simmons Self Esteem Scale.
- Profile of Mood States.
- Multidimensional Health Locus of Control.
- Modality Specific Stresses Scale.
- General Treatment Stress Scale.
- Global Illness Stress on Self and Others, Global Adjustment to Illness Scale.
- Quality of Life (QL 100 mm) Analogue Scale.
- Dialysis Relationship Quality Scale.
- Social Leisure Activities Index, Social Support Satisfaction Scale.
- General Well Being Index.
- Index of General Affect, Overall Life Satisfaction.
- Katz Activities of Daily Living.
- Time Tradeoff Measures.