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DIALYSIS – TRANSPLANTATION

Ionic dialysance allows an adequate estimate of urea distribution volume in hemodialysis patients

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Ionic dialysance allows an adequate estimate of urea distribution volume in hemodialysis patients.

Background. An adequate estimation of urea distribution volume (V) in hemodialysis patients is useful to monitor protein nutrition. Direct dialysis quantification (DDQ) is the gold standard for determining V, but it is impractical for routine use because it requires equilibrated postdialysis plasma water urea concentration. The single pool variable volume urea kinetic model (SPVV-UKM), recommended as a standard by Kidney Disease Outcomes Quality Initiative (K/DOQI), does not need a delayed postdialysis blood sample but it requires a correct estimate of dialyser urea clearance.

Methods. Ionic dialysance (ID) may accurately estimate dialyzer urea clearance corrected for total recirculation. Using ID as input to SPVV-UKM, correct V values are expected when end-dialysis plasma water urea concentrations are determined in the end-of-session blood sample taken with the blood pump speed reduced to 50 mL/min for two minutes ($U_{pwt2'}$). The aim of this study was to determine whether the V values determined by means of SPVV-UKM, ID, and $U_{pwt2'}$ (V_{ID}) are similar to those determined by the "gold standard" DDQ method (V_{DDQ}). Eighty-two anuric hemodialysis patients were studied.

Results. V_{DDQ} was 26.3 ± 5.2 L; V_{ID} was 26.5 ± 4.8 L. The (V_{ID}–V_{DDQ}) difference was 0.2 ± 1.6 L, which is not statistically significant ($P = 0.242$). Anthropometric volume (V_A) calculated using Watson equations was 33.6 ± 6.0 L. The (V_A–V_{DDQ}) difference was 7.3 ± 3.3 L, which is statistically significant ($P < 0.001$).

Conclusion. Anthropometric-based V values overestimate urea distribution volume calculated by DDQ and SPVV-UKM. ID allows adequate V values to be determined, and circumvents the problem of delayed postdialysis blood samples.

Because morbidity and mortality are strongly correlated with malnutrition [1], nutritional status of dialysis patients is a major criterion for assessing treatment adequacy. One of the advantages of measuring Kt/V during hemodialysis is the ability to calculate the patient's urea distribution volume (V). A reliable estimate of V allows the correct assessment of protein intake from urea generation rate [2], and allows lean body mass (LBM) to be calculated according to the well-established finding that 73% of LBM is body water [3]. Direct dialysis quantification (DDQ) is considered the gold standard for determining V, but it is impractical for routine use because it requires equilibrated postdialysis plasma water urea concentration [4]. The single pool variable volume urea kinetic model (SPVV-UKM) is easier to use because it does not need a delayed postdialysis blood sample [5]; end-dialysis plasma water urea concentrations (U_{pwt}) are determined in blood samples drawn immediately after the end of the dialysis session, after approximately 10 seconds of reduced blood flow to 100 mL/min ($U_{pwt10''}$). However, in order to obtain results that are consistent with the DDQ method, SPVV-UKM requires a correct estimate of dialyzer urea clearance (K_d) throughout the dialysis session. Using "formal" SPVV-UKM, K_d is calculated from a generic dialyzer transport constant (overall permeability area product, or KoA) and the prescribed blood and dialysate flows with the assumption that both these flows are constant throughout the treatment and there is no dialyzer clotting or access recirculation. However, there may be significant errors in these calculated dialyzer clearances resulting frequently in overestimation of K_d and secondary overestimation of V [6].

Ionic dialysance (ID) may accurately estimate "effective" urea clearance [7–9] (i.e., dialyzer urea clearance corrected for total recirculation) [10]. It can be calculated simply by measuring the difference in the conductivity of the outlet dialysate at two different values of inlet dialysate conductivity [11, 12]. Because ID does not need blood and dialysate samples or laboratory tests, repeated determinations are available and allow an adequate

Key words: direct dialysis quantification, single pool urea kinetic model, anthropometric-based urea distribution volume, ionic dialysance, clinical trial.

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estimate of "effective" urea clearance throughout the dialysis session.

Because V is directly proportional to urea clearance and inversely proportional to the magnitude of drop in plasma water urea concentration in UKM, by using ID as input parameter to SPVV-UKM, correct V values can be expected when end-dialysis plasma water urea concentrations are determined in blood samples taken at the end of the session with the blood pump speed reduced to 50 mL/min for two minutes ($U_{pwt2'}$) [13]. Underestimation of V secondary to the use of ID, always lower than K_d, will be compensated by overestimation of V secondary to the use of $U_{pwt2'}$, which is always higher than $U_{pwt10''}$.

The aim of this study was to determine whether the V values determined by means of SPVV-UKM, ID, and $U_{pwt2'}$ (V_{ID}) are similar to those determined by the "gold standard" DDQ method (V_{DDQ}).

METHODS

Eighty-two anuric patients on chronic thrice-weekly hemodialysis were studied in 82 dialysis sessions (one for each patient). Prescribed blood flow rate (Q_{bi}) was within the range 200 to 400 mL/min; dialysate flow rate was fixed to 500 mL/min. A total of 11 types of dialyzers were used in the study, with low-flux dialyzers used in 85% of sessions. In all of the sessions, we used an Integra machine (Hospal, Italy) equipped with the Diascan Module® (Gambro-Dasco, Medolla, Italy) for the automatic determination of ID, and the Quantiscan Module® (Gambro-Dasco) for the fractional collection of outlet dialysate. The Diascan module has a temperature-compensated conductivity probe activated at the dialysate outlet. A microprocessor increases or reduces the basal inlet dialysate conductivity (Cd_i) by 1 mS/cm for two minutes, measures the difference between the inlet and outlet (Cd_o) dialysate conductivity during this phase (Cd_{i1}, Cd_{o1}) and after Cd_i is restored to the basal value (Cd_{i2}, Cd_{o2}), and calculates ID from equation 1, which, like all of the following equations, is given in the **Appendix**.

The first measurement of ID takes about six minutes and is completed 15 minutes after the start of the session; further determinations are automatically made every 30 minutes.

The Quantiscan module is a peristaltic pump that works on an outlet dialysate line by collecting a continuous reduced volume sample. The volume of total dialysate with ultrafiltration is separately computed using continuous signals from flowmeters located within the volumetric ultrafiltration control system, and the value is displayed on the screen of the dialysis monitor. Using this device, a percent difference of only -0.2 ± 0.1 has been reported between computed and collected total dialysate volume [abstract; Arckouche W, Bene B: *Blood Purif* 19:86–87, 2001]. At each session, three blood samples were taken to determine plasma urea (U_p) and total protein (TP) concentrations. Urea concentrations in plasma water (U_{pw}) were calculated as: U_{pw} (mg/mL) = U_p (mg/dL)/[100–1.07 × TP (mg/dL)] [14]. The first blood sample was taken immediately before the start of the dialytic treatment (U_{pw0}), the second at the end of the session after the reduction of Q_{bi} to 50 mL/min for two minutes ($U_{pwt2'}$), the third sample was taken 30 minutes after the end of the session ($U_{pwt30'}$). Another blood sample was taken immediately before the start of the following dialysis session (U_{pw02}). Plasma and dialysate urea (U_{do}) and total protein concentrations were determined in duplicate using a Hitachi 917 analyzer (Tokyo, Japan).

Direct dialysis quantification (DDQ)

We used the DDQ method described by Depner et al [4]. Urea distribution volume after dialysis (V_{DDQ}) and urea generation (G) were determined according to equations 2 and 3, which were iteratively solved until V and G differed by no more than 1%. Whole body clearance (K_{wb}) was calculated according to equation 4; the two-pool Kt/V (Kt/V_{dp}) was then calculated by using treatment time (T_d), K_{wb} from equation 4, and V from equation 2.

SPVV-UKM

We used the 3-point SPVV-UKM described by Gotch [5], and as dialyzer clearance, the average ID value of repeated instantaneous determinations taken every 30 minutes. Urea distribution volume after dialysis (V_{ID}) and urea generation (G) were determined according to equations 5 and 6, iteratively solved until V and G differed by no more than 1%. The single pool Kt/V (Kt/V_{ID}) was then calculated using T_d, ID, and V from equation 5.

Computation of anthropometric volume

Anthropometric volume (V_A) was calculated using the equations 7 and 8 proposed by Watson, Watson, and Batt based on the postdialysis weight (Wt), height (Ht), gender, and age (A) [15].

Statistical analysis

The values of V_{DDQ}, obtained from the direct dialysis quantification method, were used as the reference and compared with V_{ID} and V_A values. Mean differences, standard deviations, and 95% mean confidence intervals are provided. The individual (V_{ID}–V_{DDQ}) differences were plotted against the Kt/Vdp to test whether the difference was dependent on the dose of administered dialysis; the individual (V_A–V_{DDQ}) differences were plotted against the V_{DDQ} values to test whether the difference was dependent on the value of the reference variable. In the same plots, regression lines with individual 95% confidence intervals are given with the β regression

Table 1. Initial (U_{pw0}), final ($U_{pwt2'}$), postdialysis equilibrated ($U_{pwt30'}$), predialysis at the next dialysis session (U_{pw02}), plasma water urea concentrations, blood flow rate (QB_i), ionic dialysance (ID), whole body clearance (K_{wb}), treatment time (T_d), double pool Kt/V (Kt/Vdp), and single pool Kt/V (Kt/V_{ID}) of the studied patients

	Males ($N = 50$)	Females ($N = 32$)	Total ($N = 82$)
U_{pw0} *mg/dL*	174 ± 10	181 ± 51	176 ± 44
$U_{pwt2'}$ *mg/dL*	55 ± 17	50 ± 17	53 ± 17
$U_{pwt30'}$ *mg/dL*	61 ± 18	57 ± 19	60 ± 18
U_{pw02} *mg/dL*	155 ± 38	165 ± 41	159 ± 39
Q_{bi} *mL/min*	320 ± 45[a]	285 ± 55	305 ± 50
ID *mL/min*	185 ± 20[a]	162 ± 21	176 ± 23
K_{wb} *mL/min*	167 ± 20[a]	149 ± 19	159 ± 22
T_d *minutes*	230 ± 22	225 ± 25	228 ± 23
Kt/Vdp	1.35 ± 0.19[a]	1.48 ± 0.23	1.40 ± 0.21
Kt/V_{ID}	1.48 ± 0.21[a]	1.63 ± 0.25	1.54 ± 0.23

Values are mean ± SD. To convert value for urea to mmol/L, multiply by 0.166.
[a] $P < 0.01$ vs. females.

coefficient, standard error, and the associated P value of the null hypothesis of a β regression coefficient equal to zero. The adjusted r^2 was calculated in order to measure how much of the variability of the y-axis (the difference between the tested and reference variable) was explained by the variation on the x-axis (reference variable). A probability value of less than 0.05 was considered statistically significant. The statistical analyses were made using SPSS for Windows, release 11.0 (Chicago, IL, USA).

RESULTS

Initial (U_{pw0}), final ($U_{pwt2'}$), postdialysis equilibrated ($U_{pwt30'}$), and predialysis at the next dialysis session (U_{pw02}) plasma water urea concentrations, together with prescribed blood flow (QB_i), ionic dialysance (ID), whole body clearance (K_{wb}), duration of dialysis treatment (T_d) single pool (Kt/V_{ID}), and double pool Kt/V (Kt/V_{dp}) are summarized in Table 1. The Diascan module performed a total of 601 instantaneous determinations—a mean of 7 ± 1 determinations for each patient (range 5 to 9). Ionic dialysance and whole body clearance were significantly greater in males compared with females, while Kt/V_{ID} and Kt/V_{dp} were significantly lower in males compared with females. The mean difference between Kt/V_{ID} and Kt/V_{dp} was 0.13 ± 0.06 (95% CI 0.12–0.15; $P < 0.001$). This difference significantly correlated with dialysis efficiency, suggesting the following regression equation: $Kt/V_{dp} = Kt/V_{ID} – 0.48(Kt/V_{ID}/T_d) + 0.06$. ($T_d$ = hr; adjusted $r^2 = 0.26$). Table 2 shows the anthropometric parameters of the studied patients. Body weight and height were significantly greater in males compared with females. Table 3 shows the urea distribution volume measurements. Anthropometric volume significantly overestimated V_{DDQ}; the measurement bias of V_A was 29 ± 15% (95% CI 26–33). In males, the bias was 30 ± 16% (95% CI 26–35); in females, the bias was 26 ± 13% (95% CI 22–31). Figure 1 shows the (V_A–V_{DDQ}) difference plotted against V_{DDQ}. The mean (V_A–V_{DDQ}) difference was 7.3 ± 3.3 L, which is statistically significant (95% CI 6.6–8.0; $P < 0.0001$); the (V_A–V_{DDQ}) difference was not associated with V_{DDQ} values (β coefficient −0.04; $P = 0.567$).

The mean ($V_A - V_{DDQ}$) difference in males was 8.3 ± 3.6 L (95% CI 7.3–9.3; $P < 0.0001$); the mean ($V_A - V_{DDQ}$) difference in females was 5.6 ± 2.1 L (95%

Table 2. Anthropometric parameters of the studied patients

	Males ($N = 50$)	Females ($N = 32$)	Total ($N = 82$)
Age *years*	63 ± 14	67 ± 11	64 ± 13
Height *cm*	167 ± 6[a]	153 ± 8	162 ± 10
W_0 *kg*	70.5 ± 12.3[a]	58.9 ± 11.8	66.0 ± 13.3
W_t *kg*	67.2 ± 11.8[a]	56.2 ± 11.5	62.9 ± 12.8

Abbreviations are: W_0, initial body weight; W_t, final body weight. Values are mean ± SD.
[a] $P < 0.01$ vs. females.

Table 3. Urea distribution volume measurements

	Males ($N = 50$)	Females ($N = 32$)	Total ($N = 82$)
V_{DDQ} *L*	28.7 ± 4.6	22.5 ± 3.6	26.3 ± 5.3
V_{DDQ}/wt %	43.2 ± 6.2	40.7 ± 4.9	42.2 ± 5.8
V_{ID} *L*	28.9 ± 3.9	22.7 ± 3.5	26.5 ± 4.8
V_{ID}/wt %	43.7 ± 5.8	41.0 ± 4.5	42.6 ± 5.5
V_A *L*	37.0 ± 4.7[a]	28.1 ± 5.2[a]	33.5 ± 6.5[a]
V_A/wt%	55.5 ± 4.1[a]	50.8 ± 8.1[a]	53.7 ± 6.4[a]

Values are mean ± SD.
[a] $P < 0.001$ vs. V_{DDQ}.

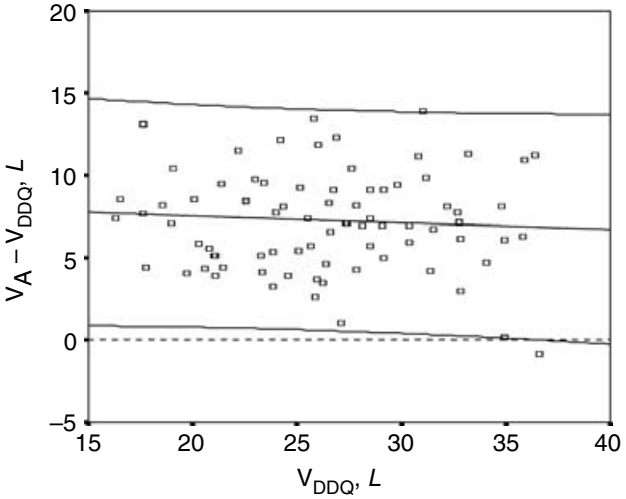

Fig. 1. Plot of the ($V_A - V_{DDQ}$) differences against V_{DDQ} values showing the regression line with 95% individual confidence intervals in 82 patients.

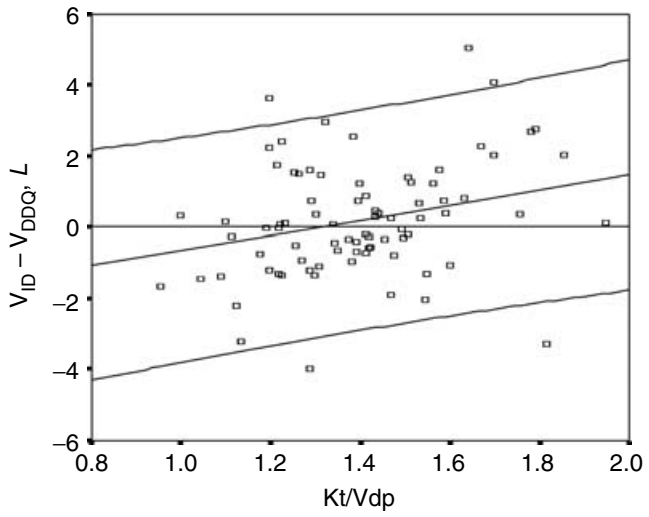

Fig. 2. Plot of the ($V_{ID} - Vt_{DDQ}$) differences against Kt/V_{dp} values showing the regression line with 95% individual confidence intervals in 82 patients.

CI 4.9–6.4; $P < 0.0001$). The (V_A–V_{DDQ}) difference in males was significantly greater when compared with the (V_A–V_{DDQ}) difference in females (2.7 L; 95% CI 1.3–4.0; $P = 0.039$).

The bias of V_{ID} was 1 ± 7% (95% CI 0–3). In males, the bias of V_{ID} was 1 ± 7% (95% CI 0–3); in females, it was 1 ± 6% (95% CI −1–3). Figure 2 shows the (V_{ID}–V_{DDQ}) difference plotted against Kt/Vdp. The mean (V_{ID}–V_{DDQ}) difference was 0.2 ± 1.6 L, which is not statistically significant (95% CI –0.1–0.6; $P = 0.242$); as expected, the (V_{ID}–V_{DDQ}) difference was significantly associated with Kt/Vdp values (β coefficient 2.114; $P = 0.01$). The mean (V_{ID}–V_{DDQ}) difference in males was 0.2 ± 1.7 L, which is not statistically significant (95% CI −0.3–0.7; $P = 0.347$); the mean (V_{ID}–V_{DDQ}) difference in females was 0.2 ± 1.4 L, which is not statistically significant (95% CI −0.3–0.7; $P = 0.475$).

DISCUSSION

The DDQ method is considered an accurate kinetic method for assessing the urea distribution volume in individual hemodialysis patients. The single pool variable volume urea kinetic model, which has been recommended as a standard by the NKF-KDOQI (National Kidney Foundation Kidney Disease Outcomes Quality Initiative), is easier to use: however, in order to obtain adequate V values, it does need a correct estimate of dialyzer urea clearance (K_d) during the entire dialysis session. Theoretically, with UKM, whole body clearance and equilibrated post-dialysis plasma water urea concentration should be used to obtain V values consistent with V_{DDQ} values. In the UKM, V is directly correlated with urea clearance, which means that the use of K_d higher than K_{wb} will lead to a systematic overestimation of V; on the other hand, V is inversely correlated with the magnitude of drop in plasma water urea concentration (U_{pw0}-$U_{pwt30'}$); this means that sampling 10 seconds after the end of the dialysis session will lead to a systematic underestimation of V because $U_{pwt10''}$ is always lower than $U_{pwt30'}$. On the basis of these relationships, it can be expected that correct V values will be obtained if the overestimation of K_{wb} using K_d is counterbalanced by the overestimation of (U_{pw0}-$U_{pwt30'}$) using $U_{pwt10''}$.

In the "formal" SPVV-UKM, K_d is calculated from blood and dialysate flow rates using the dialyzer mass transfer area coefficient (KoA). However, there may be significant errors in these calculated dialyzer clearances, resulting often in overestimation of K_d and secondary overestimation of urea distribution volume. This is the reason why, in determining if the V values obtained using "formal" SPVV-UKM are plausible, they are usually compared with the anthropometrically predicted values on the theoretical analysis that modeled single-pool V is similar to the anthropometric V when urea reduction rate approximates 0.67 [16]. Repeated determinations of ionic dialysance may constitute an accurate estimate of "effective" urea clearance during the entire dialysis session. Using ID, correct V values can be expected when end-dialysis plasma water urea concentrations are determined in the blood sample taken at the end of the session with the blood pump speed reduced to 50 mL/min for two minutes; underestimation of V secondary to the use of ID, always lower than K_d, will be compensated by overestimation of V secondary to the use of $U_{pwt2'}$, always higher than $U_{pwt10''}$.

Our study shows that by using ID and $U_{pwt2'}$ as input parameters to SPVV-UKM it is possible to obtain urea distribution volume values that are not different from the values obtained according to the DDQ method. Similar findings in a smaller group of hemodialysis patients have been reported [abstract; Manzoni C et al: *J Am Soc Nephrol* 11:324A, 2000]. In our patients, at a mean Kt/V_{dp} level of 1.4, V_{ID} values resulted only 1% higher as a mean than V_{DDQ} values, and the difference between V_{ID} and V_{DDQ} resulted significantly associated with Kt/V_{dp} values. This is in agreement with comparative theoretic analysis between double-pool and single-pool model showing that the ratio between "single-pool" V and double-pool V is a function of administered dialysis dose, and predicting to be 0.88 at Kt/V_{dp} level of 0.5, 0.97 at Kt/V_{dp} level of 1.0, and 1.00 at Kt/V_{dp} level of 1.3 [5]. This has important clinical implications, particularly in those circumstances in which a low value of Kt/V is prescribed, such as in daily hemodialysis or in patients with substantial residual renal function, and equations to convert single-pool volume in double-pool volume at any level of administered dialysis dose have been suggested [16]

and validated [17]. Our study also shows that commonly used anthropometric equations overestimated V_{DDQ} by 29% on average. This overestimation is consistent with the results from other studies. In a relatively large group of chronic stable hemodialysis patients (37 males and 17 females; mean age 56 ± 15 years; mean body weight 72.5 ± 10.3 kg), Kloppenburg et al [2] showed a 25% overestimation of V_{DDQ} by anthropometric method. Similar results, comparing anthropometric-based V with double-pool modeled V, have been reported by Schneditz et al [18]. Finally, V_{DDQ} and V_{ID} values in our patients appeared to be relatively low, and as a mean they resulted in 42% of final body weight. Our results are in agreement with V_{DDQ} values reported by Manzoni et al [19], who found in a small number of patients (eight patients) that the mean value of V_{DDQ} was equivalent to 48% of final body weight. Kloppenburg et al [2] also found, in a large hemodialysis population (54 patients), low values of V_{DDQ} with a mean V_{DDQ}/body weight ratio of 0.46 in male and of 0.42 in female patients. Recently, using data from the HEMO study, Daugirdas et al [20] found kinetically derived values for V from blood-side and dialysate-side modeling equivalent to 44% and 43% of body weight, respectively.

Many factors might lead to differences between anthropometric total body water estimates and kinetically derived urea distribution volumes [2, 20]. A measurement error in modeled V, possibly due to gastrointestinal urea sequestration has been suggested [abstract; Veeneman JM et al: *J Am Soc Nephrol* 12:A2367, 2001]. Comparing the DDQ technique to the true gold standard for measuring the urea distribution volume, the urea isotope dilution method, (V_{DIL}), Kloppenburg et al [2] found V_{DDQ} values smaller than V_{DIL} with a mean difference corresponding to 4% of body weight. Measurement errors in the isotopic determination of total body water from which anthropometric prediction equations were derived have been suggested, too, leading to an approximate 7% overestimation of total body water [20]. Variations in body composition may also contribute to the differences between anthropometric total body water estimates and kinetically derived urea distribution volume. Disproportional loss of intracellular water in critically ill patients has been described [21]. A predominant loss of muscle mass may be another possible explanation for these differences. Protein malnutrition is a common occurrence in end-stage renal disease patients before the start of dialysis [22], and it becomes even more common after patients start on hemodialysis [23]. Recently, many studies have shown that reduction of lean body mass may occur in renal patients with only a modest degree of chronic renal insufficiency [24–26]. According to these data it is not surprising that anthropometric method can overestimate urea distribution volume in hemodialysis patients.

CONCLUSION

Anthropometric volume calculated using the equations proposed by Watson overestimates urea distribution volume in dialysis patients and cannot be used to verify if V values obtained according to "formal" SPVV-UKM are plausible. The use of ionic dialysance as an input parameter to SPVV-UKM consents to obtain an accurate estimation of V_{DDQ} and circumvents the problem of delayed postdialysis blood samples. To what extent the difference between anthropometric and kinetic volumes represents a true difference or the effect of measurement errors remains the object of future studies.

APPENDIX

Ionic dialysance measurement [12]

$$\mathrm{ID(mL/min)} = (Q_{di} + Q_f) \cdot \left[1 - \frac{Cd_{o1} - Cd_{o2}}{Cd_{i1} - Cd_{i2}}\right] \quad (1)$$

(Q_{di} = dialysate flow at the inlet port of the dialyzer, in mL/min; Q_f = ultrafiltration rate in mL/min).

DDQ method [4]

$$V_{DDQ}(mL) = \frac{(V_{do} \cdot U_{do} - G \cdot (T_d + 30) - U_f \cdot U_{pw0})}{U_{pw0} - U_{pwt30'}} \quad (2)$$

$$G(mg/min) = \frac{(U_{pw02} \cdot (V + IWG) - (V \cdot U_{pwt30'})}{T_i - 30} \quad (3)$$

(Where 30 is the rebound duration; U_f the number of mL removed during the treatment; IWG the interdialytic weight gain in g; and T_i the interdialytic interval in minutes).

$$K_{wb}(ml/min) = \frac{V_{do} \cdot U_{do} \cdot \ln\left(\frac{U_{pwt30'}}{U_{pw0}}\right)}{T_d \cdot (U_{pwt30'} - U_{pw0})} \quad (4)$$

SPVV-UKM [5]

$$V_{ID}(mL) = (Q_f \cdot T_d) \cdot \left[\left[1 - \left(\frac{G - U_{pwt2'} \cdot (ID - Q_f)}{G - U_{pw0} \cdot (ID - Q_f)}\right)^{\frac{Q_f}{(ID - Q_f)}}\right]^{-1} - 1\right] \quad (5)$$

$$G(mg/min) = \alpha \cdot \frac{U_{pw02} - U_{pwt2'} \cdot \left(\frac{(V + \alpha \cdot T_i)}{V}\right)^{-1}}{1 - \left(\frac{(V + \alpha \cdot T_i)}{V}\right)^{-1}} \quad (6)$$

(Where α is the rate of interdialytic weight gain in mL/min).

Computation of anthropometric volume (V_A) [15]

$$\text{Males (L)} = 2.447 - 0.09516\ \text{A (yr)} + 0.1074\ \text{Ht (cm)} + 0.3362\ \text{Wt (kg)} \quad (7)$$

$$\text{Females (L)} = -2.097 + 0.1069\ \text{Ht (cm)} + 0.2466\ \text{Wt (kg)} \quad (8)$$

GLOSSARY OF TERMS

α: rate of interdialytic weight gain (mL/min)
A: age (years)
Cd_{i1}, Cd_{o1}, Cd_{i2}, and Cd_{o2}: conductivity of dialysate inlet and outlet streams (mS/cm)
G: urea generation rate (mg/min)
Ht: height (cm)
ID: ionic dialysance (mL/min)
IWG: interdialytic weight gain (g)
K_d: dialyzer urea clearance (mL/min)
K_{wb}: whole body clearance (mL/min)
Kt/V_{ID}: single pool Kt/V calculated using ID
Kt/V_{dp}: two-pool Kt/V
Q_{bi}: prescribed blood flow rate (mL/min)
Q_f: rate of ultrafiltration (mL/min)
Q_{di}: inlet dialysate flow rate (mL/min)
T_d: duration of treatment time (min)
Ti: interdialytic interval (min)
U_{do}: dialysate urea concentration (mg/mL)
U_f: ultrafiltration (mL)
U_{pwt0}: initial plasma water urea concentrations (mg/mL)
$U_{pwt10'}$: end-dialysis plasma water urea concentrations determined in blood samples drawn immediately after the end of the dialysis session approximately after 10 seconds of reduced blood flow to 100 mL/min (mg/mL)
$U_{pwt2'}$: end-dialysis plasma water urea concentrations determined in blood samples taken at the end of the session with the blood pump speed reduced to 50 mL/min for two minutes (mg/mL)
$U_{pwt30'}$: end-dialysis plasma water urea concentrations determined in blood samples taken 30 minutes after the end of the session (mg/mL)
U_{pw02}: plasma water urea concentration before the start of the subsequent dialytic treatment (mg/mL)
V_A: anthropometric volume (L)
V_{DDQ}: urea distribution volume according to the DDQ method (mL)
V_{ID}: urea distribution volume according to SPVV-UKM (mL)
V_{do}: outlet dialysate volume (mL)
Wt: postdialysis weight (kg)

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