Influence of the Ionic Dialysance Monitor on Kt Measurement in Hemodialysis

Francisco Maduell, MD, PhD, Manel Vera, MD, Marta Arias, MD, Nuria Serra, MD, Miguel Blasco, MD, Eduardo Bergadá, MD, Nestor Fontsere, MD, PhD, Aleix Cases, MD, PhD, and Josep M. Campistol, MD, PhD

Background: Ionic dialysance can provide accurate monitoring of dialysis dose during each hemodialysis session. Increasingly, hemodialysis machines incorporate devices that measure ionic dialysance, allowing the dialysis dose to be determined noninvasively in real time and in each session. Because Kt product was proposed as a measure of hemodialysis dose to avoid the reverse J-shaped curve between urea reduction ratio or Kt/V and mortality, we investigated whether ionic dialysance values and Kt measurements are affected by different ionic dialysance monitors (Diascan and online clearance monitoring [OCM]) and dialysis machines.

Study Design: Four-period crossover.

Setting & Participants: 31 adult long-term hemodialysis patients using 2 different ionic dialysance monitors in 4 dialysis machines: Diascan in Hospal Integra and Gambro AK-200 machines and OCM in Fresenius 4008S and 5008 machines.

Predictors: Ionic dialysance monitor and machine used in 4 hemodialysis sessions for each participant.

Outcomes: Kt and Kt/V measured by using ionic dialysance and serum urea nitrogen.

Results: Mean values for initial and final ionic dialysance were similar for Integra and AK-200 machines, both measured by using Diascan, and for the 4008S and 5008 machines, both measured by using OCM; however, OCM values tended to be greater in the 4008S and 5008 machines. Kt measured in the 4008S and 5008 machines was greater (59.6 $\pm$ 12 and 58.6 $\pm$ 11 L, respectively) than with the Integra and AK-200 machines (53.4 $\pm$ 11 and 53.8 $\pm$ 11 L). Mean urea reduction ratio and Kt/V were 78.0% $\pm$ 8% and 1.89 $\pm$ 0.43 for Diascan monitors and 79.6% $\pm$ 8% and 1.99 $\pm$ 0.44 for OCM monitors, respectively ($P < 0.01$). Differences between monitors in Kt determination were caused in part by a real difference in dialysis effectiveness (6%) and in part by an intermethod difference (4%). Kt adjusted by Kt/V differences was recalculated, and because of good correlation between Diascan and OCM, we were able to apply a formula ($Kt_{OCM} = 1.08\ Kt_{Diascan} - 2$; $r = 0.95$) that allowed both Kt quantification methods to be compared.

Limitations: Nonblinded nonrandomized small sample.

Conclusions: Kt is a valid method for judging dialysis dose in real time by using ionic dialysance measurements. Adjustments to correct intermethod differences may be necessary to ensure generalizability among ionic dialysance monitors.

Am J Kidney Dis 52:85-92. © *2008 by the National Kidney Foundation, Inc.*

INDEX WORDS: Dialysis adequacy; ionic dialysance; Kt; noninvasive monitoring; online clearance.

Editorial, p. 7

Ionic dialysance was proposed to assess dialysis efficiency for small molecules during dialysis sessions and can be calculated easily from online inlet and outlet dialysate conductivity measurements at 2 different steps of dialysate conductivity. Ionic dialysance is equivalent to urea clearance corrected for recirculation and can provide accurate monitoring of dialysis dose in all dialysis sessions.[1-4]

More and more hemodialysis machines have devices that measure ionic dialysance, allowing

From the Department of Nephrology, Hospital Clínic Barcelona, Barcelona, Spain.

Received December 17, 2007. Accepted in revised form March 11, 2008. Originally published online as doi: 10.1053/j.ajkd.2008.03.014 on May 5, 2008.

Address correspondence to Francisco Maduell, MD, PhD, Servicio de Nefrología, Hospital Clínic Barcelona, C/ Villaroel, 170, 08036 Barcelona, Spain. E-mail: fmaduell@clinic.ub.es

0272-6386/08/5201-0012$34.00/0
doi:10.1053/j.ajkd.2008.03.014

dialysis dose to be determined noninvasively in real time and in each session without increasing costs. Currently, 2 manufacturers produce devices to measure ionic dialysance and Kt. Hospal (Medolla, Italy) developed the Diascan biosensor,[1] which was first incorporated into the Monitral machine and subsequently into the Integra and AK-200 monitors (Gambro, Stockholm, Sweden). Using a slightly different method, Fresenius Medical Care (Bad Homburg, Germany) progressively introduced online clearance monitoring (OCM) into their 2008, 4008, and 5008 machines.[5]

In 1999, Lowrie et al[6] and Chertow et al[7] proposed the Kt product (K is urea clearance and t is dialysis time) as a measure of hemodialysis dose to avoid the reverse J-shaped curve between urea reduction ratio (URR) or Kt/V and mortality. A minimum Kt of 40 to 45 L/treatment for women and 45 to 50 L/treatment for men was recommended in a thrice-weekly schedule. In 2005, the same investigators[8] proposed prescribing Kt targets in terms of body surface area, a method that was validated 1 year later.[9]

The aim of this study is to verify whether ionic dialysance values and Kt measurements are affected by different ionic dialysance monitors (Diascan and OCM) and machines (Integra, AK-200, 4008S, and 5008) to be able to generalize Kt recommendations to the hemodialysis population independently of the monitor used.

METHODS

This study is a single-center open-label prospective study evaluating Kt measurement in 4 different hemodialysis machines. The study was carried out in 31 patients, 18 men and 13 women, with a mean age of 59.8 ± 15 years (range, 29 to 83 years), in a stable hemodialysis program for 37 ± 47 months. Four patients were under short daily hemodialysis and the remainder was on a thrice-weekly schedule. Underlying kidney diseases were chronic glomerulonephritis in 6 patients, nephroangiosclerosis in 8 patients, polycystic kidney disease in 3 patients, chronic tubulointerstitial nephritis in 4 patients, diabetic nephropathy in 4 patients, amyloidosis in 2 patients, lupus in 1 patient, and undiagnosed kidney disease in 3 patients.

All patients underwent 4 hemodialysis sessions with routine hemodialysis parameters: dialysis buffer with bicarbonate, 1.5- or 1.8-m^2 high-flux polysulfone or helixone filters, dialysis time of 260 ± 46 minutes, blood flow of 442 ± 39 mL/min (range, 350 to 500 mL/min), and dialysate flow of 500 mL/min. Mean dry weight was 66.3 ± 14 kg. Anticoagulation was performed routinely with low-molecular-weight heparin. All patients had a native arteriovenous fistula except for 3 who had a tunneled catheter. Residual kidney function was negligible in all patients. All patients were studied on the same day of the week (normally midweek).

The only difference among the 4 sessions in each patient was the dialysis machine. The dialysis machines evaluated were Hospal Integra, Gambro AK-200, Fresenius 4008S, and Fresenius 5008. All monitors were equipped with automatic measurement of ionic dialysance, Diascan in the Integra and AK-200 machines, and OCM in the Fresenius 4008S and 5008 machines. Allocation to a specific dialysis machine was not performed randomly or in a specified order because it was assigned to each patient according to dialysis unit organization and machine availability.

In each dialysis session, predialysis and postdialysis blood urea nitrogen (BUN) were measured. Blood samples for BUN analysis were drawn predialysis from dry needle tubing after insertion of the needle into the vascular access. Postdialysis samples were obtained immediately at the end of dialysis after slowing blood flow to 50 mL/min and stopping the ultrafiltration. Calculation of URR, Kt/V by means of the Daugirdas second-generation single-pool variable volume formula, and Kt/V by means of the Daugirdas second-generation formula with correction for rebound (Kt/V_{dp}) was performed.[10,11] Urea volume distribution (V) was calculated by using the formulas of Watson et al.[12] Kt/V using ionic dialysance (Dt/V) was calculated with Kt measured with ionic dialysance divided by V using the Watson formula.

There are 2 different methods for measurement of ionic dialysance. The Diascan device chose a step of ±1 mS/cm during a 2-minute period without changes in plasma conductivity. The Diascan device changes inlet conductivity every 30 minutes and records the change in conductivity at a second conductance meter at the dialysate waste. From this change, ionic dialysance and plasma conductivity can be calculated automatically. The OCM devices monitor the high/low inlet and outlet conductivity profiles at very frequent intervals and identify steady state as the point when dialysate conductivity becomes stable in both inlet and outlet dialysate. The time required to reach steady state is 2 to 3 minutes for each of the sequential high/low profile segments; thus, total test time for each measurement of effective conductivity clearance is in the order of 4 to 6 minutes. The target for high dialysate inlet conductivity is 15.5 mS/cm, whereas the target for low dialysate inlet conductivity is 13.5 mS/cm.[13]

To compare the Diascan and OCM biosensors, dialysis sessions with Diascan (Integra and AK-200 machines) and OCM (4008S and 5008 machines) were grouped. Because part of the differences in Kt measurements were caused by a real difference between devices, we recalculated Kt adjusted by the Kt/V differences:

$$\text{Adjusted } Kt_{OCM} = Kt_{OCM} - (Kt/V_{OCM} - Kt/V_{Diascan}) * V$$

Initial ionic dialysance, final ionic dialysance, and final Kt were recorded. Initial ionic dialysance was obtained approximately 30 minutes after beginning the session, and final ionic dialysance was obtained during the last hour of the session. Accumulated final Kt was collected from the monitors at the end of the dialysis session.

Table 1. Descriptive Patient Demographics and Hemodialysis Characteristics

Age (y)	59.8 ± 15
Men/women	18/13
Vascular access (arteriovenous fistula/ catheter)	28/3
Dialysis time (min)	260 ± 46
Blood flow (mL/min)	442 ± 39
Dialysate flow (mL/min)	500
Mean dry weight (kg)	66.3 ± 14
Interdialytic weight gain (kg)	2.31 ± 1.1
V, Watson's formula (L)	34.6 ± 5.9

Note: Values expressed as mean ± SD or number. N = 31.

All statistical analyses were performed using the RSigma Babel (Horus Hardware, Madrid) program. Results are expressed as arithmetic mean ± SD. Analysis of variance (ANOVA) for repeated-measures data was used in the analysis of differences in quantitative variables. *P* less than 0.05 is considered statistically significant. We used the linear correlation coefficient to calculate dependence between 2 variables. Kt values were compared between methods by using linear regression and Bland-Altman analyses.

RESULTS

Data were collected from 124 hemodialysis sessions during a 4-month period. Descriptive patient demographics and constant hemodialysis characteristics during the study are listed in Table 1.

Interdialysis weight gain and postdialysis weight were similar in all study situations (Table 2). Mean values for initial and final ionic dialysance were similar for the Integra and AK-200 machines, both measured by using Diascan, as well as for the 4008S and 5008 machines, measured by using OCM (Table 2). However, there was a tendency toward greater values in the 4008S and 5008 machines, with statistical significance in only initial ionic dialysance between the AK-200 monitor versus the 4008S monitor (Fig 1).

Mean values for Kt measured in the 4008S and 5008 machines (59.6 ± 12 and 58.6 ± 11 L, respectively) were greater in comparison to the Integra and AK-200 machines (53.4 ± 11 and 53.8 ± 11 L; Fig 2). However, a strong significant correlation among all machines was observed (Integra versus AK-200, 4008S, and 5008: $r = 0.945$, $r = 0.940$, and $r = 0.963$, respectively; AK-200 versus 4008S and 5008: $r = 0.922$ and $r = 0.967$; Fresenius 4008S versus 5008: $r = 0.928$).

Mean URR, Kt/V, and Kt/V_{dp} determined in dialysis sessions with the 4008S (URR, 79.8% ± 8%; Kt/V, 1.99 ± 0.46; Kt/V_{dp}, 1.75 ± 0.43) and 5008 machines (URR, 79.8% ± 8%; Kt/V, 1.99 ± 0.46; Kt/V_{dp}, 1.76 ± 0.44) were slightly greater than those obtained with the Integra (URR, 78.4% ± 8%; Kt/V, 1.91 ± 0.46; Kt/V_{dp}, 1.68 ± 0.43) and AK-200 machines (URR, 78.0% ± 8%; Kt/V, 1.89 ± 0.46; Kt/V_{dp}, 1.66 ± 0.43; $P <$ 0.05) in ANOVA repeated-measures analysis (Table 2).

Dt/V values were obtained (Table 2), which showed approximately 16% lower values in the Integra and AK-200 machines in comparison to Kt/V ($P < 0.01$) and 5% in comparison to Kt/V_{dp} ($P < 0.01$). However, Dt/V values obtained with the 4008S and 5008 machines showed 12% lower values in comparison to Kt/V ($P < 0.01$) and were similar to Kt/V_{dp} (P = not significant; Fig 3). A strong significant correlation between Dt/V measured by using Diascan (derived by ionic dialysance) and Kt/V_{dp} (derived from pre/postdi-

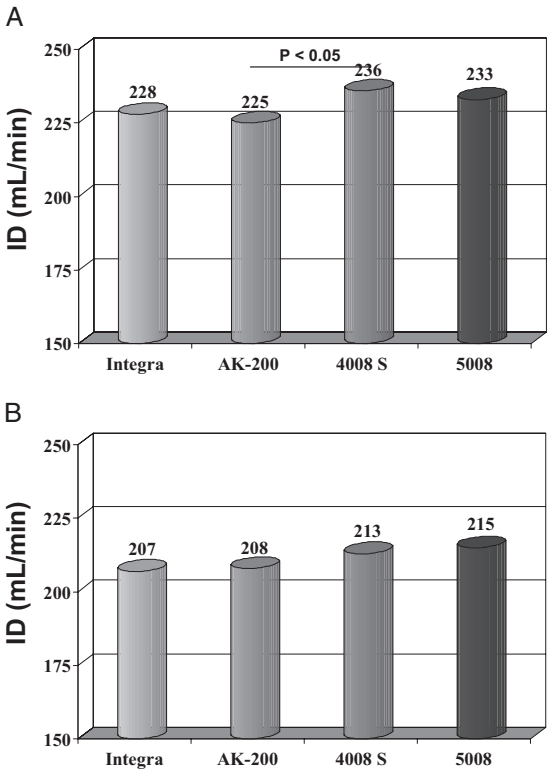

Figure 1. Comparison of different measures of (A) initial and (B) final ionic dialysance (expressed in milliliters per minute) among dialysis machines (Hospal Integra, Gambro AK-200, Fresenius 4008S, and Fresenius 5008).

Table 2. Interdialytic Weight Gain, Postdialysis Weight, URR, Kt/V, and Initial and Final Ionic Dialysance for Each Study Situation

	Hospal Integra	Gambro AK-200	Fresenius 4008S	Fresenius 5008
Interdialytic weight gain (kg)	2.22 ± 0.94	2.33 ± 1.22	2.25 ± 1.15	2.44 ± 1.11
Postdialysis weight (kg)	66.7 ± 14	66.3 ± 14	66.3 ± 14	66.3 ± 14
Initial ID (mL/min)	228 ± 36	225 ± 36	236 ± 36*	233 ± 36
Final ID (mL/min)	207 ± 32	208 ± 34	213 ± 31	215 ± 32
Kt (L)	53.4 ± 11	53.8 ± 11	59.6 ± 12†‡	58.6 ± 12†‡
Dt/V	1.57 ± 0.36	1.58 ± 0.32	1.75 ± 0.38†‡	1.72 ± 0.37†‡
URR (%)	78.2 ± 8	77.8 ± 8	79.8 ± 8‡§	79.5 ± 8‡§
Kt/V	1.89 ± 0.44	1.88 ± 0.45	1.99 ± 0.46‡§	1.98 ± 0.45†‡
Kt/V_{dp}	1.66 ± 0.41	1.65 ± 0.42	1.75 ± 0.43‡§	1.74 ± 0.42†‡

Abbreviations: URR, urea reduction ratio; ID, ionic dialysance; Dt/V, Kt/V calculated with Kt (ionic dialysance) divided by V by using the Watson formula; ANOVA, analysis of variance; Kt/V_{dp}, parameter derived from pre/postdialysis blood urea nitrogen measured from blood sample.

*$P < 0.05$ with respect to Gambro AK-200 (ANOVA repeated measures).

†$P < 0.01$ with respect to Hospal Integra (ANOVA repeated measures).

‡$P < 0.01$ with respect to Gambro AK-200 (ANOVA repeated measures).

§$P < 0.05$ with respect to Hospal Integra (ANOVA repeated measures).

alysis BUN with blood sample) was observed ($r = 0.917$), and also between Dt/V measured by using OCM and Kt/V_{dp} ($r = 0.925$; Fig 4).

To compare the Diascan and OCM biosensors, dialysis sessions with Diascan (Integra and AK-200 machines) and OCM (4008S and 5008 machines) were grouped (Table 3). The Kt values measured were 53.6 ± 11 L with Diascan and 59.1 ± 12 L with OCM ($P < 0.001$; repeated-measures ANOVA). The Kt values measured by using OCM were greater than those measured by using Diascan, showing intermethod differences. Only the 4 patients in daily hemodialysis had a Kt less than 40 L in both methods. A comparative analysis of Kt by using Diascan versus OCM was performed using regression analysis. Results of Kt values measured by using Diascan correlated closely with those of Kt values measured by using OCM ($r = 0.962$; $P < 0.001$). A Bland-Altman analysis was performed expressing the difference between methods (Table 3) and indicated an overall mean difference between Kt measured by using Diascan and OCM of 5.5 L, representing approximately 9.8%, a difference that remained constant over the range of Kt values (Fig 5). The limits of agreement indicate a possible error of −5.7% when using Kt_{OCM} instead of $Kt_{Diascan}$, which is in acceptable margins for routine practice.

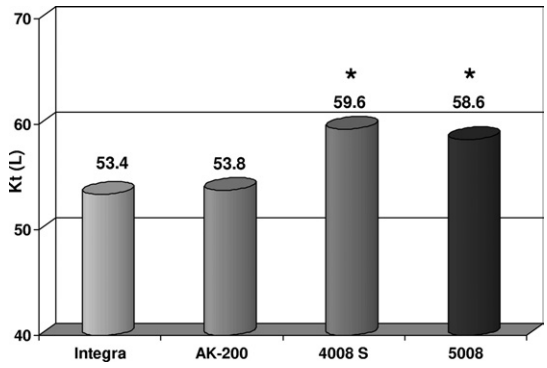

Figure 2. Comparison of Kt measurements among different dialysis machines (Hospal Integra, Gambro AK-200, Fresenius 4008S, and Fresenius 5008). Analysis of variance repeated measures, *$P < 0.01$ versus Integra and AK-200 monitors.

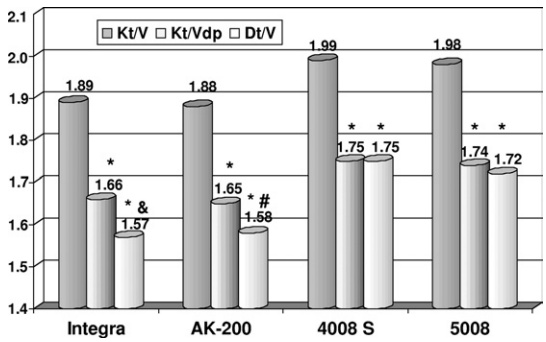

Figure 3. Comparison of Kt/V, Kt/V_{dp}, and Dt/V measurements among different dialysis machines (Hospal Integra, Gambro AK-200, Fresenius 4008S, and Fresenius 5008). Kt/V is by the Daugirdas second-generation single-pool variable volume formula, Kt/V_{dp} is by the Daugirdas second-generation formula with correction for rebound, and Dt/V is Kt measured with ionic dialysance divided by V (Watson's formula). Analysis of variance repeated measures, *$P < 0.01$ versus Kt/V; &$P < 0.01$ versus Kt/V_{dp}; #$P < 0.05$ versus Kt/V_{dp}.

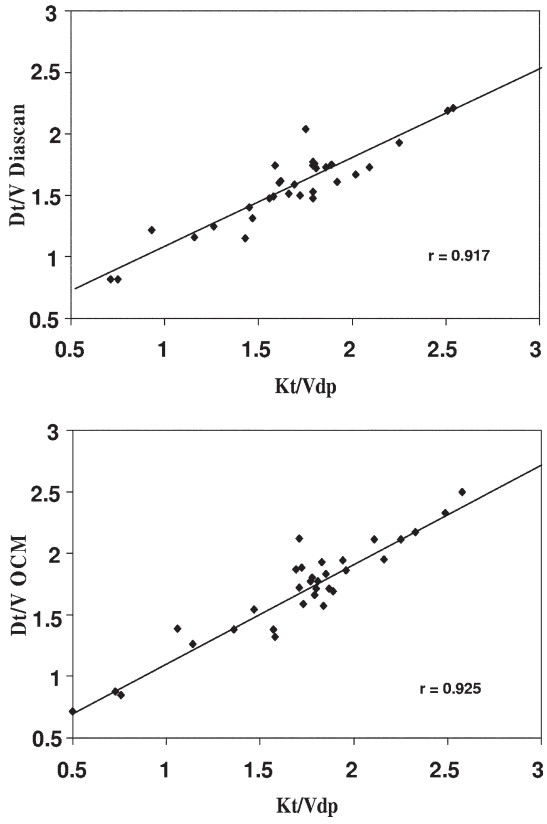

Figure 4. Correlation between Dt/V (parameter derived by ionic dialysance measured with Diascan or online clearance monitoring [OCM] monitor) and Kt/V_{dp} (parameter derived from pre/postdialysis blood urea nitrogen measured from blood sample).

The Kt values measured by using Diascan compared with those measured by using OCM adjusted by Kt/V differences were 53.6 ± 11 versus 55.7 ± 13 L ($P < 0.01$; repeated-measures ANOVA). This latter value continued to be significantly greater than those measured with Diascan, confirming the existence of intermethod differences. Again, results of adjusted Kt values measured by using Diascan correlated closely with those of Kt values measured by using OCM ($r = 0.952$; $P < 0.001$), and Bland-Altman analysis continued to express the difference between methods, indicating an overall Kt mean difference of 2.1 L, representing approximately 4% (Fig 6). The limits of agreement indicate a possible error of −7.3% when using adjusted Kt_{OCM} instead of $Kt_{Diascan}$, which is in acceptable margins for routine practice.

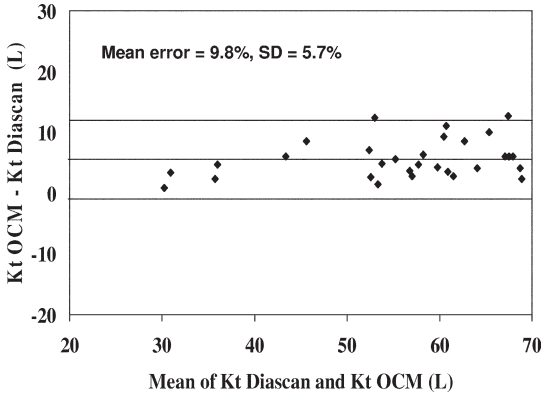

Figure 5. Amplitude of limits of agreement of Kt measured with Diascan versus online clearance monitoring (OCM) according to Bland-Altman analysis.

Because an intermethod difference was observed after this adjustment and it was associated with a good correlation coefficient in Kt values between the Diascan and OCM monitors, Kt measured by using Diascan could be modified for a more precise comparison with OCM monitors by using the following formula:

$$Kt_{OCM} = 1.08 * Kt_{Diascan} - 2$$

Table 3. Statistical Comparison Between the Diascan and OCM Modules

	Diascan	OCM	Significance (*P*)
Kt (L)	53.6 ± 11	59.1 ± 12	<0.01
Adjusted Kt_{OCM} (L)		55.7 ± 13	<0.01
Kt/V	1.89 ± 0.43	1.99 ± 0.44	<0.01
Kt/V_{dp}	1.65 ± 0.41	1.74 ± 0.42	<0.01
Urea reduction ratio (%)	78.0 ± 8	79.6 ± 8	<0.01
Dt/V	1.57 ± 0.34	1.74 ± 0.37	<0.01
Adjusted Dt/V_{OCM}		1.63 ± 0.38	<0.01

Note: Adjusted $Kt_{OCM} = Kt_{OCM} - (Kt/V_{OCM} - Kt/V_{Diascan})$ *V; adjusted Dt/V_{OCM} = adjusted Kt_{OCM}/V (Watson's formula). Significance: analysis of variance repeated measures.

Abbreviations: Dt/V, Kt/V calculated with Kt (ionic dialysance) divided by V by using the Watson formula; OCM, online clearance monitoring; Kt/V_{dp}, parameter derived from pre/postdialysis blood urea nitrogen measured from blood sample.

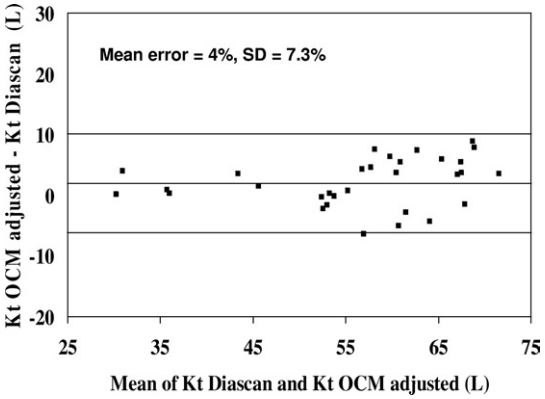

Figure 6. Amplitude of limits of agreement of $Kt_{Diascan}$ versus Kt_{OCM} adjusted to Kt/V differences according to Bland-Altman analysis. Adjusted $Kt_{OCM} = Kt_{OCM} - (Kt/V_{OCM} - Kt/V_{Diascan}) * V$. Abbreviation: OCM, online clearance monitoring.

DISCUSSION

This study is the first to compare measurement of ionic dialysance and Kt with different dialysis machines, showing that Kt is affected by the method of determination. The Diascan device (Integra and AK-200 machines) showed Kt values lower than the OCM device (4008S and 5008 machines). This difference was caused in part by a real diminished dialysis dose and in part by intermethod differences.

Generalized recommendations for dialysis dose are based on predialysis and postdialysis BUN samples, which should be measured at least once a month, although these measurements often are made bimonthly, quarterly, or less frequently. The National Kidney Foundation-Dialysis Outcomes Quality Initiative Clinical Practice Guidelines for Hemodialysis Adequacy recommend a minimum Kt/V of 1.2 and/or a URR of 65%, and the prescribed dose should be Kt/V greater than 1.3 or URR greater than 70% to prevent the delivered dose from being less than the recommended minimum dose.[14] These recommendations also were collected in European,[15] Australian,[16] and Canadian[17] clinical guidelines.

Because there often is a large difference between the prescribed and delivered dialysis dose, dialysis efficiency must be measured regularly. Recent technical advances permit direct measurement of urea clearance (effective ionic dialysance) during the course of each treatment. Because an increasing number of hemodialysis machines are equipped with ionic dialysis devices, new recommendations should be considered for continuous dialysis dose monitoring. Two companies (Hospal-Gambro with the Diascan biosensor and Fresenius Medical Care with the OCM biosensor) offer devices that could be used to achieve this goal. In 2006, Spanish practice guidelines[18] recommended the use of ionic dialysance for the follow-up of dialysis dose in patients undergoing dialysis with these kinds of monitors.

Various studies used ionic dialysance to calculate Kt/V and observed that although correlation was good, there were differences between the Daugirdas monocompartmental or bicompartmental Kt/V, showing intermethod variability.[19-21] To obtain Kt/V, V must be introduced, a vague value that can be obtained by using the anthropometric formulas of Watson et al,[12] Hume and Weyers,[22] or Chertow et al,[23] 55% of dry weight, calculations between measured Kt divided by blood Kt/V,[24] direct dialysis quantification,[25] or bioimpedanciometry.[26] Kt/V determined with ionic dialysance compared with Kt/V calculated with the second-generation formula of Daugirdas usually underestimates the correct value.[26-28]

Since 1999, Kt was proposed as an alternative in dialysis dosing with potential advantages. K and t measurements are real and cannot be manipulated by the user. The reverse J-shaped survival curve is avoided if distribution of patients in quintiles according to URR or Kt/V is replaced by Kt values.[7] The initial Kt recommendations[6] were based on sex (minimum Kt of 40 to 45 L for women and 45 to 50 L for men). In the earlier studies of Lowrie et al[6] and Chertow et al,[7] Kt was estimated on predialysis and postdialysis BUN measurements, multiplying Kt/V by V (estimated by means of bioelectrical impedance analysis or the anthropometric formula of Chertow).

In 2005, the same investigators[8] recommended individual adjustment of Kt values to body surface area. In that study, Kt was measured systematically by using OCM devices in 33,328 patients dialyzed with OCM monitors. One year later, these indications were validated[9] in 59,644 patients, also dialyzed with OCM devices in Fresenius machines, showing that in patients receiving 4 to 7, 7 to 11, or 11 L or more less than the Kt

prescribed, mortality would increase by 10%, 25%, and more than 30%, respectively.

In patients dialyzed with monitors equipped with ionic dialysance, Spanish practice guidelines[18] recommended a Kt greater than 45 L or a Kt value individualized to body surface area. In a recent study[29] of 51 patients, we reported that although all patients fulfilled Kt/V recommendations when dialysis dose was evaluated by using Kt, only 60% reached the target. These results suggest that Kt allows better discrimination of dialysis adjustment by identifying some patients who perhaps do not reach an adequate dialysis dose because of their sex or body surface area.

Because Kt recommendations were made by using OCM with Fresenius machines, and in this study, we observed intermethod differences between Diascan and OCM, a formula that allows comparison of different Kt quantification methods is required to generalize Kt recommendations independently of the monitor used.

In this study, the Kt measured by using Diascan (Integra and AK-200 machines) was 5.5 L less (~10%) than OCM (4008S and 5008 machines). No differences were found between machines that used the same ionic dialysance biosensor. Differences between Diascan and OCM in Kt measurement were caused in part by a real diminished dialysis dose. Kt/V or Kt/V_{dp} measured by using Diascan showed lower values (0.1) than those with OCM, which, when multiplied by V, represents 3.4 L of the total Kt (~6% less). This real difference between monitors could be explained by technical characteristics and no effective dialysis time during dialysis sessions caused by blood pump stops (arterial, venous, or transmembrane pressure alarms), dialysate flow control differences, or recurrent internal specific tests for each machine; for example, unlike the 4008 and 5008 machines, dialysis time does not stop in the Integra and AK-200 machines when intradialysis alarms appear, which could represent around 1 L less of Kt for each 5 minutes of no effective dialysis time at 200 mL/min of ionic dialysance.

The other reason for differences observed in Kt measurement was intermethod variation, because Kt measured by using Diascan after Kt/V adjustment compared with OCM was 2.1 L less (~4%). Initial ionic dialysance already supports this observation because when measured by using Diascan, it showed values of 10 mL/min less (~4%) compared with OCM. Because this intermethod difference was associated with a good correlation coefficient, Kt measured by using Diascan could be adjusted to achieve a more precise comparison with OCM by using the suggested formula.

We conclude that Kt is a valid method for judging dialysis dose if ionic dialysance measurements are available. This method provides accurate monitoring of dialysis dose in real time and in all dialysis sessions. To comply with Kt recommendations, adequate adjustments are required to correct the intermethod differences observed in this study so that these recommendations may be generalized independently of the method or monitor used.

ACKNOWLEDGEMENTS

Support: None.
Financial Disclosure: None.

REFERENCES

1. Peticlerc T, Goux N, Reynier AL, Bene B: A model for non invasive estimation of in vivo dialyzer performances and patient's conductivity during hemodialysis. Int J Artif Organs 16:585-591, 1993

2. Polaschegg HD: Automatic, noninvasive intradialytic clearance measurement. Int J Artif Organs 16:185-191, 1993

3. Mercadal L, Du Montcel ST, Jaudon MC, et al: Ionic dialysance vs urea clearance in the absence of cardiopulmonary recirculation. Nephrol Dial Transplant 17:106-111, 2002

4. Lindsay RM, Bene B, Goux N, Heidenheim AP, Landgren C, Sternby J: Relationship between effective ionic dialysance and in vivo urea clearance during hemodialysis. Am J Kidney Dis 38:565-574, 2001

5. Gotch FA, Peter H, Panlilio FM, Folden T, Keen M: On-line measurement of delivered Kt/V during dialysis. J Am Soc Nephol 6:600, 1995 (abstr)

6. Lowrie EG, Chertow GM, Lew NL, Lazarus JM, Owen WF: The urea {clearance x dialysis time} product (Kt) as an outcome-based measure of hemodialysis dose. Kidney Int 56:729-737, 1999

7. Chertow GM, Owen WF, Lazarus JM, Lew NL, Lowrie EG: Exploring the reverse J-shaped curve between urea reduction ratio and mortality. Kidney Int 56:1872-1878, 1999

8. Lowrie EG, Li Z, Ofsthun NJ, Lazarus JM: The online measurement of hemodialysis dose (Kt): Clinical outcome as a function of body surface area. Kidney Int 68:1344-1354, 2005

9. Lowrie EG, Li Z, Ofsthun NJ, Lazarus JM: Evaluating a new method to judge dialysis treatment using online measurements of ionic clearance. Kidney Int 70:211-217, 2006

10. Daugirdas JT: Second generation logarithmic estimates of single-pool variable volume Kt/V: An analysis of error. J Am Soc Nephrol 4:1205-1213, 1993

11. Daugirdas JT, Schneditz D: Overestimation of hemodialysis dose depends on dialysis efficiency by regional blood flow. ASAIO J 41:719-724, 1995

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

13. Gotch FA, Panlilio FM, Buyaki RA, Wang EX, Folden TI, Levin NW: Mechanisms determining the ratio of conductivity clearance to urea clearance. Kidney Int Suppl 89:S3-S24, 2004

14. National Kidney Foundation: DOQI Clinical Practice Guidelines for Hemodialysis Adequacy. Am J Kidney Dis 48:S2-S90, 2006 (suppl 1)

15. Tattersall J, Martin-Malo A, Pedrini L, et al: European Best Practice Guidelines (EBPG) on dialysis strategies. Nephrol Dial Transplant 22:S5-S21, 2007 (suppl 2)

16. Jindal K, Chan CT, Deziel C, et al: Canadian Society of Nephrology Committee for Clinical Practice Guidelines. Hemodialysis clinical practice guidelines for the Canadian Society of Nephrology. J Am Soc Nephrol 17:S1-S27, 2006 (suppl 1)

17. Johnson D, Brown F, Lammi H, Walker R: Caring for Australians with Renal Impairment (CARI). The CARI guidelines. Dialysis adequacy (PD) guidelines. Nephrology 10:S81-S107, 2005 (suppl 4)

18. Maduell F, García M, Alcázar R: Dosificación y adecuación del tratamiento dialítico. Guías SEN: Guías de Centros de hemodiálisis. Nefrología 26:S15-S21, 2006 (suppl 8)

19. Goldau R, Kuhlmann U, Samadi N, et al: Ionic dialysance measurement is urea distribution volume dependent: A new approach to better results. Artif Organs 26:321-322, 2002

20. McIntyre CW, Lambie SH, Taal MW, Fluck RJ: Assessment of hemodialysis adequacy by ionic dialysance: Intrapatient variability of delivered treatment. Nephrol Dial Transplant 18:559-562, 2003

21. Moret K, Beerenhout CH, van den Wall Bake AWL, et al: Ionic dialysance and the assessment of Kt/V: The influence of different estimated V on method agreement. Nephrol Dial Transplant 22:2276-2282, 2007

22. Hume R, Weyers E: Relationship between total body water and surface area in normal and obese subjects. J Clin Path 24:234-238, 1971

23. 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 51:1578-1582, 1997

24. Maduell F, Hdez-Jaras J, Garcia H, Calvo C, Navarro V: Seguimiento de la dosis de hemodiálisis en tiempo real. El futuro inmediato. Nefrología 17:S51, 1997 (suppl 2; abstr)

25. Keshaviah P, Star RA: A new approach to dialysis quantification: An adequacy index based on solute removal. Semin Dial 7:85-90, 1994

26. Wuepper A, Tattersall J, Kraemer M, Wilkie M, Edwards L: Determination of urea distribution volume for Kt/V assessed by conductivity monitoring. Kidney Int 64: 2262-2271, 2003

27. Peticlerc T, Bene B, Jacobs C, Jaudon MC, Goux N: Non-invasive monitoring of effective dialysis dose delivered to the haemodialysis patient. Nephrol Dial Transplant 10:212-216, 1995

28. Di Filippo S, Andrulli S, Manzoni C, Corti M, Locatelli F: On-line assessment of delivered dialysis dose. Kidney Int 54:263-267, 1998

29. Maduell F, Vera M, Serra N, et al: Kt como control y seguimiento de la dosis en una unidad de hemodiálisis. Nefrología 28:45-49, 2008