Relationship between urea clearance and ionic dialysance determined using a single-step conductivity profile

Salvatore Di Filippo, Pietro Pozzoni, Celestina Manzoni, Simeone Andrulli, Giuseppe Pontoriero, and Francesco Locatelli

Department of Nephrology and Dialysis, A. Manzoni Hospital, Lecco, Italy

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Background. On-line determination of ionic dialysance (ID) has been used to measure the clearance of small solutes like urea. However, attempts to determine the in vivo relationship between ID and urea clearance have led to discordant findings. The aim of this study was to determine the relationship between the mean values of repeated instantaneous determinations of ID throughout a dialysis session (mID), obtained using a single-step inlet dialysate conductivity profile, and the mean values of urea clearance corrected for access recirculation (K\text{eul}), total recirculation (access plus cardiopulmonary recirculation, K\text{eu2}), and the entire postdialysis urea rebound (K\text{wb}).

Methods. Eighty-two anuric patients on chronic thrice-weekly hemodialysis were studied using an Integra machine equipped with the Diascan module for the automatic determination of ID. The mean values of repeated ID measurements made at 30-minute intervals were compared with K\text{eul} (available for only 31 patients), K\text{eu2}, and K\text{wb}.

Results. The results in all 82 patients were: mID = 176 ± 23 mL/min; K\text{eu2} = 181 ± 25 mL/min; K\text{wb} = 159 ± 22 mL/min. The mean mID/K\text{wb} and mID/K\text{eu2} ratios were, respectively, 1.11 ± 0.06 and 0.98 ± 0.06. The results in the 31 patients for whom K\text{eul} values were available were: mID = 179 ± 24 mL/min and K\text{eul} = 200 ± 27 mL/min; the mean mID/K\text{eul} ratio was 0.90 ± 0.05.

Conclusion. The mean value of repeated ID determinations obtained using a single-step conductivity profile underestimates urea clearance corrected for access recirculation, and may be considered an adequate estimate of urea clearance corrected for total recirculation.

Urea is universally recognized as a marker of solute retention and removal in dialysis patients, and so determining the amount of urea transport during a dialysis session (calculated as the product of urea clearance and dialysis duration normalized for urea distribution volume, Kt/V) is currently the most widely used method for calculating the prescribed dialysis dose and quantifying that actually delivered. A number of observational studies have clearly shown that there is an inverse relationship between the delivered dialysis dose and the mortality and morbidity of chronic hemodialysis patients [1–6]. As the delivered dialysis dose may be lower than that prescribed, it is of paramount importance to know how much of the prescribed dose is actually delivered.

The delivered Kt/V is usually calculated by means of the single-pool, variable volume urea kinetic model, which requires an accurate estimate or measurement of urea clearance and the collection of blood samples for the determination of plasma urea concentrations at the start and at the end of the dialysis session [7]. As a result, the delivered dialysis dose is infrequently quantified and, indeed, current international guidelines [8, 9] recommend checking it at monthly intervals (a pragmatic rather than ideal recommendation). However, because some data suggest that the delivered dose may vary considerably from one session to another [10], more frequent measurements are desirable in clinical practice.

Using the single-pool, variable volume urea kinetic model, once the average mean urea distribution volume (V) has been established for an individual patient, the delivered Kt/V can be determined by measuring urea clearance (K) and treatment time (Td). As Td is known and V does not change rapidly in stable patients, so it seems reasonable to assume that it remains constant over prolonged periods of time (correcting for differences in final body weight between one session and another), it would be useful to have an easy, noninvasive, and economic method of calculating K in order to be able to estimate and monitor the delivered Kt/V ideally at each dialysis session.

The availability of on-line measurements of ionic dialysance (ID) may aid the monitoring of the dialysis dose at each dialysis session because instantaneous ID can be measured simply by using 2 conductivity probes placed at the dialyzer inlet and outlet, without the need for any

Key words: ionic dialysance, urea clearance, direct dialysate quantification, recirculation, conductivity, urea kinetic model.
blood or dialysate sampling [11, 12]. This allows repeated ID measurements that can be used to calculate the mean value for the dialysis session as a whole (mID). It has been suggested that ID may provide an adequate estimate of urea clearance, but there is still no agreement on the precise in vivo relationship between ID and urea clearance [12–19]. In particular, Gotch et al have recently found almost identity between ID and urea clearance corrected for access recirculation [19]; on the contrary, previous studies reported ID values very close to those of urea clearance corrected for total recirculation (i.e., access plus cardiopulmonary recirculation), thus significantly underestimating urea clearance corrected for only access recirculation [14, 18]. However, such different findings can be at least partially explained by the fact that, as recently shown, ID values may vary widely depending on the different methods used to modify inlet dialysate conductivity during their measurement [16, 19].

The aim of this study was to assess whether determining ID by means of a single-step conductivity profile (in which the inlet conductivity profile is changed to a fixed value and then restored to its baseline value) affects the relationship between urea clearance and ID observed when using a 2-step conductivity profile. To this end, we compared the mean values of repeated instantaneous ID measurements throughout the dialysis session obtained using a single-step inlet conductivity profile (mID), and the mean values of urea clearance corrected for access recirculation alone, total (access plus cardiopulmonary) recirculation, and the entire postdialysis urea rebound.

METHODS

After giving informed consent, 82 anuric patients on chronic thrice-weekly hemodialysis entered the study, which was reviewed and approved by local ethics committee. Eighty-two dialysis sessions were performed, 1 for each patient. The prescribed blood flow rate (Qbi) was between 200 and 400 mL/min, and was kept constant throughout dialysis session; the dialysate flow rate was fixed at 500 mL/min. Vascular accesses were native arterio-venous fistula in 71 patients, synthetic graft in 11 patients. Of the total of 11 dialyzer types, low-flux dialyzers were used in 85% of the sessions. All of the sessions were conducted using an Integra dialysate delivery machine (Hospal, Medula, Italy), equipped with the Diascan Module® (Gambro, Dasco, Italy) for the automatic determination of ID, and the Quantiscan Module® (Gambro, Dasco, Italy) 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 pumping rate of acid concentrate to increase or reduce the baseline inlet dialysate conductivity (CDi) by 1 mS/cm for 2 minutes. Software records the values of inlet and outlet dialysate conductivity (CDo) during this phase (CDi1, CDo1; step 1) and after CDi is moved back to the prescribed baseline value (CDi0, CDo0; step 0). ID is then calculated using Equation 1 [12], which, like all of the following equations, is given in the Appendix. The ID measurement procedure takes about 6 minutes, and the first determination 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 continuously collecting a reduced volume sample (0.1% of total dialysate flow). The volume of total dialysate with ultrafiltration (VDo) is separately computed using continuous signals from flowmeters located within the volumetric ultrafiltration control system, and displayed on the screen of the dialysis monitor. Using this device, a difference of only 0.3 ± 2.6% has been reported between the computed and collected total dialysate volume [20].

At each session, 3 blood samples were taken to determine plasma urea (Up) and total protein (TP) concentrations, in order to be able to calculate urea concentration in plasma water (Upw) using equation 2 [21]. The first blood sample was taken immediately before the start of the dialysis treatment (Upw0), the second at the end of the session at the inlet port of the dialyzer after slowing Qbi to 50 mL/min for 2 minutes (Upw12′), and the third 30 minutes after the end of the session (Upw30′). In the case of 31 of the 82 patients, an “immediate” postdialysis blood sample was also drawn at the inlet port of the dialyzer after slowing Qbi to 100 mL/min for approximately 10 seconds (Upw10′). The same 31 patients also had samples for the analysis of systemic plasma water sodium concentration, hematocrit (Htc), hemoglobin (Hb), and inlet dialysate sodium concentration (NaDi) drawn before the start of the dialysis session; systemic plasma water sodium concentration was also determined at the end of the session, and the mean value of the initial and final measurements (NaPw) was used for the analysis. Plasma and dialysate urea (UDo) and total plasma protein concentrations were determined in duplicate using a Hitachi 917 analyzer (Hitachi, Tokyo, Japan). Plasma water and dialysate ionized sodium concentrations, and Htc and Hb were measured by means of direct ionometry (Stat Profile M analyzer; Nova Biomedical, Waltham, MA, USA).

Whole body clearance (Kwb, i.e., dialyzer urea clearance corrected for total recirculation and postdialysis urea rebound) was determined according to Equation 3, using the direct dialysate quantification method described by Depner et al [22], and was then used to calculate urea clearance corrected for access recirculation (Keu1) according to Equation 4, and urea clearance corrected for both access and cardiopulmonary recirculation (Keu2) according to Equation 5.
Starting from Na_pws, plasma water sodium concentrations at the inlet (Na_pwi) and outlet (Na_pwo) ports of the dialyzer during step 1 (Na_pwi1, Na_pwo1) and step 0 (Na_pwo0, Na_pwo0) were estimated according to Equations 6 and 7, applied over a 2-minute period (considering the Donnan factor as being equal to 0.967; our unpublished data), using Keu1 as dialyzer urea clearance, and calculating cardiopulmonary recirculation (Rcp) from Equation 8. Finally, Na_pwi1 and Na_pwo0 were used to calculate the expected ID/Keu1 ratio according to Equation 9 [19].

Dialysate sodium concentration (NaDi) during ID measurement was estimated from dialysate conductivity, being the ratio between NaDi and dialysate conductivity determined during “baseline” conditions.

### Statistical analysis

The urea clearance values obtained using the direct dialysate quantification method were adopted as the reference and compared with the arithmetical mean of the ID measurements. Mean differences, standard deviations, and 95% confidence intervals are provided for each variable. The individual differences in these variables were also plotted against the possibly relevant reference variable in order to test whether the difference depended on the value of the latter. The same plots show regression lines with the β-regression coefficient, and the associated P value of the null hypothesis of a β-regression coefficient equal to zero. Adjusted R² was calculated in order to measure how much of the variability of the y axis (the difference between the tested and the reference variable) was explained by the variation on the x axis (the reference variable). A probability value of less than 0.05 was considered as statistically significant. The statistical analyses were made using SPSS for Windows, release 11.0 (Chicago, IL, USA).

### RESULTS

The urea clearances in the 82 patients were: Kwb 159 ± 22 mL/min, Keu1 181 ± 25 mL/min. The Diascan module made a total of 601 instantaneous determinations (a mean of 7 ± 1 per patient; range 5–9); the mean ID (mID) was 176 ± 23 mL/min. Among 62 patients in whom all the first 7 instantaneous ID determinations were available, these showed a linear decrease throughout the dialysis session, leading to a mean 8% reduction from the initial value by the seventh determination (Table 1).

The difference between mID and Kwb was 17 ± 9 mL/min (95% CI 15–19 mL/min; P < 0.001), and the mID/Kwb ratio was 1.11 ± 0.06, thus indicating a mean overestimate of Kwb by mID of 11%. When the (mID – Kwb) difference was plotted against Kwb (Fig. 1), no correlation was found (β coefficient -0.049; P = 0.287), thus indicating that mID always overestimates Kwb regardless of dialyzer clearance.

The difference between mID and Keu2 was -5 ± 10 mL/min (95% CI -7 to -3 mL/min; P < 0.001), and the ID/Keu2 ratio was 0.98 ± 0.06, thus indicating a mean underestimate of Keu2 by mID of only 2%. When the (mID – Keu2) difference was plotted against Keu2 (Fig. 2), there was a direct correlation with Keu2 (β coefficient -0.157; P < 0.001), thus indicating that the mean underestimate of Keu2 by mID increases with increased dialyzer clearance.

The urea clearances in the 31 patients for whom Upwt100° values were available were: Keu1 = 200 ± 27 mL/min, Keu2 = 188 ± 26 mL/min, and Kwb = 165 ± 25 mL/min. In this group of patients, the Diascan made 225 instantaneous ID determinations (a mean of 7 ± 1 per patient; range 5–9), and the mean ID (mID) was 179 ± 24 mL/min. The difference between mID and Keu1 was -21 ± 10 mL/min (95% CI -25 to -17 mL/min; P < 0.001), and the mID/Keu1 ratio was 0.90 ± 0.05, thus indicating an underestimate of Keu1 by mID of 10%. When the (mID – Keu1) difference was plotted against Keu1 (Fig. 3), there was a direct correlation with Keu1 (β coefficient

### Table 1. Mean (± SD) differences and ratios between each sequential instantaneous ID determination and the initial value

<table>
<thead>
<tr>
<th>Determination number</th>
<th>Difference mL/min</th>
<th>Ratio</th>
<th>P&lt;sup&gt;α&lt;/sup&gt;</th>
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<tr>
<td>1 (Ref.)</td>
<td>0.0</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-3.5 ± 8.6</td>
<td>0.982 ± 0.048</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>3</td>
<td>-5.8 ± 7.8</td>
<td>0.970 ± 0.041</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>4</td>
<td>-9.0 ± 9.1</td>
<td>0.953 ± 0.048</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>5</td>
<td>-10.0 ± 11.1</td>
<td>0.948 ± 0.057</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6</td>
<td>-12.0 ± 11.4</td>
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<td>&lt;0.001</td>
</tr>
<tr>
<td>7</td>
<td>-14.9 ± 12.2</td>
<td>0.923 ± 0.063</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

<sup>α</sup>Data from 62 patients with all the first 7 instantaneous ID determinations available.

<sup>α</sup>Versus initial value.

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![Fig. 1. Relationship between the (mID–Kwb) difference and Kwb values.](image)
and a mean $\Delta Na_{Di}$ (that is the difference between inlet dialysate sodium concentrations at baseline and during step 1) of $6.67 \pm 7.25$ mEq/L could be calculated. The mean $Na_{pws}$ was $142.68 \pm 1.91$ mEq/L, the mean $R_{cp}$ was $0.08 \pm 0.03$, and the mean $Q_{ei}$ was $253 \pm 39$ mL/min. Applying these values to Equations 6 and 7, it was possible to derive a mean plasma water sodium concentration at the inlet port of the dialyzer at $142.86 \pm 1.86$ mEq/L during step 0 and $142.41 \pm 1.88$ mEq/L during step 1 ($Na_{pwi}$) (Fig. 4), thus resulting in a mean $\Delta Na_{pwi}$ (that is the difference between inlet plasma water sodium concentrations at baseline and during step 1) of $0.45 \pm 0.51$ mEq/L. The expected mean $m_{ID}/K_{eul}$ ratio in these patients (calculated according to Equation 9) was $0.93 \pm 0.03$, a value approaching the observed $m_{ID}/K_{eul}$ value of $0.90 \pm 0.05$.

**DISCUSSION**

In clinical practice, the delivered $Kt/V$ is usually determined by means of the single-pool, variable-volume urea kinetic model, and usually calculated monthly because of the need for pre- and postdialysis blood samples. Nevertheless, some data suggest that dose delivery may vary considerably from one session to another [10], and so more frequent determinations are desirable.

In 1993, two different authors described the mathematics underlying the noninvasive measurement of urea clearance during dialysis [11, 12]. The differences in conductivity between the dialysate inlet and outlet at 2 different dialysate inlet conductivity values makes it possible to calculate ionic dialysance, which can be considered as being similar to sodium dialysance (because of the very close correlation between the conductivity of an electrolyte solution and its sodium content), and to urea clearance, because of the similar molecular weights of sodium chloride and urea. In order to make the most of the conductivity method (i.e., to obtain the delivered dialysis dose easily...
from ionic dialysance), it is necessary to know the relationship between urea clearance throughout the dialysis session (determined according to the direct dialysate quantification method), and the mean value of repeated ionic dialysance measurements. Our results in 82 patients show that the ID determined by the Diascan Module incorporated in the Integra dialysate delivery machine provides an adequate estimate of urea clearance corrected for total recirculation (Keu2), as the mID/Keu2 ratio indicates a mean underestimate of Keu2 by mID of only 2%; on the other hand, mID underestimated Keu1 by 10% and overestimated Keu3 by 11%.

The significant underestimate of Keu1 by mID is a theoretically expected result insofar as ID should be equal to Keu1 only when the plasma water sodium concentration at the dialyzer inlet port (Na\textsubscript{pwi}) is kept constant during ID measurement [11]. On the other hand, if Na\textsubscript{pwi} changes during ID measurement, ID underestimates Keu1 to a degree predicted by Equation 9, which, according to the underestimate, is directly proportional to ΔNa\textsubscript{pwi} and inversely proportional to ΔNa\textsubscript{Di}. This explains the considerably different results obtained by Gotch et al., with their 2-step conductivity profile for the determination of ID, which indicated an ID/Keu1 ratio approaching identity (1.01) and an ID/Keu2 ratio of 1.06 [19]. In their study, the changes in dialysate conductivity during ID measurements (an increase to a fixed value of 155 mEq/L, followed by decrease to a fixed value of 135 mEq/L) were planned a priori in order to minimize the ΔNa\textsubscript{pwi}/ΔNa\textsubscript{Di} ratio, which was actually very close to zero (0.03). In our 31 patients for whom we derived Na\textsubscript{pwi} during step 0 (Na\textsubscript{pwi0}) and step 1 (Na\textsubscript{pwi1}) from the measured values of systemic plasma water concentration, dialysate conductivity, and cardiopulmonary recirculation, we found a mean change in Na\textsubscript{pwi} and Na\textsubscript{Di} during the ID determinations of, respectively, 0.45 mEq/L and 6.67 mEq/L, thus giving a mean ΔNa\textsubscript{pwi}/ΔNa\textsubscript{Di} ratio of 0.07. On the basis of these results and Equation 9, we should therefore have expected to find a mean underestimate of Keu1 by mID of 7%, which is slightly different from the actual underestimate of 10%.

This discrepancy can be explained by possible inaccuracies in deriving ΔNa\textsubscript{pwi} and ΔNa\textsubscript{Di} (i.e., the 2 factors required to calculate the expected ratio between ID and Keu1). An inaccurate determination of ΔNa\textsubscript{Di} could have been due to the fact that the ratio between Na\textsubscript{Di} and dialysate conductivity calculated during step 0 was also used to derive Na\textsubscript{Di} during step 1, whereas this ratio could actually be different because of the 2 different dialysate conductivity values during steps 1 and 0 (13.71 ± 0.61 mS/cm and 14.39 ± 0.22 mS/cm); however, this was not the case because the ratio between dialysate sodium concentration and dialysate conductivity remains constant over the range of conductivity values observed in this study (our unpublished data).

On the contrary, concern may arise in the case of the determination of ΔNa\textsubscript{pwi} because this was calculated (not measured) only taking into account the effect of cardiopulmonary recirculation, and not considering the possible effect of the diffusive transport of sodium across the dialyzer that actually occurred during ID determination.

Our data confirm the results of previous studies using a single-step conductivity profile for the determination of ID that found similarity between ID and Keu2, and an underestimate of Keu1 by ID. Lindsay et al. [18] reported a mean ID/Keu1 ratio of 0.95 and a mean ID/Keu2 ratio of only 0.99 in 8 patients with no access recirculation and a consequent dialyzer urea clearance (Kd) equal to Keu1. Similar results were obtained by Mercadal et al., who observed a mean underestimate of Keu1 by ID of 10% when Keu1 was more than 180 mL/min (as it was in our patients) [14], and identity between ID and Keu1 in the absence of cardiopulmonary recirculation, when Na\textsubscript{pwi} is inevitably kept constant during ID determination [23]. Taken together, these results clearly confirm that the ratio of ID to urea clearance greatly depends on the method used to modify inlet dialysate conductivity during the determination of ID, as has previously been pointed out in other reports [16, 19].

CONCLUSION

Our results show for the first time in a relatively large population of hemodialysis patients that the mean value of repeated ionic dialysance determinations obtained using a single-step inlet dialysate conductivity profile underestimates urea clearance corrected for access recirculation, but provides a clinically adequate estimate of urea clearance corrected for total recirculation. They also further underline the importance of dialysate inlet conductivity during ionic dialysance measurements in determining the relationship between ionic dialysance and urea clearance, which may explain the different results obtained in previous studies using a 2-step conductivity profile.

APPENDIX

Ionic dialysance (ID) measurement

\[
ID \text{ (mL/min)} = (Q_{Di} + Q_{f}) \times \left[1 - \frac{C_{Do1} - C_{Do0}}{C_{Di1} - C_{Di0}}\right] \quad \text{(Equation 1)}
\]

Q\textsubscript{Di}, dialysate flow at the inlet port of the dialyzer, in mL/min; Q\textsubscript{f}, ultrafiltration rate, in mL/min; C\textsubscript{Di1}, inlet dialysate conductivity during step 1, in mS/cm; C\textsubscript{Do1}, outlet dialysate conductivity during step 1, in mS/cm; C\textsubscript{Di0}, inlet dialysate conductivity during step 0, in mS/cm; C\textsubscript{Do0}, outlet dialysate conductivity during step 0, in mS/cm.
Urea concentration in plasma water (Upw)

\[ \text{Upw}(\text{mg/mL}) = \frac{\text{U}_0}{100 - 1.07 \cdot TP} \]  (Equation 2)

U, plasma urea concentration, in mg/dL; TP, plasma total protein concentration, in g/dL.

DDQ method

\[ K_{ab}(\text{mL/min}) = \frac{V_{D0} \cdot \text{U}_{D0} \cdot \ln \left( \frac{\text{Upw0}'}{\text{Upw0}} \right)}{T_d \cdot (\text{Upw30} - \text{Upw0})} \]  (Equation 3)

\[ K_{ca0}(\text{mL/min}) = K_{ab} \cdot \frac{\text{Upw0}'}{\text{Upw10}'} \]  (Equation 4)

\[ K_{ca2}(\text{mL/min}) = K_{ab} \cdot \frac{\text{Upw10}'}{\text{Upw20}'} \]  (Equation 5)

V_{D0}, volume of total dialysate with ultrafiltration, in mL; U_{D0}, dialysate urea concentration, in mg/mL; U_{up0}, urea plasma water concentration at the start of the dialytic session, in mg/mL; U_{up20}, urea plasma water concentration at the end of the session after slowing Q_{bi} to 50 mL/min for two minutes, in mg/mL; U_{up30}, urea plasma water concentration at 30 minutes after the end of the session, in mg/mL; U_{up10}' urea plasma water concentration at the end of the session after slowing Q_{bi} to 100 mL/min for approximately 10 seconds, in mg/mL; T_d, dialysis time, in min.

Plasma water sodium concentration at the inlet (Na_{pwi}) and outlet port of the dialyzer (Na_{pwo})

\[ \text{Na}_{pwo}(\text{mEq/L}) = \frac{\text{Na}_{pwi}}{Q_{ci}} \left( \alpha \times \text{Na}_{pwi} - \text{Na}_{Di} \right) \]  (Equation 6)

\[ \text{Na}_{pwi}(\text{mEq/L}) = \left( 1 - \frac{R_{cp}}{\text{Q}_{ci}} \right) \times \frac{\text{Q}_{ci} \times \text{Na}_{pwi} + R_{cp} \times \text{Q}_{ci} \times \text{Na}_{pwo}}{\text{Q}_{ci}} \]  (Equation 7)

where Q_{ci} = Q_{bi} \cdot [F_{pw} \cdot \text{Ht}/100 \cdot (F_{p} - F_{r})] [24];

F_{p} = 1 - 0.0107 \cdot \text{Hb} (g/dl) and F_{p} = 1 - 0.0107 \cdot TP (g/dl) [21];

Q_{bi} = Q_{bi} \cdot [1 - (Q_{bi} - 200)/2000] [25]

Na_{pwi}, systemic plasma water concentration, in mEq/L; K_{ca0}, urea clearance corrected for access recirculation, in L/min; Q_{bi}, blood water flow, in L/min; \( \alpha \), Donnan factor; Na_{Di}, dialysate sodium concentration at the inlet port of the dialyzer, in mEq/L; R_{cp}, cardiopulmonary recirculation; Q_{bi}, effective blood flow, in L/min; Q_{bi}, nominal blood flow, in L/min.

Cardiopulmonary recirculation (Rcp)

\[ R_{cp} = \frac{\text{Upw10} - \text{Upw10}'}{\text{Upw20} - \text{UpwV}} \]  (Equation 8)

where UpwV = Upw10' - K_{ca0} \cdot Q_{ci} - Upw10' / UpwV, urea plasma water concentration at the outlet port of the dialyzer, in mg/mL.

Expected ratio between ionic dialysance (ID) and urea clearance corrected for vascular access recirculation (K_{eu1})

\[ \frac{\text{ID}}{K_{eu1}} = 1 - \frac{\alpha \times \Delta \text{Na}_{pwi}}{\Delta \text{Na}_{Di}} \]  (Equation 9)

where \( \Delta \text{Na}_{pwi} = (\text{Na}_{pwi1} - \text{Na}_{pwi0}) \) and \( \Delta \text{Na}_{Di} = (\text{Na}_{Di1} - \text{Na}_{Di0}) \)

Napw0, plasma water sodium concentration at the inlet port of the dialyzer during step 1, in mEq/L; Napw0, plasma water sodium concentration at the inlet port of the dialyzer during step 0, in mEq/L; NaDi1, dialysate sodium concentration at the inlet port of the dialyzer during step 1, in mEq/L; NaDi0, dialysate sodium concentration at the inlet port of the dialyzer during step 0, in mEq/L.

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Reprint requests to Dr. Salvatore Di Filippo, Department of Nephrology and Dialysis, A. Manzoni Hospital, Via dell’Eremo 9/11, 23900 Lecco, Italy.

E-mail: nefrologia@ospedale.lecco.it

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