How to remove accumulated iodine in burn-injured patients

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Abstract

Background. Absorption of large quantities of iodine, as induced by the use of topical antimicrobial povidone–iodine in burn-injured patients, may cause metabolic and electrolyte abnormalities as well as renal failure. To diminish iodine levels, haemodialysis was previously reported to be a suitable therapy. We therefore studied the kinetics of iodine in order to define the most optimal dialysis strategy.

Methods. Two patients with elevated iodine levels (93.6 and 81.2 mg/L) underwent continuous dialysis with blood flows $Q_B$ 150 and 120 mL/min. Blood was sampled from the inlet and outlet dialysis line at several time points during a 7-h and 39-h 10-min period, respectively. Samples were analysed for iodine with the inductively coupled plasma mass spectrometry (ICPMS) method. Kinetic analysis was performed using one and two compartmental models, deriving kinetic parameters: plasmatic volume $V_1$, extraplasmatic volume $V_2$ and intercompartmental clearance $K_{12}$. The calibrated kinetic model of Patient 2 was further used to simulate different dialysis strategies: 12-h per day with $Q_B$ 240, 6-h per day with $Q_B$ 480 and 240, and 12-h every 2 days with $Q_B$ 240. For each strategy, the mean average plasmatic and extraplasmatic concentration (TAC\textsubscript{p} and TAC\textsubscript{ep}) was calculated during 48 h.

Results. Iodine seemed to follow one compartmental kinetics when serum sample collections were limited to the first 7 h of dialysis (Patient 1), but iodine appeared to be distributed in two volumes ($V_1=19.4$ L, $V_2=38.0$ L and $K_{12}=55$ mL/min) when a longer observation period was taken into account (Patient 2). The simulations disclosed that 12-h dialysis per day with $Q_B$ 240 or continuous dialysis with $Q_B$ 120 resulted in the lowest TAC\textsubscript{p} (18.2 and 19.0 μg/L) and TAC\textsubscript{ep} (34.4 and 36.1 μg/L).

Conclusion. In patients with elevated iodine levels, especially when associated with renal failure, haemodialysis with a minimum 12-h duration with sufficient blood flow should be the first choice to remove iodine.

Keywords: burn injury; compartmental behaviour; dialysis strategy; iodine; kinetic modelling

Introduction

Bacterial growth is a major problem in burn injury patients. Since complete wound closure by skin grafting following debridement is often not possible within the first days of the therapeutic process of these patients, the topical antimicrobial agent povidone–iodine (PVP-I) for burn dressing is widely used to avoid infection [1]. PVP-I is also used in the treatment of other extensive wounds.

Iodine is essentially excreted by the kidneys (77%) and captured by the thyroid glands (20%) [2]. It has repeatedly been reported that the absorption of large quantities of iodine may induce metabolic and electrolyte abnormalities, including hyperchloraemic metabolic acidosis, hypernatraemia, hyperosmolarity, abnormalities of cardiac conduction and thyroid function, and renal failure [3–5]. In burn patients, such toxic complications may be induced when iodine absorption at the disrupted skin site exceeds urinary excretion. Renal failure, either due to iodine per se or to any other cause (dehydration, drug toxicity, interstitial nephritis), can further worsen the iodine accumulation. On the other hand, renal insufficiency of whatever cause may be aggravated by the use of PVP-I [1].

As the discontinuation of topical PVP-I therapy alone is not able to immediately normalize iodine levels in case of sudden important complications, haemodialysis therapy could be a valid alternative to control these levels. This is especially true since iodine is a small water-soluble compound which very likely can be removed by simple diffusion. Although several studies reported a decrease of iodine concentrations with haemodialysis [3,6–9], no data are available about the effective removal of this low-molecular weight toxic agent (MW 253) out of the patient’s body by haemodialysis, and about its kinetics. Knowledge of kinetic behaviour during dialysis could offer valuable suggestions of how to optimize dialytic removal. Therefore, the present study aims at unravelling the kinetic behaviour of iodine in two patients with elevated iodine blood levels who were treated with haemodialysis after life-threatening cardiac conduction disturbances.
Table 1. Cell counts and serum levels of both patients on admission and pre-dialysis

<table>
<thead>
<tr>
<th></th>
<th>Patient 1</th>
<th>Pre-dialysis</th>
<th>Patient 2</th>
<th>Pre-dialysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leukocyte count (10³/µL)</td>
<td>16.52</td>
<td>12.46</td>
<td>10.45</td>
<td>22.80</td>
</tr>
<tr>
<td>Platelet count (10³/µL)</td>
<td>191.0</td>
<td>150.0</td>
<td>96.0</td>
<td>433.0</td>
</tr>
<tr>
<td>Blood Urea Nitrogen (mg/dL)</td>
<td>18.2</td>
<td>71.0</td>
<td>92.5</td>
<td>44.4</td>
</tr>
<tr>
<td>Creatinine (mg/dL)</td>
<td>0.74</td>
<td>2.61</td>
<td>2.20</td>
<td>2.56</td>
</tr>
<tr>
<td>Sodium (mmol/L)</td>
<td>134</td>
<td>157</td>
<td>138</td>
<td>142</td>
</tr>
<tr>
<td>Potassium (mmol/L)</td>
<td>2.8</td>
<td>4.1</td>
<td>4.5</td>
<td>4.4</td>
</tr>
<tr>
<td>Chloride (mmol/L)</td>
<td>104</td>
<td>116</td>
<td>108</td>
<td>104</td>
</tr>
<tr>
<td>GOT (ALT) (IU/L)</td>
<td>45</td>
<td>34</td>
<td>51</td>
<td>26</td>
</tr>
<tr>
<td>GPT (ALT) (IU/L)</td>
<td>22</td>
<td>18</td>
<td>155</td>
<td>38</td>
</tr>
<tr>
<td>Iodine (mg/L)</td>
<td>–</td>
<td>93.6</td>
<td>–</td>
<td>81.2</td>
</tr>
</tbody>
</table>

GOT: glutamic oxaloacetic transaminase; AST: aspartate aminotransferase; GPT: glutamic pyruvic transaminase; ALT: alanine aminotransferase. Just before the start of the continuous dialysis on Day 17.

Subjects and methods

Patients

The first patient, a 47-year-old man, was admitted to the hospital because of deep second- and third-degree flash burns covering 80% of the total body surface area (head, neck, torso, upper limbs, lower limbs and hands), caused by a chemical explosion. There were no pulmonary lesions. Debridement was performed 3, 4, 6, 12, 27 and 28 days after admission. Wound care was continuously performed from the first day of admission, with the antimicrobial iodine-containing solutions iso-Betadine® Dermicum (PVP-I 10%) liquid solution (for showering diluted to a final 1% solution) and iso-Betadine® Gel (PVP-I 10%), and the iodine-free topical agents Flaminial® and Flammacerium®, After septic shock with metabolic acidosis (39 days after admission) and resuscitation due to asystole (40 days after admission), the patient developed multiple organ failure with acute kidney injury for which haemodialysis was started. After a 30-h treatment with continuous dialysis (detailed description below), the patient died.

The second patient was a 40-year-old woman, who was admitted to a non-university hospital because of septic shock due to community-acquired pneumonia with Streptococcus pyogenes. Because of renal insufficiency and progressive ischaemia at both the lower and upper extremities with extensive skin blisters and eventually leading to necrosis of both feet, the patient was transferred to the Burn Centre of the Ghent University Hospital for further care. She underwent computed tomography of the thorax with contrast agents on Day 8 and 10, and 4-h dialysis sessions on Day 5, 8, 10, 12, 13 and 15. The wounds were treated from the first day of admission with the antimicrobial iodine-containing solutions iso-Betadine® Dermicum (PVP-I 10%) and iso-Betadine® Gel (PVP-I 10%). The iso-Betadine® treatment was stopped from Day 13 on. On Day 17, the recurrence of renal insufficiency required continuous dialysis, which was started for 39.2 h. After two additional intermittent dialysis sessions lasting 4 h on the 23rd and 25th day, and bilateral amputation of the feet, the patient was discharged from the Burn Centre and further recovered.

The laboratory data for both patients on admission and immediately before the start of continuous dialysis are shown in Table 1.

Continuous dialysis

Both patients were haemodynamically unstable and were for that reason started on slow continuous dialysis. This was performed with the Genius® single pass batch dialysis system and FX80 haemodialysers (Fresenius Medical Care, Bad Homburg, Germany). This system uses a double-sided roller pump that generates equal blood and dialysate flows, and consists of a closed dialysate tank of 90 L in which fresh and spent dialysate are stored together, but remain separated based on density differences [10,11]. Blood and dialysate flow rates were 150 mL/h in both patients, except during the first 6 h of dialysis in Patient 2 (400 mL/h). The dialysate containers were switched every 7–8 h (Patient 1) and 6–8 h (Patient 2).

Blood and dialysate sampling

In the first patient, blood samples were taken at different time points during the first 7 h of dialysis. Blood was sampled from the inlet alone at the start and from the inlet and outlet blood line after 15, 30, 60, 120, 180, 240, 300 and 420 min. In the second patient, blood was sampled from the inlet and outlet blood line just after dialysis start, after 2 h 40 min and further each time after the Genius® container was changed: i.e. after 6 h 15 min, 12 h 15 min, 18 h 10 min, 24 h 20 min, 32 h 10 min, and just before dialysis discontinuation after 39 h 10 min. An extra blood sample was taken 23 h 20 min after the end of the dialysis under evaluation. All samples were centrifuged, and plasma was analysed for iodine with inductively coupled plasma mass spectrometry (ICPMS).

In both patients, routine blood sampling was performed at different time points. From those samples, we only subtracted data for urea and creatinine.

Calibration of the kinetic model

The iodine plasma concentrations were used to fit into a one-compartmental model (Figure 1A), which is theoretically characterized by a homogeneous solute concentration with different and variable inputs and outputs. In case iodine plasma concentrations did not follow a one-exponential curve, concentrations were fitted into a two-compartmental model, like the model applied for the study of the kinetics of urea and other small soluble solutes [12] (Figure 1B).

From the corresponding inlet and outlet plasma concentrations (Cp and Cb), blood flow (Qt) and ultrafiltration flow (QUF) dialysate clearance Kd (millilitre per minute) was calculated as the mean clearance of the individual calculated clearances:

\[ K_D = \frac{C_D - C_P}{C_D} \cdot \frac{Q_D}{C_D} + \frac{C_P}{C_D} \cdot Q_{UF} \]  

(1)

Ultrafiltration flow Q_{UF} was taken into account to calculate convective clearance [second part of equation (1)] and the variation of total distribution volume in time.

The time variation of the iodine compartmental concentrations, C1 and C2, was determined by solving the mass balance equations in both volumes V1 and V2:

\[ \frac{d(V_1 \cdot C_1)}{dt} = -K_2 \cdot (C_2 - C_1) \]  

(2)

with K2 and K4 (millilitre per minute) the thyroid uptake and renal clearance, and A the iodine absorption rate (milligram per minute). In both anuric patients, thyroid uptake and regal clearance were zero. Since only the number of tubes of iso-Betadine® Gel (PVP-I 10%) used for wound care per unit of time was known, and not the effective absorption into the tissue, a series of calculations was performed in Patient 1, ranging A from...
From routine blood sampling, we found urea and creatinine reduction ratios of, respectively, 55% and 54% after 7-h dialysis in Patient 1, and 81 and 77% after 40-h dialysis in Patient 2.

Figure 2 shows the inlet and outlet concentrations during the study in Patient 1 (Figure 2A) and in Patient 2 (Figure 2B). The plasmatic iodine reduction ratio after 7 h of dialysis was 78% (Patient 1) and 60% (Patient 2), and increased to 83% after 24 h and 95% after 48 h in Patient 2. For Patient 1, kinetic fitting gave results suggesting the presence of only one single compartment (Figure 2A—broken line). Prolonged evaluation in Patient 2 however disclosed a second, extraplasmatic compartment (Figure 2B—broken line). The extraplasmatic iodine concentrations ($C_{ep}$) were on average 17.0±9.1 mg/L higher compared to the plasmatic concentrations ($C_{p}$), with a maximum discrepancy around 33 mg/L between the fifth and sixth hour of dialysis. From the 11th hour on, the percentage difference between the plasmatic and extraplasmatic concentration remained constant at 53%. This concentration difference resulted in a post-dialysis rebound, as shown in Figure 2B, where the calculated plasmatic iodine concentration (11.84 mg/L) only deviates 1% from the in vivo measured concentration (11.97 mg/L). The extraplasmatic reduction ratio in Patient 2 was 20%, 64% and 88% after 7, 24 and 48 h, respectively.

Dialyser clearances were, respectively, 120±7 and 77±16 mL/min (Table 3). The different calculated and fitted kinetic parameters for each patient are also summarized in Table 3. Based on the data of Patient 1, a well-fitted curve was obtained with the one-compartment model. Iodine was distributed in a single volume of 30.1 and 25.6 L when accounting for an absorption rate $A$ of 0.16 and 1.11 mg/min, respectively (column A in Table 3). For Patient 2, however, a well-fitting curve could only be obtained assuming a distribution in two compartments. Calculations then resulted in a total distribution volume $V_{tot}$ ($V_1 + V_2$) of 57.4 L, with $V_1$ equal to 19.4 L and $V_2$ 38.0 L, while intercompartmental clearance $K_{12}$ was 55 mL/min (column B in Table 3).

Knowing about the two-compartmental behaviour of iodine, the data of Patient 1 were introduced in the two-compartmental model (with given $K_{12}$=55 mL/min), and fitting was performed on both volumes ($V_1$ and $V_2$) and the absorption rate $A$. The solution converged towards a single volume of 26.2 L with an absorption rate $A$ of 1.03 mg/L.

Table 2. Simulations of different dialysis strategies

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Duration</th>
<th>$Q_D$ mL/min</th>
<th>$K_D$ mL/min</th>
<th>BV L</th>
<th>RR$_{p,6h}$ %</th>
<th>RR$_{ep,6h}$ %</th>
<th>TAC$_p$ μg/L</th>
<th>TAC$_{ep}$ μg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td>Continuous</td>
<td>120</td>
<td>77</td>
<td>345.6</td>
<td>57</td>
<td>16</td>
<td>19.0</td>
<td>36.1</td>
</tr>
<tr>
<td>1×/day</td>
<td>12</td>
<td>240</td>
<td>154</td>
<td>345.6</td>
<td>77</td>
<td>24</td>
<td>18.2</td>
<td>34.4</td>
</tr>
<tr>
<td>1×/day</td>
<td>6</td>
<td>480</td>
<td>308</td>
<td>345.6</td>
<td>77</td>
<td>24</td>
<td>22.9</td>
<td>37.6</td>
</tr>
<tr>
<td>1×/2 days</td>
<td>6</td>
<td>240</td>
<td>154</td>
<td>172.8</td>
<td>77</td>
<td>24</td>
<td>31.5</td>
<td>44.3</td>
</tr>
<tr>
<td>1×/2 days</td>
<td>12</td>
<td>240</td>
<td>154</td>
<td>172.8</td>
<td>77</td>
<td>24</td>
<td>29.1</td>
<td>40.8</td>
</tr>
</tbody>
</table>

$Q_D$: blood flow; $K_D$: dialyser clearance; BV: blood volume; RR$_p$: plasmatic reduction ratio; RR$_{ep}$: extraplasmatic reduction ratio; TAC$_p$: time averaged plasmatic concentration; TAC$_{ep}$: time averaged extraplasmatic concentration. Left section: introduced values; right section: calculated results.
min, which lies within our estimated range of 0.16–1.11 mg/min (column C in Table 3).

Then, we used the two-compartmental model of Patient 2 to mathematically compare several dialysis strategies and to define the most optimal solution with regard to iodine removal. The plasmatic and extraplasmatic concentrations during different dialysis strategies are shown in Figure 3. After 6 h of dialysis, the plasmatic reduction ratios are 57% ($Q_B$ 120 mL/min), 77% ($Q_B$ 240 mL/min) and 89% ($Q_B$ 480 mL/min), while the extraplasmatic reduction ratios are 16% ($Q_B$ 120 mL/min), 24% ($Q_B$ 240 mL/min) and 31% ($Q_B$ 480 mL/min) (Table 2—right part). The lowest TAC times in the 48-h period are obtained for the strategy of daily 12 h with $Q_B$ 240 (18.2 μg/L) and the continuous dialysis with $Q_R$ 120 (19.0 μg/L). The corresponding extraplasmatic TAC’s are then 34.4 and 36.1 μg/L (Table 2—right part).

Fig. 2. Iodine concentrations during dialysis in Patient 1 (A) and Patient 2 (B). Measured blood inlet and outlet concentrations are shown as squares and triangles, respectively, and the diamond illustrates the measured rebound value. In Patient 1, kinetic fitting was based on a one-compartmental model (curve a). In Patient 2, intradialytic kinetic fitting was based on a two-compartmental model, resulting in plasmatic (curve b) and extraplasmatic concentrations (curve c). The kinetic fitting of a one-compartmental model during 39 h 10 min (curve d) and 7 h in Patient 2 (curve e) are also added. With the calibrated two-compartmental model, the post-dialysis plasmatic (curve f) and extraplasmatic concentrations (curve g) were calculated.
Table 3. Kinetic parameters

<table>
<thead>
<tr>
<th></th>
<th>A Patient 1</th>
<th>B Patient 2</th>
<th>C Patient 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kinetic model</strong></td>
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<td>2-comp</td>
<td>2-comp</td>
</tr>
<tr>
<td><strong>Calculated input parameters</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Dialyser clearance $K_D$ (mL/min)</td>
<td>120</td>
<td>77</td>
<td>120</td>
</tr>
<tr>
<td>Thyroid capture $K_T$ (mL/min)</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Renal clearance $K_R$ (mL/min)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Start concentration (μg/L)</td>
<td>93.6</td>
<td>81.2</td>
<td>93.6</td>
</tr>
<tr>
<td>Absorption rate (mg/min)</td>
<td>0.16–1.11</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Intercompartmental clearance $K_{12}$ (mL/min)</td>
<td>–</td>
<td>–</td>
<td>55</td>
</tr>
<tr>
<td><strong>Fitted parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume $V_1$ (L)</td>
<td>30.1–25.6</td>
<td>19.4</td>
<td>26.2</td>
</tr>
<tr>
<td>Total distribution volume $V_{tot}$ (L)</td>
<td>–</td>
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<tr>
<td>Intercompartmental clearance $K_{12}$ (mL/min)</td>
<td>–</td>
<td>55</td>
<td>–</td>
</tr>
<tr>
<td>Absorption rate $A$ (mg/min)</td>
<td>–</td>
<td>–</td>
<td>1.03</td>
</tr>
</tbody>
</table>

**Discussion**

Haemodialysis is one of the most evident therapeutic options to remove iodine from the body. Insight into the kinetic behaviour of iodine could be a valuable tool to optimize removal by dialysis. Therefore, the present study was undertaken to investigate the distribution of iodine in the body by evaluating its removal during continuous haemodialysis in two patients with elevated iodine blood levels (observation period of 7 and 39.2 h, respectively).

When considering Patient 1, our finding was that iodine is distributed in a single volume (~25 to 30 L). When considering Patient 2 over a much longer observation period, however, we found that a second compartment becomes apparent from which iodine is only slowly released (intercompartmental clearance of only 55 mL/min). In both patients, the plasmatic compartment has a volume comparable to that found in the literature (30–40% of body weight) [2]. It is plausible that the distribution over the second compartment went unnoticed in the first patient due to the relatively short observation period, especially because transport between the extraplasmatic and plasmatic compartment is slow.

With respect to the dialyser clearance, iodine is comparable to urea and other small solutes [12]. Intercompartmental clearance is more comparable to that of β2-microglobulin ($K_{12}$ 30–80 mL/min) [14,15]. However, iodine is distributed in a much larger plasmatic volume ($V_1$ 19.4 L, compared to 1.8 L for $β_2$-M) and larger total distribution volume (55% TBW, compared to 25–36% TBW for $β_2$-M) [15,16]. Hence, iodine plasmatic as well as extraplasmatic concentrations will decrease more slowly than those of $β_2$-M.

From the reduction ratios after 7 h of dialysis (60–78% in the two patients), it can be concluded that iodine is removed quite efficiently from the plasma during 7 h of slow dialysis. This is mainly due to the large plasmatic compartment. However, only when considering the second patient who was followed much longer during dialysis, the second compartment with a slow transport to the plasmatic compartment became apparent. In order to decrease relatively quickly the initial iodine concentration both from the plasmatic and extraplasmatic compartment (RR$_{p,6h}$ and RR$_{sp,6h}$ in Table 2) and to obtain low TAC’s for a longer period, the optimal removal strategy in patients with elevated iodine levels appears to be long dialysis with sufficient blood flow. Earlier studies equally underscored the need for long dialysis in the case of removal of other solutes known to be distributed in a large total volume and/or more than two volumes [17,18]. Those findings are confirmed here by our kinetic simulations for iodine.

While normal blood levels for iodine are in the range 0.045–0.08 mg/L, the studied patients showed iodine blood levels which were more than a thousand-fold higher. In their review of burn patients, Hunt et al. [13] reported iodine serum levels as a function of the burn total body surface area (TBSA in the range of 0 to more than 30%) after 5 days of topical therapy. Extrapolating these data, plasma iodine concentrations should be in the range of 89 and 113 mg/L for burns covering 80% of TBSA, corresponding to the pre-dialysis iodine concentration of our burn-injured patient (Patient 1). Although not burned, our second patient showed similar concentration levels. Our data thus underscore the importance of measuring serum iodine levels in patients submitted to substantial quantities of this compound.

The actual concentration at which toxic symptoms may occur is still not exactly known. Several studies reported the presence of iodine intoxication related to wound care of open burn wounds with PVP-I [1,3,7,13,19,20], PVP-I (mediastinal) irrigation after surgery [6,8,21,22] or simultaneous irrigation [23]. Furthermore, since different case reports attribute mortality to iodine levels of 10 to 30 mg/L [3,19], iodine should be removed to avoid such levels. Several studies report a positive clinical impact of dialysis therapy on the degree of toxicity or on the evolution of renal function [3,6–9]. However, none of these studies considered the kinetic behaviour of iodine. The present study adds to those findings showed that prolonged or continuous dialysis with sufficient blood flow is the best choice to reduce iodine levels. In addition, in view of the different findings in Patient 1 and 2, our data show that in solutes with slow shifts from the extraplasmatic to the plasmatic compartment, kinetic studies based on shorter dialysis sessions without knowledge of post-dialysis rebound, might be inadequate to unravel the existence of a second compartment, and hence, the advantage of prolonged dialysis, once more underscoring the importance of prolonged sample collection.

It could be argued that the difference in observed dialysis duration among our patients is the reason for the different kinetic behaviour (distribution in one compartment in Patient 1 and in two compartments in Patient 2). However, when only considering the iodine concentrations of Patient 2 during the first 7 h of her prolonged dialysis session, there was also a one-compartmental distribution found with a total volume of 30.0 L (Figure 2B — curve e). This is analogous with the findings in Patient 1 during the 7 h of observation. In contrast, one-compartmental kinetic fitting
on the entire 39-h 10-min data resulted in a curve (Figure 2B—curve d) which fitted insufficiently compared to the curve obtained with the two-compartmental fitting. Furthermore, the maximum difference between plasmatic and extraplasmatic concentrations is seen between 4 and 8 h of dialysis, indicating a minor influence of the extraplasmatic volume on plasmatic concentration up to at least 8 h of dialysis.

Iodine accumulation should also be taken into account when iodine-containing drugs are administered (amiodarone), since serum iodine concentrations might remain markedly elevated for several months [24,25], or when iodine-containing contrast agents are administered.

Finally, we should remark that it would have been more appropriate for iodine kinetics were derived from high-efficiency dialyses in more than two patients. Due to the haemodynamically unstable condition of the patients, however, slow continuous dialysis seemed to be the only dialysis option. Furthermore, since the problem of iodine intoxication was better understood after our kinetic analysis

Fig. 3. Plasmatic (bold line and filled symbols) and extraplasmatic concentrations (thin line and open symbols) for different dialysis strategies: continuous dialysis with $Q_u$ 120 (circles—A and B), every day 6 h with $Q_u$ 480 (triangles—A), every day 12 h with $Q_u$ 240 (rhombi—A), every day 6 h with $Q_u$ 240 (triangles—B) and every 2 days 12 h with $Q_u$ 240 (rhombi—B). The plasmatic TAC is indicated as full line (continuous dialysis), dotted line (every day 12 h—A; every 2 days 12 h—B) and dashed line (every day 6 h—A and B).
more often patients are already being started on dialysis at much lower iodine concentrations.

In conclusion, iodine administration may cause iodine accumulation, resulting in significant complications, especially in patients with renal insufficiency. The present kinetic study unravelled that iodine is distributed in a large plasmatic and extraplasmatic volume with slow transport to the plasmatic compartment. Hence, long dialysis with sufficient blood flow is necessary to remove iodine in patients with elevated levels.

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Conflict of interest statement. The results presented in this paper have not been published previously in whole or part, except in abstract format.

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