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ORIGINAL ARTICLE

Maintenance haemodialysis with low dialysate flow rates in Senegal

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ABSTRACT

Introduction: The objective of the study reported here was to demonstrate that maintenance haemodialysis using a reduced dialysate flow rate of 300 mL/min (RQ_D) is not inferior to haemodialysis using the standard flow rate of 500 mL/min (SQ_D) in respect of the delivered dose of dialysis.
Methods: A prospective, single-centre, sequential study was performed at the haemodialysis centre of Pikine Hospital in Dakar. Twenty patients were included. During the first week, three haemodialysis sessions were performed with SQ_D and during the second week three haemodialysis sessions were conducted with RQ_D for each patient.
Results: For SQ_D, the mean eKt/V was 1.38 ± 0.58. There were 38 (63%) sessions with eKt/V greater than 1.2 and 16 patients (80%) had adequate dialysis, based on the average eKt/V. For RQ_D, the mean eKt/V was 1.2 ± 0.43 with 25 sessions (42%) having an eKt/V greater than 1.2. There were 11 patients (55%) with adequate dialysis. The dialysis dose was higher with the SQ_D prescription ($P < 0.001$). Ten patients with dry weight ≤60 kg had adequate dialysis with RQ_D. Cases of hypokalaemia were significantly higher with the SQ_D ($P = 0.001$).
Conclusions: RQ_D appears to be inferior in terms of dialysis dose. However, for patients with dry weight ≤60 kg, adequate dialysis could be delivered with RQ_D, consequently allowing substantial saving of water in haemodialysis.

Keywords: low flow dialysate rates; dialysis dose; dry weight; Senegal.

INTRODUCTION

Water is a scarce natural resource due to global warming and climate change [1-3] and approximately half of the world's population lives in water-scarce regions [4,5]. Haemodialysis requires large amounts of clean water and it is therefore sensible to consider the possibility of reducing the usage, especially in water-scarce regions. For a patient on conventional haemodialysis treated with three sessions of 4 hours per week, approximately 18,000 litres of dialysis water are used per year [6]. Moreover, up to a quarter of the water entering the dialysis unit's water treatment system is discarded as waste [7]. Questions are now emerging about how to conserve water by using less during haemodialysis procedures. The prevalence of chronic haemodialysis is relatively low in sub-Saharan Africa and many patients die due to lack of access to this treatment [8,9]. African countries face huge economic challenges in the management of patients with end-stage kidney disease [10] because of the high cost of haemodialysis. This is related to factors such as scarce human resources, the high cost of consumables and high water consumption, among others. Molano-Triviño et al. [11] and Leypoldt et al. [12] have reported that patients can receive an adequate dialysis dose with a reduced dialysate flow of 400 mL/min or even 300 mL/min. Similar results were reported in a more recent study by Guillermina et al., who used a flow

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rate of 300 mL/min [13], which saved 48 litres of water in a 4-hour haemodialysis session. In other words, a 40% reduction in the consumption of water can be achieved.

Low dialysate flow haemodialysis is not well studied in sub-Saharan Africa. We therefore conducted this preliminary study by comparing standard dialysate flow haemodialysis (500 mL/min, SQ_D) with reduced dialysate flow haemodialysis at 300 mL/min (RQ_D).

METHODS

A prospective, single-centre, sequential study was conducted over a 2-week period in the haemodialysis centre of Pikine Hospital in Dakar, Senegal. Twenty patients were involved in the study. SQ_D haemodialysis and RQ_D haemodialysis were compared with regard to measures of dialysis adequacy [urea reduction ratio (URR)], equilibrated Kt/V (eKt/V), postdialysis kalaemia and dialysis-related adverse events.

We included clinically stable patients who had been on conventional haemodialysis for at least three months, having 4-hour treatments two or three times a week. They all had a functional arteriovenous fistula (AVF) and an average ultrafiltration (UF) rate of 1000 mL/h. Patients who declined to participate and those who required an AVF flow rate greater than 1500 mL/min were not included.

During the first week of the study, all patients had three dialysis sessions with SQ_D and, during the second week, all had three dialysis sessions with RQ_D. Blood samples were taken before and after each dialysis session for measurement of serum urea, serum creatinine and serum potassium concentrations. Apart from the dialysate flow rates, the dialysis prescription remained unchanged throughout the protocol, including the blood flow rates and anticoagulant use. Polysulfone high-flux dialysers were used throughout. The centre uses an AQUAbase water treatment system and B Braun Dialog+® dialysis machines.

The primary outcome was the proportion of patients with eKt/V ≥1.2. The secondary outcomes included the proportion of patients with URR ≥ 65%, postdialysis serum potassium concentrations and dialysis-related adverse events.

Definitions

eKt/V was calculated using pre- and postdialysis urea concentrations according to the Daugirdas formula [14]. We calculated the average eKt/V and URR over the three sessions for each patient. Adequate dialysis was defined by a mean eKt/V ≥1.2 and/or a mean URR ≥ 65%. Intradialytic hypotension was defined as systolic blood pressure (BP) <90 mmHg for patients with systolic BP <160 mmHg at the start of the session, and systolic blood pressure <100 mmHg for patients with systolic blood pressure ≥160 mmHg at the start of the session [15]. Intradialytic hypertensive crisis was defined as the occurrence of World Health Organization (WHO) grade III hypertension (systolic ≥180 mmHg and/or diastolic ≥110 mmHg) during the dialysis session in a patient who had normal blood pressure or grade I HPT at the start of the session. Hyperkalaemia was defined as serum potassium ≥5.3 mmol//L and hypokalaemia as serum potassium ≤3.5 mmol/L. Other adverse events such as cramps, vomiting, headaches or the need to reduce UF were also noted.

Data analysis

The data were collected using a standardised data collection form and summarized using frequencies and proportions for the categorical variables, and means and standard deviations for the numerical variables. To compare frequencies, we used the McNemar test for paired data, and means were compared with Student's t-test for paired data. A significance threshold was set at $P < 0.05$.

This study was approved by the Research Ethics Committee of Cheikh Anta Diop University in Dakar (reference no. CER/UCAD/AD/MsN/021/2021).

RESULTS

Table 1 summarizes the baseline characteristics of the participants. The mean age of the patients was 44.1 ± 13.6 years. There were 14 men and 6 women. The mean duration of dialysis follow-up was 53.1 ± 24.2 months. The mean dry weight of the patients was 63.28 ± 14.50 kg. All patients had three dialysis sessions per week for a total of 120 haemodialysis sessions performed. The mean duration of the dialysis sessions was 4.1 ± 0.31 hours. The average blood flow rate was 322.5 ± 14.5 mL/min and the average UF rate was 621.8 ± 207.7 mL/h.

Table 2 provides a comparison of the dialysis using standard and low dialysate flow rates. For the SQ_D prescription, the average eKt/V per session was 1.38 ± 0.58 and there were 38 sessions (63%) with an eKt/V >1.2. The average URR was 69 ± 19%, with 49 sessions (82%) having URR > 65%. There were 16 patients (80%) with adequate dialysis. The mean predialysis serum potassium concentration was 4.9 ± 0.7 mmol/L and the mean postdialysis concentration was 3.2 ± 0.8 mmol/L, including 40 sessions (67%) with postdialysis hypokalaemia. There were no cases of predialysis hypokalaemia. There were 22 sessions (37%) with predialysis hyperkalaemia and no cases of postdialysis hyperkalaemia. Regarding the tolerance of the dialysis sessions, no patient developed any adverse event during the sessions.

For the RQ_D prescription, the average eKt/V was 1.2 ± 0.43 and there were 25 sessions (42%) with eKt/V >1.2. The average URR was 65 ± 17%, with 27 sessions (45%) having a URR >65%. There were 11 patients (55%) with adequate dialysis. The mean predialysis serum potassium concentration was 4.7 ± 0.5 mmol/L and the mean postdialysis value was 3.3 ± 0.8 mmol/L, including 27 sessions (45%) with postdialysis hypokalaemia. There were no cases of predialysis hypokalaemia. There were 20 sessions (33%) with predialysis hyperkalaemia and no cases of postdialysis hyperkalaemia. Regarding the tolerance of the dialysis sessions, no patient developed any adverse event during the sessions.

Table 1. Characteristics of study participants.

Variables	Mean (%)
Mean age (years)	44.10 ±13.65
Sex	
Men	14 (70)
Women	6 (30)
Duration of the dialysis session (h)	
4	18 (90)
5	2 (10)
Dialyser surface area (m²)	
1.5	6 (30)
1.8	13 (65)
2	1 (5)
Blood flow (mL/min)	
300	3 (15)
320	12 (60)
330	2 (10)
350	3 (15)
Dialysate potassium concentration (mmol/L)	
2	20 (100)
3	0 (0)
Vascular access	
Arteriovenous fistula	20 (100)
Central venous catheter	0 (0)

Compared to the RQ_D prescription, the dialysis dose was significantly higher with the SQ_D prescription in terms of mean eKt/V ($P < 0.001$) and URR ($P = 0.001$). Both prescriptions were equivalent in terms of potassium clearance but postdialysis hypokalaemia was more frequent with the SQ_D prescription (Table 2).

The 11 patients with adequate dialysis with the RQ_D prescription had lower dry weights than those with inadequate dialysis (57.4 vs 70.4 kg; $P = 0.001$) (Table 3), with 10 of the 11 participants having a dry weight ≤60 kg. The average eKt/V of these patients with RQ_D was 1.5 and the average URR 71% (Table 4).

DISCUSSION

We found that a dialysate flow rate of 300 mL/min provided an adequate dialysis dose in 55% of our patients. Albalate et al. [16] previously showed that reducing the dialysate flow rate from 500 mL/min to 400 mL/min resulted in a slight decrease in urea clearance that could be compen-

Table 2. Comparison of variables with standard and low dialysate flow rates.

Variables	SQ_D	RQ_D	P
Patients with adequate dialysis (%)	16 (80)	11 (55)	<0.001
Mean eKt/V	1.38 ± 0.58	1.20 ± 0.43	<0.001
eKt/V ≥ 1.2	38 (63%)	25 (42%)	0.004
Mean URR (%)	69 ± 19	65 ± 17	0.001
URR ≥65 (%)	49 (82)	27 (45)	<0.001
Mean predialysis serum potassium (mmol/L)	4.9 ± 0.7	4.7 ± 0.5	0.023
Pre-dialysis hyperkalemia (%)	22 (37)	20 (33)	0.774
Pre-dialysis hypokalaemia (%)	0 (0)	0 (0)	
Mean postdialysis serum potassium (mmol/L)	3.2 ± 0.8	3.3 ± 0.8	0.016
Post-dialysis hyperkalaemia (%)	0 (0)	0 (0)	
Post-dialysis hypokalaemia (%)	40 (67)	27 (45)	0.001
Mean predialysis serum urea (g/L)	1.09 ± 0.41	1.07 ± 0.35	0.286
Mean postdialysis serum urea (g/L)	0.297 ± 0.18	0.34 ± 0.16	0.004
Adverse events (%)	0 (0)	0 (0)	

Abbreviations: URR, urea reduction ratio; SQ_D, standard dialysate flow at 500 mL/min; RQ_D, reduced dialysate flow at 300 mL/min.

Table 3. Characteristics of patients with RQ_D according to dialysis dose.

Characteristics	Adequate dialysis (N = 11)	Inadequate dialysis (N = 9)	P
Age	46.2 ± 13.2	41.4 ± 16.5	0.521
Male/female ratio	6/5	8/1	0.105
Duration of the dialysis session (h)	4 ± 0	4.2 ± 0.4	0.213
Blood flow (mL/min)	315 ± 16	331 ± 17	0.015
Dialyser surface area (m^2)	1.6	1.7	0.051
Dry weight (kg)	57.4	70.4	0.024
Mean URR	71 ± 17	60 ± 15	0.001
Mean eKT/V	1.3 ± 0.6	1.1 ± 0.5	0.001

Abbreviations: URR, urea reduction ratio; RQ_D, reduced dialysate flow at 300 mL/min.

Table 4. Characteristics of patients with RQ_D according to dry weight.

Characteristics	Weight ≤60 kg (N = 10)	Weight >60 kg (N = 10)	P
Age (years)	43.3 ± 16.2	44.6 ± 11.4	0.514
Sex ratio (men/women)	5/5	5/5	1.000
Duration of the dialysis session (h)	4.2 ± 0.4	4 ± 0	0.325
Blood flow (mL/min)	314 ± 10	331 ± 14	0.051
Dialyser surface area (m^2)	1.6	1.8	0.054
Mean URR	71 ± 17	60 ± 14	0.001
Mean eKT/V	1.5 ± 0.6	1.0 ± 0.3	0.001

Abbreviations: URR, urea reduction ratio; RQ_D, reduced dialysate flow at 300 mL/min.

sated for by an 8–9 min increase in dialysis time. Kashiwagi et al. [17] also showed that a reduction in dialysate flow from 500 mL/min to 400 mL/min resulted in a slight decrease in urea clearance that could be compensated for by a 5% increase in blood flow rate. Molano-Triviño et al. [11] and Leypoldt et al. [12] reported on studies, in Colombia and the United States, respectively, that patients can receive an adequate dialysis dose with a dialysate flow rate of 400 mL/min or even 300 mL/min. Similar results were reported by Guillermina B et al. [13]. The lower dialysis dose reported with RQ_D in our study could possibly be compensated for by extending the duration of the sessions by a few minutes or by increasing the blood flow rates.

In our study, less postdialysis hypokalaemia occurred with the RQ_D prescription, a potential advantage given the risk of arrhythmia related to postdialysis hypokalaemia.

One should also examine the impact of low-flow dialysis on morbidity and mortality. Kirchner et al. [18] reported on one year of treatment with 500 mL/min dialysate flow and the following year with 300 mL/min dialysate flow, and found no difference in respect of morbidity and mortality. In a Colombian study, the authors compared the 5-year mortality of patients with low dialysate flow (400 mL/min) with patients with flows of 500 mL/min and found no difference between the two groups [11].

The use of low flow dialysate also has an environmental and economic impact. Haemodialysis uses large volumes of water. If we extrapolate this to the whole of Senegal, which has 1047 haemodialysis patients [19], we estimate that at approximately 19 million litres of water are used for dialysis each year. Reducing the dialysate flow rate from 500 mL/min to 300 mL/min will result in a 40% saving in water use. This is important for poor countries such as Senegal, where a large proportion of the population does not have easy access to drinking water [20].

In this study, we quantified the dialysis dose by assessing the clearance of urea, a molecule of low molecular weight. The question that remains is how larger solutes are cleared when low dialysate flows are prescribed. Camacho et al.

[21] compared low flow dialysate flows (300 mL/min) with high flow (800 mL/min) with respect to the clearance of protein-bound molecules such as p-cresol sulphate and indoxyl sulphate. They found that the clearance of p-cresol sulphate at low dialysate flow rates was about 50% of that at high flow rates. Three trials measured serum beta2-microglobulin levels to quantify the dialysis dose [11]. One found no difference in serum beta2-microglobulin clearance between dialysate flow rates of 300, 500 and 800 mL/min [11,22]. The two other trials found that the serum beta2-microglobulin concentrations were independent of the dialysate flow rates and, in one, it was related to the type of dialysis membrane [11,23,24].

Our study has some limitations in that it was a relatively small, single-centre investigation of short duration on each treatment arm.

CONCLUSIONS

Haemodialysis with the SQ_D prescription was superior to the RQ_D treatment in terms of delivered dialysis dose. However, adequate dialysis could be achieved with reduced dialysate flow rates in a substantial proportion of patients, and for all patients with dry weight <60 kg. This approach should therefore be considered as a treatment option for selected patients in low-income and water-scarce countries.

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