Port J Nephrol Hypert 2008; 22(4): 313-317

Intradialytic blood volume monitoring and its effect on haemodynamic instability

Vítor Ramalho, Beatriz Malvar, Pedro Pessegueiro, Manuel Amoedo, Carlos Pires, João Aniceto

Dialysis Unit, Fresenius Medical Care. Évora, Portugal.

Received for publication: 22/01/2008
Accepted in revised form: 15/08/2008

ABSTRACT

Background: Haemodynamic instability with symptomatic hypotension is a major intradialytic complication in patients on chronic haemodialysis. It occurs due to fluid removal during haemodialysis that exceeds the transference capacity between compartments. One strategy for reducing hypotensive events is avoiding excessive and fast blood volume reductions.

Methods: The authors retrospectively analysed haemodialysis treatments of 18 end stage renal patients with frequent hypotensive episodes during a period of 17 months. Fourteen patients were female and 5 patients had diabetes. The mean age was 77.8±12.6 years and mean follow-up 57±25.7 months.

Fresenius 4008H delivery systems with a blood volume monitor module were used during the study. The patients were evaluated at 5 different phases: one month before blood volume monitoring (month -1) and at one, four, seven and fifteen months of blood volume monitoring haemodialysis. Several variables were evaluated, including net ultrafiltration/haemodialysis session, mean arterial pressure, net mean arterial pressure/haemodialysis session (mean arterial pressure at the beginning of the session minus mean arterial pressure at the 4th hour of treatment), intradialytic hypotensive episodes, Kt/V, phosphorus, albumin and haemoglobin.

Results are presented in mean and standard deviation. Statistical analysis was performed using Wilcoxon and t-tests for a significance level of $p<0.05$.

Results: There was a 30% reduction in net mean arterial pressure/haemodialysis session after initiating blood volume monitoring, from 20.89±19.08 mmHg at month -1 to 14.85±16.82 mmHg at 15th month, ($p<0.05$). This result was independent of net ultrafiltration/haemodialysis session during that period, with month -1 showing 2274±527 mL *vs.* 15th month 2247.87±482.24 mL, ($p>0.05$). The incidence of symptomatic intradialytic hypotensive episodes was considerably lower with blood volume monitoring haemodialysis: 0.78±0.63 intradialytic hypotensive episodes/patient at month -1 *vs.* 0.26±0.52 intradialytic hypotensive episodes/patient at 15th month, ($p<0.05$).

No statistically significant difference was observed in Kt/V, albumin and haemoglobin levels before and after the introduction of blood volume monitoring. Phosphorus level reduced between months -1 and 15 ($p=0.03$).

The subgroup of diabetic patients also improved with blood volume monitoring, having better haemodynamic stability and less intradialytic hypotension (month -1 had 0.79±0.61 intradialytic hypotensive episodes/patient *vs.* 0.49±0.70 intradialytic hypotensive episodes/patient at 15th month, $p<0.05$).

Conclusions: Blood volume monitors with online control of ultrafiltration reduced 77% of the symptomatic hypotensive episodes, with lower mean arterial pressure variability and without affecting intradialytic water removal. Maximal benefit was obtained after 4 months of treatment and persisted during the 15 months analysed. Similar results were found in the diabetic subgroup of patients.

Key-Words:
Blood volume monitoring; diabetic patients; haemodialysis; haemodynamic instability; intradialytic hypotension; relative blood volume.

INTRODUCTION

Intradialytic hypotension (IDH) is a common complication in patients on chronic haemodialysis (HD), occurring in more than 20% of HD sessions[1,2]. IDH morbidity encompasses a broad range of clinical symptoms, from complaints of patients not feeling well, visual complaints, cramping and nausea, to life-threatening conditions such as cerebral infarction, mesenteric and cardiac ischemia. It thus seems desirable to minimise the frequency of intradialytic hypotensive episodes (IHE)[2,3].

Several factors have been implicated in the pathogenesis of IDH, including autonomic dysfunction, cardiac dysfunction and reduction in effective blood volume[1,4]. The initiating factor seems to be a decrease in blood volume, which stems from the imbalance between ultrafiltration (UF) rate and plasma refilling rate[1,5]. Blood volume monitors (BVM) that continuously and non-invasively measure relative blood volume (RBV) changes during HD help maintain an adequate volume in the intravascular compartment, therefore avoiding IDH[6-8]. We studied the impact of intradialytic blood volume monitoring on haemodynamic instability.

SUBJECTS AND METHODS

Eighteen hypotension-prone end stage renal patients, 14 female and 4 male, five diabetics, on chronic haemodialysis were included in this study. No patient was on anti-hypertensive drugs during the course of the study. All patients completed the study and none were excluded. Patient characteristics are shown in Table 1.

Table 1

Clinical characteristics of patients	
Patients (*n*)	18
Gender (male/female)	4/14
Age (years)	77.8±12.6
Mean follow up (months)	57±25.7
Underlying disease	
Diabetes mellitus	5
Chronic glomerulonephritis	2
Hypertension	5
Other or unknown	6

Haemodialysis treatments were performed three times a week for 4 hours each time, using bicarbonate buffered dialysate (sodium 140 mmol/L, potassium 2.0 mmol/L, calcium 1.25 mmol/L, magnesium 0.25 mmol/L, bicarbonate 35 mmol/L), polysulphone membranes (F60, Fresenius) and Fresenius 4008H delivery system with a BVM module. Blood flow ranged from 300 to 400 ml/min and dialysate flow was 800 ml/min.

Blood volume monitoring was performed using a real-time online ultrasonic BVM. This instrument measures the velocity of sound across flowing blood in the extracorporeal circuit. The variability of the velocity of sound depends on changes in the density of total protein content. RBV may be determined at any given time from changes in protein concentration relative to initial starting value. This method has been validated as a precise and reliable measurement of RBV, with very low noise signal ratio (<0.2%).

The determination of target RBV consisted of a two-week trial during which the critical RBV values associated with symptomatic IDH were recorded. During this trial period the BVM monitored RBV values without the online ultrafiltration control feature activated. The BVM monitor decreases UF by 50% when the instant RBV is within 5 percent points of the target RBV. We defined the target RBV by adding one percent to the critical RBV measurement previously attained. The RBV value during the study did not vary significantly.

The haemodialysis sessions of those patients were retrospectively analysed over a 17 month period with five evaluation phases: one month before BVM introduction (month -1) and at one, four, seven and fifteen months after starting BVM. The variables evaluated were net UF/HD session, mean arterial pressure (MAP), net MAP/HD session, intradialytic hypotensive episodes, Kt/V, phosphorus, albumin and haemoglobin values.

The MAP was determined by the formula systolic blood pressure +2 x diastolic blood pressure/3. The difference between MAP at the beginning of the session and MAP at the 4th hour of treatment is the net MAP/HD session.

The IHE were defined as a sudden decrease of blood pressure during HD, associated with muscle cramps, dizziness, chest pain, or blacking out in response to volume replacement.

Results are presented in mean and standard deviation. The Shapiro test was used to determine the normality of variables and the Wilcoxon and t-tests for statistical analysis (significance level of $p<0.05$).

RESULTS

Ultrafiltration volume

Measurements were taken at over 200 HD sessions in each phase of the study. UF volume was not significantly different over the 5 periods. In month -1 the net UF/HD session was 2274±527 mL and at 15th month 2247.87±482.24 mL; $p>0.05$ (Fig. 1). Patients' dry weights were comparable before initiating BVM and at 15th month; dry weight at month -1 was 50.8±9.7Kg and at 15th month 50.9±10.3Kg ($p>0.05$).

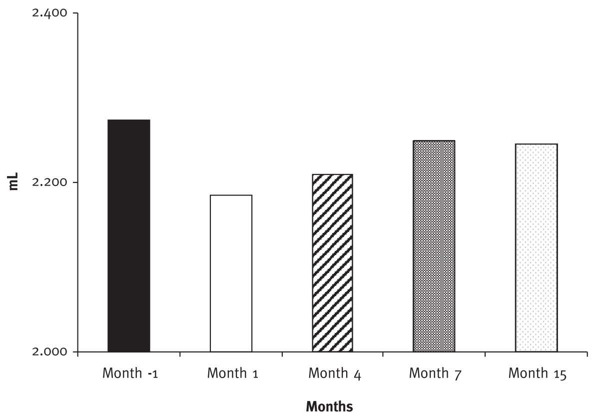

Figure 1

Ultrafiltration volume/HD session over the 17 month period ($p>0.05$).

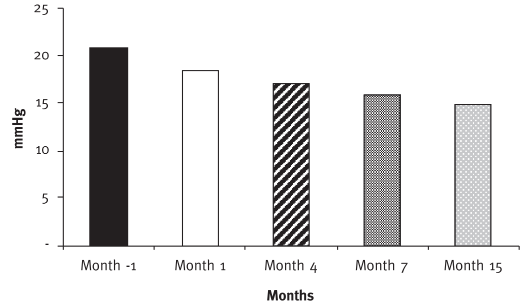

Figure 2

Net MAP/HD session in the 5 phases of the study. Month -1 *vs.* 1st month $p=0.07$; month -1 *vs.* 4th month $p=0.01$; month -1 *vs.* 7th month $p=0.001$ and month -1 *vs.* 15th month $p=0.002$.

Mean arterial pressure

There was a progressive reduction in the net MAP/HD session after BVM introduction. At the end of the study (15th month) the average MAP was 30% lower (month -1: 20.89±19.08 mmHg *vs.* 15th month: 14.85±16.82 mmHg, $p<0.05$) (Fig. 2). The net systolic and diastolic blood pressure variability decreased during the treatment sessions (net SBP: $p=0.03$ and net DBP: $p=0.001$).

Intradialytic hypotensive episodes

The incidence of IHE reduced significantly after BVM. The benefit began immediately after one month of treatment and lasted the entire period. A 78% reduction of IHE was achieved at month 15 (0.78±0.63 IHE/patient at month -1 *vs.* 0.26±0.52 IHE/patient at 15th month, $p<0.05$) (Fig. 3).

Other variables

The other variables evaluated did not differ significantly pre- and post-BVM haemodialysis, with the exception of phosphorus. Comparative analysis of Kt/V, albumin and haemoglobin values at months -1 and 15 had a p value superior to 0.05 (Fig. 4).

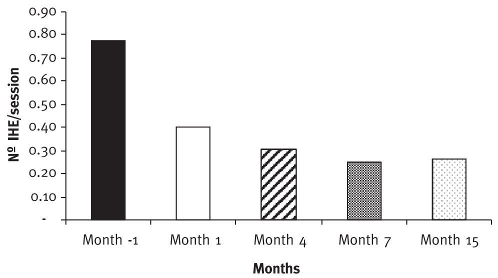

Figure 3

Intradialytic hypotensive episodes incidence ($p<0.05$).

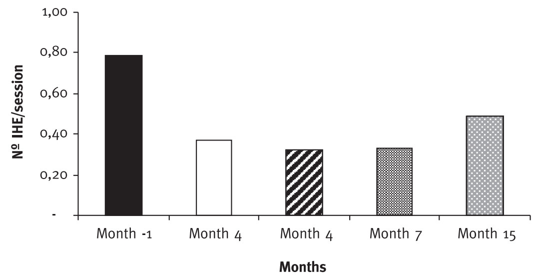

Figure 6

Intradialytic hypotensive episodes incidence in diabetic patients ($p<0.05$).

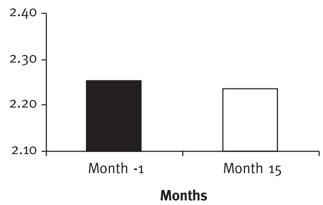

Figure 4

Kt/V pre- and post-BVM ($p>0.05$).

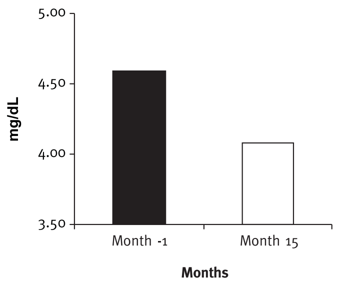

Figure 5

Phosphorus pre- and post-BVM ($p=0.03$).

Phosphorus blood levels reduced between months -1 and 15 ($p=0.03$) (Fig. 5).

Diabetic patients

When separately analysed, the diabetic subgroup of patients also benefited from the introduction of BVM haemodialysis. They had better haemodynamic stability and less IDH (month -1: 0.79±0.61 IHE/patient *vs.* 15th month: 0.49±0.70 IHE/patient, $p<0.05$) (Fig. 6).

DISCUSSION

Several therapeutic options have been used to combat IHE. The introduction of bicarbonate dialysis, high dialysate sodium concentrations, sodium modelling and cool dialysis have gone towards improved IDH management[9]. Online blood volume continuous monitoring during HD has allowed more precise control of ultrafiltration rate and blood volume preservation[10].

There are conflicting data in the literature on the predictive value of RBV changes for the occurrence of IDH[1]. A large observational study, recently reviewed by Locatelli *et al.*[11], demonstrated that RBV reduction during HD had no power in predicting IHE[12]. Harmen *et al.*[13] concluded that RBV changes during HD had a considerable intra- and inter-individual variability, which was also not related to IHE incidence. Other authors have experienced different results with blood volume monitoring in HD. They describe an overall improvement in the treatment tolerance, intradialytic cardiovascular stability and a reduction of IHE[6,10,14,15]. Carlo Basile[7] recommends routine RBV measuring during HD, with major benefits in hypotension-prone patients.

In our study there was a reduction in IHE incidence after initiating BVM haemodialysis. This reduction started after the first month and lasted throughout the study. Between months -1 and 15 there was a 78% drop in IHE. Furthermore, the net MAP/HD session also diminished. A 30% reduction in the 15th month was achieved. These results sustain the patients' better haemodynamic outcome with BVM.

There is concern over the fact that BVM haemodialysis could lead to patient undertreatment due to less fluid removal and to a state of overhydration. Some studies suggest the opposite; new systems for BVM and automatic biofeedback may not only reduce IHE, but also add to treatment efficacy[8].

Our patients' UF volume/session HD did not differ pre- and post-BVM. Patients' dry weights were also constant throughout the study. The comparative analysis of other variables including Kt/V, albumin and haemoglobin values was also not statistically significant. The phosphorus blood levels decreased between months -1 and 15. The patients' quality of treatment was unaffected.

The autonomic insufficiency common in diabetic patients makes them more susceptible to IDH[16]. The diabetic subgroup of patients had similar benefits from BVM treatment, with less IHE and better intradialytic cardiovascular stability.

We can conclude that using blood volume monitors with online control of ultrafiltration reduces IHE, with lower MAP variability without affecting intradialytic water removal, in hypotension-prone patients.

Conflict of interest statement. All the authors work in a Fresenius Medical Care dialysis unit.

References

1 Dasselaar J, Huisman P, de Jong P, Franssen C. Measurement of relative blood volume changes during haemodialysis: merits and limitations. *Nephrol Dial Transplant* 2005;20:2043-2049

2 Daugirdas JT. Pathophysiology of dialysis hypotension: an update. *Am J Kidney Dis* 2001;38 (Suppl 4):S11-S17

3 Schreiber MJ. Clinical dilemmas in dialysis: managing the hypotensive patient. *Am J Kidney Dis* 2001;38 (Suppl 4):S1-S10

4 Daugirdas JT. Dialysis hypotension: a hemodynamic analysis. *Kidney Int* 1991;39:233-246

5 van der Sande FM, Kooman JP, Leunissen KM. Intradialytic hypotension – new concepts on an old problem. *Nephrol Dial Transplant* 2000;15:1746-1748

6 Steuer RR, Leypoldt JK, Cheung AK, Senekjian HO, Conis JM. Reducing symptoms during haemodialysis by continuously monitoring the hematocrit. *Am J Kidney Dis* 1996;27:525-532

7 Basile C. Should relative blood volume changes be routinely measured during the dialysis session? *Nephrol Dial Transplant* 2001;16:10-12

8 Ronco C, Brendolan A, Milan M, Rodeghiero M, Zanella M, Greca G. Impact of biofeedback-induced cardiovascular stability on haemodialysis tolerance and efficiency. *Kidney Int* 2000;58:800-808

9 Sherman RA. Modifying the dialysis prescription to reduce intradialytic hypotension. *Am J Kidney Dis* 2001;38 (Suppl 4):S18-S25

10 Santoro A, Mancini E, Paolini F. Blood volume regulation during haemodialysis. *Am J Kidney Dis* 1998;32:739-748

11 Locatelli F, Buoncristiani U, Canaud B, Köhler H, Petitclerc T, Zucchelli P. Haemodialysis with on-line monitoring equipment: tools or toys? *Nephrol Dial Transplant* 2005;20:22-33

12 Andrulli S, Colzani S, Mascia F *et al*. The role of blood volume reduction in the genesis of intradialytic hypotension. *Am J Kidney Dis* 2002;40:1244-1254

13 Krepel HP, Nette RW, Akçahuseyin E, Weimar W, Zietse R. Variability of relative blood volume during haemodialysis. *Nephrol Dial Transplant* 2000;15:673-679

14 Santoro A, Mancini E, Basile C, *et al*. Blood volume controlled haemodialysis in hypotensive-prone patients: a randomized, multicenter controlled trial. *Kidney Int* 2002;62:1034-1045

15 Basile C, Giordano R, Vernaglione L, *et al*. Efficacy and safety of haemodialysis treatment with the Hemocontrol™ biofeedback system: a prospective medium-term study. *Nephrol Dial Transplant* 2001;16:328-334

16 Sato M, Horigome I, Chiba S, *et al*. Autonomic insufficiency as a factor contributing to dialysis-induced hypotension. *Nephrol Dial Transplant* 2001;16:1657-166

Correspondence to:
Dr Vítor Ramalho
Largo Sr da Pobreza
7000-811 Évora, Portugal
Email: vmramalho@hotmail.com