

Reliability of delivered dialysate sodium concentration

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Abstract

Background

The results of studies investigating the effects of hyponatraemic dialysates have been mixed, with some reporting positive effects including reduction in blood pressure and inter-dialytic weight gains, whereas others have not been able to demonstrate any effect. These studies assume that setting a lower dialysate sodium results in the delivery of a hyponatraemic dialysate. We therefore measured delivered sodium to determine reliability.

Methods

We measured dialysate sodium in 10 BBraun Dialog +® and 6 Fresenius 4008H dialysis machines, which had been set up to deliver a sodium of 136 mmol/l, using flame photometry and indirect ion selective electrode (ISE) methods

Results

Dialysate conductivity was 13.85 ± 0.05 mS/cm, but dialysate sodium measured by flame photometry was 141.8 ± 2.9 mmol/l, and 142.5 ± 2.4 mmol/l by ISE. Both dialysis machines delivered a dialysate sodium in excess of the 136 mmol/l set, with a mean bias of 7.0 ± 2.1 mmol/l for the Dialog +®, and 3.7 ± 2.6 for the 4008 with the flame photometer method, and a mean bias of 6.3 ± 1.3 mmol/l for the Dialog +®, and 6.8 ± 3.7 for the 4008 by ISE.

Conclusion

It is assumed that by setting a dialysate sodium concentration then that dialysate sodium concentration is delivered. However we found that the dialysate sodium concentration delivered was greater than that set, despite the dialysis machines reporting a conductivity measurement in keeping with a lower sodium dialysate. Trials of lowered dialysate sodium therefore need to measure dialysate sodium concentrations to ensure what has been set is delivered.

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INTRODUCTION

Despite advances in dialysis technology, the 5 year survival of patients with chronic kidney disease requiring dialysis (CKD5d) remains lower than that for patients with some of the more common solid organ malignancies. Cardiovascular mortality remains the commonest cause of death, and excess extracellular water has been reported to be a primary risk factor [1]. Thirst drives fluid intake and inter-dialytic weight gains. Sodium intake has a major effect on thirst and weight gain [2].

During haemodialysis most sodium removal is achieved by ultrafiltration, although altering the dialysate sodium concentration, could potentially allow a diffusive sodium component. Traditionally lowered dialysate sodium concentrations were reported to lead to less thirst, and lower inter-dialytic weight gains and lower systolic blood pressure [3], whereas high dialysate sodium concentrations increased thirst, inter-dialytic weight gains and hypertension [4]. Although some observational studies have reported lower weight gains and lower blood pressure with lowering the dialysate sodium concentration [5,6], other studies only noted a minor effect [7], and others reported increased mortality associated with lower dialysate sodium [8]. As such there has been debate as to the optimum choice of dialysate sodium [9].

To explain the difference in results reported between centres, some have suggested that the effect of reducing dialysate sodium dietary sodium could be neutralised by high dietary sodium intake [10]. An alternative explanation is that the delivered dialysate sodium concentration is not that prescribed, and one study reported that although there was overall a negligible difference between delivered and prescribed dialysate sodium there was quite a large range in differences for the individual patient [11]. To investigate this further we measured dialysate sodium and compared this to that set on the haemodialysis machine, as a quality assurance audit.

Methods

We measured sodium in fresh dialysate, made by combining ultrapure dialysis water, with sodium bicarbonate (Bibag, Fresenius MC, Bad Homburg, Germany). and an acid electrolyte concentrate (Kimal, Uxbridge, UK) within the haemodialysis machine (Fresenius 4008H, Fresenius MC, Bad Homburg, Germany, BBraun Dialog +®, BBraun, Melsungen, Germany). The final dialysate composition was: set to deliver a sodium concentration of 136 mmol/l, potassium 1 or 2 mmol/l, calcium 1.35 mmol/l, magnesium 0.5 mmol/l, bicarbonate 32 mmol/l, acetate 3 mmol/l, and glucose 5.5 mmol/l..Haemodialysis machines were regularly serviced, and dialysate conductivity checked against a standard curve generated using four standards. Dialysate sodium samples were measured using flame photometry (Flame photometer IL 943, Instrumentation Laboratory, Warrington, UK.), using appropriate calibration standards and Roche aqueous controls and optical filters , and with a standard multi-channel biochemical analyser using an indirect ion selective electrode (ISE) (Roche Modular P® analyser, Roche Diagnostics Limited, Burgess Hill, UK) The coefficient of variation for the ISE method for measuring sodium in an aqueous solution was 1.01% for a sodium concentration of 120 mmol/l and 0.57% for a sodium concentration of 160 mmol/l, and 0.4% for the flame photometer at both concentrations respectively [12].

Compliance with ethical standards

This audit of standard routine clinical practice fulfilled the UK NHS guideline for clinical audit and service development, and complied with the UK National Health Service (NHS) guidelines for clinical audit and service development, (UK NHS guidelines for clinical audit and service development, <http://www.hra.nhs.uk/documents/2013/09/defining-research.pdf>, and <http://www.gov.uk/government/publications/health-research-ethics-committees-governancearrangements>).

Statistics

Results are displayed as mean \pm standard deviation. Student's paired t test and Bland Altman analysis were used to compare different methods of sodium measurement (Graph Pad 6.0, Prism, San Diego and Analyse-It 3.0, Analyse-It, Leeds, UK). Statistical significance was taken at $p < 0.05$

Results

Fresh dialysate samples were obtained from 10 BBraun Dialog +® and 6 Fresenius 4008H dialysis machines. The mean haemodialysis machine conductivity was 13.85 ± 0.05 mS/cm, and dialysate sodium measured by flame photometry was 141.8 ± 2.9 mmol/l, and that for ISE method 142.5 ± 2.4 mmol/l. There was no statistical difference between the flame and ISE measurements mean bias -0.7 ± 2.9 mmol/l (Figure 1). Both dialysis machines delivered a dialysate sodium in excess of the 136 mmol/l set, with a mean bias of 7.0 ± 2.1 mmol/l for the Dialog +®, and 3.7 ± 2.6 for the 4008 with the flame photometer method, and a mean bias of 6.3 ± 1.3 mmol/l for the Dialog +® (Figure 2), and 6.8 ± 3.7 for the 4008 using the ISE method (Figure 3).

Discussion

The results of studies reporting on the effect of lowering dialysate sodium to improve blood pressure control and reduce inter-dialytic weight gains have been varied [3, 5-9]. However the premise underpinning all these studies was that the delivered dialysate sodium was that set on the haemodialysis machine. There have been reports that batch dialysate sodium concentration made using a central delivery system have delivered higher dialysate sodium than that set on the dialysis machine [13]. We individualise dialysate composition, rather than using a central delivery system. As such the final dialysate composition is made in the dialysis machine by mixing set proportions of an "acid" concentrate with a "bicarbonate" concentrate and dialysis water to produce the desired final dialysate electrolyte composition, which is checked by measuring conductivity. Conductivity is a measure of the amount of electrical measure of the of electrical current conducted through a dialysate and reflects the electrolyte concentration, and as sodium is the predominant cation, is used as a surrogate measure of sodium concentration. In our study the dialysate sodium was set to deliver a sodium concentration of 136 mmol/l, and with a potassium of 1-2 mmol/l, calcium 1.35 mmol/l and magnesium 0.5 mmol/l, so we would have expected a final dialysate conductivity between 13.8-13.9 mS/cm, which compares to 13.85 ± 0.05 mS/cm recorded. As such the dialysis machine reported the expected dialysate conductivity, but instead of delivering a dialysate sodium of 136 mmol/l, delivered a much higher dialysate sodium.

We measured sodium in the fresh dialysate using two methods; flame photometry and by ISE. Flame photometry utilises the principle that light of a characteristic wavelength is emitted when an alkali metal salt, such as sodium, absorbs energy when it is ionised by a non-luminous flame. The intensity of light emitted is detected by a photocell and is proportional to the concentration of the alkali metal salt in the solution. For reliability appropriately prepared standards are required for calibration [14]. Flame photometry is labour intensive whereas the ISE method allows a rapid throughput of samples. The flame method measures the total sodium concentration in the sample, including both the ionic form and that complexed with anions. In contrast, the indirect ISE does not measure serum sodium complexed to other molecules [15]. As dialysate does not contain proteins or lipids, then this is not such a problem compared to measuring sodium in plasma. During ISE measurement, buffers are added to the sample to adjust the activity of the solution, and the result automatically adjusted using calibration curves based on reference standards of known sodium activity [15]. Although termed ion selective, the sodium selective electrode can also respond to potassium ions, but not to the same sensitivity [16], however the concentration of sodium in our samples greatly exceeded that of potassium. As ISEs measure activity, they can sometimes under-estimate ion activity at high concentrations, when ions "crowd" close to the electrode membrane. We found a similar sodium concentration in fresh dialysate using both methods, whereas previous reports have noted significant bias when measuring plasma and urinary sodium concentrations, presumably due to the lack of sodium complexing with other molecules in fresh dialysate [17,18].

Our finding that patients supposedly set to dialyse against a hyponatraemic dialysate were dialysing against a much higher dialysate is of concern. The dialysis machine measured and displayed a lower conductivity suggesting that a hyponatraemic dialysate was being delivered. The question arises as to why this should happen, and for two different makes of dialysis machines. This could have been due to a technical problem with calibrating sodium conductivity. However the machines had been checked with a conductivity monitor and calibrated using a set of four standards, and the difference in measured sodium ranged from 0-11 mmol/l, whereas if there had been a technical problem with the standards or calibrating machines we would have expected a similar offset between set and measured sodium for all machines tested. Manufacturers are allowed a small margin of error in the sodium content of both the acid concentrate and bicarbonate, which would lead to a difference in set dialysate sodium concentration and the final dialysate composition. However as some dialysis machines have a positive feedback system designed to correct differences in desired and measured dialysate conductivity, then this type of error should have been corrected.

Our experience highlights the need to regularly check the final dialysate composition, rather than simply relying on conductivity reported by the dialysis machine. As although dialysis machines are fitted with alarms to notify the user of an abnormally high or low dialysate conductivity, they did not alarm as the conductivity recorded appeared appropriate for the set dialysate composition. The inability to deliver a desired dialysate sodium would potentially have a major effect on the clinical outcomes of studies reporting on the effect of change in dialysate sodium concentration [19]. So although a personalised dialysate sodium may be preferable [20], there are technical difficulties in measuring and delivering a personalised dialysate sodium [21,22]

The authors have no conflicts of interest

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Figure 1. Bland Altman plot of dialysate sodium measured by flame photometry and indirect ion selective electrode in dialysate samples set to deliver 136 mmol/l

Figure 2. Bland Altman plot of dialysate sodium measured by flame photometry and set dialysate sodium of 136 mmol/l

Figure 3. Bland Altman plot of dialysate sodium measured by indirect ion selective electrode and set dialysate sodium of 136 mmol/l