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The effect of draw-up volume on the accuracy of electrolyte measurements from neonatal arterial lines

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Objectives: Contamination by infusate of blood samples withdrawn from arterial lines has been recognized but not well documented for neonates. The aim of this study was to investigate, using *in vitro* and *in vivo* studies, the effects of different draw-up volumes (withdrawn from the line prior to the sample being taken) on the concentration of sodium.
Methods: *In-vitro study:* The tip of an umbilical artery catheter (dead space 0.6 mL), infused with half normal saline containing 1 unit/mL of heparin was placed in a beaker of normal saline. The line was flushed with 1 mL of this infusate just before each sample was taken. Volumes from 0.5 mL to 2.0 mL of infusate/normal saline were withdrawn in 0.1 mL increments from a three-way tap and discarded. A sample was then taken from the line into a blood gas syringe for analysis of the sodium concentration by the 860 Blood Gas Analyzer (Chiron Diagnostics, Bayer, Scoresby). Control samples were taken from the beaker. *In-vivo study:* A 22 gauge intravenous catheter was inserted into a vein of an adult male volunteer. The dead space was also 0.6 mL. The line was flushed with 5 mL of half-normal saline immediately before sampling. Draw-up volumes of 0.6, 0.9, 1.3, and 1.6 mL were withdrawn and discarded. 10 mL was used as a control. A 0.5-mL blood sample was then taken and the electrolyte concentrations analysed immediately.
Results: *In-vitro:* A minimum draw-up volume of 1.3 mL was required before the sodium concentration was not significantly different from the control samples. *In-vivo:* A minimum draw-up volume of 1.6 mL was required before the sodium concentration was not significantly different from the control samples. There were similar trends in the effect of draw-up volume for glucose, calcium, potassium, chloride and lactate.
Conclusion: A minimum volume of 1.6 mL should be withdrawn from neonatal arterial lines (dead space 0.6 mL) before taking blood for analysis.

Key words: arterial cannula; blood specimen collection; infant, newborn; sodium concentration.

Arterial lines used in neonates are infused with heparinized saline. Blood taken from them for analysis may be contaminated by the infusate in the cannula and line. Others have investigated the effect of the volume of infusate and blood withdrawn from the line (the draw-up volume) on the subsequent arterial blood gas values.[1–5] No previous study has investigated the effect on electrolyte measurement in samples from catheters with a dead space of less than 1 mL in increments of less than 1 mL.

The aim of this study was to determine the minimum draw-up volume (i.e. the volume, needed to flush the infusate out of the line prior to a sample being taken) to prevent contamination from the half-normal saline infusate using sodium concentration as a reference. This study was designed to determine the draw-up volume for premature babies, therefore the effect of 0.1 mL increments was investigated.

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METHODS

In vitro study

An umbilical arterial catheter (Argyle; Sherwood Medical, St Louis, USA) connected to a three-way tap (Connecta TH; Ohmeda, Helsingborg, Sweden) was infused with heparinized half-normal saline. The volume of the catheter and three-way tap was 0.6 mL. The catheter tip was submerged in a beaker of normal saline which was covered to prevent evaporation. Before each sample was taken the line was flushed with 1 mL of infusate and then a volume of infusate and normal saline was withdrawn from the three-way tap in 0.1 mL increments ranging from 0.5 mL to 2 mL and discarded. A 0.5 mL sample was withdrawn into a heparinized blood gas syringe (Arterial Blood Sampler; Chiron Diagnostics) for analysis for sodium concentration by the 860 Blood Gas Analyzer (Chiron Diagnostics). The draw-up volume for each sample was determined by block randomization into groups of eight. The sampling schedule was devised to minimize the effects of time on the individual results. Three separate experiments were performed over 2 days and the results combined. Control samples of normal saline were taken directly from the beaker with a blood gas syringe.

Power calculation was performed on 10 samples taken from an ampoule of normal saline. The mean (SD) sodium concentration was 148.62 (0.38) mmol/L. A sample size of three in each group would be adequate to show a difference between

means of 1 mmol/L (α 0.05, β 0.2). These were compared with the Student's *t*-test.

In vivo study

A vein of a consenting adult male was cannulated with a 22-gauge needle and connected to a line, T-connector and three-way tap similar to those used with premature babies (pressure monitoring line; Surgicare, Braeside, Victoria, Australia). The dead space of the cannula and arterial line was also 0.6 mL. The line was infused with heparinized half-normal saline. The technique for clearing the line and sampling the blood was identical to the *in vitro* experiment except that the line was flushed with 5 mL of infusate prior to sampling, and the draw-up volumes used were 0.6, 0.9, 1.3, and 1.6 mL, with 10 mL being used for the control. The order in which the volumes were taken was determined by block randomization into groups of four. Four samples were taken at each volume.

Power calculation was performed on four samples taken from the line before the experiment started. The mean (SD) sodium concentration was 140.5 (0.78) mmol/L. A sample size of four in each group would be adequate to show a difference between means of 2 mmol/L (α 0.05, β 0.2). Differences between means were compared using the Student's *t*-test.

The 860 Blood Gas Analyzer (Chiron Diagnostics) operator's manual gives figures for the precision testing of measured sodium concentration. The standard error of the mean (SEM) for sodium concentration in syringe specimens ranges from 0.05 to 0.1 – corresponding to 'within-run standard deviations' from 0.25 to 0.49 mmol/L.

Table 1 Sodium concentrations by draw-up volume in the *in vitro* study

Draw-up volume mL	*n*	Mean sodium (mmol/L)	SEM	*P* value*
0.5	4	126.1	0.55	< 0.0001
0.6	4	133.7	0.94	< 0.0001
0.7	4	138.7	0.41	< 0.0001
0.8	8	142.8	0.48	< 0.0001
0.9	8	144.9	0.25	< 0.0001
1.0	8	146.7	0.47	0.0003
1.1	8	147.0	0.33	0.0005
1.2	8	148.2	0.48	0.0037
1.3	12	149.8	0.26	0.06
1.4	8	149.7	0.49	0.065
1.5	8	149.6	0.42	0.05
1.6	4	149.6	0.53	0.067
1.7	4	150.4	0.23	0.18
1.8	4	150.5	0.31	0.22
1.9	4	150.9	0.19	0.42
2.0	4	150.7	0.17	0.29
Control	8	151.6	0.81	

*Student *t*-test comparing the difference for each draw-up volume with the control; SEM, standard error of the mean.

RESULTS

In vitro study

Table 1 shows the concentration of sodium at different draw-up volumes. A minimum draw-up volume of 1.3 mL was required before there was no statistically significant difference from the control samples. Draw-up volumes of 1.4–1.6 mL show differences that approach statistical significance.

In vivo study

Table 2 shows the measurements of sodium and other electrolytes at different draw-up volumes from 0.6 to 1.6 mL. A minimum draw-up volume of 1.6 mL was required before the difference in sodium concentration from the control samples was not statistically significant. Similar trends were shown for glucose, calcium, potassium, chloride and lactate in the same samples.

DISCUSSION

Before taking neonatal arterial blood for analysis, the line must be cleared of infusate to prevent contamination. These studies have shown, using a half-normal saline infusion which is standard in this neonatal unit, that the accuracy of sodium and other electrolyte concentrations is dependent on the volume withdrawn to clear the line. For a cannula and line volume of 0.6 mL the volume withdrawn should not be less than 1.6 mL to prevent dilution from the infusate. The results were similar for the *in vitro* and *in vivo* studies.

In the *in vivo* study, which started with a draw-up volume of 0.6 mL, the difference in sodium measurement compared with a draw-up volume of 1.6 mL was 8 mmol/L. That is, if the draw-up volume was only 0.6 mL the sodium would be approximately 8 mmol/L lower than if the draw-up volume were 1.6 mL. If such a difference did occur because the line

Table 2 Serum electrolyte concentrations by draw-up volume in the *in vivo* study.

Draw-up volume mL (*n*)	Sodium (mmol/L)	*P* value	*Potassium (mmol/L)	*P* value*	Chloride (mmol/L)	*P* value*	Calcium (mmol/L)	*P* value*	Lactate (mmol/L)	*P* value*	Glucose (mmol/L)	*P* value
0.6 (4)	131.1 (0.92)	0.001	3.1 (0.16)	0.033	99.8 (0.48)	0.025	1.06 (0.01)	0.0047	1.20 (0.03)	0.003	7.2 (0.11)	0.0058
0.9 (4)	134.8 (1.51)	0.051	3.7 (0.47)	0.33	101.8 (1.0)	0.27	1.09 (0.02)	0.053	1.27 (0.05)	0.086	7.7 (0.22)	0.21
1.3 (4)	137.5 (0.68)	0.035	3.5 (0.09)	0.11	102.3 (0.48)	0.31	1.14 (0.03)	0.53	1.32 (0.05)	0.2	8.0 (0.07)	0.78
1.6 (4)	139.2 (0.58)	0.46	3.7 (0.1)	0.18	102.5 (0.65)	0.43	1.16 (0.02)	0.92	1.39 (0.03)	0.85	8.1 (0.16)	1.0
10 (4)	139.8 (0.43)		4.3 (0.34)		103.5 (0.96)		1.16 (0.02)		1.40 (0.03)		8.1 (0.15)	

*Student *t*-test comparing the difference for each draw-up volume with the 10 mL control. Values are mean (SE).

was not cleared properly it could have a major effect on clinical decision making.

In both studies, the differences between the means observed between controls and the study samples when the draw-up volumes approached 1.6 mL were small. This difference may not be clinically important but serves to illustrate that even small differences in draw-up volume can influence the measurement of sodium. Small differences such as these may have little effect on clinical decision making if the measured value is well within the normal range. However if the true value is at or about the limits of normality then an even smaller difference may give a result that leads to inappropriate clinical decision making (i.e. starting an unnecessary treatment or continuing inappropriate treatment).

The lowest standard error for a sodium measurement in these studies was 0.17 (Table 1). This is greater than the precision stated for by the 860 Blood Gas Analyzer (Chiron Diagnostics) for a reference sodium concentration. Therefore it is unlikely that the observed differences were due to machine imprecision.

In the *in vivo* studies, the concentrations of glucose, calcium, potassium, chloride and lactate approached the control value as the draw-up volume increased. The power of the study was not calculated to assess these measurements and so statistically significant differences are not evident at draw-up volumes approaching 1.6 mL. However, the fact that there was a strong trend for each of these measurements to change with the draw-up volume adds robustness to the suggestion that the effect seen with sodium was real and not an artifact of the sodium measurement.

This is the first study to investigate the effects of the withdrawal volume on the measurement of sodium concentration in increments of less than 1 mL, in lines with a small dead space used for neonatal intensive care. The minimum draw-up volume of 1.6 mL, to ensure that the effect of contamination from the infusate is minimized, is 1 mL more than the dead space volume in the arterial line, a value very similar to other studies that have investigated the effects of draw-up volume on arterial blood gas and electrolyte measurements.[1–5]

Minimizing the amounts of blood withdrawn from arterial lines, especially if this blood is then discarded, is needed to reduce blood loss from critically ill neonates. However, if samples are to be clinically useful they must be as accurate as possible. The only way to achieve this is to ensure that the line is adequately cleared of infusate before the blood sample is taken.

CONCLUSION

When using an arterial line, with a dead space volume of 0.6 mL in a neonate, at least 1.6 mL should be withdrawn from the line prior to taking a sample for electrolyte analysis to avoid contamination.

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