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ARTIGO ORIGINAL

Agreement and Correlation of pH, Bicarbonate, Base Excess and Lactate Measurements in Venous and Arterial Blood of Premature and Term Infants*

Concordância e Correlação das Medidas de pH, Bicarbonato, Excesso de Base e Lactato no Sangue Venoso e Arterial de Recém-Nascidos de Termo e Prematuros

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RESUMO

JUSTIFICATIVA E OBJETIVOS: Determinar o grau de concordância e correlação entre amostras arteriais e as obtidas através de um cateter venoso umbilical, com relação ao pH, bicarbonato, excesso de base (BE) e lactato, em recém-nascidos prematuros e de termo, criticamente doentes.

MÉTODO: Foram obtidas amostras para gasometria (0,5 – 1 mL), por punção de artéria radial, e, dentro do limite de 5 minutos, do cateter venoso umbilical. O método de Bland-Altman foi utilizado para demonstrar a concordância entre as medidas. Os limites de concordância foram definidos como a diferença média ± 2 DP. Para as correlações foi utilizado o método de Pearson.

RESULTADOS: Cento e seis amostras (53 pares) de 53 pacientes foram analisadas para bicarbonato, pH e BE. Foi dosado lactato em 49 pares de amostras. Houve concordância em 94,3% dos pares de amostras para o pH, e este mesmo percentual foi observado para o bicarbonato. Para o excesso de base, a concordância foi de 96,2%, e de 91,8% para o lactato. As diferenças médias foram 0,03 unidade para o pH, -1,2 mmol/L para o bicarbonato, -0,24 mmol/L para o excesso de base e 0,33 mmol/L para o lactato. Os coeficientes de correlação de Pearson (*r*) foram 0,87 para o pH, 0,76 para o bicarbonato, 0,86 para o excesso de base e 0,95 para o lactato.

CONCLUSÕES: Os valores venosos isolados não podem ser usados como equivalentes aos arteriais para a avaliação do estado ácido-básico em recém-nascidos. As amostras venosas poderiam ser usadas de forma serial, para monitorizar tendências ao longo do tempo.

Unitermos: artérias, gasometria, recém-nascido, veias

SUMMARY

BACKGROUND AND OBJECTIVES: Determine the extent of agreement and correlation between arterial samples and venous (obtained from a venous umbilical catheter), with respect to measurements of pH, bicarbonate, base excess and lactate, in critically ill term and premature newborns.

METHODS: Arterial blood samples (0.5-1 mL) were obtained for gas analysis by radial artery puncture, and, within the limit of 5 minutes, samples were obtained from venous umbilical catheters. Bland-Altman plots were used to depict agreement between arterial and venous measurements. Limits of agreement were defined as the mean difference ± 2SD (Standard Deviation). Correlation was assessed by Pearson's method.

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RESULTS: A hundred and six samples (53 pairs) were taken from 53 patients for analysis of bicarbonate, pH and base excess. Lactate was analyzed in 49 pairs of samples. Differences were within the limits of agreement in 94.3% of pairs of samples for pH, and the same percentage was observed for bicarbonate. There was agreement in 96.2% of pairs for base excess, and in 91.8% for lactate. Mean differences were 0.03 units for pH, -1.2 mmol/L for bicarbonate, -0.24 mmol/L for base excess and 0.33 mmol/L for lactate. Pearson's correlation coefficients (*r*) were 0.87 for pH, 0.76 for bicarbonate, 0.86 for base excess and 0.95 for lactate.

CONCLUSIONS: Although single venous values cannot be used as equivalent to arterial for assessing acid base status in newborns, venous blood samples can be used serially for monitoring trends over time.

Key Words: arteries, blood gas analysis, newborn, veins

INTRODUCTION

Arterial blood sampling is usually the standard method for measurements of bicarbonate, pH, BE and lactate. In newborns, arterial lines are frequently placed in umbilical vessels for blood sampling, since arterial punctures may be difficult, especially in low-weight premature infants. Additionally, radial artery puncture is painful, and can lead to complications like local hematomas, infection and occlusion or embolization of the artery, with distal ischemic injury[1]. These risks increase with repeated punctures[2]. The use of umbilical artery catheters also poses a risk, especially for neonatal thrombosis, which carries a significant mortality rate[3]. It has been experimentally demonstrated that the presence of arterial catheter is enough to start the local fibrin formation[4]. Blood sampling from the umbilical arterial catheter induces a decrease in cerebral blood volume and cerebral oxygenation, depending on the volume e sampling velocity[5,6].

Central venous catheters are interesting alternative sources of blood samples. Venous umbilical catheters are the easiest venous line for premature newborns, and are a common procedure in neonatal intensive care units. As these catheters have usually diameters larger than 3-French, blood sampling is feasible, since protocols for manipulation with aseptic technique are adopted. One study have demonstrated that central venous pH, bicarbonate, BE and lactate show a high level of agreement with respective arterial values in adult patients[7]. The purpose of our study was investigating the extent of agreement between arterial and venous samples, when obtained from a venous umbilical catheter, with respect to acid-basis status, in critically ill term and premature newborns.

METHODS

The study was undertaken in the 17-bed Neonatal Intensive Care Unit (NICU) within a tertiary hospital in São Paulo, Brazil. Premature and term infants born from March to September, 2005, were the potential subjects. Inclusion criteria were the need for blood gas analysis in a critically ill newborn, the presence of a venous umbilical catheter with the tip placed at inferior vena cava below the diaphragm (with placement confirmed by chest and abdominal radiograph), and an informed consent form signed by one or both of the parents. The local ethics committee approved the study. Infants with congenital heart diseases, with significant intracardiac shunt, were excluded.

Arterial blood samples (0.5-1 mL) were obtained by radial artery puncture with 25G (Gauge) or 27G needles, in 3 mL heparinised syringes. As simultaneously as possible (up to 5 minutes), samples were obtained from venous umbilical catheters, by the "push-pull" method: after flushing the dead space of the catheter with saline, 1 mL of blood was aspirated into a 10 mL non-heparinised syringe. The blood was reinfused, and this procedure was repeated at least 3 times[8,9]. The syringe was removed, and a new 3-mL heparinised syringe was attached, and 0.5-1 mL of blood was sampled for gas analysis and lactate dosage. The measurements were performed within 15 minutes, using a Rapid Lab 865 analyzer (Bayer, USA). Multiple samples from the same patient were not allowed.

Data were analyzed with the statistical package SPSS 10.0 (SPSS, USA). The Bland-Altman plots were used to depict agreement between arterial and venous measurements. Limits of agreement were defined as the mean of differences ± 2 SD[10]. Pearson's correlation coefficients were also determined.

RESULTS

A hundred and six samples (53 pairs) of central venous and arterial blood were taken from 53 patients for analysis of bicarbonate, pH and base excess. Lactate was analyzed in 49 pairs of samples, from the 53 patients. Mean gestational age from patients was 34.3 weeks (range 27 – 40.7 weeks). The mean of birth weight was

2.21 kg (range 0.88–3.5 kg). 14 patients (26.6%) were premature infants with birth weight lower than 1.5 kg. The mean age at the moment of the sampling was 31.3 hours (range 1-240 hours). All the patients were under respiratory assistance, either invasive (73%) or noninvasive (27%), and 22 (41.5%) of them were receiving vasoactive drugs (dobutamine or dopamine, or both). The most frequent diagnoses were respiratory distress syndrome (54.7%), pulmonary hypertension (17%) and neonatal sepsis (11%). Table 1 shows characteristics of the samples and table 2 the difference means, limits of agreement and correlation coefficients.

Figure 1 depicts Bland-Altman plot for arterial and venous pH. Differences were within the limits of agreement in 94.3% of pairs of samples. The same percentage was observed for bicarbonate (Figure 2). There was agreement in 96.2% of pairs for base excess (Figure 3), and in 91.8% for lactate (Figure 4).

Table 1 – Characteristics of Samples

Variables	Number of Samples	Mean (SD)	Range
Arterial pH	53	7.33 (0.11)	6.96 to 7.53
Venous pH	53	7.29 (0.10)	6.99 to 7.54
Arterial bicarbonate	53	18.54 (3.45)	10.5 to 33.4
Venous bicarbonate	53	19.75 (3.96)	11.4 to 34.2
Arterial base excess	53	-6.60 (3.74)	-17.5 to 4.3
Venous base excess	53	-6.35 (3.82)	-18.4 to 4.1
Arterial lactate	49	3.24 (1.88)	1.18 to 8.69
Venous lactate	49	2.91 (1.47)	0.76 to 6.73

Table 2 – Agreement and Correlation between Arterial and Venous Samples

Variables	N	MD (95% CI)	Limits of Agreement (MD ± 2 SD)	*r* (Significance)
pH (units)	53	0.03 (0.018 to 0.048)	-0.07 to 0.14	0.87 ($p < 0.001$)
Bicarbonate (mmol/L)	53	-1.21 (-1.92 to -0.50)	-6.49 to 4.06	0.76 ($p < 0.001$)
Base excess (mmol/L)	53	-0.24 (-0.84 to 0.35)	-4.68 to 4.19	0.83 ($p < 0.001$)
Lactate (mmol/L)	49	0.33 (-0.14 to 0.52)	-1.00 to 1.67	0.95 ($p < 0.001$)

r = Pearson's correlation coefficient CI = Confidence Interval
MD = Mean difference

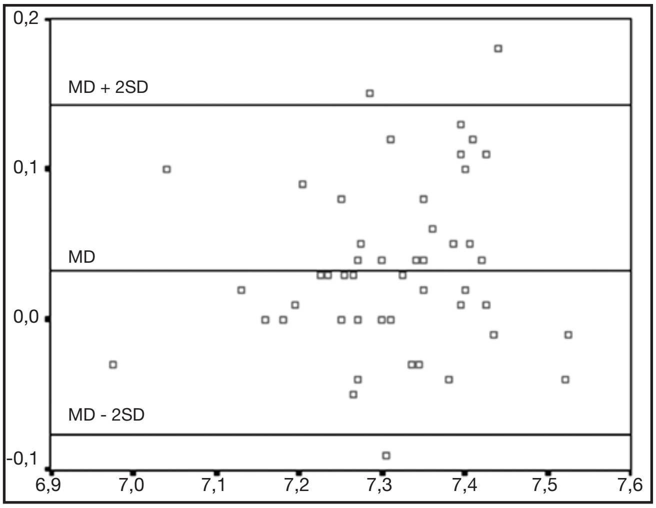

Figure 1 – Bland-Altman Plot of the Means of Arterial and Venous pH Measurements (X) and their Differences (Y).
There was agreement in 50/53 pairs of samples (94.3%). MD: mean difference SD: Standard Deviation

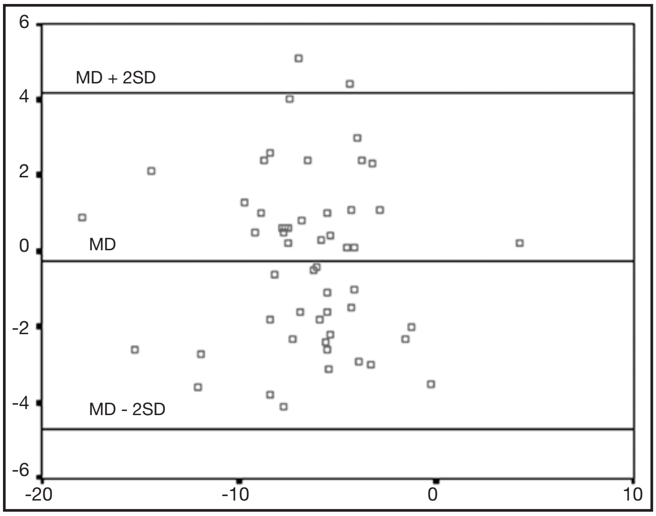

Figure 2 – Plot of the Means of Arterial and Venous Base Excess Measurements (X) and their Differences (Y).
There was agreement in 51/53 pairs of samples (96.2%).

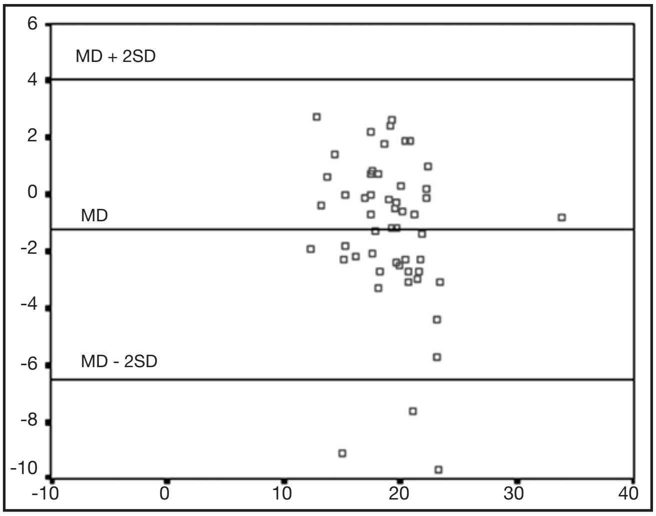

Figure 3 – Plot of the Means of Arterial and Venous Bicarbonate Measurements (X) and their Differences (Y).
There was agreement in 50/53 pairs of samples (94.3%).

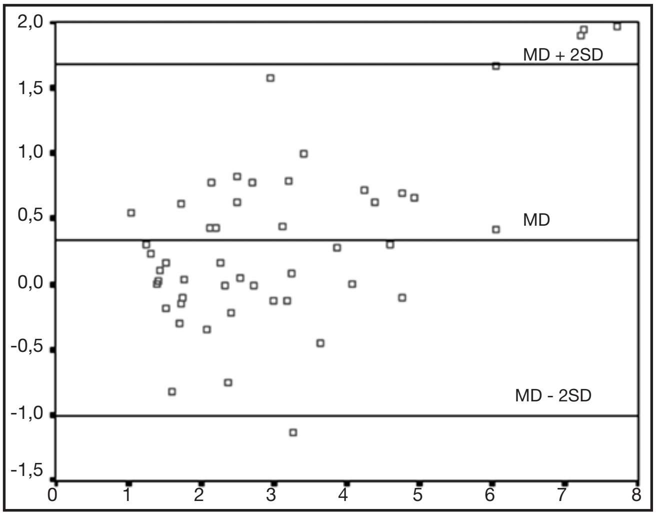

Figure 4 – Plot of the Means of Arterial and Venous Lactate Measurements (X) and their Differences (Y).
There was agreement in 45/49 pairs of samples (91.8%).

DISCUSSION

The assessment of acid-base status is essential in the management of critically ill newborns. Measurements of pH and base-excess are not only important in diagnosis of acidosis, but are also useful to monitor the progression of disease[2]. Lactate is a marker of impaired tissue oxygenation, as resultant of hypoxia or hypovolemia, and has been demonstrated to be a predictor of poor outcome in children with shock or sepsis[11,12].

Umbilical catheters also can lead to serious complications to premature and term newborns, like thrombosis or sepsis, but, if the association of an umbilical arterial line could be avoided, the overall risks would be potentially diminished. We can assume that collecting blood from a venous umbilical catheter is not more hazardous then collecting from arterial ones. Some studies have suggested that venous pH [1] or pH, bicarbonate, base excess and lactate[7,13] show good statistical agreement when compared in arterial and venous samples. The limits of agreement used in these studies were in accordance with the Bland and Altman statement, that the interval between 2 SD for the mean difference is not clinically significant[10]. In spite of the general acceptance of this statement by the authors, clinicians may not have the same opinion. In the study of Rang et al., 45 emergency physicians were asked about the acceptable level of difference between arterial and venous values for blood gases. The limits stated by the clinicians were quite narrower than the 2 SD around the mean difference[14]. This limited survey suggests physicians responsible for patient care would not be comfortable with the level of disagreement between arterial and venous samples.

Our study shows mean differences greater than previously reported in adult patients[1,7]. The sample was reasonably small, limited by the difficulties of simultaneous blood collecting in low birth weight infants, precluding analysis of subgroups. Despite of this, the confidence intervals were narrow for the mean difference (Table 2), indicating that this sample is in fact representative. There were also a high percentage of patients with hemodynamic compromise, as demonstrated by the number of patients with inotropic support. The study of Adrogue et al. has demonstrated that when the hemodynamic compromise is critical, agreement between arterial and central venous pH is poor. The proposed mechanism is that the disproportionate decrement in cardiac output leads to an increased ventilation-to-perfusion ratio with arterial hypocapnia. The venous hypercapnia results from a greater addition of CO_2 per unit of blood transversing the capillaries of the hypoperfused peripheral tissues[15,16]. This influence of CO_2 can explain the lower correlation of arterial and venous bicarbonate that we observed ($r = 0.76$), as bicarbonate is a calculated value, based on CO_2 level. According with our data, for using arterial and venous measurements of pH, base excess, bicarbonate and lactate interchangeably, clinicians would have to accept a range of disagreement up to ± 0.1 unit for pH, ±5.2 mmol/L for bicarbonate, ±4.4 mmol/L for base excess and ±1.3 mmol/L for lactate. We think that with these data, single venous blood values cannot be used as equivalents to arterial ones, but venous blood samples from umbilical catheters can be useful in serial collects for identifying trends over time. This recommendation is supported by the high correlation observed between arterial and venous measurements for pH, base excess and especially for lactate.

REFERENCES

01. Kelly AM, McAlpine R, Kyle E - Venous pH can safely replace arterial pH in the initial evaluation of patients in the emergency department. Emerg Med J, 2001;18:340-342.
02. Yildizdas D, Yapicioglu H, Yilmaz HL et al - Correlation of simultaneously obtained capillary, venous, and arterial blood gases of patients in a paediatric intensive care unit. Arch Dis Child, 2004;89:176-180.
03. Coleman MM, Spear ML, Finkelstein M et al - Short-term use of umbilical artery catheters may not be associated with increased risk for thrombosis. Pediatrics, 2004;113:770-774.
04. Chidi CC, King DR, Boles ET - An ultrastructural study of the intimal injury induced by an indwelling umbilical artery catheter. J Pediatr Surg, 1983;18:109-115.
05. Roll C, Huning B, Kaunicke M et al - Umbilical artery catheter blood sampling volume and velocity: impact on cerebral blood volume and oxygenation in very-low-birthweight infants. Acta Paediatr, 2006;95:68-73.
06. Schulz G, Keller E, Haensse D et al - Slow blood sampling from an umbilical artery catheter prevents a decrease in cerebral oxygenation in the preterm newborn. Pediatrics, 2003;111:E73-E76.
07. Middleton P, Kelly AM, Brown J et al - Agreement between arterial and central venous values for pH, bicarbonate, base excess, and lactate. Emerg Med J, 2006;23:622-624.
08. Moureau NL - Drawing blood through a central venous catheter. Nursing, 2004;34:28.
09. Barton SJ, Chase T, Latham B et al - Comparing two methods to obtain blood specimens from pediatric central venous catheters. J Pediatr Oncol Nurs, 2004;21:320-326.
10. Bland JM, Altman DG - Statistical methods for assessing agreement between two methods of clinical measurement. Lancet, 1986;1:307-310.
11. Hatherill M, Waggie Z, Purves L et al - Mortality and the nature of metabolic acidosis in children with shock. Intensive Care Med, 2003;29:286-291.
12. Duke TD, Butt W, South M - Predictors of mortality and multiple organ failure in children with sepsis. Intensive Care Med, 1997;23:684-692.
13. Brandenburg MA, Dire DJ - Comparison of arterial and venous blood gas values in the initial emergency department evaluation of patients with diabetic ketoacidosis. Ann Emerg Med, 1998;31:459-465.
14. Rang LC, Murray HE, Wells GA et al - Can peripheral venous blood gases replace arterial blood gases in emergency department patients? CJEM, 2002;4:7-15
15. Adrogue HJ, Rashad MN, Gorin AB et al - Assessing acid-base status in circulatory failure. Differences between arterial and central venous blood. N Engl J Med, 1989;320:1312-1316.
16. Adrogue HJ, Rashad MN, Gorin AB et al - Arteriovenous acid-base disparity in circulatory failure: studies on mechanism. Am J Physiol, 1989;257:F1087-F1093.