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REVIEW ARTICLE

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The case for venous rather than arterial blood gases in diabetic ketoacidosis

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Abstract

Objectives: For patients with diabetic ketoacidosis (DKA), arterial blood gas (BG) sampling for measurement of pH and bicarbonate has been considered an essential part of initial evaluation and monitoring of progress. There is growing evidence that venous values can be clinically acceptable alternatives to arterial measurements. This article summarizes the recent evidence regarding the validity of venous BG sampling in DKA.

Methods: Medline search for the years 1995 to present, hand search of reference lists, search of online evidence-based medicine sites.

Results: In patients with DKA the weighted average difference between arterial and venous pH was 0.02 pH units (95% limits of agreement −0.009 to +0.021 pH units) and between arterial and venous bicarbonate was −1.88 mEq/L.

Conclusions: There is reasonable evidence that venous and arterial pH have sufficient agreement as to be clinically interchangeable in patients with DKA who are haemodynamically stable and without respiratory failure. There is some evidence that venous and arterial bicarbonate also agree closely in DKA but this requires confirmation.

Key words: *diabetes*, *pH*, *venous blood gas*.

Introduction

Diabetic ketoacidosis (DKA) is a life-threatening endocrine emergency characterized by hyperglycaemia, ketonaemia and metabolic acidosis. Traditionally, arterial blood gas (BG) sampling for measurement of pH and bicarbonate has been considered an essential part of initial evaluation and monitoring of progress. Arterial BG sampling is, however, painful for patients and carries a small risk of complications such as local haematoma, arterial injury and thrombosis, embolism and infection. Additionally, this procedure carries a small but appreciable risk of needle stick injury to health-care workers, with the consequent risk of transmission of blood borne viruses such as hepatitis C and HIV.

Over the last 50 years, a number of small studies have suggested that pH can be accurately estimated

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from venous blood and 'arterialized' venous blood.[1–7] Some have reported that venous pH is almost identical to arterial pH.[1,6,7] There is now a growing body of evidence from the emergency medicine and critical care settings suggesting that arterial and venous pH agree within clinically acceptable limits and a small number of studies suggest that venous and arterial bicarbonate agree closely. If this is accepted, it might be time for us to move from arterial BG to venous BG analysis in DKA.

This article aims to summarize the evidence regarding the validity of venous BG sampling in DKA.

Methods

Medline searches for the years from 1966 to present were conducted using the terms 'arterial', 'venous', 'blood gas', 'pH', 'bicarbonate', 'agreement', 'correlation' and these terms with 'DKA' or 'diabetic ketoacidosis'. Titles and abstracts were reviewed to identify papers potentially addressing the research question. Full texts of these were obtained and reviewed. A hand search of the reference lists of published papers on the topic was also conducted as was cross-referencing with the emergency medicine on-line evidence-based medicine site, Best Bets (http://www.bestbets.org). Where specific data items were not included in the paper, attempts were made to contact authors by email or traditional mail to obtain these items. Papers that did not report at least average difference between arterial and venous samples were excluded.

Results

Six studies have investigated agreement between arterial and venous pH.[8–13] Three of these have included patients with DKA[8,10,11] and report a weighted average difference between arterial and venous pH of 0.02 pH units ($n = 258$). Ninety-five per cent limits of agreement (where reported) were –0.009 to +0.021 pH units. The other three looked at a mixed group with respiratory and metabolic illness and respiratory failure, respectively. They report a weighted average difference between arterial and venous pH of 0.037 pH units ($n = 763$). Ninety-five per cent limits of agreement (where reported) were within the range –0.11 to +0.04 pH units. The data from these studies are summarized in Table 1.

Four studies explored agreement between arterial and venous bicarbonate,[11–14] only one of these identifies a specific DKA subgroup[11] (Table 2). For the DKA group the weighted average difference between arterial and venous bicarbonate was –1.88 mEq/L ($n = 21$). For the mixed group it was –0.99 mEq/L ($n = 763$). Ninety-five per cent limits of agreement were within in the range –2.73 to +5.13 mEq/L.

Discussion

Most textbooks of adult medicine continue to recommend arterial BG analysis as the investigation of choice for estimation of pH and bicarbonate in DKA. As mortality in DKA is related among other things to the

Table 1. Summary of agreement between arterial and venous pH

Study	Number of subjects	Type of patient	Average difference (pH units)	Range of difference (pH units)	Standard deviation of average	95% limits of agreement (pH units)
Brandenburg and Dire 1998[8]	38	DKA	0.03	0–0.11	Not provided	Not provided
Ma *et al.* 2003[10]	200	DKA	0.015	Not provided	0.006	–0.009 to +0.021
Kelly *et al.* 2001[9]	246	Respiratory and metabolic illness	0.04	–0.16 to +0.06	0.005	–0.11 to +0.04
Rang *et al.* 2002[12]	218	Respiratory and metabolic illness	0.036	Not provided	Not provided	Not provided
Middleton *et al.* 2005[13]	168	ICU patients – respiratory and metabolic illness	0.028	–0.03 to 0.10	Not provided	–0.066 to 0.010
Gokel *et al.* 2000[11]	100	Uraemia	0.04	0.01–0.10	0.02	Not provided
	21	DKA	0.05	0.02–0.08	0.01	Not provided
	31	Healthy subjects	0.05	0.02–0.08	0.01	Not provided

DKA, diabetic ketoacidosis.

Table 2. Summary of agreement between arterial and venous bicarbonate

Study	Number of subjects	Type of patient	Average difference (mEq/L)	Range of difference (mEq/L)	Standard deviation of average (mEq/L)	95% limits of agreement (mEq/L)
Kelly *et al.*[14]	246	Respiratory and metabolic illness	−1.20	−13.1 to +8.5	0.25	−2.73 to +5.13
Rang *et al.* 2002[12]	218	Respiratory and metabolic illness	−1.5	Not provided	Not provided	Not provided
Middelton *et al.* 2005[13]	168	ICU patients – Respiratory and metabolic illness	0.521	−3.0 to +3.7	Not provided	−1.81 to 2.85
Gokel *et al.* 2000[11]	100	Uraemia	−1.72	−0.60 to −2.80	0.42	Not provided
	21	DKA	−1.88	−0.90 to −2.80	0.41	Not provided
	31	Healthy subjects	−1.66	−0.50 to −2.90	0.58	Not provided

DKA, diabetic ketoacidosis.

degree of acidosis, determination of acid-base status has prognostic as well as diagnostic significance.[15] There is now a growing weight of evidence that, in general, venous and arterial pH have sufficient agreement as to be clinically interchangeable. Available data suggests this is also likely to be true in patients with DKA, however, this is based on three small studies and a total of 93 patients with proven DKA. Unanswered questions include whether this level of agreement remains true in patients with respiratory compromise or with circulatory instability. This is an area worthy of further study. There is some evidence that venous and arterial bicarbonate also agree closely in DKA, but this is based on a single study involving just 21 patients so should be regarded with some caution. Given the limitations of the data and study designs, there is reasonable evidence that venous and arterial pH have sufficient agreement as to be clinically interchangeable in patients that are haemodynamically stable without respiratory failure.

If venous pH was accepted as an alternative to arterial measurement, this has some potential benefits for patients, hospital staff and processes. Arterial BG sampling is painful and carries a small risk of complications. It also carries a small risk to staff of blood borne infections secondary to needle stick injury. Venous BG analysis (especially if drawn from an established i.v. access) would facilitate monitoring of pH and bicarbonate at more frequent intervals thus checking resolution of the physiological disturbance.

A potential limitation of venous BG analysis is that it might be more difficult to identify mixed acid-base disorders,[8] thus if this is suspected arterial analysis (and potentially comparison with venous values) might be justified.

Conclusion

There is reasonable evidence that venous and arterial pH have sufficient agreement as to be clinically interchangeable in DKA patients who are haemodynamically stable without respiratory failure. Unanswered questions include whether this level of agreement remains true in patients with respiratory compromise or with circulatory instability. This is an area worthy of further study. There is some evidence that venous and arterial bicarbonate also agree closely in DKA but this requires confirmation.

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Competing interests

The author is a member of the Editorial Board of *Emergency Medicine Australasia*.

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