

Research article

Use of a rapid arterial blood gas analyzer to estimate blood hemoglobin concentration among critically ill adults

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Abstract

Objective To evaluate whether measurement of the hemoglobin (Hb) concentration with a blood gas analyzer approximates that determined by a conventional coulter counter in critically ill adults.

Design Prospective patient series.

Setting A 32-bed cardiovascular, neurosurgical, trauma and medical–surgical intensive care unit in a single Canadian center.

Patients We consecutively recruited 202 critically ill adults, the majority of whom had recent cardiac or vascular surgery, neurosurgery or trauma.

Measurements The nurse obtained a single arterial blood sample within a few hours of the patient's admission to the intensive care unit. The Hb concentration was determined from each blood sample in a masked fashion, using both a blood gas analyzer and a conventional laboratory coulter counter.

Main results A total of 202 consecutive paired analyses were conducted. There was a highly significant correlation between the coulter counter and blood gas analyzer methods of Hb measurement ($r^2 = 0.98$, 95% confidence interval [CI] = 0.97–0.99; $P < 0.0001$). Using the method of Bland and Altman, the overall mean difference in Hb concentration between the coulter counter and the blood gas analyzer was -4.3 g/l (95% CI = -11.0 to 2.4). Of the 11 (5.4%) Hb measurements that extended beyond the upper and lower 95% CI, 10 (5.0%) were within ± 3 g/l of these confidence limits.

Conclusions An arterial blood gas analyzer may provide a valid alternative method to the traditional coulter counter for the rapid assessment of Hb concentration among critically ill adults. Since issues related to its safety, quality control, data entry and cost savings have yet to be addressed, however, use of such point of care testing should be viewed as a supplement to conventional laboratory testing.

Keywords arterial blood gas, coulter counter, critical care, hemoglobin concentration, intensive care unit

Introduction

The frequent collection of blood specimens in the intensive care unit (ICU) may contribute to iatrogenic blood loss [1,2], compounding the problem of acute anemia that is frequently found among individuals with active hemorrhage, with a bleeding diathesis or with hemodilutional anemia [3]. The lag time in the diagnosis of severe acute anemia, due to long laboratory turnaround times, may have important clinical consequence [2,4,5]. The availability of arterial blood gas (ABG) analyzers in most

ICUs and hospital laboratories enables rapid analysis of not only traditional blood gas elements, such as pH and pO_2 , but also Hb concentration. Because little is known about the accuracy of ABG analysis for the determination of Hb concentration, we prospectively evaluated its use in a critical care setting.

Methods

This study was conducted at the Hamilton General Hospital, a 32-bed medical and surgical ICU covering treatment that

includes trauma, neurosurgical and cardiovascular subspecialty care. All consecutive patients admitted to the ICU during the period between 18 June and 16 July 2000 were included. As part of their routine admitting bloodwork, an arterial whole blood specimen was obtained from each patient by his/her ICU nurse, shortly after admission to the ICU. A portion of that specimen was placed directly into a heparinized ABG gas syringe, while the remainder was placed in an EDTA vacuum collection tube. The ABG syringe was transported on ice to the hospital core laboratory and analyzed using a calibrated Chiron 855 ABG analyzer (Chiron Diagnostics, Medfield, MA, USA). The EDTA blood specimen tube was transported at room temperature to the same core laboratory, where a calibrated Beckman Coulter Gen-S coulter counter (Beckman Coulter Corporation, Kendal, FL, USA) was used to measure the Hb concentration. Processing of the ABG and coulter counter specimens was carried out by different laboratory technologists, who were masked to each other's test results. The Chiron 855 ABG analyzer determines the Hb concentration using a spectrophotometric carbon monoxide oximeter module, and has a within-run precision of ± 3 g/l and an accuracy within ± 3 g/l [6]. The Beckman Coulter Gen-S system has a within-run precision of ± 1.2 g/l and an accuracy within ± 2 g/l [7].

All data were entered into the hospital's patient care computer. These data were subsequently abstracted by one author and entered into an Excel 5.0 file (1994 Microsoft Corporation). The mean coulter counter and ABG Hb values were compared using an unpaired *t* test. We also calculated the square of the Pearson correlation coefficient (r^2) for the Hb concentration measured by the ABG analyzer versus that measured by the coulter counter. We then applied the method of Bland and Altman to plot the average of each coulter counter and ABG Hb pair against the coulter counter – ABG Hb difference for that same pair [8]. The r^2 value was also calculated for the relationship between the average Hb concentration and the coulter counter – ABG Hb difference. All data are presented with a 95% CI, and statistical significance was set at a two-sided *P* value of 0.05. The Hamilton Health Sciences Corporation Research Ethics Board granted permission to conduct this study.

Results

A total of 202 patients were included in this study. The mean age was 64.1 years, 65% were male, and the initial mean Acute Physiology and Chronic Health Evaluation II score was 20.0 (Table 1). More than one-half of the participants had undergone cardiac surgery, while most of the remaining patients had experienced neurosurgery, vascular surgery or major trauma.

The mean Hb concentration measured by the coulter counter was 102.9 g/l (standard deviation = 22.7 g/l), while that measured by the ABG was 107.2 g/l (standard deviation = 23.2 g/l) (mean difference = 4.3 g/l; $P = 0.060$). There

was a strong and highly significant positive correlation between the coulter counter and the ABG methods of Hb determination ($r^2 = 0.98$, 95% CI = 0.97–0.99; $P < 0.0001$) (Fig. 1).

Figure 2 presents the average Hb concentration plotted against the corresponding coulter counter – ABG Hb difference [8]. The overall mean coulter counter – ABG Hb difference was -4.3 g/l, with lower and upper 95% CI limits of -11.0 and 2.4 g/l, respectively. A total of 11 measurements (5.4%) extended beyond the upper or lower 95% CI limit (Fig. 2). Of the six points that were beyond the upper 95% CI limit, all remained within 3 g/l above that limit; of the five measurements extending below the lower 95% CI limit, however, only one was more than 3 g/l beyond that limit (Fig. 2). There was a weakly significant relationship between the mean Hb and the coulter counter – ABG Hb difference ($r^2 = 0.03$, 95% CI = 0.001–0.10; $P = 0.02$), suggesting a minimal trend in the coulter counter – ABG Hb difference with a rising Hb concentration.

Discussion

We compared the use of an ABG analyzer with the use of a traditional coulter counter for the evaluation of the Hb concentration among 202 critically ill adults. We observed that the ABG analyzer provides a reasonable estimate of the Hb concentration over a broad array of values, but typically overestimates the Hb value by approximately 4.3 g/l.

One limitation to the current study is that we did not define which patients were actively bleeding, or which had received a red cell transfusion or colloid or crystalloid infusions. It is very probable that all study participants had received some quantity of intravenous fluids, while many had probably received either autologous or donor red cells at the time of their surgery. Since the coulter counter and ABG specimens were collected at the same time, dynamic fluid or whole blood shifts should not have biased our results. The average Hb concentration observed herein was 105 g/l, ranging from as low as 59.5 g/l to as high as 225 g/l (Fig. 2). Since there was little evidence of a systematic trend in the number of outliers at either Hb extreme, ABG analysis appears to provide a consistent approximation of the Hb concentration for most Hb values seen within the ICU setting.

New and simpler methods for point of care testing have evolved to the extent that they appear to be highly accurate within the critical care setting [2,9]. In a study comparing point of care testing, using an on-site hemocytometer, with a laboratory coulter counter among 187 cardiac surgical ICU patients, the r^2 value for the measured Hb concentration was 0.97 [10]. We also observed a strong correlation ($r^2 = 0.98$) between the two methods assessed herein, and found that fewer than 6% of the coulter counter – ABG differences were beyond the average value of -4.3 g/l and its lower and upper 95% CI limits of -11.0 and 2.4 g/l, respectively. Furthermore,

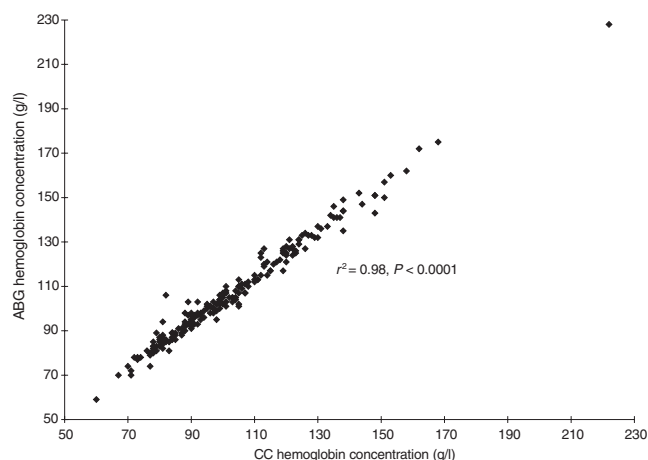
Table 1

Characteristics of 202 critically ill adults who underwent concomitant determinations of arterial blood gas and coulter counter hemoglobin concentrations

Characteristic	Measurement
Number (%) of males	132 (65.3)
Mean (SD) age (years)	64.1 (15.5)
Mean (SD) APACHE II score	20.0 (6.7)
Number (%) of patients admitted to the ICU according to specialty service	
Cardiac surgery	103 (51.0)
Neurosurgery	37 (18.3)
Vascular surgery	24 (11.9)
Trauma	12 (5.9)
Medicine	11 (5.4)
Other	15 (7.4)
Total	202 (100.0)
Mean (SD) length of stay in the ICU (days)	3.4 (4.6)
Number (%) of patients deceased at completion of data collection	28 (13.9)
Mean (SD) hemoglobin concentration shortly after admission to the ICU (g/l)	
Coulter counter	102.9 (22.7)
Arterial blood gas analyzer	107.2 (23.2)
Average of both methods	105.0 (22.9)

APACHE II, Acute Physiology and Chronic Health Evaluation II; ICU, intensive care unit; SD, standard deviation.

Figure 1

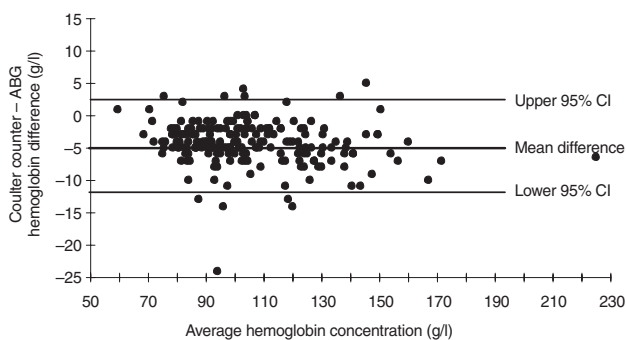


Hemoglobin concentration measured by coulter counter (CC) versus an arterial blood gas analyzer (ABG) among 202 critically ill adults.

only one of these 11 points surpassed the 95% confidence limits by more than 3 g/l.

It is reasonable to conclude that direct measurement of Hb concentration using an ABG analyzer may provide a valid

Figure 2



Average hemoglobin concentration versus the coulter counter – arterial blood gas (ABG) hemoglobin difference among 202 critically ill adults. CI, confidence interval.

alternative method to a traditional coulter counter. In only the rarest situation is a precise estimate of the Hb concentration necessary in caring for the critically ill patient [11]. Since the ABG analyzer appears to overestimate the 'true' Hb concentration by 4.3 g/l, on average, there remains a margin of safety that would neither place a patient in a state of unrecognized life-threatening anemia, nor lead to an unnecessary red cell transfusion. In a recently conducted, randomized clinical trial

of 357 critically ill patients with cardiovascular disease, those who were maintained at a Hb concentration between 70 and 90 g/l had no difference in 30-day or 60-day mortality rates compared with those patients whose Hb was maintained between 100 and 120 g/l [11]. Within facilities where the ABG analyzer is available, it is thus reasonable for each facility to assess the accuracy of its own ABG analyzer relative to its current laboratory method of Hb determination. By performing fewer complete blood counts there may be less iatrogenic blood loss, a faster therapeutic turnaround time and, perhaps, some cost savings [9].

Since we determined the ABG Hb concentration within a hospital core laboratory, our findings do not necessarily apply to the situation of true point of care testing; nonetheless, many ICUs have been equipped with their own ABG analyzers for several years [12]. Point of care testing may become the standard of practice [9], but there is a further need for research on its utility within the ICU [2]. If testing is not handled by the main hospital laboratory, both central computer data entry and quality control may be sacrificed. A large, simple, multicenter, prospective study might optimally address the safety and cost savings of ABG Hb analysis in the ICU. In the mean time, use of point of care tests in the ICU, such as the ABG Hb determination, should be not be viewed as a replacement for conventional laboratory services, but as a supplement [2].

Competing interests

None declared.

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