CLINICAL PRACTICE

Control of blood gas measurements in intensive-care units

DANIEL ROBERTS PATRICIA OSTRYZNIUK ELFRIEDE LOEWEN
AILSA SHANKS TRACY WASYLUK LORRAINE PRONGER
IAN HASINOFF EDWARD ROBERTS THOMAS A. J. MCEWEN

The frequency of blood gas measurement in two adult intensive-care units was assessed for 7 months before and 12 months after introduction of a protocol of indications for such investigation. Demographic, diagnostic, outcome, and intervention data were collected prospectively. There were no differences in demographic characteristics, severity or type of illness, survival, or frequency of arterial or pulmonary artery catheter use between the two observation periods, but the frequency of blood gas analysis fell by 44% ($p < 0.001$) after the protocol was introduced.

Lancet 1991; **337**: 1580–82.

Introduction

The frequency of blood gas measurements within intensive-care units may be driven by many factors other than clearly defined clinical indications. The decision to measure blood gases may be delegated by clinicians and may also be influenced by fear of litigation, ease of access to arterial blood because of widespread use of arterial lines,[1] routine work-patterns within the unit, and the tacit assumption that if patients are sufficiently unwell to require intensive care then they are "ill enough to require regular investigation whether they obviously need it or not".

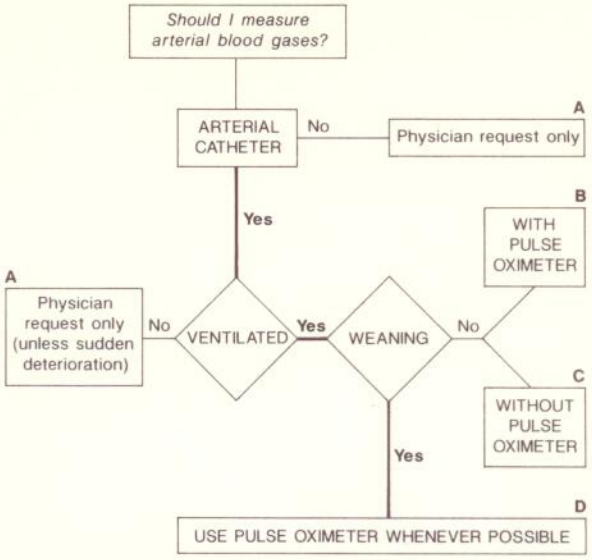
Measurements of blood gases are the most frequently used laboratory investigations in intensive-care units,[1-3] but there is surprisingly little information available about the appropriate indications for or optimum frequency of such tests.[1-4] Before this study, arterial and mixed-venous gases were measured routinely or as required in the adult medical and surgical intensive-care units at our hospital, without reference to any written protocol. We describe a prospective analysis of the effects of such a protocol, designed to give rational indications on which to base a decision to measure blood gases.

Methods

Before written guidelines were introduced, baseline data were collected for all patients admitted to the adult medical and surgical intensive-care units at the Health Sciences Centre between July 11, 1988, and Feb 15, 1989. We recorded total daily blood gas measurements (from July 1, 1988), ventilator-dependent patient days, demographic information (including age, sex, and up to 3 admission and 3 discharge diagnoses), daily therapeutic intervention scoring system (TISS) scores,[5] the highest APACHE II score[6] recorded in the first 24 h after admission to the unit, length of stay on the unit, and survival. All information was entered into a computer database (Critical Care Management Systems, Chelmsford, Ontario, Canada).

Independently of this baseline data collection, a multidisciplinary committee (comprised of two intensive-care clinicians, the head nurses of both intensive-care units, and two senior respiratory technicians) drew up a written protocol of indications for blood gas analysis. The committee first met in May, 1988, and to reduce bias its members were instructed not to reveal any discussions or decisions to other staff before the protocol was implemented. For further comparison the frequency of blood gas analysis and the total number of ventilator-dependent patient days were determined retrospectively for 1987, before any discussions had taken place.

ADDRESS: **Section of Critical Care, Department of Medicine, University of Manitoba, Health Sciences Centre, Winnipeg, Manitoba, Canada** (D. Roberts, FRCPC, P. Ostryzniuk, RN, E. Loewen, RT, A. Shanks, RN, T. Wasyluk, MSc, L. Pronger, RN, I. Hasinoff, FRCPC, E. Roberts, MSc, T. A. J. McEwen, MS). Correspondence to Dr D. E. Roberts, Room GH-723, Health Sciences Centre, 820 Sherbrook Street, Winnipeg, Manitoba R3A 1R9, Canada.



MEASURE MIXED VENOUS GASES 12-HOURLY, EXPIRED GASES DAILY, UNLESS OTHERWISE REQUESTED BY PHYSICIAN.

BYPASS PROTOCOL AND SUMMON PHYSICIAN IF SUDDEN CLINICAL DETERIORATION.

Fig 1—Protocol.

A: Request physician's advice if oximetry arterial saturation <85%; dyspnoea; respiratory rate >30/min; mean blood pressure ≤70 mm Hg; or hourly urine output ≤0·5 ml/kg.

B: 12-hourly blood gases if stable. No need for extra measurements on F_IO_2 change if oximetry oxygen saturation >85%.

C: 12-hourly blood gases if stable. Further measurement on F_IO_2 change ≥0·1.

D: Measure blood gases within 30 min of mode change or if respiratory rate >30/min, paradoxical breathing pattern, or haemodynamic changes.

The protocol is set out in fig 1. Appropriate use of pulse oximeters was encouraged.[7,8] For most patients the lowest acceptable limit for arterial oxygen saturation was set at 90% or higher if so determined by a physician; an arterial oxygen saturation of 85% was tolerated as a lower limit in chronically hypoxic patients with clinically acceptable oxygen delivery. Physicians and nurses were instructed to measure blood gases when clinically required, irrespective of the algorithm. End-tidal CO_2 was not routinely monitored because its reliability has been questioned[9] and there is little evidence to support use of continuous mixed venous oximetry.[10]

All intensive-care-unit staff were informed about the protocol immediately before its implementation on Feb 16, 1989. All staff nurses were asked to complete a detailed survey to evaluate their perceptions of the effects of the policy. Nurses were also asked to report and record all adverse effects in patients which might have arisen because of the new policy. Formal prospective assessment of the effects of the new protocol continued until Feb 15, 1990. At the end of the study all arterial blood gas measurements were reviewed for one month before and after the start of the new protocol to assess its effect on the frequency of grossly abnormal results.

The Wilcoxon rank-sum test was used to compare the frequency of blood gas determinations and the number of ventilator-dependent patient days before and after the protocol was introduced.

TABLE I—PATIENT DETAILS

—	Baseline (n=647)	Protocol (n=1236)
Age (yr)*	58·0 (8·0)	58·2 (8·0)
TISS5*	37·5 (12·1)	34·2 (12·9)
APACHE II6*	19·9 (4·9)	19·1 (4·8)
Stay (days)	4·0	4·1
Days with arterial line (%)	93·5	91·3
Days with PA catheter (%)	46·8	45·8
Survivors	549 *(84·9%)*	1051 *(85·0%)*

*Mean (SD). PA = pulmonary artery.

TABLE II—ICU ACTIVITY AND BLOOD GAS MEASUREMENTS

Period	Patient days	Ventilator-dependent days	All blood gas measurements	Daily blood gases per patient
1987 (12 mo)	4480	3379	44 659	9·97
Baseline (7 mo)	2583	1883	22 110	8·56
Protocol (12 mo)	5065	3656	24 109	4·76

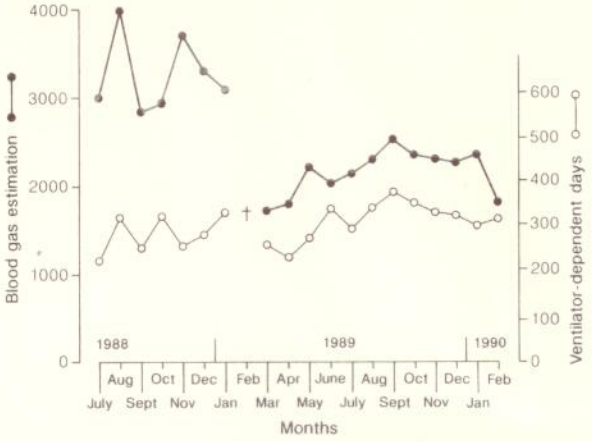


Fig 2—Differences in blood gas measurements (●——●) and ventilator-dependent days (○——○) between baseline and intervention periods.

Total blood gases $p<0·001$. Total ventilator days $p>0·05$ (Wilcoxon). †Data for Feb, 1989, not included because of mid-month introduction of protocol.

Results

647 consecutive patients were prospectively studied during the 7 months before and 1236 consecutive patients during the 12 months after introduction of the protocol. Both groups were similar with respect to age, sex, length of stay, TISS and APACHE II scores, and survival, as well as use of arterial and pulmonary artery catheters (table I). The distribution of the ten most common principal diagnoses was similar over the two periods (shown as before *vs* after introduction): after coronary artery bypass graft 13·4 *vs* 11·9%, pneumonia 6·5 *vs* 4·4%, after myocardial infarction 5·4 *vs* 6·2%, septic shock 4·9 *vs* 4·1%, after abdominal aortic aneurysm repair 4·9 *vs* 3·2%, multiple trauma 3·2 *vs* 4·9%, congestive heart failure 2·2 *vs* 2·7%, after aortofemoral/axillofemoral bypass graft 2·0 *vs* 2·4%, aortic or mitral stenosis 1·9 *vs* 0·2%, chronic airways obstruction 1·5 *vs* 2·3%, and others (each less than 2%) 53·9 *vs* 57·6%.

There was a striking 44% fall in the frequency of blood gas measurements after the protocol was introduced (table II) although the numbers of patient ventilator-dependent days were similar when the different lengths of baseline (7 months) and post-intervention observation are taken into account. Fig 2 shows more clearly the consistent effect of introduction of the protocol on monthly totals of blood gas samples ($p<0·001$) and ventilator-dependent patient days ($p>0·05$). Arterial blood gas results during August, 1988 (baseline), and August, 1989 (post policy), were reviewed to assess the number that indicated severe hypoxia (PO_2 <60 mm Hg on F_IO_2 ≤0·6 [60%]) or severe hypercapnia (PCO_2 >55 mm Hg). The proportions of such abnormal values were similar: 141/1617 (8·7%) baseline *vs* 91/926 (9·8%)

($p > 0{\cdot}1$), respectively. The nursing survey revealed no adverse event that might have resulted from a decreased frequency of blood gas sampling. Most respondents (40/41) were very satisfied with the policy and felt that it encouraged clinical decision-making consistent with their training and skills.

The total material and labour cost of a blood gas measurement in our unit was $3·73 (Canadian) on Sept 1, 1988. This sum includes 4 min nursing time, 5 min work for a respiratory technician, and syringe, swabs, and latex gloves, but does not include any allowance for maintenance of the blood gas analyser, capital equipment costs, or a physician's time for interpretation of the results, and is lower than other North American estimates.[3]

Discussion

Browning et al[4] have reported a 24% reduction in arterial blood gas sampling in a surgical intensive-care unit after introduction of an algorithm in which pulse oximetry was not used. Their observation periods were short and we cannot directly compare the study populations, but the effect of introduction of their policy, as measured by the percentage of inappropriate samples, was only partly sustained. We found that our policy was practical and sustainable, and its use in our adult intensive-care units led to a 44% fall in blood gas measurements. This reduced workload enabled redeployment of a full-time respiratory technician and an automated blood gas analyser, and an estimated recoverable annual saving of $81 000 (Canadian). We could not identify any other factor—including diagnosis, severity of illness, or length of patient stay—that could otherwise account for the observed fall in blood gas estimations. Although it is possible that the fall might reflect a general change in staff attitudes towards expenditure, rather than the introduction of a specific policy, such an effect should have led to a fall in all routine tests. However, the frequency of 123 other laboratory tests was also monitored and no significant difference was observed in 115 tests where no interventions were implemented (unpublished data).

Blood gas sampling frequency observed during the baseline period of this study was similar and actually slightly lower than that retrospectively calculated for 1987 (table II), and we feel it unlikely that this baseline frequency was unusually high. Muakkassa et al[1] reported a similarly high volume of arterial blood gas determinations in adult intensive-care patients, which they attributed largely to an almost invariable use of arterial catheters,[1] and a similar ease-of-use argument might also apply to pulmonary artery catheters. The proportion of our patients with such ready access to arterial and mixed-venous blood was similar in baseline and intervention periods (table I).

No algorithm, however straightforward, will always be adhered to. Ours had the advantage of simplicity, with few steps involved and few parameters to consider. Nevertheless, new members of staff may have taken a while to be familiar with the protocol, and pulse oximeters did not function in some patients with poor peripheral perfusion, so that more frequent blood gas measurements were required (this risk had been anticipated when the protocol was designed). In our unit pulse oximetry is readily available, but other units may find its availability limits application of this protocol.

We found no evidence of morbidity or mortality attributable to the policy and no incident of severe, unexpected hypoxia or hypercapnia was observed by the nurses or physicians. Analysis of the frequency and percentage of grossly abnormal arterial blood gas results showed no significant increase after the protocol was introduced, perhaps a reflection of more appropriate use of continuous arterial oxygen saturation monitoring.[8] The effect of the policy has been sustained over 12 months of observation, and it has been popular with nursing and clinical staff. Apart from the obvious cost savings there may also be a benefit from a reduced number of false-positive results and a reduced risk of introduction or spread of infection.[11,12]

This study was partly funded by grants from the Manitoba Health Services Commission and the Manitoba Medical Services Foundation.

REFERENCES

1. Muakkassa FF, Rutledge R, Fakhry SM, Meyer AA, Sheldon GF. ABGs and arterial lines: the relationship to unnecessarily drawn arterial blood gas samples. *J Trauma* 1990; **30:** 1087–95.
2. Raffin TA. Indications for arterial blood gas analysis. *Ann Intern Med* 1986; **105:** 390–98.
3. Martin TG, Elenbaas RM, Pingleton SH. Use of peak expiratory flow rates to eliminate unnecessary arterial blood gases in acute asthma. *Ann Emerg Med* 1982; **11:** 70–73.
4. Browning JA, Kaiser DL, Durbin CG. The effect of guidelines on the appropriate use of arterial blood gas analysis in the intensive care unit. *Respir Care* 1989; **34:** 269–76.
5. Cullen DJ, Civetta JM, Briggs BA, et al. Therapeutic intervention scoring system: a method for quantitative comparison of patient care. *Crit Care Med* 1974; **2:** 57–60.
6. Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. *Crit Care Med* 1985; **13:** 818–29.
7. Chapman KR, D'Urzo A, Rebuck AS. The accuracy and response characteristics of a simplified ear oximeter. *Chest* 1983; **83:** 860–64.
8. Mihm FG, Halperin BD. Noninvasive detection of profound arterial desaturations using a pulse oximetry device. *Anesthesiology* 1985; **63:** 85–87.
9. Hoffman RA, Krieger BP, Kramer MR, et al. End-tidal carbon dioxide in critically ill patients during changes in mechanical ventilation. *Am Rev Respir Dis* 1989; **140:** 1265–68.
10. Pearson KS, Gomez MN, Moyers JR, Carter JG, Tinker JH. A cost/benefit analysis of randomized invasive monitoring for patients undergoing cardiac surgery. *Anesth Analg* 1989; **69:** 336–41.
11. Thorson SH, Marini JJ, Pierson DJ, Hudson LD. Variability of arterial blood gas values in stable patients in the ICU. *Chest* 1983; **84:** 14–18.
12. Smoller BR, Kruskall MS. Phlebotomy for diagnostic laboratory tests in adults. Pattern of use and effect on transfusion requirements. *N Engl J Med* 1986; **314:** 1233–35.