The Effect of Arterial Blood Gas Values on Extubation Decisions

Adil Salam MD, Mihai Smina MD, Pritee Gada MD, Lisa Tilluckdharry MD, Anupama Upadya MD, Yaw Amoateng-Adjepong MD PhD, and Constantine A Manthous MD

BACKGROUND: No studies have examined the clinical utility of arterial blood gas (ABG) values during spontaneous breathing trials (SBTs) for making extubation decisions. Nonetheless many intensive care units measure ABGs during an SBT to determine, in conjunction with other data, whether the SBT was successful. OBJECTIVE: Determine how often ABG values change extubation decisions. METHODS: Each patient was assessed at the bedside by one of 3 critical care attending physicians. Each assessment was made at the end of the SBT in which ABGs were obtained with the expectation of extubation. When a nurse, respiratory therapist, or resident was available, he or she also simultaneously and independently evaluated the patient and then reassessed with the ABG values. Physiologic data were recorded before and during the SBT, as the attending physician performed the bedside assessment. RESULTS: Eighty-three patients were studied during 100 SBTs. Heart rate, respiratory rate, and mean blood pressure increased. Blood oxygen saturation (measured via pulse oximetry [F_{IO_2}]) and the P_{aO_2}/F_{IO_2} ratio decreased significantly during SBTs. Concordant clinical and ABG assessment (to attempt a trial of extubation) led to extubation in 86 patients, 76 of whom remained extubated after 72 hours. Following 14 of the SBTs, the patients were not extubated. Seven of these were judged by the attending physicians to fail both clinically and following review of ABG values. Seven were judged successful clinically, but the patients were not extubated because the attending physician thought the ABG values were unfavorable. Bedside nurses, who assessed 72 SBTs, had 1 case in which the ABG values changed their extubation opinion. Resident-trainees assessed 76 cases and had 5 changes of opinion based on ABG values. Respiratory therapists assessed 77 patients and had 4 such cases. The average changes in heart rate and blood pressure of patients not extubated were double those of extubated patients, but there were no significant differences in respiratory rate or P_{aO_2}/F_{IO_2} ratio between those groups. Ten patients (11.6%) were extubated based on the attending physician's decision but required re-intubation within 72 hours. CONCLUSION: These data suggest that ABG values did not change extubation decisions in 93% of cases. However, in 7 cases the ABG values changed the extubation decision. If even a few of those cases would have failed extubation without knowledge of the ABG values, the increased patient risk and cost associated with failed extubation would more than offset the relatively small cost of collecting ABG values from all patients who undergo SBT. *Key words: arterial blood gas, ABG, ventilator weaning, mechanical ventilation, spontaneous breathing tests, extubation.* [Respir Care 2003;48(11):1033–1037. © 2003 Daedalus Enterprises]

Introduction

The past decade has seen substantial advances in weaning patients from mechanical ventilation.[1] Most frequently the clinician uses a spontaneous breathing trial (SBT) to determine a patient's readiness for liberation from the ventilator. Then the patient is assessed for ability to breathe

Adil Salam MD, Mihai Smina MD, Pritee Gada MD, Lisa Tilluckdharry MD, Anupama Upadya MD, Yaw Amoateng-Adjepong MD PhD, and Constantine A Manthous MD are affiliated with the Pulmonary and Critical Care Medicine Section, Department of Internal Medicine, Bridgeport Hospital, Yale University School of Medicine, Bridgeport, Connecticut.

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Correspondence: Constantine A Manthous MD, Bridgeport Hospital, 267 Grant Street, Bridgeport CT 06610. E-mail: pcmant@bpthosp.org.

without an artificial airway (extubation). There is no agreement as to whether arterial blood gas (ABG) values improve bedside assessment in making extubation decisions. Nonetheless, many centers measure ABGs during SBTs and use ABG values in conjunction with clinical data to make extubation decisions. We hypothesized that ABG values do not significantly improve routine bedside assessment and that they would not frequently lead to changes in extubation decisions.

Methods

The investigations review board of our hospital approved the study protocol. Between September 2001 and August 2002, patients in our medical-cardiac intensive care unit (ICU) who received mechanical ventilation via endotracheal tube were assessed when they had completed an SBT. In our ICU, weaning is guided by a protocol that is carried out by bedside nurses, respiratory therapists (RTs), and resident-trainees, who are supervised by 5 board-certified intensivists. Patients who were hemodynamically stable and whose ratio of P_{aO_2} to fraction of inspired oxygen (P_{aO_2}/F_{IO_2}) was $>$ 120 mm Hg were generally assessed during 2–3 min of unassisted breathing through the endotracheal tube, with or without continuous positive airway pressure. Those with a rapid shallow breathing index (ie, respiratory frequency divided by tidal volume) $<$ 125 breaths/min/L usually undergo SBT with T-piece and continuous positive airway pressure or pressure support of $\leq$ 7 cm H_2O for 0.5–2 hours. The SBT is terminated if one or more of the following occurs: (1) the patient develops severe distress despite attempts of bedside personnel to attenuate the anxiety, (2) heart rate increases by $>$ 20 beats/min, (3) systolic blood pressure increases by $>$ 20 mm Hg, (4) respiratory rate is $>$ 35 breaths/min, (5) tidal volume decreases to $<$ 0.3 L, (6) sustained blood-oxygen desaturation (measured via pulse oximetry [S_{pO_2}]) to $<$ 90% while inspiring 50% oxygen.

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Patients who successfully complete an SBT are further assessed with an ABG measurement; if the result is favorable, the patient is considered for a trial of extubation. In our ICU some patients who successfully complete the SBT are not extubated if the clinician thinks the patient still requires an artificial airway. Patients who were extubated to comfort care or had a tracheostomy were excluded from this study.

The following data were gathered from each patient: age, sex, ICU admission Acute Physiologic and Chronic Health Evaluation (APACHE) II score, reason for intubation, number of days of ventilation, hemoglobin on the morning of the SBT, ABG values on full ventilatory support prior to and during the SBT, P_{aO_2}/F_{IO_2} ratio, heart rate, respiratory frequency, mean arterial pressure, and oxygen saturation as measured by oximetry (S_{pO_2}) while on the ventilator and during the SBT, at the time the attending physician performed the bedside assessment.

Each patient was assessed at the bedside by one of 3 critical care attending physicians. Each assessment was made at the end of the SBT in which ABGs were obtained with the expectation of extubation. When a nurse, respiratory therapist, or resident was available, he or she also simultaneously and independently evaluated the patient and then reassessed with the ABG values. The attending physician (and, if available, resident-trainee, bedside nurse, and/or RT) assessed the patient clinically prior to being told the ABG values, recorded whether he or she would extubate based on the clinical assessment, and then reassessed and rerecorded their decision after learning the ABG values. Clinician study participants included 3 attending physicians, 76 residents, 72 nurses, and 77 RTs.

Patients were extubated per the instructions of the attending physician. Those who remained extubated at 72 hours were classified as having a successful extubation even if subsequent reintubation was necessary during the same hospitalization. Extubation was classified as a failure only if reintubation was required within 72 hours.

Results were analyzed with spreadsheet software (Excel; Microsoft, Redmond, Washington; and EpiInfo 2002 public-domain software, available at http://www.cdc.gov/epiinfo/about.htm). The number of cases in which ABG values led clinicians to change the extubation decision were determined. The nonpaired Student's *t* test was used to compare physiologic variables of cases in which the decision was made not to extubate to those who were extubated. Differences were considered statistically significant when $p < 0.05$.

Results

Eighty-three patients were studied during 100 separate consecutive SBTs. Mean $\pm$ SD patient age was 65 $\pm$ 15 years (range 24–94 y). Fifty-six percent were male. The mean $\pm$ SD APACHE II score was 23 $\pm$ 8. The reasons for ICU admission and intubation included pneumonia (34), chronic obstructive pulmonary disease exacerbation (18), airway protection (16), congestive heart failure (11), sepsis (9), asthma (5), and cardiac arrest (2). The mean $\pm$ SD days intubated was 5.4 $\pm$ 4 days. Among patients who underwent more than 1 SBT, 4 were successfully extubated (ie, for $>$ 72 h) but required intubation later in their hospitalizations; these were counted as separate intubation/extubation episodes. Twelve patients who were not extubated based on the attending physician's evaluation

had repeat SBTs and were subsequently extubated. One patient underwent 3 SBTs before extubation.

During the SBTs, mean ± SD heart rate increased from 83.7 ± 13.3 beats/min to 93.3 ± 15.3 beats/min ($p < 0.001$), mean ± SD respiratory frequency increased from 14.8 ± 3.8 breaths/min to 23.8 ± 5.5 breaths/min ($p < 0.001$), and mean ± SD arterial blood pressure increased from 87.6 ± 15.0 mm Hg to 93.6 ± 17.7 mm Hg ($p < 0.001$). P_{aO_2}/F_{IO_2} decreased significantly, from 244 mm Hg to 224 mm Hg ($p = 0.02$). Tables 1 and 2 list physiologic and ABG data from the 76 patients who were successfully extubated and the 10 who failed extubation. Table 3 compares changes in physiologic and ABG data from patients who were extubated and those who were not.

Seven patients failed their initial SBT on the basis of the changes in their physiologic variables and their ABG values. Seven additional patients who passed the SBT clinically were not extubated by the attending physician on the basis of ABG values. Table 4 lists data from those 7 patients before and during the SBT. Patients with "unacceptable" ABGs were more likely to have a heart rate increase of > 20 beats/min (risk ratio 6.1, 95% confidence interval 1.5–25.1) and a respiratory frequency increase of > 15 breaths/min (risk ratio 5.1, 95% confidence interval 1.3–20.2), compared to patients who both passed the SBT and had acceptable ABG values. The 2 patient groups were no different in terms of age, APACHE II score, duration of mechanical ventilation, or changes in mean arterial pressure.

Of the 72 cases assessed by the bedside nurses, there was only one in which the ABG values changed the extubation decision. Resident-trainees, who assessed 76 cases, changed 5 decisions based on ABG values. RTs, who assessed 77 cases, changed 4 decisions. There was no pattern of interobserver agreement in cases in which the ABG changed extubation decisions.

Ten patients who were extubated required reintubation within 72 hours. Only two of those had heart rate increases of > 20 beats/min or respiratory rate increases of > 15 breaths/min during the SBT, and the rate of extubation failure was not greater among those who had such heart or respiratory rate increases than among those who did not.

Discussion

Failed extubations are not uncommon in most ICUs, the failure rate ranging from 2 to 20%.[2] Since failed extubation is associated with greater hospital morbidity and mortality and longer length of stay,[2,3] it is imperative to identify screening techniques that minimize the number of failed extubations. Irrespective of techniques used to choose patients,[1] the SBT is the first test of extubation readiness. The patient cannot be considered for extubation unless he or she remains objectively and subjectively comfortable during the SBT, which lasts 30–120 min. In many institutions ABG samples are drawn at the end of a clinically successful SBT, to confirm or refute the bedside clinical impression. To our knowledge no study has assessed how often ABG values change extubation decisions. In the present study ABG values appear to have altered the decision in about 1 out of every 13 (7 of 93) cases in which the patient would have been extubated if the clinicians had not known the ABG values. This led to a doubling of the

Table 1. Physiologic and Blood Gas Analysis Data*

Patient	Before Spontaneous Breathing Trial							During Spontaneous Breathing Trial						
	HR	MAP	RR	P_{aO_2}/F_{IO_2}	pH	P_{CO_2}	P_{O_2}	HR	MAP	RR	P_{aO_2}/F_{IO_2}	pH	P_{CO_2}	P_{O_2}
Weaning Unsuccessful ($n = 10$)														
1	85	78	12	274	7.46	36	137	87	95	13	202	7.44	39	101
2	80	90	9	162	7.50	34	81	84	70	32	240	7.42	44	96
3	74	83	11	376	7.53	40	113	70	85	22	253	7.52	43	76
4	73	74	12	220	7.45	39	110	80	76	28	172	7.45	39	86
5	93	102	24	260	7.48	47	104	93	103	24	174	7.42	55	87
6	93	73	16	167	7.35	49	67	94	76	18	215	7.41	46	86
7	60	111	14	151	7.51	54	91	78	109	22	185	7.39	58	74
8	78	72	13	192	7.42	42	77	80	71	26	200	7.43	39	80
9	73	88	16	242	7.46	37	93	70	96	20	235	7.51	32	104
10	61	84	14	395	7.49	40	395	76	96	26	214	7.30	69	107
Weaning Successful ($n = 76$)	84	88	14	242	7.43	40	105	93	93	23	226	7.41	43	95

*There were 76 (aggregate) successful extubations and 10 unsuccessful extubations.
HR = heart rate
MAP = mean arterial pressure
RR = respiratory rate
P_{aO_2}/F_{IO_2} = ratio of P_{aO_2} to fraction of inspired oxygen

Table 2. Changes in Physiologic Variables of Successfully and Unsuccessfully Extubated Patients

	Extubation Successful (n = 76)	Extubation Unsuccessful (n = 10)	p
Δ HR (beats/min)	9.5	4.2	0.06
Δ MAP (mm Hg)	5.2	2.2	0.7
Δ RR (breaths/min)	8.7	9	0.9
Δ P_{aO_2}/F_{IO_2}	−16.6	−35.5	0.51

Δ = change
HR = heart rate
MAP = mean arterial pressure
RR = respiratory rate
P_{aO_2}/F_{IO_2} = ratio of P_{aO_2} to fraction of inspired oxygen

Table 3. Changes in Physiologic Variables During Spontaneous Breathing Tests Among Patients Who Were Extubated Versus Those Who Were Not Extubated

	Extubated (n = 86)	Not Extubated (n = 14)	p
Δ HR (beats/min)	8.3	17.2	0.001
Δ MAP (mm Hg)	5.3	10.2	0.28
Δ RR (breaths/min)	8.6	11.1	0.15
Δ P_{aO_2}/F_{IO_2}	−20.7	−10.0	0.65

Δ = change
HR = heart rate
MAP = mean arterial pressure
RR = respiratory rate
P_{aO_2}/F_{IO_2} = ratio of P_{aO_2} to fraction of inspired oxygen

rate of delayed extubation after the initial SBT in this cohort.

Though it is clear that ABG values impacted the extubation decisions in this cohort, it is uncertain if the decisions were correct. Some readers might make different clinical decisions based on the ABG values in Table 4 (ie, might have extubated a patient who had otherwise passed the trial). A study to examine definitively whether ABG values correctly predict extubation outcomes would entail extubating all patients, irrespective of their ABG values, even if the pre-test likelihood of failure was very high. In our hospital the current practice includes consideration of the ABG values in decision-making; our clinicians would not have allowed otherwise. It is noteworthy, however, that patients with unfavorable ABG values were more likely to show significant heart rate and/or respiratory rate increases during SBTs. In particular, 3 patients (see Table 4, patients 5, 6, and 7) had increases that might have prompted some practitioners to stop the SBT before getting to the ABG. Unfortunately, increases in heart rate and respiratory rate by themselves were not predictive of extubation outcomes, as has been found previously.[4]

No study has examined the utility of ABG values for guiding SBT/extubation decision-making. One study examined the effects of weaning postoperative cardiac patients using oximetry/capnography versus periodic ABG analysis and found no difference in outcomes between groups.[4] Some published studies that were not specifically intended to determine the utility of ABG values have used ABGs to judge readiness[5,6] and others have not.[7,8] Accordingly, there does not appear to be consensus as to whether ABGs are routinely necessary for extubation readiness testing, and no national organization explicitly states a policy on this issue. Indeed, lack of explicit consensus guidelines has led to substantial heterogeneity of practice, and many use techniques that are not supported by an evidence-based medicine approach.[9]

There are 2 important limitations to the present study. First, we examined only SBTs that were being performed to test for extubation readiness. Some patients in our institution perform SBTs for "exercise," and ABG analysis is performed to assure that the patient is exchanging gases

Table 4. Physiologic and Blood Gas Analysis Data Before and During Spontaneous Breathing Tests Among Patients Who Were Not Extubated

Patient	Before Spontaneous Breathing Trial							During Spontaneous Breathing Trial						
	HR	MAP	RR	P_{aO_2}/F_{IO_2}	pH	P_{CO_2}	P_{O_2}	HR	MAP	RR	P_{aO_2}/F_{IO_2}	pH	P_{CO_2}	P_{O_2}
1	74	107	18	305	7.38	28	122	82	118	16	220	7.31	34	88
2	75	93	10	365	7.30	37	146	103	110	30	252	7.23	42	226
3	80	78	12	188	7.49	52	75	83	80	20	172	7.42	60	69
4	113	116	12	166	7.34	42	83	108	104	17	316	7.32	44	158
5	98	102	20	190	7.29	26	114	122	120	14	202	7.25	31	81
6	93	81	16	502	7.49	36	201	114	72	35	230	7.21	70	115
7	73	73	12	176	7.44	45	88	96	114	32	126	7.48	47	63

HR = heart rate
MAP = mean arterial pressure
RR = respiratory rate
P_{aO_2}/F_{IO_2} = ratio of P_{aO_2} to fraction of inspired oxygen

adequately. Second, this study was designed to determine whether ABG values change extubation decision-making. Since there is no way of knowing for sure whether the 7 patients who were not extubated because of unfavorable ABG values would have tolerated extubation, we cannot assert with certainty that the ABG analyses averted untoward outcomes. In fact, there is a cost of failing to extubate a patient who is ready for extubation, and the relative cost/effect on outcome of failed extubation versus failing to extubate a ready patient is not clear. Consequently, we suspect that some practitioners will use these data as grounds not to measure ABGs (since ABGs only affected 7 of 100 decisions and maybe some of those incorrectly). Others will assert that the cost of prolonged stay associated with even a few failed extubations that can be averted with ABG analysis offsets the relatively small cost of ABG analysis for all patients who undergo SBTs. Accordingly, our study does not address whether knowledge of ABG values affected outcomes; rather we demonstrate that ABGs infrequently affected physician behavior.

Conclusions

ABG values did not affect clinical decision-making in 93% of our cases. Allied health care personnel and physicians-in-training appear to be able in a majority of cases to predict the success or failure of an extubation trial without knowing the ABG values. Nonetheless, ABG values (at a cost of $5/test in our hospital) *may* be helpful in a sufficient number of cases as to be cost-beneficial overall.

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