# Indication-Based Guideline for Arterial Blood Gas Analysis after Cardiac Surgery

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***Objective:*** *To determine whether an indication-based guideline can decrease the use of arterial blood gas (ABG) tests in cardio-surgical patients.*
***Material and Method:*** *This before and after study was conducted in a university-based national tertiary referral hospital. Postoperative patient age more than 18 years who were admitted to the cardiac intensive care unit were included. Seventy patients were randomly selected during January 2013 to September 2013 and data were retrospectively collected and recorded as a control group (Group C). Another seventy patients were prospectively investigated during January 2015 to May 2015 and served as a guideline group (Group G). Whereas patients in Group C were subjected to ABG testing every four hours, Group G patients received ABG testing according to the protocol set forth in a newly developed indication-based guideline for arterial blood gas analysis.*
***Results:*** *There were no statistically significant differences in demographic and perioperative data between groups. The median number of ABG tests per patient was 8 (range 4 to 47) in Group C and 4 (range 2 to 15) in Group G ($p<0.01$). There were no significant differences between groups for postoperative course, morbidity, or mortality.*
***Conclusion:*** *The indication-based guideline for arterial blood gas analysis significantly reduced the number of ABG tests in postoperative cardiac ICU patients without adversely affecting patient outcomes. Accordingly and based on these findings, this ABG test guideline should be implemented in daily clinical practice.*

***Keywords:*** *Blood gas analysis, Intensive care unit, Cardiac surgery patient*

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Postoperative cardiac surgery patients can develop rapid and significant changes in cardiovascular, respiratory, and other major organ systems, requiring meticulous observation in the intensive care unit (ICU) particularly during the immediate postoperative period[1-3]. Monitoring of these patients includes observing clinical signs and symptoms, as well as ongoing evaluation of laboratory data. In 2007, Melanson et al reported that 25.7% of ABG tests in a large tertiary care hospital were ordered or performed without comprehensible indication[4].

In our institute, the previous protocol of ABG tests are upon arrival in the ICU, after ventilator setting adjustments, decreased oxygen saturation (pulse oximetry), and significant hemodynamic changes, such as hypertension, hypotension, arrhythmia including 4-hourly routinely even in patients with hemodynamic and respiratory stability. As a consequence of routine 4-hourly testing until discharge from the surgical cardiac ICU, an amount of 27,000 US dollars per year was spent particularly on arterial blood gas (ABG) testing alone in 2013. Moreover, excessive and unnecessary use of laboratory investigations can result in wasted patient care resources[5,6].

In 2007, Merlani et al[7] developed a guideline for ABG testing in non-cardiac surgical patients, which resulted in a significant decrease in ABG tests without any adverse impact on patient outcome. Based on our review of the literature, no published ABG testing guideline has been evaluated among postoperative

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cardiac surgery patients during their stay in the intensive care unit (ICU). The rationale of this study was to improve process efficiency by developing an indication-based guideline for arterial blood gas analysis. The objective of this study was to determine whether an indication-based guideline can decrease the number of arterial blood gas (ABG) tests in cardio-surgical patients without adversely affecting clinical outcome.

**Material and Method**

This study was approved by the Institutional Review Board (Si 723/2014). Written informed consent was obtained from all patients who participated in the prospectively evaluated guideline group (Group G). One hundred and forty patients aged more than 18 years and scheduled to have open heart surgery with cardiopulmonary bypass and postoperative ventilator support were included. Seventy patients were retrospectively collected during January 2013 to September 2013 and served as a control (Group C); another seventy patients were prospectively investigated with an indication base guideline during January 2015 to May 2015 and comprised as a guideline group (Group G).

In the control group, ABG test was performed every 4 hours until discharge from the ICU. ABG tests were performed in all patients after arrival at the ICU, after change of ventilator settings, and prior to extubation. For the retrospectively reviewed patients in Group C, ABG analysis was performed immediately after extubation and then every 4 hours for the duration of the patient's stay in the ICU. In the guideline group, ABG testing was performed once a day according to the guideline (Fig. 1), which was developed by cardiac surgeon, cardiac anesthesiologist and nurses from cardiovascular surgical intensive care unit.

***Data collection***

In all patients, frequency of ABG testing and outcome parameters (especially complication-related outcome parameters) were recorded. Outcome parameters included severe metabolic or respiratory acidosis/alkalosis, threatening cardiac arrhythmia (atrial fibrillation with rapid ventricular response, ventricular tachycardia), and re-intubation. The process of the study was continuously monitored and supervised by a cardiac surgeon and a cardiac anesthesiologist (SS).

***Statistical analysis***

For sample size calculation, routine ICU data was used. Accordingly, the average number of ABG tests during the first 3 days of ICU admission was 20. Assuming a 25% reduction in ABG tests with the initiation of the indication-based guideline, the required sample size was 70 patients in each group, with a type I error of 0.05 and a power of 90%.

Data were analyzed using PASW Statistics for Windows, 18.0 Chicago: SPSS, Inc. Quantitative data are compared using Student's t-test or Mann-Whitney U test and presented as mean $\pm$ standard deviation (SD) or median (minimum, maximum). Categorical data were compared using Chi-square test, Fisher's exact test, or Mann-Whitney U test and presented as number with percentage. A *p*-value less than 0.05 was considered to be statistically significant.

**Results**

One hundred and forty patients were enrolled and evaluated 70 retrospectively and 70 prospectively. No patients were excluded from both group during the course of the study. One patient in Group G was re-intubated due to cardiac arrest on postoperative day two, but return of spontaneous circulation thereafter without any sequelae.

There were no significant differences between groups for baseline characteristics and perioperative data (Table 1). For Group C and Group G, average durations for ICU stay were $1.8\pm1.4$ and $1.7\pm1.4$ days and average ventilator time was $14.0\pm12.0$ and $14.9\pm10.5$ hours, respectively.

The median of total number of ABG tests per patient was 8 (4, 47) and 4 (2, 15) in Group C and Group G, respectively The total number of ABG tests was 674 and 325 in Group C and Group G, respectively ($p<0.01$) (Table 2). One patient in Group G had reoperation for bleeding. As such, the number of ABG tests on arrival in the ICU was 71 in the guideline group.

Consistent with established protocol, ABG analysis was performed in both groups prior to extubation. In Group C, five patients were extubated by surgeons without ABG testing. Two patients had two ABG tests prior to extubation due to failure of first extubation attempt. As a result, the number of ABG tests before extubation in Group C was 67. In Group G, three patients were extubated in the ICU without ABG tests and two patients had two ABG tests prior to extubation.

As described in Table 2, additional arterial blood gas tests had to be performed in both groups after initial abnormal test results and subsequent treatment. Median cost of ABG testing per patient

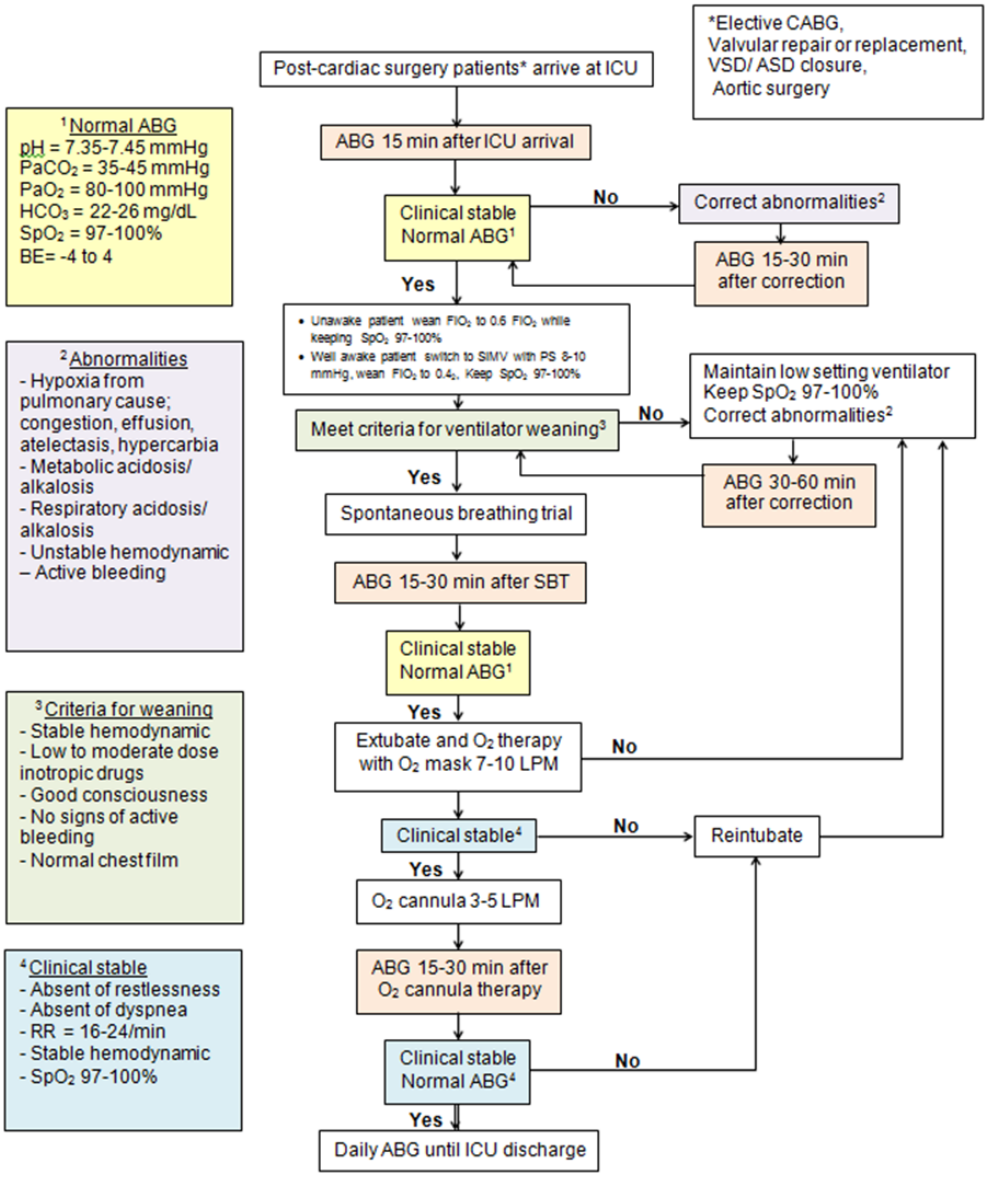


**Fig. 1** Flow chart for Arterial Blood Gas (ABG) requests for Post-cardiac surgery patients.

during ICU stay was 40 (range: 20 to 235) and 20 (range: 10 to 75) US$ in Group C and Group G, respectively.

## Discussion

Implementation of an indication-based ABG testing guideline resulted in a 50% reduction in number of ABG tests, with savings in both cost and manpower, as compared to the normal ABG protocol at our center. The new guideline had no adverse effect on patient outcomes and no respiratory complications or events were missed as a result of less ABG testing. Regarding event-triggered ABG tests, Group G and Group C had 20 and 36 ABG tests over the established testing protocol for each group (Table 2).

Inappropriate use of diagnostic investigations is a major concern for clinicians and hospitals[8-10]. In 1985, a restrictive lab test strategy was developed and proved that it could significantly reduce the frequency of redundant analyses[6]. ABG is an often performed test in the ICU. It has been proposed that ease of access to arterial blood via arterial catheter alone can lead to an increase in ABG testing in an ICU setting[11,12]. As a

**Table 1.** Patient baseline characteristics and perioperative data

| | Group C (n = 70) | Group G (n = 70) | *p*-value |
|---|---|---|---|
| Age (yr) | | | 0.39 |
| <60 | 28 (40.0) | 33 (47.1) | |
| ≥60 | 42 (60.0) | 37 (52.9) | |
| Gender: male | 34 (48.6) | 41 (58.6) | 0.24 |
| Type of operation | | | 0.46 |
| Coronary bypass graft surgery | 27 (38.6) | 29 (41.4) | |
| Coronary bypass graft surgery with valve repair | 8 (11.4) | 6 (8.6) | |
| Valve replacement/repair | 33 (47.1) | 29 (41.4) | |
| Closure of ASD with or without valve repair | 2 (2.9) | 6 (8.6) | |
| Perioperative periods | | | |
| Operation time (min) | 233.2±81.8 | 217.9±72.8 | 0.25 |
| Cardiopulmonary bypass time (min) | 114.6±49.7 | 110.5±46.2 | 0.61 |
| Aortic cross-clamping time (min) | 85.3±46.1 | 75.7±34.8 | 0.17 |
| Ventilator time (h) | 14.0±11.9 | 14.9±10.5 | 0.64 |
| Length of intensive care unit stay (d) | 1.8±1.4 | 1.7±1.4 | 0.63 |

Data presented as mean ± SD or n (%)
Group C = Control group; Group G = Guideline group; ASD = atrial septal defect

**Table 2.** Total number of arterial blood gas (ABG) analysis at each time point

| | Group C (n = 70) | Group G (n = 70) | *p*-value |
|---|---|---|---|
| Upon intensive care unit arrival | 70 | 71 | 0.32 |
| After change of ventilator setting | 189 | 64 | <0.01 |
| Prior to extubation | 67 | 70 | 0.41 |
| Post-extubation | 68 | 45 | <0.01 |
| Routine schedule (4-hourly vs. daily) | 244 | 55 | <0.01 |
| Metabolic acidosis | 18 | 10 | 0.68 |
| Hypoxia ($PaO_2$ <80 mmHg) | 9 | 4 | 0.44 |
| Hypercarbia ($PaCO_2$ >45 mmHg) | 9 | 6 | 0.13 |
| Total | 674 | 325 | <0.01 |

Data presented as number
Group C = Control group; Group G = Guideline group; $PaO_2$ = partial pressure of oxygen in arterial blood; $PaCO_2$ = partial pressure of carbon dioxide in arterial blood

consequence of continually increasing costs within healthcare systems, more restrictive guidelines and standardized operating procedures have been implemented[5,9,13-18]. Recommendations for appropriate ABG testing focus on patient condition, rather than following of scheduled routines. A guideline for routine laboratory and chest radiographic testing has been implemented in cardiac surgery patients that it could significantly reduce ABG tests without any impact on length of ICU stay, re-admission to ICU, hospital mortality, or ventilator days[17]. In 1997, Pilon et al[19] reported the effect of implementing a guideline for ABG measurements in surgical patients in the ICU. They measured the number and indication of each test two periods retrospectively, two years and one year prior to the introduction of the guideline and up to 13 months after guideline implementation. Similar to this study, they found no impact on patient outcomes, including ventilation time; however, the number of ABG tests decreased by up to 50%. The reported savings of $19.18 per patient was similar to the $20.40 per patient per day savings that found in the present study. The overall findings and conclusions from this study are consistent with those of other similar studies, all of which suggest departing from conventional ICU ABG testing protocols and transitioning to indication-based ABG

testing guidelines.

**Limitations**

The relevance and validity of our findings could be questioned or affected by the retrospective-prospective design of our study. Our control cohort was evaluated retrospectively and our guideline group was evaluated prospectively. Given the dynamism that is associated with change and improvement in the ICU setting, the differences in evaluation time periods must be acknowledged as a potential study limitation.

**Conclusion**

The indication-based guideline for arterial blood gas analysis significantly reduced the number of ABG tests in postoperative cardiac ICU patients without adversely affecting patient outcomes. Accordingly and based on these findings, this ABG test guideline should be implemented in daily clinical practice.

**What is already known in this topic?**

Health care resources are limited. An efficacy guideline for ABG testing in non-cardiac surgical patients has been proposed.

**What this study adds?**

Our indication-based guideline for arterial blood gas analysis is safe and sound for cardiac surgical patient.

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**Trial registration**

Clinicaltrials.gov; NCT 02516943.

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**Potential conflicts of interest**

None.

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## *แนวทางการการวิเคราะห์ก๊าซในเลือดแดงผู้ป่วยในหออภิบาลผู้ป่วยหลังผ่าตัดหัวใจมีผลลดค่าใช้จ่ายโดยผู้ป่วยปลอดภัย*

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***วัตถุประสงค์:*** *เพื่อศึกษาว่าแนวทางการดูแลผู้ป่วยในหออภิบาลผู้ป่วยหลังผ่าตัดหัวใจว่าสามารถลดจำนวนครั้งของการวิเคราะห์ก๊าซในเลือดแดงได้โดยไม่เกิดภาวะแทรกซ้อนแก่ผู้ป่วย*

***วัสดุและวิธีการ:*** *เป็นการศึกษาเปรียบเทียบก่อนและหลังการใช้แนวทางการดูแลผู้ป่วยในโรงพยาบาลของคณะแพทยศาสตร์ เมื่อคณะกรรมการวิจัยในคนของโรงพยาบาลยินยอมให้ทำการศึกษา ผู้วิจัยได้จึงรวบรวมข้อมูลของผู้ป่วยที่มีอายุมากกว่า 18 ปีที่เข้ารับการรักษาตัวในหออภิบาลผู้ป่วยหลังผ่าตัดหัวใจ การวิจัยได้สุ่มผู้ป่วย 70 ราย เข้ารับการรักษาระหว่างเดือนมกราคม ถึง เดือนกันยายน พ.ศ. 2556 โดยรวบรวมข้อมูลย้อนหลัง (กลุ่มควบคุม) และผู้ป่วยอีก 70 รายเข้ารับการรักษาระหว่างเดือนมกราคม ถึง เดือนพฤษภาคม พ.ศ. 2558 โดยรวบรวมไปข้างหน้า (กลุ่มศึกษา) ผู้ป่วยกลุ่มควบคุมได้รับการวิเคราะห์ก๊าซในเลือดแดงทุก 4 ชั่วโมง และผู้ป่วยกลุ่มศึกษาได้รับการวิเคราะห์ก๊าซ ในเลือดแดงตามแนวทางการดูแลผู้ป่วยที่จัดทำขึ้นใหม่ บันทึกข้อมูลทั่วไป ข้อมูลการผ่าตัด ข้อมูลหลังการผ่าตัด และจำนวนครั้งของการวิเคราะห์ก๊าซในเลือดแดง*

***ผลการศึกษา:*** *ข้อมูลทั่วไป ข้อมูลการผ่าตัด และ ข้อมูลหลังการผ่าตัดของผู้ป่วยทั้งสองกลุ่มไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ ค่ามัธยฐานของจำนวนครั้งของการวิเคราะห์ก๊าซในเลือดแดงของกลุ่มควบคุม และกลุ่มศึกษาเท่ากับ 8 (พิสัย 4-47) และ 4 (พิสัย 2-15) ตามลำดับ ($p<0.01$) ไม่พบความแตกต่างกันอย่างมีนัยสำคัญทางสถิติของการรักษาหลังผ่าตัด รวมทั้งไม่มีอัตราการเกิดภาวะแทรกซ้อน หรืออัตราตาย*

***สรุป:*** *การวิเคราะห์ก๊าซในเลือดแดงตามแนวทางการดูแลผู้ป่วยในหออภิบาลผู้ป่วยหลังผ่าตัดหัวใจของการศึกษาครั้งนี้สามารถลดจำนวนครั้งของการวิเคราะห์ก๊าซในเลือดแดงโดยไม่เกิดภาวะแทรกซ้อน ดังนั้นจึงแนะนำให้ใช้แนวทาง การดูแลผู้ป่วยนี้ในเวชปฏิบัติได้*