Use of a Pulse Oximeter in an Adult Emergency Department*  
Impact on the Number of Arterial Blood Gas Analyses Ordered

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**Study objectives:** To assess the impact of pulse oximetry (SpO₂) on the indications and the number of arterial blood gas (ABG) levels ordered in an adult emergency department (ED).

**Design:** A prospective study during a 2-month period in 1993 with a pulse oximeter available and a comparison with the same period in 1992 without the oximeter.

**Setting:** An adult medical ED of a university hospital in France.

**Patients:** All patients who underwent ABG or SpO₂ measurements.

**Interventions:** During the prospective study, residents ordered ABG or SpO₂ measurements at their discretion. The reasons for their ordering were reviewed by two independent experts who determined whether their choice was justified. The data were compared with those for 184 consecutive patients who had ABG measurements in 1992.

**Measurements and results:** The study included 152 patients. SpO₂ alone was used in 33 patients; ABG levels were measured in 119 patients. The use of SpO₂ did not result in the ordering of fewer useful ABG determinations. One hundred and five (88%) ABG measurements were justified. There were fewer unjustified ABG determinations in 1993 when the pulse oximeter was available than in 1992 when it was not (14 of 119 vs 54 of 184; p<0.001) mainly because fewer ABG determinations were ordered for miscellaneous nonrespiratory indications (13 of 119 vs 43 of 184; p<0.01).

**Conclusion:** The availability of a pulse oximeter did not affect the ordering of useful ABG measurements but allowed a significant reduction of unjustified ABG measurements. Substantial cost savings could be achieved by using SpO₂ in an ED. *(CHEST 1998; 113:1042-47)*

**Key words:** adult emergency department; arterial blood gas; pulse oximetry

**Abbreviations:** ABG=arterial blood gas; ED=emergency department; SaO₂=arterial oxygen saturation; SpO₂=pulse oximetry

Pulse oximetry (SpO₂), a noninvasive method of measuring arterial oxygenation, is easy to use and provides immediate results plus continuous assessment. In addition, it can be used at sites outside the hospital. Pulse oximeters are now commonly used in surgical and intensive care settings, but there are fewer data available on its use and safety in an adult emergency department (ED). SpO₂ also may reduce the cost of patient charge by reducing the demand for arterial blood gas (ABG) analysis. The economic advantage of using SpO₂ in the ED can be realized only if the reduction of the number of ABG measurements is due to fewer useless orders for them without losing any useful ABG measurements. A previous study by Kellerman et al suggested a reduction of the number of ABG determinations ordered but did not provide any information as to a possible decrease in the number of useful ABG measurements. These results are therefore difficult to interpret. This prospective study assesses the impact of SpO₂ on the indications and on the number of ABG measurements ordered in an adult ED.

**Materials and Methods**

**Clinical Data**

This study was conducted in the adult medical ED of Hôpital Louis Mourier at Colombes, France, a 450-bed university hospi-
tal staffed by residents and faculty of the Faculté Xavier Bichat, Paris, France. All the patients presenting at the adult ED are managed by residents with a senior grade clinician in charge. The study consisted of two parts: a prospective study followed by a retrospective analysis. The prospective study was conducted between February 15 and March 25, 1993, during which period a pulse oximeter (Criticare 504 P; Criticare Systems, Inc; Waukesha, Wis) was available to residents in the ED. All the patients who presented at the ED were eligible to take part in the prospective study. Residents ordered SpO₂ alone, ABG, or SpO₂ plus ABG measurements on their own initiative and without being given any guidelines. ABGs were sampled by nurses and promptly analyzed using an oximeter (ABL 520 CO-Oximeter; Radiometer; Copenhagen, Denmark). SpO₂ measurement was taken by residents or nurses by placing the pulse oximeter probe on the finger. Whatever they ordered, residents were required to record the reason for their request and for the selection, and whether they would have ordered ABG measurements if the SpO₂ was not available. These data were reviewed by two independent intensive care and emergency physicians, who were unaware of the value of SpO₂ or of ABG levels. They determined whether the choice of test was justified or unjustified. Unjustified meant that either no test at all should have been performed (in such a case, the test was referred to as useless) or the wrong test was performed (ie, SpO₂ in place of ABG, or the inverse); in such a case, the test was referred to as inappropriate. The experts considered ordering ABG tests to be justified when assessment of alveolar ventilation or acid-base status was necessary in addition to arterial oxygenation, whatever the disorder. They considered SpO₂ to be justified when assessment of arterial oxygenation only was needed. This study deliberately chose not to edict strict criteria for deciding whether or not the resident’s decisions were appropriate since the purpose was to assess whether routine clinical practice was affected by the introduction of a noninvasive tool. The study preferred to rely on simple clinical judgment of the cases. For instance, asthmatic and COPD patients who presented with very mild respiratory impairment simply required an SpO₂ determination, whereas all others required an ABG determination in order to assess alveolar ventilation. The outcome for the patients (hospitalized or nonhospitalized) also was recorded.

The impact of SpO₂ on ABG measurement ordering was assessed by comparing these data with those for all patients who underwent ABG measurements during the same period in the preceding year, 1992. The data from this retrospective study were reviewed by the experts in the same way.

### Table 1—Indications for SpO₂ and ABG Orderings When Pulse Oximetry Was Available

<table>
<thead>
<tr>
<th>Indications</th>
<th>No.</th>
<th>%</th>
<th>SpO₂ Measurements</th>
<th>No.</th>
<th>%</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic respiratory disease</td>
<td>1</td>
<td>3</td>
<td>14</td>
<td>12</td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>8</td>
<td>24</td>
<td>25</td>
<td>21</td>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td>Suspected pulmonary embolism</td>
<td>1</td>
<td>3</td>
<td>12</td>
<td>10</td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>Asthma</td>
<td>3</td>
<td>10</td>
<td>21</td>
<td>18</td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0.06</td>
</tr>
<tr>
<td>Miscellaneous respiratory disorders</td>
<td>8</td>
<td>24</td>
<td>7</td>
<td>6</td>
<td></td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Left ventricular failure</td>
<td>2</td>
<td>6</td>
<td>15</td>
<td>12</td>
<td></td>
<td>0.3</td>
</tr>
<tr>
<td>Altered consciousness</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td></td>
<td>0.9</td>
</tr>
<tr>
<td>Drug overdose</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Metabolic disorders</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>6</td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>Miscellaneous nonrespiratory disorders</td>
<td>8</td>
<td>24</td>
<td>13</td>
<td>11</td>
<td></td>
<td>&lt;0.05</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>33</strong></td>
<td><strong>100</strong></td>
<td><strong>119</strong></td>
<td><strong>100</strong></td>
<td></td>
<td></td>
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</table>

### Statistical Analysis

Results are expressed as means±SDs or as numbers of patients. Patient groups were compared using an unpaired Student’s t test for continuous variables and the χ² test for categorical variables. A p≤0.05 was considered to be significant.

### RESULTS

A total of 152 patients (70 men and 82 women) aged 59±23 years were included among those who made 1,521 visits to the ED during the prospective study period in 1993. SpO₂ alone was used for 33 patients (SpO₂ group), while ABG levels were measured in 119 patients (ABG group). Thirty-five of the latter 119 patients had both SpO₂ and ABG levels measured. The age and the gender of the two groups were comparable. The indications for SpO₂ or ABG measurement are showed in Table 1. The main reasons for performing SpO₂ alone were pneumonia, miscellaneous respiratory disorders, usually unexplained dyspnea, or miscellaneous nonrespiratory disorders which included thoracic pain. SpO₂ measurement alone was chosen because the patient’s status was considered to be nonsevere in 79% of cases. The result of this measurement led to oxygen administration for 7 (21%) patients; none required mechanical ventilation. Review of the SpO₂ indications showed that only 1 of the 33 patients would have required ABG measurement for left ventricular failure for immediate care, but this had no deleterious consequence for the patient. Most of the SpO₂ measurements (25 of 33 [76%]) were justified, whereas 7 of 33 (21%) were useless. The residents indicated that they would have ordered ABG determinations for 19 of the 33 (58%) patients had the pulse oximeter not been available. Three (16%) of these potential ABG measurement orders would have been useless in the opinion of the experts.
ABG measurements were ordered mainly when knowledge of PaCO₂ and pH values appeared to be useful, eg, in chronic respiratory diseases, asthma, or severe respiratory or hemodynamic disorders. Patients with miscellaneous respiratory and nonrespiratory disorders had SpO₂ performed more frequently than ABG determinations (Table 1). SpO₂ was used in conjunction with ABG measurement to evaluate immediately the severity of hypoxemia and to monitor it. Ordering an ABG was considered justified after review for 105 of 119 (88%) patients. Five (4%) patients did not require any measurement and SpO₂ alone would have been sufficient in 9 (8%) patients. Table 2 summarizes the opinions of the experts as to the pertinence of the SpO₂ and ABG measurement.

The outcomes for patients who underwent SpO₂ and ABG measurement were not significantly different. Most of them were not hospitalized (12 of 33 vs 35 of 119), while the others were hospitalized in a medical department (18 of 33 vs 75 of 119) or in the ICU (3 of 33 vs 9 of 119).

The retrospective study for the same period in 1992, when SpO₂ was not available, included 184 patients who underwent ABG determinations from 1,408 visits to the ED. The age (57±23 years) and gender (103 men and 81 women) were similar to those in 1993. Fewer ABG measurements were performed in 1993, when the pulse oximeter was available, than in 1992 (119 of 1,521 vs 184 of 1,408; p<0.001). This accounted for a 35% reduction. This difference persisted when the comparison was performed according to an “intention to order ABG” (ABG measurements actually performed+ABG determinations that would have been ordered by the residents in the absence of the pulse oximeter in 1993). In this condition, 138 of 1,521 ABG measurements would have been performed in 1993 and 184 of 1,408 in 1992 (p<0.001). This would have resulted in a 25% reduction. This difference will be discussed later.

The ABG measurements ordered in 1992 and 1993 are shown in Table 3. There were significantly fewer ABG determinations ordered for miscellaneous nonrespiratory disorders in 1993 than in 1992 when the pulse oximeter was not available (13 of 119 vs 43 of 184; p<0.01). Only 12% of the ABG measurements performed in 1993 (14 of 119) were considered by the experts as unjustified; this may be compared with 29% (54 of 184) of the ABG determinations performed in 1992 (p<0.001). This reduction of unjustified ABG measurements mainly was due to the decrease of useless ABG determinations performed for miscellaneous nonrespiratory disorders; this accounted for 23% (3 of 13) in 1993 and 67% (29 of 43) in 1992 (p<0.01 [Figure 1]).

**DISCUSSION**

The main finding of this prospective study is that the availability of SpO₂ reduces the number of ABG measurements ordered without any detriment to the patient. The economic consequences are important.

The latest pulse oximeters use spectrophotometry plus plethysmography to display arterial oxygen saturation (SaO₂) by measuring differences in the absorption of light in two different wavelengths in a pulsatile blood flow. Because of the two wavelengths used, differentiation can be made only between oxyhemoglobin and deoxyhemoglobin; thus, the presence of other unmeasured hemoglobin species (eg, carboxyhemoglobin and methemoglobin) will affect the accuracy of the SpO₂ value. Because they require a pulsating signal, they are usually not useful when the blood flow is very poor. SpO₂ is well correlated to SaO₂ when it is >70%.1,9 Most pulse oximeters appear to become inaccurate in conditions of profound hypoxemia (SaO₂ of 40 to 70%), with SpO₂ overestimating SaO₂. Pulse oximetry has limited ability to predict PaO₂ when SpO₂>90%, because of the shape of the oxyhemoglobin saturation curve. Because the SaO₂ curve is affected by pH and temperature, the results of SpO₂ could mislead the physician into predicting PaO₂ in cases of acid-base disorders or abnormal body temperature.

Despite these limitations, SpO₂ generally provides a good assessment of arterial oxygenation. It is now commonly used in many ICUs and during anesthesia for continuously monitoring oxygenation and detect-

<table>
<thead>
<tr>
<th>Table 2—Decisions of Experts in Regard to SpO₂ or ABG Measurement</th>
</tr>
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<tr>
<td></td>
</tr>
<tr>
<td><strong>SpO₂</strong> <em>(n=33)</em></td>
</tr>
<tr>
<td>Justified No. %</td>
</tr>
<tr>
<td>25 76</td>
</tr>
<tr>
<td>Useless No. %</td>
</tr>
<tr>
<td>7 21</td>
</tr>
<tr>
<td>Inappropriate No. %</td>
</tr>
<tr>
<td>1 3</td>
</tr>
</tbody>
</table>

Clinical Investigations
ing an arterial desaturation before clinical signs appear.\textsuperscript{1-4} It also has been used in the prehospital setting\textsuperscript{11,12} and in EDs.\textsuperscript{5,6} Nevertheless, few data are available on the indications for measuring SpO\textsubscript{2} in the ED. In some studies, SpO\textsubscript{2} was used for the prompt recognition and treatment of hypoxia\textsuperscript{6} or for continuous monitoring of patients with respiratory distress.\textsuperscript{5} In the pediatric ED, SpO\textsubscript{2} has been used instead of measurement of the ABGs as an indicator of illness severity,\textsuperscript{13} especially during acute exacerbations of asthma.\textsuperscript{14-16} The main advantage of the pulse oximeter is that it prevents the ordering of useless ABG determinations, and this could lead to substantial savings in the cost of patient care. This has been studied in ICUs\textsuperscript{3,17,18} but in only one study was the investigation conducted in the ED setting, as far as is known.\textsuperscript{7} This study\textsuperscript{7} reported a decrease in the number of ABG measurements ordered but gave little information about the reasons for ordering ABG determinations and did not specify the indications for SpO\textsubscript{2} measurement. Thus, it is difficult to assess accurately whether the availability of SpO\textsubscript{2} reduced the number of useless ABG determinations. It also is impossible to determine whether some potentially useful ABG measurements were missed. In such a case, any beneficial economic impact would be outweighed by the deleterious consequences of not performing useful ABG determinations.

The present study describes the use of a pulse oximeter in an adult ED, by comparing the indications for ordering SpO\textsubscript{2} or ABG determinations, and evaluates whether the availability of SpO\textsubscript{2} reduced the number of useless ABG measurements performed without affecting the ordering of useful ABG measurements. No specific guidelines for using SpO\textsubscript{2} were given to the residents at any time during the study period. They were simply told that they could measure SpO\textsubscript{2} or take an ABG sample at their discretion; furthermore, the residents were instructed on how to fill out the form for each patient. This form was very simple, and none of the tests was performed without a form. The reasons for choosing one test rather than the other were straightforward. Measurement of SpO\textsubscript{2} alone mainly was indicated when the patient’s clinical status was considered not to be severe and when an arterial oxygenation assessment was sufficient, whatever the clinical diagnosis. In contrast, ABG determinations were performed when the residents thought it was necessary to assess alveolar ventilation and acid-base status. Based on the estimated severity of the patient’s condition by the residents, ABG or SpO\textsubscript{2} measurements were performed without difference in patients with chronic respiratory diseases, acute left ventricular failure (especially in elderly patients), and metabolic disorders. On the other hand, patients with miscellaneous respiratory disorders (mainly dyspnea of unknown origin) and nonrespiratory disorders had SpO\textsubscript{2} alone performed significantly more frequently than they had ABG measurements. These two indications accounted for nearly 50% of all of the measurements using SpO\textsubscript{2} alone. We found that, despite not having any guideline, the residents used the same reasoning as the experts for deciding on whether to order SpO\textsubscript{2} alone or ABG measurements. It is, thus, not surprising that the experts considered more than 75% of all SpO\textsubscript{2} measurements and 88% of ABG determinations justified. Explicit guidelines would probably further reduce ABG ordering. However, the very aim of this study was to assess only whether the simple introduction of the oximeter allowed a reduction of ABG measurement ordering even in the absence of any guideline for use. There was no difference in the outcomes of patients who underwent SpO\textsubscript{2} and ABG measurement. If the

\begin{table}
\centering
\begin{tabular}{|l|c|c||c|c|c|}
\hline
\textbf{Indications} & \textbf{1902} & \textbf{1903} & \textbf{p Value} \\
\hline
Chronic respiratory disease & 15 & 8 & 14 & 12 & 0.3 \\
Pneumonia & 29 & 16 & 25 & 21 & 0.2 \\
Suspected pulmonary embolism & 13 & 7 & 12 & 10 & 0.3 \\
Asthma & 21 & 12 & 21 & 18 & 0.1 \\
Pneumothorax & 5 & 3 & 0 & 0 & 0.1 \\
Miscellaneous respiratory disorders & 12 & 6 & 7 & 6 & 0.8 \\
Left ventricular failure & 22 & 12 & 15 & 12 & 0.9 \\
Altered consciousness & 6 & 3 & 3 & 2 & 0.7 \\
Drug overdose & 2 & 1 & 2 & 2 & 0.7 \\
Shock & 3 & 2 & 0 & 0 & 0.2 \\
Metabolic disorders & 13 & 7 & 7 & 6 & 0.7 \\
Miscellaneous nonrespiratory disorders & 43 & 23 & 13 & 11 & <0.01 \\
\hline
Total & 184 & 100 & 119 & 100 & \\
\hline
\end{tabular}
\caption{Comparison of Indications for ABGs Before (1992) and After (1993) Introduction of Pulse Oximeter in ED}
\end{table}
patient outcome is an indicator of the severity of the underlying illness, it appears that SpO₂ was not reserved for the less severely ill patients but really for situations in which assessing arterial oxygenation was sufficient. Useless SpO₂ measurements had no consequence for the patient and could not be considered as unacceptable additional tests. The introduction of a pulse oximeter into the ED in this investigation did not lead to significant deleterious events, since only one patient with severe left ventricular failure did not have a useful ABG measurement and that was without immediate clinical consequence. In contrast, more than half of the patients who had only SpO₂ would have undergone ABG measurements in the absence of a pulse oximeter, and some of these ABG determinations would have been useless. The results of SpO₂ allowed oxygen therapy to be started in many patients without the need for an ABG measurement.

The impact of the introduction of SpO₂ on the ABG determinations ordered also was assessed using an approach different from simple filling out of forms. The previously mentioned results were compared with those for patients who underwent ABG measurements during the same period of the previous year. This was different from a previous study, which compared two consecutive 2-month periods, one without and the other with SpO₂. The populations in the same part of the year should be more comparable than those of two consecutive periods; when two consecutive periods are used, the disorders could change with the climatic changes. The characteristics of the patients and indications for ABG measurements in 1992 and 1993 were comparable. In addition, the residents present during the two study periods had no prior opinions about the usefulness of SpO₂; this was in contrast to the residents in consecutive studies. The introduction of the pulse oximeter reduced the number of ABG determinations performed and changed the orders for ABG measurements. The reduction in ABG orders in 1993, compared with the same time period in 1992, was due to a significant decrease in the indications for miscellaneous nonrespiratory disorders. But SpO₂ could not be the only reason for this result because of fewer notations of “intention to order ABG” (ABG measurements performed+ABG measurements which would have been performed in the absence of a pulse oximeter) in 1993 than in 1992. The effects of the form that the residents had to fill in and of the change in residents between the two study periods might not be negligible. Nevertheless, according to the experts’ evaluation, the introduction of SpO₂ resulted in a significant reduction of unjustified ABG measurements, in particular those ordered for miscellaneous nonrespiratory disorders, which dropped from 67% in 1992 to 23% in 1993. Kellerman et al found that the introduction of a pulse oximeter into an ED decreased ABG orders by 37%, mainly due to fewer ABG determinations ordered to assess oxygenation. They did not describe the clinical indications for ABG measurements in detail. They found a significant reduction in unjustified ABG measurements, as in this study, but also described a similar decrease in the number of justified ABG determinations. This differs from the finding of an increase in justified ABG determinations (from 71% to 88%) in this study when the pulse oximeter was available. It is difficult to compare the two studies because different criteria were used to justify ABG measurements. Other studies have fo-
cused on the effect of SpO2 on the number of ABG determination orders outside the ED. The use of SpO2 reduced ABG measurement orders by 10.3% to 46.3%. This decrease in the number of ABG determinations performed could provide substantial cost savings. Indeed, ABG analysis costs about $17 (US currency) at our institution. In this study, ABG measurement savings were represented by the number of ABG determinations that would have been performed if there were no pulse oximeter. That means 19 ABG measurements would have been performed during the 2-month period, thus saving $323 (US currency). Thus, the pulse oximeter should decrease patient costs in the ED by $1,938 (US currency) a year, assuming a constant rate of cost of ABG measurements throughout the year. As the price of a similar pulse oximeter is $2,500 (US currency), its cost would be covered in less than 18 months of use. However, this study was a before-and-after study and its results should be confirmed by a randomized trial.

In conclusion, the availability of a pulse oximeter in an adult ED did not affect the ordering of useful ABG measurements, but it did result in a significant reduction in the number of unjustified ABG determinations, mainly because of fewer ABG measurements ordered for miscellaneous nonrespiratory indications. SpO2 should provide substantial savings in patient care costs in the ED.

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REFERENCES
1 Milm F, Halperin B. Noninvasive detection of profound arterial desaturations using a pulse oximetry device. Anesthesiology 1985; 62:85-87
3 Bierman MI, Stein KL, Snyder JV. Pulse oximetry in the postoperative care of cardiac surgical patients: a randomized controlled trial. Chest 1992; 102:1367-70