Arterial oxygen partial pressure and cardiovascular surgery in elderly patients

Bruno Chenuel*, Mathias Poussel, Phi-Linh Nguyen Thi, Jean-Pierre Villemot, Philippe Haouzia

Abstract

Arterial blood gas assessment is still routinely performed in candidates for a cardiovascular surgery. Whether sampling arterial blood is useful in an elderly patient with a near normal lung function and who meets all other criteria for operability, is unknown. Therefore, it was our purpose to provide reference values for arterial blood gases in these patients and to examine how the level of arterial oxygen partial pressure (PaO₂) might influence postoperative outcome. We retrospectively studied arterial blood gases in 201 patients, aged 70–92 years with normal or near normal ventilatory function awaiting a planned cardiovascular surgery. PaO₂ averaged 81.6 ± 7.6 mmHg and PaCO₂ averaged 37.7 ± 3.2 mmHg. Both were independent of age. Factors associated with mortality according to bivariate analysis were: gender (female), type of surgery (valve replacement), and a low PaO₂ with strictly no ventilatory abnormality. In conclusion, PaO₂ values in elderly patients with cardiac disease and normal ventilatory function are greater than those obtained by extrapolation from healthy younger subjects. PaO₂ measurement should be recommended prior to cardiovascula surgery in elderly patients since a low PaO₂ with strictly normal ventilatory function is significantly associated with an increased risk for postoperative mortality.

Keywords: Arterial blood gases; Cardiovascular surgery; Elderly; Mortality risk; Pulmonary function test

1. Introduction

With the progressive increasing life expectancy, a growing number of elderly people is liable to undergo a cardiac surgical procedure [1, 2]. The normalcy, or otherwise, of the pulmonary function is crucial to determine in candidates for a cardiovascular surgery. This preoperative evaluation becomes essential in elderly patients since extensive comorbidities presented in this population greatly influences their surgical outcome [3]. This question is even more critical for resting arterial blood gas tension, which remains the cornerstone in the evaluation of respiratory disease severity.

However, a rational, data based, preoperative strategy in elderly is still needed [4]. Reference values for arterial oxygen partial pressure (PaO₂) in subjects older than 70 years have mostly been obtained by extrapolation of the linear regressions assessed in younger subjects [5]. Such an extrapolation appears to be misleading, since in contrast to the decrease in PaO₂ with aging obtained from such a prediction, PaO₂ of healthy old people does not differ considerably from that of middle age individuals [4, 6]. However, the possible relevance of such findings is problematic since the concept of ‘healthy’ elderly people is not simple to define and may not be useful when dealing with surgical decision in patients over 80 years old. Indeed, all the studies which have tried to assess ‘normal’ values for arterial blood gases in the elderly have logically excluded comorbidities, such as candidates for a cardiovascular surgery, even if their pulmonary function is not altered [7].

Moreover, numerous preoperative risk scores have been developed and are commonly used to predict mortality after heart surgery but the specific role of a low PaO₂ in a sample of elderly patients has not been yet evaluated as an independent preoperative risk factor [8].

Therefore, we analyzed arterial blood gases from a large population of elderly subjects with cardiovascular disease but normal pulmonary function, prior to a planned cardiovascular surgery. We intended to determine if sampling arterial blood in these patients is still relevant in the preoperative strategy, when non-invasive criteria for surgery are already met. Therefore, our aim was two-fold:
1) to determine blood gas values in a preoperative elderly population with cardiovascular disease but for whom surgery was proposed based on the absence of clinical or non-invasive functional respiratory abnormalities, 2) to assess the relationship between preoperative arterial blood gas status, lung function and short-term outcome after surgery (i.e. morbidity and mortality during the first month following surgery).

2. Material and methods

2.1. Patients

We retrospectively studied 201 patients over 70 years old. All patients were examined in our department from January 1999 to June 2003 to assess their preoperative pulmonary function before a planned cardiovascular surgery. The surgical procedures were: aortic valve replacement (n=57), mitral valve replacement (n=19), coronary artery bypass grafting (n=72), aortic aneurysm repair (n=39), femoral artery bypass (n=14).

All subjects with symptoms or diagnosis of active respiratory, renal, hepatic, neurologic, hematologic or metabolic diseases; patients with a known chronic respiratory disease or acute pulmonary edema, were excluded. Thus, only patients with no ventilatory abnormalities on their pulmonary function tests defined by pulmonary volumes, forced expiratory volume in one second (FEV\(_1\)) and forced vital capacity (FVC) higher than 80% of the expected value and a FEV\(_1\)/forced vital capacity (FVC) ratio >70%, were included.

2.1.1. Pulmonary function testing

The flow/volume curve and lung volumes were assessed by an open-circuit spirometry (Vmax, SensorMedics, Yorba Linda, CA). Functional residual capacity (FRC) was measured by the helium dilution-technique using a water-sealed spirometer (Pulmonet III, SensorMedics, Yorba Linda, CA). All measurements were performed according to the European Respiratory Society recommendations and respiratory-function data were compared with the predicted normal values obtained by the European Community for Steel and Coal and expressed as percentage of the normal value [9].

2.1.2. Arterial sampling

Arterial blood gases were drawn at rest from the radial artery of the non-dominant arm while the patient was comfortably sat for at least 10 min. A sterile, self-filling and disposable pre-heparinized system was used to take 1.5 ml of arterial blood (DRIHEP Plus, Vacutainer Systems, Becton Dickinson, USA).

2.1.3. Blood gas analysis

\(\text{PaO}_2\) and carbon dioxide partial pressure (\(\text{PaCO}_2\)) were determined within 10 min after sampling (ABL 600, Radiometer, Copenhagen, Denmark). Room temperature and barometric pressure were recorded on a daily basis and were used to adjust calibrations and measurements. Quality control of the blood-gas equipment was performed twice a day, using standard solution.

All patients were informed on the risks of the radial artery puncture and gave their verbal consent. The use of the results for research purpose, obtained in these patients, was approved by our Local Ethics Committee.

2.2. Statistical analysis

Results are expressed as mean ± S.D. Patient characteristics, preoperative arterial blood gas status, lung function relationships with short-term outcome after surgery (morbidity and mortality) were analyzed using Pearson \(\chi^2\), Fisher exact, analysis of variance, and Wilcoxon Kruskal–Wallis. Variables significant at a 0.05 level were subsequently used in multivariate analyses (logistic regression model) of the factors associated with short-term outcome after surgery.

Data were recorded on Excel files. Statistical analysis was performed using SAS version 9.1 statistical software.

3. Results

3.1. Sample description

Two hundred and one patients (71 women and 130 men) were studied, aged from 70 to 92 years. The mean age was 77.2 ± 4.7 years and 33.8% of them were aged 80 or over. Only 4% of patients can be classified as morbidly obese with a body mass index of 33 or over. Demographic information is summarized in Table 1.

3.2. Spirometric values

Lung volumes are reported in Table 2.

The patients awaiting a valve replacement showed a significantly lower TLC and VC than other groups (from \(P=0.0007\) to \(P=0.04\)).

According to the criteria of inclusion, FEV\(_1\) ranged from 80 to 155% of the predicted value (mean: 105.4 ± 15.3%) and FVC ranged from 80 to 144% (mean: 102.4 ± 15.5%). FEV\(_1\)/FVC ratio ranged from 70 to 100% (mean: 78.5 ± 5.3%). Patients with mitral valvulopathy had the lowest, albeit still within the expected range, FEV\(_1\), and FVC (Table 2).

Despite a normal FEV\(_1\)/FVC ratio, 93 patients demonstrated a decrease of more than 20% of the expected value of the Maximal mid-expiratory flow rate (\(\text{FEF}_{25-75}\)), leading to a concave shape of the flow/volume curve. This ‘concave flow/volume curve’ group had a significant lower (although within the expected range) value in FVC, FEV\(_1\), and FEV\(_1\)/FVC ratio (Table 2). This pattern could not be related to the nature of the cardiovascular disease.

Table 1

<table>
<thead>
<tr>
<th>Demographic information</th>
<th>Women (n=71)</th>
<th>Men (n=130)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>77.8 ± 4.8</td>
<td>77 ± 4.7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>154.2 ± 6</td>
<td>167.3 ± 7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>63.7 ± 12.5</td>
<td>72.3 ± 10.9</td>
</tr>
<tr>
<td>BMI (kg/m(^2))</td>
<td>26.7 ± 4.4</td>
<td>25.8 ± 3.2</td>
</tr>
</tbody>
</table>

Values were expressed as mean ± S.D.
3.3. Arterial blood-gases

The average PaO$_2$ was 81.6 ± 7.6 mmHg. The frequency distribution is shown on Fig. 1. There was no difference in mean PaO$_2$ between women and men or between the clinical subgroups (Table 4). Table 5 presents reference values for arterial blood gases distinguished by sex in our population.

However, PaO$_2$ of the group with a concave flow/volume curve was found significantly less than in the other groups (80.4 ± 7.5 vs. 82.6 ± 7.6 mmHg, P=0.0397). No significant correlation was found between arterial oxygen tension and age.

There were significant correlations between PaO$_2$ and VC (% VC=79.18±0.30 PaO$_2$; r$^2=0.02; P=0.047$) and between PaO$_2$ and FEV$_1$ (PaO$_2$=76.40±2.30 FEV$_1$; r$^2=0.034$; 

![Frequency distribution of PaO$_2$ in 201 elderly patients. Average PaO$_2$ was 81.6 ± 7.6 mmHg range: 66.5–105 mmHg). Dotted vertical lines represent the lower and upper limits estimated 5th and 95th percentile: mean±1.65×S.D.). The solid vertical line shows the mean PaO$_2$.](https://academic.oup.com/icvts/article-abstract/7/5/819/678172)
Surgical procedure

Methods

Forty-six patients presented postoperative complications which led to a significant increase in the length of stay (averaged hospital stay’s length: 8.9±2.4 days). Forty-six patients presented postoperative complications which led to a significant increase in the length of stay (average: 18±8 days). The postoperative complications consisted of: respiratory infection (22), life-threatening cardiac arrhythmia (6), excessive bleeding (5), persistent low cardiac output (3), sternal dehiscence (3), renal failure requiring dialysis (2), respiratory failure (2), septicemia (1), mediastinitis (1), stroke (1).

Fourteen died within the first month after the surgical procedure. The causes of death were: multivisceral failure (7), postoperative valve rupture (3), respiratory distress syndrome (2), myocardial infarction (2).

Mean PaO2 was not different between survivors and non-survivors. In the group of survivors, no difference was found in PaO2 between patients with simple and complicated outcomes (82.1±7.4 mmHg for both).

Results reveal statistically significant relationships between morality and the type of surgery (valve replacement, *P*=0.014), gender (female, *P*=0.021), and a low PaO2 with strictly no ventilatory abnormality on the flow-volume curve (*P*=0.0125) (Fig. 2).

4. Discussion

This study provides adequate reference values for PaO2 for elderly patients with cardiovascular disease with near normal spirometric values prior to a surgical treatment. These patients represent one of the most common populations of elderly people who are liable for a surgical treatment.

4.1. What reference values for PaO2 in the elderly?

The traditional view assumes that physiological PaO2 values decrease with aging [5]. However, recent studies have already pointed out that PaO2 in subjects above 70 years is higher than expected from extrapolation [6, 7]. Therefore, it appears that using linear regression of PaO2 against age
to establish reference values in the elderly leads to a systematic underestimation [9]. Our results clearly show that even in a population with a known cardiac disease and no or slight alteration of their ventilatory function, the averaged PaO₂ is as high as 80 mmHg. More precisely, 124 patients (61.7%) had a PaO₂ higher than 80 mmHg and only 11 patients (5.5%) had a PaO₂ lower than 70 mmHg. Thus, the normalcy of PaO₂ in the general healthy elderly population should be considered at least equal or superior to this value.

4.2. Relationship between spirometric values and PaO₂

Despite a normal FEV₁ and FEV₁/FVC ratio, close to 50% of the patients demonstrated a concave aspect of the flow/volume curve reflected by a reduction in FEF₂₅–₇₅%. In addition we found: 1) a correlation between normal FEV₁ and PaO₂ (P = 0.0015) as patients with chronic obstructive pulmonary disease [10], and 2) a significant reduction in PaO₂ in the patients with a reduction in FEF₂₅–₇₅% (‘concave flow/volume curve’). However, the difference was very small and PaO₂ remained high. The relevance of such a link as well as the meaning of this concave pattern observed in some patients is unclear. It could be related to a specific effect of aging i.e. an age-related decrease in elastic recoil [11]. We cannot rule out the role of the cardiac diseases in our patients, as previously shown by Fowler et al. [12], since left ventricular failure and mitral stenosis may have caused airway narrowing and bronchial hyperresponsiveness [13], even without any obvious pulmonary edema [14]. This is supported by the fact that the ‘concave flow/volume curve’ is significantly more pronounced in patients with mitral disease.

4.3. Short-term postoperative outcome and PaO₂

We report a short-term postoperative mortality of 11.3% for the overall surgical procedures, in agreement with the literature [1, 15]. Our statistical analysis showed that the preoperative risk factors associated with operative mortality were female sex and valve surgery. Age per se and PaO₂ were not a predictor but we found that a low PaO₂ with no ventilatory abnormalities of the flow/volume curve was a risk factor for postoperative mortality. Thus, the main objective to systematically assess PaO₂ prior to planned heart surgery is to diagnose a clear hypoxemia which is not linked to a known respiratory disease, requiring further investigations to assess its origin and ideally its treatment before surgery.

In conclusion, PaO₂ in elderly people with cardiovascular disease awaiting surgery and with no or slight ventilatory abnormalities have been shown systematically greater than those obtained by classical extrapolation from younger subjects, averaged 80 mmHg. A decrease in PaO₂ below 70 mmHg in this population is therefore to be regarded as hypoxemia, which needs further investigations since it seems to be associated with a higher risk of postoperative mortality when isolated.

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References


