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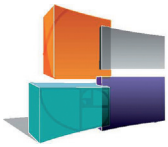

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Original article

Incidence and prediction of inadequate preoxygenation before induction of anaesthesia

Incidence et facteurs prédictifs d'échec de préoxygénation avant induction anesthésique

C. Baillard [a,*], F. Depret [a], V. Levy [b], M. Boubaya [b], S. Beloucif [a]

[a] *EA 3409, department of anaesthesiology and critical care medicine, Avicenne university hospital, Paris-13 university, AP–HP, 125, route de Stalingrad, 93009 Bobigny, France*
[b] *Clinical research unit, Avicenne university hospital, Paris-13 university, AP–HP, 125, route de Stalingrad, 93009 Bobigny, France*

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ABSTRACT

Background. – Preoxygenation aims to obtain an expired oxygen fraction (FEO_2) $\geq$ 90%. Little is known about the incidence and predictors of inadequate preoxygenation in the clinical setting.
Patients and methods. – Over a 12-month period, 1050 consecutive preoperative patients were prospectively included. Preoxygenation was performed for 3 minutes with a facial mask using a machine circuit and 12-L/min oxygen flow. Inadequate preoxygenation was defined as an $FEO_2 < 90\%$. A logistic regression was performed to identify incidence and independent predictors.
Results. – The patient characteristics were: age 51 ± 20 years, 47% male, BMI of 26 ± 5 kg/m^2, and ASA score (median [extremes]) of 2 [1–4]. Inadequate preoxygenation was observed in 589 patients (56%). The effective FiO_2 delivered was lower in the patients with inadequate preoxygenation than in those with adequate preoxygenation, 95 ± 3% vs. 98 ± 2%, $P < 0.001$. The difference between the FiO_2 and the FEO_2 was higher (12 ± 6% vs. 6 ± 3%, $P < 0.0001$) in patients with inadequate preoxygenation compared with those with adequate preoxygenation. The independent risk factors for inadequate preoxygenation were: firstly, bearded male (odds ratio [OR] of 9.1 [2.7–31.4] $P < 0.001$); secondly, beardless male (OR 2.4 [1.6–3.4] $P < 0.001$), thirdly, ASA score of 4 (OR 9.1 [2.6–31.2] $P < 0.015$); fourthly, ASA score of 2–3 (OR 2.4 [1.6–3.4] $P < 0.015$); fifthly, lack of teeth (OR 2.4 [1.2–4.5] $P < 0.006$), and lastly age > 55 years (OR 1.8 [1.2–2.7] $P < 0.005$).
Conclusion. – Inadequate preoxygenation, defined as an $FEO_2 < 90\%$ despite 3-min tidal volume breathing, was a common occurrence. The predictive factors share an overlap with those previously identified for difficult mask ventilation.

Mots clés :
Préoxygénation
Anesthésie générale
Voies aériennes

RÉSUMÉ

Objectifs. – Peu de données sont actuellement disponibles concernant l'incidence et les facteurs prédictifs d'un échec de préoxygénation en pratique clinique.
Patients et méthodes. – Au cours d'une période de 12 mois, 1050 patients consécutifs ont été prospectivement inclus. La préoxygénation était réalisée en volume courant pendant 3 minutes en utilisant le circuit machine avec un débit d'oxygène de 12 litres par minutes. Une $FEO_2 < 90$ % à l'issue de la préoxygénation définissait un échec. Une analyse univariée puis multivariée ont été réalisées pour identifier les facteurs indépendants d'échec de préoxygénation.
Résultats. – Les caractéristiques des patients étaient : âge 51 ± 20 ans, 47 % hommes, IMC 26 ± 5 kg/m^2, et score ASA : 2 [1–4]. L'incidence globale d'échec de préoxygénation était retrouvée chez 589 patients (56 %). La FiO_2 délivrée était plus faible chez les patients avec échec de préoxygénation comparée aux patients correctement préoxygénés, 95 ± 3 % vs 98 ± 2 %, $p < 0{,}001$. Les facteurs de risques indépendants d'échec de

* Corresponding author.
E-mail address: christophe.baillard@avc.aphp.fr (C. Baillard).

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préoxygénation étaient : premièrement, les hommes barbus (*odds ratio* [OR] of 9,1 [2,7–31,4] $p < 0{,}001$) ; deuxièmement, le sexe masculin (OR 2,4 [1,6–3,4] $p < 0{,}001$) ; troisièmement, un score ASA 4 (OR 9,1 [2,6–31,2] $p < 0{,}015$) ; quatrièmement, un score ASA 2–3 (OR 2,4 [1,6–3,4] $p < 0{,}015$) ; cinquièmement, l'édentation (OR 2,4 [1,2–4,5] $p < 0{,}006$) et finalement, l'âge > 55 ans (OR 1,8 [1,2–2,7] $p < 0{,}005$).

Conclusion. – L'échec de préoxygénation défini par une $FEO_2 < 90$ % à l'issue de 3 minutes de ventilation spontanée en volume courant est une situation courante. Les facteurs de risques observés sont communs à ceux préalablement identifiés pour la prédiction de la ventilation au masque difficile.

1. Introduction

The standard practice of preoxygenating with 100% oxygen before the induction of general anaesthesia is strongly recommended because it delays the onset of arterial hemoglobin desaturation during a potential prolonged apnea [1,2]. The oxygen loading process during preoxygenation involves factors related to alveolar, arterial, tissue, and venous compartments and those that interact with the delivered fraction of inspired oxygen (FiO_2) [3]. Because most of the oxygen is stored in the lungs as a function of residual functional capacity (FRC), the primary goal is to maximize the alveolar fraction of oxygen, which depends on the effective FiO_2 delivered. When most of the nitrogen in the lung is replaced by oxygen, the expired oxygen (FEO_2) increases to slightly greater than 90%, satisfying the recommendation for adequate preoxygenation [2]. The FEO_2 measurement is clearly the best evidence ensuring proper FRC loading with oxygen. Various techniques for accomplishing preoxygenation have been evaluated, and the most frequently recommended is 3 min of normal tidal volume breathing (TVB) of 100% oxygen using a standard breathing systems. Eight deep breaths in 60 seconds is considered a suitable alternative technique [1,2]. There is a close relationship between the FEO_2 that can be reached following preoxygenation and the subsequent duration of apnea without arterial hemoglobin desaturation [4]. However, there are few data regarding the frequency and predictors of failure to achieve adequate preoxygenation (defined as an $FEO_2 \geq 90\%$). The aim of this study was to determine in a large, unselected population in a clinical setting the incidence of inadequate preoxygenation (defined as an $FEO_2 < 90\%$ after a 3-min TVB) and its predictive factors. We hypothesized that certain predictive factors for inadequate preoxygenation could also be factors for difficult mask ventilation.

2. Materials and methods

The study design was approved by the Institutional Review Board (CEERB, Paris-North Hospital, Paris-7 university, Assistance Publique des Hôpitaux de Paris, France). Because there was no randomization and only routine care was performed, waived informed consent was authorized by the CEERB. Adult patients scheduled for orthopedic, vascular, gynecologic, ENT, or abdominal surgery or for gastrointestinal endoscopy under general anaesthesia were prospectively evaluated for inclusion in this study over a 12-month period. Patients undergoing regional anaesthesia were excluded. Since the aim of this study was to investigate the factors associated with an inadequate preoxygenation, regardless of other known factors such as COPD, trauma or shock patients, we excluded patients requiring oxygen upon arrival to the operating room, or presenting with a $SpO_2 < 98\%$ while breathing room air.

The sample size was determined using a method based on a multiple logistic regression model. Assuming from a pilot study an overall probability of inadequate preoxygenation of 50% and a probability of risk factor occurrence between 0.3% and 0.5%, with an alpha of 0.05, a power of 0.8 and a coefficient of determination between factors between 0.05 and 0.15, a sample size of 1000 subjects was necessary for an odds ratio of 1.5.

The following information was collected during the preoperative visit and after the patient had been educated about the preoxygenation technique: age, sex, ASA score, as well as recognized risk factors for difficult mask ventilation (body mass index [BMI] greater than 26, calculated as weight in kilograms divided by the square of the height in meters), presence of a beard, lack of teeth and history of snoring [5,6].

All the patients were supine (excepted for obese patients: head-up position 10°) and routinely monitored using electrocardiography, non-invasive blood pressure measurement, pulse oximetry, FEO_2 and end-tidal carbon dioxide tension ($EtCO_2$) before general anaesthesia induction. After priming the anaesthesia circuit (Primus Dräger, Lübeck, Deutschland) with oxygen, the patients were asked to breath normally (tidal volume breathing) for 3 minutes (using a timer). Preoxygenation was performed with a facial mask, by experienced nurses anaesthetits or anesthesiologists, using a machine circuit with a preset gas flow of 12 L/min O_2. The size (3, 4, or 5) of the single-use facemask (Intersurgical Limited, Wokingham, United Kingdom). The capnographic waves was used to achieve the best fit for each patient and an appropriate alveolar gases measurement. During preoxygenation, FiO_2, FEO_2 and $EtCO_2$ were measured breath-by-breath with a calibrated gas analyzer located in the ventilator with a sample line connected to the filter placed between the Y-piece and the mask. The individual study period ended at the outset of preoxygenation, and the anaesthesia procedure was performed as per usual.

The data are summarized as the means and standard deviations for continuous data. Categorical variables are presented as absolute and relative frequencies. Marginal associations between an inadequate preoxygenation ($FEO_2 < 90\%$) and the patient's risk factors for inadequate preoxygenation were assessed using a Chi^2 test for categorical variables and a Student's *t*-test for continuous variables.

The data on sex and the presence of a beard were placed into three categories: women, men without beards and men with beards. All the factors with $P < 0.20$ in the univariate analysis were included in a multiple logistic regression model with a backward stepwise procedure for variable selection. The multivariate analyze were adjusted for FiO_2. All the tests were two-sided, at a 0.05 significance level. The analyses were performed using R statistical software version 2.12.0.

3. Results

A total of 1050 patients were included in this study (Table 1). Of these, 299 patients were scheduled for orthopedic surgery, 170 patients for gastrointestinal endoscopy, 156 patients for vascular surgery, 155 patients for abdominal surgery, 111 patients for ENT surgery, 107 patients for gynecologic surgery, and 52 patients for other surgeries. The patient characteristics included age 51 ± 20 years, 47% male, a BMI of 26 ± 5 kg/m^2 and a median ASA score (median [extremes]) of 2 [1–4]. The incidence of risk factors for