Cardiothoracic Anesthesia, Respiration and Airway

Design of oxygen delivery systems influences both effectiveness and comfort in adult volunteers

[Le modèle des systèmes de distribution d'oxygène influence l'efficacité et le confort chez des volontaires adultes]

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Purpose: The aim of this investigation was to compare the efficiency of four oxygen delivery systems in healthy volunteers.

Methods: The subjects received oxygen at flow rates of 3.0 and 5.0 L·min⁻¹ via a face mask, nasal cannulae, and two kinds of new open- and microphone-type oxygen delivery systems (OxyArm™ and Mike Cannula) in a random sequence, and values of partial arterial pressures of oxygen (PaO₂) were measured. The comfort of these devices was also evaluated.

Results: A significant, oxygen flow dependent increase in PaO₂ was obtained with all devices tested. PaO₂ was significantly higher when the face mask was used [217.5 ± 19.9 (mean ± SD) mmHg at 5 L·min⁻¹) than when the Mike Cannula was used (177.5 ± 14.8 mmHg). The face mask was the least comfortable and OxyArm was the most comfortable among the devices tested.

Conclusion: The results of our evaluation suggest that comfort and clinical performance should be considered when using oxygen delivery devices for patients who require oxygen supplementation.

Objectif : Le but de la présente étude était de comparer l'efficacité de quatre systèmes de distribution d'oxygène chez des volontaires sains.

Méthode : Les sujets ont reçu, suivant une séquence aléatoire, des débits d'oxygène de 3,0 et 5,0 L·min⁻¹ au moyen d'un masque, d'une canule nasale et de deux nouveaux prototypes ouverts et de type microphone (OxyArm™ et Mike Cannula). Les pressions artérielles partielles (PaO₂) ont été mesurées. Le confort a été évalué pour chacun des appareils utilisés.

Résultats : Une augmentation significative de la PaO₂, dépendante du débit d'oxygène, a été obtenue avec tous les appareils. La PaO₂ a été significativement plus élevée avec le masque [217,5 ± 19,9 (moyenne ± écart type) mmHg à 5 L·min⁻¹] qu'avec le Mike Cannula (177,5 ± 14,8 mmHg). Le masque était l'appareil le moins confortable et le OxyArm le plus confortable.

Conclusion : Nos résultats indiquent que le confort et la performance clinique doivent être pris en compte au moment d'utiliser des appareils de distribution d'oxygène pour un apport complémentaire.

TREATMENT of respiratory insufficiency and postoperative hypoxemia most usually requires oxygen supplementation.¹ Oxygen can be administered to patients using a variety of face masks and nasal cannulae. It has been reported that there are no significant differences in partial pressure of arterial carbon dioxide (PaCO₂) or oxygen saturation measured by pulse oximetry (SpO₂) when using various devices.^{2,3} Such devices deliver a variable inspired oxygen concentration (FiO₂), especially in patients with chronic obstructive pulmonary disease or during the postoperative nocturnal period.⁴ Not only do some patients find face masks uncomfortable or claustrophobic, but these masks also hinder speech. While nasal cannulae lie in close proximity with the nose, mouth breathing presents a problem.

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Recently, new minimal contact open oxygen delivery systems have become available for clinical use.⁵

In this study, we compared the efficiency of four oxygen delivery systems in healthy volunteers.

Methods

After obtaining institutional Ethics Committee on Human Research approval and informed consent from the subjects, ten conscious adult volunteers [mean ($\pm$ SD) age: 34 ± 6 yr, height: 171.5 ± 10.3 cm, weight: 65.7 ± 6.5 kg] were enrolled in this study. All of the subjects were graded ASA I, and none of the subjects had obesity (body mass index > 28), an upper respiratory tract infection or nasal obstruction. The subjects were requested to lie in a supine position and to breathe quietly. Because it is difficult to accurately measure FiO_2 when using these oxygen delivery systems, we measured partial arterial pressures of oxygen (PaO_2) and PaCO_2 to evaluate the effectiveness of the oxygen delivery systems tested. A catheter was inserted into the left radial artery of each subject, and PaO_2 breathing room air ($\text{FiO}_2 = 0.21$) was measured as a control with a calibrated blood gas analyzer (ABL 700™, Radiometer Japan, Tokyo, Japan). The subjects were then given oxygen at 3.0 and 5.0 $\text{L}\cdot\text{min}^{-1}$ via the different oxygen delivery systems in a random sequence. Oxygen was delivered via a calibrated flowmeter. A so-called Hudson face mask (OxygenMask™; Kobayashi Medical, Osaka, Japan), nasal cannulae (ATOM Nasal Oxygen Cannula; Tokyo, Japan), and two kinds of microphone-type open oxygen delivery systems, OxyArm™ (EPI, Tokyo, Japan) and Mike Cannula (Yamato Medical Gases, Tokyo, Japan), were tested in this study (Figure 1 - also presents the cost of the devices tested). After a 15-min period using each device at the chosen flow rate, an arterial blood sample was taken for analysis. The subjects were also asked to evaluate the comfort of these oxygen delivery systems by using a numeric scale ranging from 0 to 100 (0 as most comfortable and 100 as most uncomfortable).

Data are expressed as means $\pm$ SD. All data were analyzed using one-way analysis of variance (ANOVA) for repeated measurements, and Fisher's test was used as a post hoc test. In all comparisons, $P < 0.05$ was considered significant.

Results

The PaCO_2 values when using each device ranged from 35.4 to 43.2 mmHg, and there was no significant difference in the values of PaCO_2 between the devices or between different oxygen flow rates (data not shown). The PaO_2 values obtained are shown in Figure 2. There was no significant difference in the

FIGURE 1 The oxygen delivery systems tested. A = Hudson face mask (OxygenMask™; Kobayashi Medical, Osaka, Japan), B = nasal cannulae (ATOM Nasal Oxygen Cannula; Tokyo, Japan), C = OxyArm™ (EPI, Tokyo, Japan) and D = Mike Cannula (Yamato Medical Gases, Tokyo, Japan).

FIGURE 2 Changes in arterial partial pressure of oxygen (PaO_2) during exposure to air or oxygen at flow rates of 3.0 and 5.0 $\text{L}\cdot\text{min}^{-1}$ using • = face mask, black square = nasal cannulae, black triangle = OxyArm, upside down black triangle = Mike Cannula. * $P < 0.05$ vs PaO_2 in room air, † $P < 0.05$ vs PaO_2 using the face mask at the same oxygen flow rate.

PaO_2 values between devices when breathing room air. PaO_2 significantly increased in a flow-dependent manner for each device tested. ANOVA for repeated measurements revealed a significant difference between the PaO_2 values obtained using each device. At oxygen flow rates of 3.0 $\text{L}\cdot\text{min}^{-1}$ and 5.0 $\text{L}\cdot\text{min}^{-1}$, the value of PaO_2 obtained using the face mask was significantly higher than that obtained using the Mike Cannula.

With regard to comfort, the face mask was the least comfortable (56.8 ± 12.6) of the devices tested (36.7 ± 10.2 for nasal cannulae, 20.1 ± 5.6 for OxyArm, and 24.5 ± 7.9 for Mike Cannula, $P = 0.04$) at the oxygen flow rate of 3.0 $\text{L}\cdot\text{min}^{-1}$. When the oxygen flow rate was increased to 5.0 $\text{L}\cdot\text{min}^{-1}$, the OxyArm was the most comfortable (24.3 ± 6.5 , $P = 0.03$), while the scores increased significantly with the nasal cannulae (54.2 ± 13.2) and Mike Cannula (43.2 ± 9.9) and remained the same with the face mask (58.3 ± 13.2).

Discussion

The majority of postoperative patients do not require precise control of the concentration of oxygen admin-

istered, and the performance of currently available devices for delivery of oxygen is variable. The traditional face mask continues to be used widely for delivery of oxygen to patients. This study showed that, in healthy volunteers, a satisfactory increase in PaO_2 was obtained by using all four oxygen delivery systems in an oxygen flow-dependent manner, without changes in PaCO_2 . In this study, the face mask was the best and the Mike Cannula the worst with respect to PaO_2 . Although the OxyArm is an open-type oxygen delivery system, it has a diffuser consisting of both a cup and pin to deliver a premixed and high concentration of oxygen to the mouth and nose.⁵ The technique for using the Mike Cannula is similar to that for using OxyArm; however, when the Mike Cannula is used, oxygen is blown directly to the face and the concentration of oxygen varies with inspired flow rate.

Patient compliance with the face mask is not good, largely due to the claustrophobic feeling generated and the necessity for its removal to speak comfortably. When the nasal cannulae or Mike Cannula are used, oxygen is blown directly to the mouth and/or nose, and discomfort becomes more marked when the oxygen flow rate is increased. The OxyArm had the best comfort score, independent of oxygen flow rate, presumably because of its oxygen premixing system.⁵ Furthermore, Nolan *et al.*⁶ reported that a face mask is often removed for routine nursing tasks and that patients are frequently hypoxemic during these periods. It is also quite conceivable that the open- and microphone-type oxygen delivery systems tested in this study would have to be removed from the mouth/nose less frequently than would the other two devices tested.

On the other hand, costs and benefits of the devices should be also taken into consideration.⁷ The face mask and nasal cannulae are the cheapest among the devices tested (Can\$ 6.00 and 4.50, respectively). The price of the OxyArm (Can\$ 18.80) is interesting with regard to oxygen delivery performance and comfort. The Mike Cannula is the most expensive (Can\$ 150) because the non-disposable device was developed for home oxygen therapy. Therefore, the Mike Cannula seems to be inappropriate for routine postoperative oxygen supplementation.

The results of our evaluation suggest that comfort and clinical performance should be considered when using oxygen delivery devices for patients who need supplemental oxygen. Consideration must be also given to potential differences in performance between the healthy volunteers studied herein and patients in the clinical context.

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