Gatto *et al. J Anesth Analg Crit Care* (2022) 2:23
https://doi.org/10.1186/s44158-022-00051-w

Journal of Anesthesia, Analgesia and Critical Care

BRIEF COMMUNICATION

Open Access

Difference in PaO_2/FiO_2 between high-flow nasal cannula and Venturi mask in hypoxemic COVID-19 patients

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Abstract

The ratio between arterial blood partial pressure of oxygen and fraction of inspired oxygen (PaO_2/FiO_2) was largely used for grading and managing the respiratory failure in non-mechanically ventilated COVID-19. In these patients, the assessment of the true FiO_2 in the inspired mixture may be difficult with consequent inaccuracies in PaO_2/FiO_2 assessment. In 30 severe COVID-19 patients, we observed that PaO_2/FiO_2 values measured immediately before and after the transition from high-flow nasal cannula (HFNC) to one commercially available Venturi mask O_2 therapy were similar (bias mean value 0, standard deviation 23 mmHg). In COVID-19 patients recovering from respiratory failure, PaO_2/FiO_2 is not different whether measured with a commercially available Venturi mask or HFNC.

Keywords: COVID-19, ICU, HFNC, PaO_2/FiO_2

Introduction

During the SARS-CoV-2 pandemic, the ratio between arterial blood partial pressure of oxygen and fraction of inspired oxygen in the inspired mixture (PaO_2/FiO_2, mmHg) was largely used for defining the severity of the respiratory failure and its progression, for deciding the appropriate respiratory support, and, consequently, for using specific pharmacological therapy [1]. Therefore, a careful assessment of PaO_2/FiO_2 is fundamental. As it is well known, PaO_2/FiO_2 is not the ideal variable for measuring the PO_2 alveolar-arterial gradient because it does not consider PCO_2 and its not linear relationship with FiO_2 regardless of the alveolar-arterial gradient [2]. Moreover, PaO_2/FiO_2 was initially proposed in mechanically ventilated patients, where FiO_2 is carefully measured. In non-mechanically ventilated patients, as patients in conventional O_2 mask or high-flow nasal cannula (HFNC), the assessment of the true FiO_2 in the inspired mixture may be problematic, specifically in dyspneic/tachypneic patients with high inspiratory peak flow or with the mouth breathing during HFNC [3, 4]. Therefore, PaO_2/FiO_2 values during the transition through the different methods of O_2 delivery could lead to misinterpretation of the degree of respiratory dysfunction. For the above reasons, we decided to investigate whether the transitions from HFCN and Venturi mask (VM), or vice versa, alter PaO_2/FiO_2 values because of potential undetected differences in true FiO_2.

Methods

Thirty consecutive patients admitted to our COVID-19 intensive care unit (ICU) because of severe respiratory failure due to SARS-CoV-2 infection and undergoing weaning from respiratory supports were included. As for internal protocol, after weaning from mechanical ventilation and $SpO_2 > 90\%$ with $FiO_2 < 0.7$ in HFNC (flow rate 60 L/min), the patients alternated HFNC and VM (FIAB S.p.A., model OS/60K, Florence, Italy) at the same FiO_2 levels with a progressive de-escalating time scheme. Twenty minutes after the transition from HFNC

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Table 1 Clinical characteristics of the patients

Age, years (median, IQR)	63 (53–72)
Sex, male (*n*, %)	17 (56,7)
First test HFNC (*n*, %)	29 (96,7)
ICU LOS prior test (days, median, IQR)	5 (3–8)
IMV prior test (*n*, %)	16 (53,3)
NIV prior test (*n*, %)	23 (76,7)
IMV length prior test (days, median, IQR)	2 (0–6)
NIV length prior test (days, median, IQR)	1 (0–2)
RASS score during HFNC (median, IQR)	0
RASS score during VM (median, IQR)	0

HFNC high-flow nasal cannula, *ICU LOS* length of stay in intensive care unit, *IMV* invasive mechanical ventilation, *NIV* non-invasive mechanical ventilation, *RASS* Richmond Agitation-Sedation Scale, *VM* Venturi mask

Table 2 Blood gases values and vital signs in HFNC and VM

	HFNC	VM	*p*-value
PaO_2/FiO_2 (mmHg)	127 (100–147)	118 (107–152)	0.604
PaO_2 (mmHg)	59.0 (55.0–64.8)	60.0 (50.2–70.0)	0.906
P (A-a) O_2 (mmHg)	236 (196–266)	242 (203–264)	0.122
FiO_2	0.50 (0.45–0.50)	0.50 (0.40–0.50)	0.180
SaO_2 (%)	91.10 (88.40–93.40)	92.10 (87.00–94.20)	0.688
$PaCO_2$ (mmHg)	39.20 (34.70–42.10)	36.60 (32.00–40.90)	0.001
pH	7.49 (7.46–7.51)	7.50 (7.47–7.52)	0.323
RR (breaths/min)	21 (17–25)	23 (20–28)	0.013
MAP (mmHg)	90 (87–93)	90 (87–95)	0.311
HR (beats/min)	75 (60–85)	80 (64–90)	0.189

Data are presented as median (IQR). *RR* respiratory rate, *MAP* median arterial pressure, *HR* heart rate, *HFNC* high-flow nasal cannula, *VM* Venturi mask, *PaO_2/FiO_2* arterial blood partial pressure of oxygen and fraction of inspired oxygen, *PaO_2* arterial blood partial pressure of oxygen, *P (A-a) O_2* alveolar-arterial PO_2 gradient, *FiO_2* fraction of inspired oxygen, *SaO_2* saturation of oxygen, *$PaCO_2$* partial pressure of carbon dioxide

to VM or vice versa, we collected respiratory rate (RR), mean arterial pressure, heart rate, FiO_2, PaO_2, the partial pressure of carbon dioxide ($PaCO_2$), and pH in the arterial blood and calculated alveolar-arterial PO_2 gradient ($P(A\text{-}a)O_2$) [5]. To evaluate the differences between HFNC and VM, analysis of variance, linear regression analysis, and Bland-Altman method were used [6]. The study was approved by the ethical committee (658/2020/OSS*/AOUMO SIRER ID 417), and informed consent was obtained from participants.

Results

Patients' characteristics were detailed in Table 1. Twenty-nine patients received HFNC first and only one VM first. The PaO_2/FiO_2 measured in HFNC were like those measured in VM (Table 2) with a significant linear relationship ($R^2 = 0.51$, $p < 0.01$). In the Bland-Altman analysis, the mean value and standard deviation of the bias were 0 and 23 mmHg (Fig. 1). The RR and $PaCO_2$ values resulted to be different ($p = 0.013$ and $p = 0.001$) with RR higher and $PaCO_2$ lower in VM compared to HFNC (Table 2). In patients previously treated with HFNC, $PaCO_2$ was lower during VM in 25 patients (86.2%), and the difference was up to 5 mmHg in only 4 patients (13.8%).

Discussion

Our data indicate that after 20 min from HFNC to VM transition and vice versa, PaO_2/FiO_2 remain similar with only a small and not significant difference. Previous studies suggested that HFNC may improve oxygenation and decrease work of breathing compared to conventional O2 therapy [7–9]. In contrast with previous reports, our results may suggest that there may be an underestimation of FiO_2 with Venturi device yielding overestimation

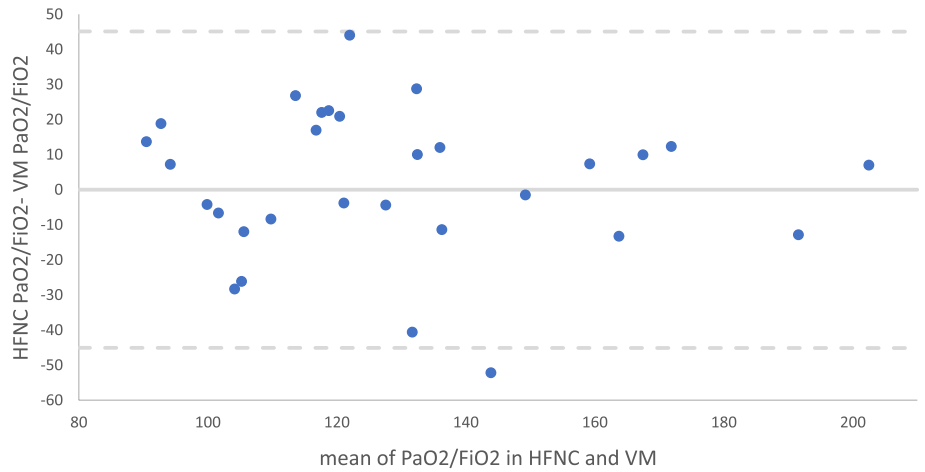

Fig. 1 Bland and Altman diagram. The continuous line represents mean bias; the dashed lines represent 1.96 standard deviations. HFNC high-flow nasal cannula, VM Venturi mask

of PaO_2/FiO_2 in contrast with the accurate delivery of FiO_2 with HFNC. Anyway, in this specific population under these circumstances, both these two phenomena have clinically acceptable limits of agreement. Moreover, we observed that RR differed between the two methods despite the very short period of exposure (20 min). The main part of the sample transitioned to VM after having received HFNC, so it cannot exclude a possible carry-over effect for $PaCO_2$ in this transition. Moreover, a possible carry-over effect cannot be excluded also for PaO_2/FiO_2 ratio. Rather than reducing work of breathing, the association of lower RR with a consensual increase of $PaCO_2$ supports the hypothesis that HFNC, compared to VM, could improve oxygenation with less requirement of alveolar ventilation for maintaining PaO_2 level. However, the low number of patients and the lack of assessment of the true FiO_2 limit any further speculation on this point.

In conclusion, our study demonstrated that although in HFNC and VM the FiO_2 is only estimated and may vary with the patient's respiratory pattern, PaO_2/FiO_2 measured with a VM may be considered a reliable parameter for respiratory dysfunction evaluation in severely hypoxemic patients during the transitions from different O_2 delivery methods.

Abbreviations

HFNC: High-flow nasal cannula; VM: Venturi mask; ICU: Intensive care unit; RR: Respiratory rate; $P(A\text{-}a)O_2$: Alveolar-arterial PO_2 gradient; MAP: Median arterial pressure; HR: Heart rate; PaO_2/FiO_2: Arterial blood partial pressure of oxygen and fraction of inspired oxygen.

Acknowledgements

Modena Covid-19 Working Group (MoCo19)
Intensive care unit: Massimo Girardis, Alberto Andreotti, Emanuela Biagioni, Filippo Bondi, Stefano Busani, Giovanni Chierego, Marzia Scotti, Lucia Serio, Annamaria Ghirardini, Marco Sita, Stefano De Julis, Lara Donno, Lorenzo Dall'Ara, Carlotta Farinelli, Laura Rinaldi, Ilaria Cavazzuti, Elena Ferrari, Irene Coloretti, Sophie Venturelli, Elena Munari, Martina Tosi, Erika Roat, Ilenia Gatto, and Caciagli Valeria
Immuno-Lab: Andrea Cossarizza, Caterina Bellinazzi, Rebecca Borella, Sara De Biasi, Anna De Gaetano, Lucia Fidanza, Lara Gibellini, Anna Iannone, Domenico Lo Tartaro, Marco Mattioli, Milena Nasi, Annamaria Paolini, and Marcello Pinti
Infectious Disease Unit: Cristina Mussini, Giovanni Guaraldi, Marianna Meschiari, Alessandro Cozzi-Lepri, Jovana Milic, Marianna Menozzi, Erica Franceschini, Gianluca Cuomo, Gabriella Orlando, Vanni Borghi, Antonella Santoro, Margherita Di Gaetano, Cinzia Puzzolante, Federica Carli, Andrea Bedini, and Luca Corradi
Respiratory Diseases Unit: Enrico Clini, Roberto Tonelli, Riccardo Fantini, Ivana Castaniere, Luca Tabbì, Giulia Bruzzi, Chiara Nani, Fabiana Trentacosti, Pierluigi Donatelli, Maria Rosaria Pellegrino, Linda Manicardi, Antonio Moretti, Morgana Vermi, and Caterina Cerbone
Virology and Molecular Microbiology Unit: Monica Pecorari, William Gennari, Antonella Grottola, Giulia Fregni Serpini, and Mario Sarti

Authors' contributions

GI, BE, VS, and GM designed the study, enrolled the patients, analyzed data, and wrote the paper. BS and CI reviewed and edited the manuscript. All authors read and approved the final manuscript.

Funding

None

Availability of data and materials

The datasets used and/or analyzed during this study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the ethical committee (658/2020/OSS*/AOUMO SIRER ID 417), and informed consent was obtained from participants.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Received: 4 February 2022 Accepted: 11 May 2022
Published online: 24 May 2022

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