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

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# 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

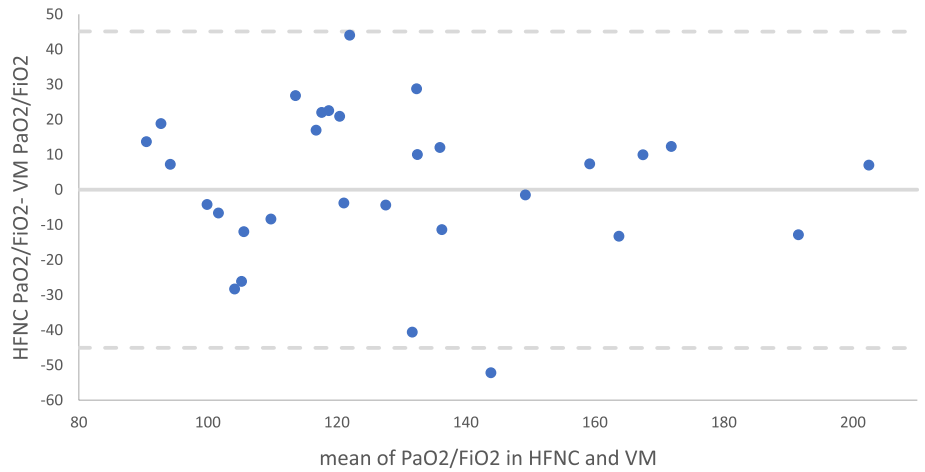


**Fig. 1** Bland and Altman diagram. The continuous line represents mean bias; the dashed lines represent 1.96 standard deviations. HFNC high-flow nasal cannula, VM Venturi mask

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

#### References

1. World Health Organization (2021). COVID-19 clinical management: living guidance, 25 January 2021. World Health Organization. https://apps.who.int/iris/handle/10665/338882. License: CC BY-NC-SA 3.0 IGO.
2. Aboab J, Louis B, Jonson B, Brochard L (2006) Relation between PaO2/FIO2 ratio and FIO2: a mathematical description. Intensive Care Med. 32(10):1494–1497
3. Redding JS, McAfee DD, Gross CW (1978) Oxygen concentrations received from commonly used delivery systems. South Med J. 71(2):169–172
4. Baha AS, Simon S (2013) Essentials of Anaesthetic Equipment (Fourth Edition). Churchill Livingstone, pp 99–110
5. Lumb A, Thomas C (2020) Nunn's Applied Respiratory Physiology, 9th edition. Elsevier, Philadelphia
6. Altman DG, Bland JM (1983) Measurement in medicine: the analysis of method comparison studies. J R Stat Soc Ser D (The Statistician). 32(3):307–317
7. Ricard JD (2012) High flow nasal oxygen in acute respiratory failure. Minerva Anestesiol. 78(7):836–841
8. Lee CC, Mankodi D, Shaharyar S, Ravindranathan S, Danckers M, Herscovici P, Moor M, Ferrer G (2016) High flow nasal cannula versus conventional oxygen therapy and non-invasive ventilation in adults with acute hypoxemic respiratory failure: a systematic review. Respir Med. 121:100–108
9. Vargas F, Saint-Leger M, Boyer A, Bui NH, Hilbert G (2015) Physiologic effects of high-flow nasal cannula oxygen in critical care subjects. Respir Care. 60(10):1369–1376

## Publisher's Note