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Short Report

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Impact of SpO_2 targets and pulse oximeter brand on oxygen flow requirements and oxygenation

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Introduction

Oxygenation targets are defined by maximum and minimum SpO_2 boundaries in an effort to avoid both hypoxemia and hyperoxemia. However, these limits are difficult to impose clinically in part due to confounding factors of SpO_2 measurement accuracy[1]. The impact of skin pigmentation on oximeter accuracy has been the subject of justified awareness in the scientific literature and lay press[2] owing to potential exacerbation of health inequities. Other factors may have an impact at least as important for oxygen therapy management, including the choice of the SpO_2 target[3-6] and oximeter brand[7].

Several SpO_2 targets have been recommended for management of patients with hypoxemic respiratory failure, from 92±2%[3] to 96±2%[4, 5]. In spontaneously breathing patients on oxygen therapy, the choice of the SpO_2 target has been shown to modulate oxygen flow, with an increase by more than three-fold for 4% differences in SpO_2 targets[8]. This three-fold increase in oxygen delivery may have significant impact in evaluating the patient's severity of illness, on the decision to escalate or de-escalate respiratory support and for the oxygen utilization[9].

In addition, the oximeter brand may influence the oxygen flow required to maintain a target level of oxygenation[1]. Indeed, it has been recently shown that oximeter brand also influences SpO_2 measurements with mean bias up to 4% between commonly used pulse oximeters[7]. It is not known if the error related to the brand of the oximeter can have an additional impact on the choice of the SpO_2 target and of what magnitude. The objective of this short-term physiological study was to evaluate the impact of the combination of different SpO_2 target and oximeter brand on oxygen flow requirements and oxygenation parameters.

Methods

We conducted a prospective randomized cross-over study in 20 stable ICU subjects requiring oxygen therapy delivered through a nasal canula after cardiac surgery (Clinicaltrials identifier: NCT05590130). Subjects were prospectively included from December 2022 to March 2023 at our institution (Institut Universitaire de Cardiologie et de Pneumologie de Québec, IUCPQ). Subjects without adequate SpO_2 signal were excluded. The study was approved by the institutional ethics committee and all subjects provided signed informed consent. Four randomized periods of study in 10-minute blocks were conducted, with a combination of two different SpO_2 targets (90% and 94%) while using two different oximeters (Nonin, Plymouth, MN and Philips FAST, Eindhoven, Netherlands). The mean bias between these oximeters was 4% in our previous work [7]. At the end of each period, we recorded the oxygen flow and obtained arterial blood gases. Arterial oxygen saturation, SaO_2 was determined by multiwavelength oximetry (Radiometer ABL 800Flex OSM-3, Mississauga, ON, Canada). We compared the four periods for the oxygen flow (primary endpoint), the rate of occult hypoxemia (defined as SaO_2<90% and SpO_2≥90%) and occult hyperoxemia (defined as SaO_2>96% and SpO_2≤96%), oxygen partial weaning (flow < 0.5L/min) or complete weaning and the rate of high O_2 flow requirements (> 5L/min) (secondary endpoint).

Results

Twenty subjects were studied (mean age 68±8 years, 16 were men (80%), all had light skin pigmentation (Fitzpatrick skin scale 1 or 2) reflecting the local population, none had shock. At baseline, SpO_2 was 93.4±1.8% and oxygen flow was 2.1±1.4 L/min.

Oxygen flow requirements in the different study periods are displayed in the Figure 1. Differences in mean oxygen flow during monitoring with the Nonin with an SpO_2 target of 90% and Philips with an SpO_2 target of 94% were not statistically different (P=0.74). However, all other comparisons for the oxygen flow requirements were statistically different. The influence of the oximeter brand on oxygen flow was of similar amplitude as the influence of SpO_2 targets, as suggested by the oxygen ratio (Figure 1). For the same SpO_2 target, the oxygen flow was significantly increased by a factor three to four when using the Nonin oximeter in comparison with the Philips oximeter. With the same oximeter, the oxygen flow requirement was increased by a factor 3.6 to 4.7 with the SpO_2 target of 94% vs. 90%.

The combination of these factors resulted in greater discrepancies. Oxygen flow was reduced by a factor of 15 between the condition of a high SpO_2 target attained with an oximeter that underestimated oxygenation (Nonin-94%) and a low SpO_2 target attained with an oximeter that tended to overestimate oxygenation (Philips-90%). This study does not consider skin pigment as all subjects were light skinned.

The data concerning the impact of the tested SpO_2 targets and oximeter brands as well as the combination of both on arterial blood gases and short-term clinical outcomes are displayed in the Table1. The rate of complete oxygen weaning was 55% in the Philips-90% period and 0 to 5% in other periods, P<0.001. No subject had oxygen flow above 5L/min during the Philips-90% period, while eight (40%) had high oxygen flows (mean ±

SD of 10.9±5.5L/min) during the Nonin-94% period, P<0.001. Oxygenation parameters (SaO_2, PaO_2) were similar during Nonin-90% and Philips-94%. Conversely, there were statistically significant differences for oxygenation parameters and for other comparisons, including higher rate of occult hyperoxemia during the Nonin-94 period (Table 1).

Discussion

In a population of subjects requiring conventional oxygen therapy after cardiac surgery, the SpO_2 target, the oximeter brand and the two in combination had a major impact on oxygen utilization, oxygen weaning and occult hyperoxemia. The same patient might require 15 times more oxygen, depending on the choice of the SpO_2 target and oximeter brand. The impact of a 4% difference for the SpO_2 target and the oximeter brand had an equivalent impact on oxygen flow requirements. The SpO_2 target and the oximeter brand combined had at least additive effects. More than half of subjects were considered weaned from oxygen with one combination (Philips-90%) while almost half required high oxygen flows with another combination (Nonin-94%).

Although the impact of SpO_2 targets or oximeter brand has been overlooked, these data suggest that these simple parameters considered in isolation and more importantly in combination can have a relevant impact on day-to-day clinical management. These differences can alter important decisions related to hospital discharge, admission to intensive care or escalation of respiratory support (conventional oxygen to nasal high flow to intubation) as well as for clinical research, particularly if oxygen-free days are used to describe patient outcomes[1, 10]. It should be noted that all subjects in this study had light skin pigmentation and it is likely that in dark-skinned subjects the rate of oxygen weaning might be greater, as well as the incidence of occult hypoxemia[11].

The results found in the present study are in line with previous reports. In the present study, the bias between the two tested oximeters was the same as in a previous study with similar population (stable ICU subjects with light skin pigmentation)[7]. In addition, the impact on oxygen flow requirements with a 4% difference in the SpO_2 target was similar to what was found in a previous study[8]. No study previously reported the impact of the combination of these confounding factors on oxygen flow.

This study has some limitations. The study has a small sample size, however, the small number necessary to demonstrate an effect with the studied conditions, demonstrates that the effect is consistent for all subjects. We included only subjects with light skin pigmentation and the impact might have been different in other populations. It is likely that the occult hypoxemia would be more frequent in patients with dark skin pigmentation in the Philips 90 period. Finally, we only evaluated the short term effects of the outcome and hospital length of stay may be related to other clinical and biological determinants (respiratory rate, fever, inflammation parameters in the cases of pneumonia…).

This study shows that the choice of a SpO_2 target, of the oximeter brand and the combination of both have a clinically relevant impact, at least equivalent to the skin pigmentation factor. These data on oxygen use may also be significant during a pandemic[9] or in resource constrained environments. In many low-income and lower-middle-income countries, access to oxygen remains a difficult priority to ensure adequate treatment for patients with acute respiratory failure [12, 13].

These confounders can also have an impact in the context of research, where finding the optimal SpO_2 target appears to be a quest for the Holy Grail. The most recent randomized controlled studies evaluating different SpO_2 targets did not consider the confounding factors for SpO_2 measurements[1, 14]. If the targets of 90%, 94% or 98% are used undiscerningly, without consideration for oximeter brand or skin pigmentation, the impact on clinical management and on the results of clinical trials comparing different oxygenation targets may be conflicting.

These parameters alone or in combination have a significant impact on oxygen management and must be taken into account when the SpO_2 target is chosen for a given patient and for future research that seek optimal oxygenation targets in patients with

acute respiratory failure. When bias of individual oximeters are not considered, the difference in selected oxygen targets may result in similar SaO_2, defeating the objective of elucidating SpO_2 targets on outcomes in respiratory failure.

While the world is rightly concerned over inaccuracies related to skin pigment (which demonstrates social awareness and may exacerbate health inequities), errors induced by the oximeter used are equally important (but often ignored) and, together with skin pigment, magnify errors. The simplicity of oximetry use belies a plethora of confounding factors which are frequently not considered and have clinically important impact on patient management and outcomes in clinical trials[15].

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Figure Legend

Figure 1: Mean oxygen flow utilization in the different study conditions comparing two SpO_2 targets (90 and 94%) and two oximeters brand (Philips and Nonin): Philips 90, Nonin 90, Philips 94, and Nonin 94. SpO_2 targets of 90% are represented with hatched bars while SpO_2 targets of 94% are represented with plain bars. Nonin conditions are represented with blue bars while Philips conditions are represented with light orange bars. Oxygen Ratio were 1.2 (Philips 94/Nonin 90), 4.2 (Nonin90/Philips90), 3.1 (Nonin94/Philips94), 3.6 (Nonin94/Nonin90), 5.0 (Philips94/Philips90) and 15.3 (Nonin94/Philips90).

	Philips 90	Nonin 90	Philips 94	Nonin 94	P value[e]
O_2 flow[a] (L/min)	0.4±0.7	1.7±1.9	2.0±2.1	6.1±5.3	0.001
SpO_2 (%)	90.8±1.3[b]	89.9±1.1	94.0±1.1	94.1±0.6	<0.001
Arterial blood gases					
SaO_2 (%)	91.2±1.7	94.0±1.3	93.8±1.2	97.1±1.0	<0.001
PaO_2 (mmHg)	63.3±5.3	72.3±4.7	71.9±6.5	90.6±6.2	<0.001
$PaCO_2$ (mmHg)	40.2±4.5	40.7±4.6	40.5±4.2	41.0±4.5	0.30
Lactates (mmoles/L)	1.9±1.3	1.8±1.1	1.8±1.1	1.8±1.2	0.57
Other oxygenation and outcome parameters					
O_2 partial or complete weaning, n (%)	15 (75)	6 (30)	6 (30)	0 (0)	<0.001
O_2 complete weaning, n (%)	11 (55)	0 (0)	0 (0)	0 (0)	<0.001
O_2 > 5L/min, n (%)	0 (0)	2 (10)	3 (15)	8 (40)	<0.001
Occult hypoxemia[c], n (%)	3 (15)	0 (0)	0 (0)	0 (0)	NS
Occult hyperoxemia[d], n (%)	0 (0)	0 (0)	0 (0)	16 (80)	<0.001

Table 1: Results of oxygen flow, arterial blood gases and other oxygenation and outcome parameters at the end of each study period in the 20 included subjects. Results are expressed as mean±SD or n(%).

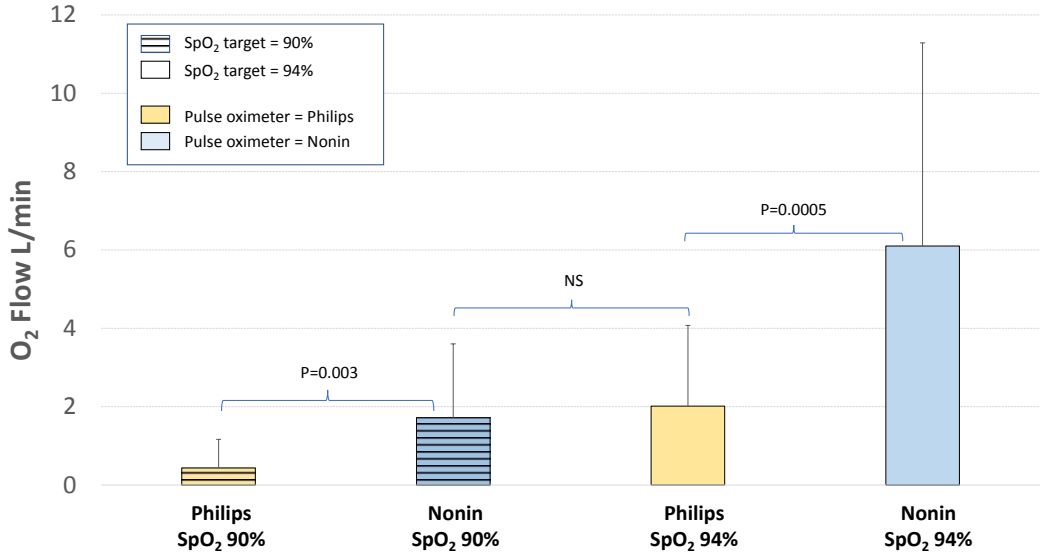
[a]Average of oxygen flow values at 8:00, 8:30, 9:00, 9:30 and 10:00 minutes for each study period

[b]11 subjects were weaned from oxygen in the period ''Philips 90'', with SpO_2 values above 90% without oxygen support

[c]Occult hypoxemia was defined as follow: SaO_2<90% and SpO_2≥90%

[d]Occult hyperoxemia was defined as follow: SaO_2>96% and SpO_2≤96%

[e]ANOVA with repeated measurements were used for continuous measurements and generalized linear mixed model for nominal data



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