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LETTER

ORI monitoring allows a reduction of time with hyperoxia in critically ill patients: the randomized control ORI^2 study

Sigismond Lasocki[*], Antoine Brochant, Maxime Leger, Thomas Gaillard, Pierre Lemarié, Soizic Gergaud and Pauline Dupré

Dear Editor,

After decades of fear of hypoxia, it is now widely accepted that hyperoxia is deleterious too [1, 2]. This is the rationale for recent recommendations to target peripheral oxygen saturation (SpO2) ≤ 96% [3]. However, SpO2 monitoring may not be sufficient since elevated partial arterial oxygen pressure (PaO2) is not recognized once SpO2 ≥ 98%, indeed, critically ill patients may spend as much as 60% of the time with hyperoxia [4]. The oxygen reserve index (ORI), measured non-invasively by a pulse-oximeter, correlates to elevated PaO_2 (for PaO2 > 80–100 mmHg [5]). We hypothesized that using ORI to set oxygen in critically ill patients would reduce the time with moderate hyperoxia ($PaO_2 \geq 100$ mmHg) compared to monitoring SpO2 (with upper limits) alone.

We randomized 150 adult patients, mechanically ventilated for a predictable duration ≥ 2 days to either ORI or control group (ClinicalTrial: NCT02878460; see esm). All the patients were monitored using Rainbow® pulse-oximeter sensors connected to ROOT monitors (MASIMO, USA). Nurses were instructed to decrease O2 rate when ORI was ≥ 0.01 (ORI group) or when SpO2 was ≥ prescribed upper limit (control group) (Supplementary Fig. 1e). Seventy-five patients were analyzed in the ORI group and 71 in the control group (Supplementary Fig. 2e). Patients in both groups were similar, except for the presence of shock at ICU admission (48 (64%) vs 32 (45%) in ORI and control groups, $p = 0.022$; Table 1e). Patients were most often admitted for urgent surgery and had frequent lung damage. The median duration of follow-up was similar (6 (2–13) vs 5 (2–16) days, $p = 0.71$). We analyzed 2455 arterial blood gasses, 1545 days and 36.929 h of oxygen therapy (medians 166 (56–306) vs 111 (40–396) h/patient for ORI and control groups, $p = 0.58$). ORI monitoring allowed a significant reduction in the percentage of days with hyperoxia (14 (0–33) vs 33 (11–56)% for ORI vs control, $p = 0.003$) without an increase in the percentage of days with hypoxia (Supplementary Fig. 3e). The percentage of time (in hours) spent with PaO2 ≥ 100 or ≥ 120 mmHg was also much lower using ORI (Table 1). We observed no statistically significant differences in mean daily PaO_2 or FiO_2, but the time spent with a FiO2 of 0.21 was greater in the ORI group (Table 1). There was no difference in any other clinical outcome.

The use of ORI monitoring to titrate oxygen rates allowed an important reduction of the time spent with hyperoxia compared with the use of SpO2 alone, probably because nurses are reluctant to decrease oxygen rates when SpO2 is in a normal range. A nurse-driven protocol to adjust FiO2 according to SpO2 was already in place in our unit, explaining why the percentage of time with hyperoxia we observed in the control group was much less than usually reported (30 vs 60%) [4]. This strategy to decrease oxygen rate according to ORI (which detects high PaO2) may thus be even more efficient in units where there is no protocol to adjust oxygen rates. SpO2 could remain a warning for hypoxia and ORI for hyperoxia. Larger studies are needed to evaluate the clinical benefit of this strategy.

*Correspondence: sigismond@lasocki.com
Département Anesthésie-Réanimation, UBL Université d'Angers, CHU Angers, 4 rue Larrey, 49933 Angers Cedex 9, France

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Table 1 Main outcomes

	ORI (*n* = 75)	Control (*n* = 71)	*p*
Primary outcomes			
Percentage of days with hyperoxia, %	14 (0–29)	28 (9–50)	0.003*
Number of days with hyperoxia	1 (0–2)	2 (1–3)	0.023
Secondary outcomes			
Percentage of days with hypoxia, %	12 (0–31)	5 (0–20)	0.31
Number of days with hypoxia	1 (0–3)	1 (0–2)	0.24
Number of days under oxygen therapy	7 (3–13)	5 (2–17)	0.78
ABG (number during follow-up)	14 (5–25)	10 (5–25)	0.82
Duration of oxygen therapy (hours)	166(56–306)	111(40–396)	0.58
Percentage of time (hours) with PaO2 ≥ 100 mmHg, %	7.4 (0–24.8)	17.3 (3.8–43.1)	0.0069
Percentage of time (hours) with PaO2 ≥ 120 mmHg, %	0 (0–7.2)	5.6 (0–18.1)	0.0037
Mean daily PaO2, mmHg	84 ± 25	83 ± 28	0.36
Mean FiO2/patient	0.32 (0.26–0.43)	0.36 (0.30–0.43)	0.07
Hours of MV under an FiO2 = 0.21, hours	0(0–34)	0(0–8)	0.0036
MV duration, days	6 (3–12)	4.5 (2–14)	0.45
MV free days at day 28, days	19 (2–25)	19 (0–25)	0.82
At least one atelectasis	22 (29)	18 (25)	0.59
VAP	18 (24)	24 (34)	0.19
ICU LOS, days	8 (4–17)	8 (5–17)	0.68
ICU mortality	16 (21)	17 (24)	0.84

Values are median (Q1–Q3), mean ± SD or *n* (%)

H hyperoxia defined as a PaO2 ≥ 100 mmHg, *h* hypoxia defined as a PaO2 < 60 mmHg, *ABG* arterial blood gases, *FiO2* fraction of inspired oxygen, *PaO2* arterial partial pressure of oxygen, *MV* mechanical ventilation, *VAP* ventilator-associated pneumonia, *ICU* intensive care unit, *LOS* length of stay

*$p < 0.0294$ considered significant according to Pocock's correction for intermediate analysis (see esm for methods)

Electronic supplementary material
The online version of this article (https://doi.org/10.1007/s00134-019-05732-9) contains supplementary material, which is available to authorized users.

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Compliance with ethical standards

Conflicts of interest
SL received speaking fees from MASIMO. All the other authors declare that they have no conflict of interest.

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References

1. Chu DK, Kim LH, Young PJ, Zamiri N, Almenawer SA, Jaeschke R, Szczeklik W, Schunemann HJ, Neary JD, Alhazzani W (2018) Mortality and morbidity in acutely ill adults treated with liberal versus conservative oxygen therapy (IOTA): a systematic review and meta-analysis. Lancet 391:1693–1705
2. Kilgannon JH, Jones AE, Parrillo JE, Dellinger RP, Milcarek B, Hunter K, Shapiro NI, Trzeciak S, Emergency Medicine Shock Research Network I (2011) Relationship between supranormal oxygen tension and outcome after resuscitation from cardiac arrest. Circulation 123:2717–2722
3. Siemieniuk RAC, Chu DK, Kim LH, Guell-Rous MR, Alhazzani W, Soccal PM, Karanicolas PJ, Farhoumand PD, Siemieniuk JLK, Satia I, Irusen EM, Refaat MM, Mikita JS, Smith M, Cohen DN, Vandvik PO, Agoritsas T, Lytvyn L, Guyatt GH (2018) Oxygen therapy for acutely ill medical patients: a clinical practice guideline. BMJ 363:k4169
4. Suzuki S, Eastwood GM, Peck L, Glassford NJ, Bellomo R (2013) Current oxygen management in mechanically ventilated patients: a prospective observational cohort study. J Crit Care 28:647–654
5. Applegate RL 2nd, Dorotta IL, Wells B, Juma D, Applegate PM (2016) The relationship between oxygen reserve index and arterial partial pressure of oxygen during surgery. Anesth Analg 123:626–633