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Apneic Oxygenation for Securing Tracheal Intubation in a Resource-Limited Setting: A Prospective Study at the Essos Hospital Center (Cameroon)

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Abstract **Original Research Article**

Background: Peri-intubation hypoxemia remains a frequent and potentially life-threatening complication of airway management, particularly in resource-limited settings. Apneic oxygenation has been proposed as a simple, low-cost strategy to extend safe apnea time during tracheal intubation. ***Materials and Methods:*** We conducted a prospective, controlled, before-after study in the operating theatre of Essos Hospital Center (Yaoundé, Cameroon) over a 4-month period. Adult patients undergoing elective or emergency tracheal intubation were enrolled. During the control phase, patients received standard preoxygenation alone. During the intervention phase, apneic oxygenation was systematically administered via nasal cannula at a flow rate of 10 L per minute during laryngoscopy. The primary outcome was the incidence of oxygen desaturation below 90%. Secondary outcomes included the lowest oxygen saturation during intubation, time to desaturation, and first-pass intubation success. ***Results****:* A total of 160 patients were included, with 80 patients in each phase. The incidence of desaturation below 90% was significantly lower in the intervention group than in the control group (9% vs. 28%; P<0.001). The median lowest oxygen saturation increased from 91% (interquartile range, 88 to 95) to 96% (interquartile range, 94 to 98) (P<0.001). The median safe apnea time increased from 65 to 110 seconds (P<0.001). First-pass success was higher in the intervention group, although the difference did not reach statistical significance (90% vs. 82%; P=0.12). ***Conclusion****:* Apneic oxygenation significantly reduces the risk of peri-intubation hypoxemia and prolongs safe apnea time. This simple and cost-effective intervention may represent a valuable strategy for improving airway safety, particularly in resource-limited settings.

Keywords: Apneic oxygenation, Peri-intubation hypoxemia, Tracheal intubation, Resource-limited settings, Patient safety, Preoxygenation.

INTRODUCTION

Securing tracheal intubation remains a critical challenge in anesthesiology and critical care, particularly in resource-limited settings where peri-intubation complications, notably hypoxemia, remain common. Peri-intubation hypoxemia is associated with substantial morbidity, including cardiac arrest, hypoxic brain injury, and increased mortality, underscoring the need for optimized oxygenation strategies during airway management [1,2].

Apneic oxygenation is based on the physiological principle of continuous oxygen diffusion into the alveoli in the absence of active ventilation, driven by a maintained alveolar-capillary gradient. This mechanism allows for the extension of safe apnea time and delays the onset of critical desaturation during airway instrumentation. Multiple studies, including systematic reviews and meta-analyses, have demonstrated that apneic oxygenation improves peri-intubation oxygen saturation and reduces the incidence of hypoxemia [3,4].

More recently, advances in oxygen delivery systems, particularly high-flow nasal oxygen, have further expanded the clinical applications of apneic oxygenation, showing improved oxygenation profiles in critically ill patients undergoing intubation [5]. Although apneic oxygenation has been extensively evaluated in high-income settings, data on its effectiveness and feasibility in low-resource environments, particularly in sub-Saharan Africa, remain limited. In this context, we conducted a prospective study to assess the impact of apneic oxygenation on the safety of tracheal intubation at the Essos Hospital Center.

Materials and Methods

Study Design and Setting

We conducted a prospective, quasi-experimental before–after study in the operating theatre of Essos Hospital Center (Yaoundé, Cameroon) over a 4-month period, from November 1, 2025, through February 28, 2026. The study was designed to assess the effect of apneic oxygenation on the safety of tracheal intubation under routine anesthetic conditions.

Participants

Consecutive adult patients (≥18 years of age) requiring tracheal intubation for elective or emergency procedures were eligible for inclusion. Exclusion criteria were a baseline oxygen saturation of less than 85% on room air, advanced pregnancy (third trimester), and any contraindication to nasal oxygen administration, including significant nasal obstruction or recent nasal surgery.

Intervention

During the control phase (November–December 2025), patients underwent standard pre-oxygenation with 100% oxygen delivered via a well-sealed face mask for 3 to 5 minutes before induction of anesthesia and laryngoscopy. During the intervention phase (January–February 2026), apneic oxygenation was systematically administered through a nasal cannula at a flow rate of 5 to 10 liters per minute. Oxygen delivery was initiated immediately after induction and maintained continuously throughout laryngoscopy until successful tracheal intubation. All intubations were performed by trained anesthesia providers according to institutional standards, using either direct or video laryngoscopy at the discretion of the operator.

Outcomes

The primary outcome was the incidence of oxygen desaturation below 90% at any point during the intubation procedure. Secondary outcomes included the lowest peripheral oxygen saturation (SpO_2) recorded during intubation, the time from induction to desaturation, the rate of successful intubation on the first attempt, and the occurrence of procedure-related adverse events, including severe hypoxemia (SpO_2 <80%), bradycardia, and cardiac arrest.

Statistical Analysis

Continuous variables are reported as medians with interquartile ranges and were compared using the Mann-Whitney U test. Categorical variables are presented as counts and percentages and were compared using the chi-square test or Fisher's exact test, as appropriate. All statistical tests were two-sided, and a *p* value of less than 0.05 was considered to indicate statistical significance. Analyses were performed with the use of SPSS software, version 26 (IBM).

Results

Study Population

A total of 160 patients were included in the analysis, with 80 patients assigned to the control phase and 80 to the intervention phase. Complete outcome data were available for all patients. Baseline sociodemographic and clinical characteristics were well balanced between groups, with no statistically or clinically meaningful differences, thereby supporting the internal validity of the before-after comparison. The sociodemographic and clinical characteristics of the study population are presented in Table 1.

Table I: Baseline Sociodemographic and Clinical Characteristics of the Study Population

Characteristic	Control (n=80)	Intervention (n=80)	Effect Size (95% CI)	p-value
Age - years (mean ± SD)	42.1 ± 15.2	41.3 ± 14.1	MD -0.8 (-5.6 to 4.0)	0.72
Female sex - n (%)	34 (42.5%)	36 (45.0%)	OR 1.11 (0.59-2.09)	0.77
BMI - kg/m² (mean ± SD)	25.1 ± 4.3	24.8 ± 4.1	MD -0.3 (-1.7 to 1.1)	0.65
Hypertension - n (%)	13 (16.3%)	12 (15.0%)	OR 0.91 (0.39-2.10)	0.84
Diabetes mellitus - n (%)	7 (8.8%)	6 (7.5%)	OR 0.84 (0.26-2.66)	0.77
Chronic kidney disease - n (%)	5 (6.3%)	6 (7.5%)	OR 1.21 (0.35-4.18)	0.77
Prior abdominal surgery - n (%)	17 (21.3%)	16 (20.0%)	OR 0.92 (0.43-1.98)	0.83
Prior orthopedic surgery - n (%)	10 (12.5%)	9 (11.3%)	OR 0.89 (0.33-2.37)	0.81
Emergency procedure - n (%)	22 (27.5%)	25 (31.3%)	OR 1.20 (0.61-2.36)	0.69
Baseline SpO_2 (%) - mean ± SD	97.2 ± 1.8	97.5 ± 1.6	MD +0.3 (-0.2 to 0.8)	0.24

Our findings demonstrated that 27.5% of patients in the control group experienced desaturation (<90%), compared with only 8.8% in the intervention group. Apneic oxygenation achieved an absolute risk reduction of 18.7% and a relative risk of 0.32. These differences were highly statistically significant ($p < 0.001$), indicating a robust and clinically meaningful benefit of the intervention (Table II).

Table II: Primary Outcome: Incidence of Peri-Intubation Hypoxemia

Outcome	Control (n=80)	Intervention (n=80)	Absolute Risk Difference (95% CI)	Relative Risk (95% CI)	Control SE	Intervention SE	*p*-value
SpO_2 desaturation <90% - n (%)	22 (27.5%)	7 (8.8%)	-18.7% (-30.5 to -6.9)	0.32 (0.15-0.68)	5.0%	3.1%	<0.001

Apneic oxygenation significantly improved oxygenation during intubation (table III). The median lowest SpO_2 increased from 91 % to 96 %, and the median time to desaturation was prolonged by 45 seconds, reflecting enhanced safety during apnea. The proportion of patients without desaturation (<90 %) rose from 72.5 % to 91.3 %, with a relative risk of 1.26 (95 % CI, 1.08-1.46), indicating a clinically meaningful benefit. Inclusion of mean values and standard errors further supports the robustness and reliability of these findings.

Table III: Secondary Outcomes: Oxygenation Dynamics

Variable	Control (n=80)	Intervention (n=80)	Effect Size (95% CI)	*p*-value
Lowest SpO_2 (%) - median [IQR]	91 [88–95]	96 [94-98]	Median difference ≈ +5 [3-7]	<0.001
Time to desaturation (s) - median [IQR]	65 [50–80]	110 [90-130]	Median difference ≈ +45 [30-60]	<0.001
No desaturation (<90%) - no. (%)	58 (72.5%)	73 (91.3%)	RR 1.26 (1.08-1.46), ARD 18.7% (6.9-30.5)	0.002
Mean lowest SpO_2 (%) - mean ± SD	90.8 ± 3.5	95.6 ± 2.4	MD +4.8 [3.9-5.7]	<0.001
SE of lowest SpO_2 (%)	0.39	0.27	-	-

Procedural outcomes were comparable between groups, indicating that the addition of apneic oxygenation did not compromise intubation conditions. The first-pass success rate increased from 82.5 % to 90.0 %, although this difference was not statistically significant (OR 1.91; 95 % CI, 0.74–4.92; *p*=0.12). Rates of difficult intubation and high Cormack-Lehane grades were similar, with overlapping confidence intervals, suggesting no clinically meaningful differences. Video laryngoscopy utilization and median duration of laryngoscopy were comparable, and additional metrics-including the mean number of attempts and operator-reported difficulty scores-confirmed procedural equivalence.

Table IV: **Procedural Outcomes and Intubation Conditions**

Variable	Control (n=80)	Intervention (n=80)	Effect Size (95% CI)	*p*-value
First-pass success n (%)	66 (82.5%)	72 (90.0%)	OR 1.91 (0.74-4.92)	0.12
Difficult intubation* - n (%)	12 (15.0%)	9 (11.3%)	OR 0.72 (0.28-1.88)	0.48
Cormack-Lehane grade III-IV - n (%)	11 (13.8%)	10 (12.5%)	OR 0.89 (0.36-2.21)	0.80
Use of video laryngoscopy - n (%)	18 (22.5%)	21 (26.3%)	OR 1.22 (0.57-2.59)	0.67
Duration of laryngoscopy (s) - median [IQR]	35 [28-45]	33 [25–42]	Δ median -2 s (-6 to +2)	0.18
Number of attempts - mean ± SD	1.18 ± 0.45	1.10 ± 0.31	MD -0.08 (-0.24 to +0.08)	0.32
Intubation difficulty score** - median [IQR]	3 [2-4]	3 [2-3]	Δ median -0.5 (-1 to 0)	0.21

*Defined as more than one laryngoscopy attempt.
**Standardized 1-5 Likert scale for operator-reported difficulty.

Adverse events were infrequent in both groups. Although the incidence of severe hypoxemia was lower in the intervention group, the confidence interval crossed unity, indicating statistical uncertainty. Other complications, including bradycardia and hypotension, were rare and comparable between groups. No increase in adverse events was observed with apneic oxygenation, supporting a favorable safety profile without evidence of harm.

Event	Control (n=80)	Intervention (n=80)	Absolute Risk Difference (95% CI)	Relative Risk (95% CI)	p-value*
Severe hypoxemia (<80%) - n (%)	8 (10.0%)	2 (2.5%)	-7.5% (-15.8 to 0.8)	0.25 (0.06-1.08)	0.05
Bradycardia n (%)	5 (6.3%)	3 (3.8%)	-2.5% (-10.4 to 5.4)	0.60 (0.15-2.39)	0.72
Hypotension - n (%)	9 (11.3%)	7 (8.8%)	-2.5% (-12.7 to 7.7)	0.78 (0.31-1.96)	0.79
Cardiac arrest - n (%)	1 (1.3%)	0 (0.0%)	-1.3% (-5.0 to 2.5)	-**	1.00

*p-values calculated using Fisher's exact test for all comparisons due to small event counts.
**Relative risk not estimated owing to zero events in the intervention group; estimation would be unstable and potentially misleading.

DISCUSSION

In this prospective, quasi-experimental study conducted in a resource-limited setting, the implementation of apneic oxygenation during tracheal intubation was associated with a substantial and clinically meaningful reduction in peri-intubation hypoxemia. The incidence of oxygen desaturation below 90% decreased from 27.5% to 8.8%, corresponding to an absolute risk reduction of 18.7% and a relative risk of 0.32. These findings are consistent across multiple oxygenation endpoints, including higher nadir SpO_2 values and prolonged safe apnea time, and were achieved without adversely affecting procedural conditions or increasing complications.

Our findings are concordant with a growing body of literature supporting the effectiveness of apneic oxygenation in airway management. Randomized and observational studies have demonstrated that nasal oxygen delivery during laryngoscopy can significantly reduce hypoxemia and prolong apnea tolerance [6-9]. For example, Semler *et al.,*reported improved oxygenation parameters in critically ill patients receiving apneic oxygenation, although the magnitude of benefit varied depending on baseline hypoxemia severity [6]. Similarly, Sakles *et al.,*observed a reduction in desaturation events during emergency intubations when apneic oxygenation was used [7]. More recent meta-analyses have confirmed these findings, indicating that apneic oxygenation reduces the risk of hypoxemia, particularly in high-risk populations [10,11]. However, heterogeneity across studies remains substantial, with some trials reporting modest or non-significant effects, especially in patients with severe shunt physiology or limited oxygen reserve [12]. In this context, the magnitude of effect observed in our study appears particularly notable and may reflect differences in baseline practices, patient selection, and protocol adherence.

The benefits of apneic oxygenation are grounded in well-established physiological principles. During apnea, continuous oxygen uptake from the alveoli creates a negative pressure gradient that facilitates passive oxygen flow from the upper airway to the lungs [13]. This mechanism allows oxygenation to be maintained despite the absence of active ventilation, thereby extending the duration of safe apnea. Our data demonstrate a median increase of 45 seconds in time to desaturation, which is clinically significant in the context of airway management. Even short extensions in apnea tolerance can reduce operator stress, improve first-pass success, and decrease the risk of catastrophic complications such as cardiac arrest [14]. The observed increase in the proportion of patients without desaturation further underscores the clinical relevance of this intervention.

Importantly, the use of apneic oxygenation did not adversely affect procedural conditions. First-pass success rates, laryngoscopic views, and intubation difficulty scores were comparable between groups. These findings are consistent with previous studies showing that apneic oxygenation does not interfere with airway visualization or technique [15,16]. Although a non-significant increase in first-pass success was observed, the study was not powered to detect differences in procedural outcomes. Nonetheless, the absence of any negative impact on intubation performance supports the integration of apneic oxygenation into routine practice.

The safety analysis revealed no increase in adverse events associated with apneic oxygenation. While the incidence of severe hypoxemia (<80%) was lower in the intervention group, the confidence interval crossed unity, reflecting limited statistical power for rare events. Rates of bradycardia, hypotension, and cardiac arrest were low and comparable between groups. These findings align with prior studies demonstrating the safety of apneic oxygenation, even in critically ill populations [17,18]. The absence of harm, combined with the observed benefits, supports a favorable risk–benefit profile.

A key strength of this study is its conduct in a low-resource environment, where airway management challenges are often compounded by limited equipment and staffing constraints. In such settings, simple, low-cost interventions can have a disproportionate impact on patient outcomes. Apneic oxygenation via standard nasal cannula requires minimal resources and can be readily implemented without advanced technology. Our findings therefore have important implications for global anesthesia practice, particularly in low- and middle-income countries, where hypoxemia remains a major contributor to perioperative morbidity and mortality [19,20].

CONCLUSION

The implementation of apneic oxygenation during tracheal intubation was associated with a substantial and clinically meaningful reduction in peri-intubation hypoxemia, accompanied by consistent improvements in oxygenation parameters. The intervention significantly increased the nadir oxygen saturation observed during intubation and prolonged the duration of safe apnea, thereby enhancing the physiological safety margin during airway management. Importantly, these benefits were achieved without any compromise in procedural performance, including first-pass success, laryngoscopic conditions, or perceived intubation difficulty. The absence of an increase in adverse events further supports the favorable safety profile of apneic oxygenation. Although the study was not powered to detect differences in rare complications, the direction of effect consistently favored improved

patient safety. These findings reinforce the physiological rationale underlying apneic oxygenation and are consistent with a growing body of evidence supporting its role in preventing critical desaturation. From a practical perspective, apneic oxygenation represents a simple, low-cost, and readily scalable intervention that requires minimal additional resources. Its integration into routine airway management protocols can be achieved without substantial organizational changes or the need for advanced equipment. This is particularly relevant in resource-limited settings, where the burden of hypoxemia-related complications remains high and access to sophisticated airway devices may be constrained.

LIMITATIONS

Several limitations should be acknowledged. First, the before–after design may be subject to temporal confounding and unmeasured biases, although baseline characteristics were well balanced and procedural variables were comparable. Second, the single-center nature of the study may limit generalizability. Third, the sample size, while adequate for the primary outcome, may have been insufficient to detect differences in rare adverse events or secondary procedural outcomes. Additionally, operator experience and adherence to the protocol, although standardized, may have varied and influenced outcomes. Finally, the study did not include patients with profound baseline hypoxemia, which may limit applicability to the most critically ill populations.

Conflict of Interest

The authors declare that they have no conflicts of interest relevant to this work.

Author Contributions

Serge NGA NOMO and Aristide KUITCHET conceived and designed the study. Cristela IROUME and Bonaventure JEMEA were responsible for data collection and verification. Serge NGA NOMO performed the statistical analysis and drafted the manuscript. All authors contributed to data interpretation, critically revised the manuscript for important intellectual content, and approved the final version for publication.

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