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ORIGINAL RESEARCH AIRWAY MANAGEMENT

The role of Oxygen Reserve Index (ORI) monitoring in optimizing apneic ventilation for laparoscopic cholecystectomy

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ABSTRACT

Background & objective: The Oxygen Reserve Index (ORI) is a non-invasive parameter utilizing multi-wavelength pulse co-oximetry. ORI can provide early warnings of deteriorating oxygenation before changes are reflected in SpO_2 levels. This study aimed to investigate the feasibility of non-ventilated intubation in patients undergoing cholecystectomy as a means to achieve safe intubation without nasogastric tube placement, with reduced trauma and cost, and improved time efficiency.

Methodology: After obtaining ethical committee approval and informed consent, 64 patients aged 18–60 years with ASA physical status I–II and Mallampati scores < 2 scheduled for cholecystectomy were enrolled. Standard monitoring was applied. Preoxygenation was performed using 100% oxygen with 8 breaths over 60 seconds, targeting an ORI value of 0.4. Patients were not ventilated by mask from induction to intubation. The ORI value at induction and at the 2nd minute (after allowing for muscle relaxation) were recorded. If the ORI dropped below 0.24 before the second minute, mask ventilation was initiated and the time was noted. Patients were evaluated for nasogastric tube requirement, surgeon satisfaction, and postoperative sore throat/laryngospasm. Correlations between ORI and BMI, age, and gender were analyzed.

Results: Based on the ORi™ threshold of 0.24, patients were divided into two groups: ORi™ < 0.24 and ORi™ ≥ 0.24. ROC analysis indicated threshold values of 80 kg for weight and 30 kg/m² for BMI. In the postoperative period, sore throat (30.8% vs. 2.6%) and laryngospasm (11.5% vs. 0%) were significantly higher in the ORi™ < 0.24 group. Regarding surgeon satisfaction, only 23.1% of surgeons were satisfied in the ORi™ < 0.24 group compared to 65.8% in the ORi™ ≥ 0.24 group, indicating significantly lower satisfaction in the former (P = 0.001).

Conclusion: We believe that apneic ventilation following induction may be safely applied in patients with BMI ≤ 30 when adequate preoxygenation is confirmed using ORI.

Abbreviations: FEV1: forced expiratory volume in one second, FVC: forced vital capacity, ORI: Oxygen Reserve Index

Keywords: Oxygen Reserve Index, apneic ventilation, body mass index

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1. INTRODUCTION

Arterial blood gas (ABG) analysis is the most definitive indicator of oxygenation status. However, its invasive nature limits its frequent use in clinical settings.[1] In high-risk populations—such as obese patients prone to rapid desaturation—accurate intraoperative monitoring of oxygenation status is essential. The use of the Oxygen Reserve Index (ORI) is particularly appropriate for obese patients, those in the Trendelenburg position, and during laparoscopic surgeries where the risk of atelectasis is high.[2] Desaturation is defined as a drop in oxygen saturation to < 90% from a baseline > 90%, or a further decline when the baseline is already < 90%.[3] During apnea, the rate of oxygen desaturation is influenced by hemoglobin concentration and the rate of oxygen consumption.[4] Saturation levels falling below 70% significantly increase the risk of arrhythmias, hemodynamic instability, hypoxic brain injury, and death.[5,6]

Obesity is a complex and chronic disease that significantly impacts respiratory physiology. It leads to increased work of breathing and reduced compliance of the chest wall. In morbidly obese individuals, there is a marked reduction in total lung capacity, vital capacity, forced expiratory volume in one second (FEV1), and forced vital capacity (FVC). Additionally, due to their elevated metabolic demands, these patients exhibit higher oxygen consumption rates.[7,8]

Pulse oximetry is a standard modality for perioperative monitoring. Its ability to detect hypoxemia is based on the hemoglobin–oxygen dissociation curve, offering around 90% sensitivity and specificity.

The Oxygen Reserve Index (ORi) (Masimo Corp., Irvine, CA, USA) is an advanced, continuous, and non-invasive parameter that provides a relative indication of arterial partial pressure of oxygen (PaO_2). Regression analyses have demonstrated a significant correlation between ORi and PaO_2, particularly when $PaO_2 \leq 240$ mmHg ($r^2 = 0.536$). An ORi value > 0.24 indicates a PaO_2 above 100 mmHg. ORi values range between 0 and 1 as PaO_2 increases from 80 to 200 mmHg. In contrast, SpO_2 cannot provide readings above 100%, even if PaO_2 is significantly elevated. Therefore, to more accurately assess a patient's oxygenation and prevent hypoxemia, it is recommended to use ORi alongside SpO_2.[8-10] Although ORi does not directly measure PaO_2, it can detect declines in oxygenation earlier than changes are seen in SpO_2 levels.

ORI monitoring can be particularly beneficial in patients at risk for inadequate preoxygenation, those with difficult mask ventilation, hypoxemic patients with aspiration risk, rapid sequence induction scenarios, obese individuals, ICU intubations, and invasive ventilation cases. It has also been shown to provide early warnings of desaturation in select patient groups, contributing to improved patient safety.[11-14]

Table 1: Demographic data of the population

Variables		Median (IQR) / n (%)
Age (years)		52 (39–60)
Gender	Female	45 (70.3)
	Male	19 (29.7)
ASA	1	16 (25)
	2	48 (75)
Allergy		10 (15.6)
Weight (kg)		80 (68.5–88.5)
Height, (cm)		162 (158–169)
BMI, (kg/m^2)		29.7 (25.8–33.05)
ORi^{TM} < 0.24		26 (40.6)

IQR: Interquartile range; BMI: Body mass index, ORi^{TM}: oxygen reserve index

2. METHODOLOGY

This prospective observational study was conducted with the approval of the Ethics Committee 2 of Ankara Bilkent City Hospital (E2-22-2605), and written informed consent was obtained from all participants. A total of 64 patients, aged between 18 and 60 years, classified as American Society of Anesthesiologists (ASA) physical status I–II, and with a Mallampati score < 2, who were scheduled for elective laparoscopic cholecystectomy, were enrolled.

On the day of surgery, following identity verification and confirmation of the surgical site, patients were positioned on a warmed operating table. Standard monitoring was applied, including ECG, non-invasive arterial blood pressure, peripheral oxygen saturation (SpO_2), and the Oxygen Reserve Index (ORI).

Preoxygenation was achieved by administering 100% oxygen via 8 deep breaths over 60 seconds. When the ORI value reached 0.4, intravenous anesthesia induction was initiated using propofol (2–2.5 mg/kg), fentanyl (1–2 µg/kg), and rocuronium (0.6–1.0 mg/kg). During muscle relaxation, patients were not ventilated via mask. The ORI value at the time of induction and at the 2nd minute post-induction was recorded. If the ORI dropped below 0.24 before the 2-minute mark, mask ventilation was initiated, and the time of intervention was noted. Endotracheal intubation was then performed using a standard, atraumatic technique after achieving adequate muscle relaxation.

Throughout the surgical procedure, hemodynamic parameters (blood pressure, heart rate, SpO_2) were

monitored and recorded every 5 minutes. Intra-abdominal pressure values were also monitored and documented. The duration of surgery was calculated in minutes, based on the recorded start and end times.

Surgeon satisfaction during the procedure was assessed using a 3-point Likert scale (0: not satisfied, 1: partially satisfied, 2: satisfied). In the postoperative period, patients were evaluated for sore throat and laryngospasm, which were recorded as binary outcomes (present/absent).

In addition, potential correlations between ORI values and demographic variables such as age, gender, and body mass index (BMI) were evaluated using statistical methods.

Statistical Analysis

Data distribution was assessed using the Shapiro-Wilk test to confirm non-parametric characteristics. Descriptive statistics were reported as median and interquartile range (IQR) for continuous variables, and as numbers and percentages for categorical variables. The Mann-Whitney U test was applied for non-normally distributed continuous variables. Categorical variables were analyzed using the chi-square test. Receiver operating characteristic (ROC) analysis was performed to identify cut-off points for continuous variables that were statistically significant. Sensitivity and specificity were calculated for variables converted into categorical form based on these cut-offs. $P < 0.05$ was considered statistically significant. Data analysis was performed using SPSS version 23.0 for Windows (SPSS Inc., Chicago, IL, USA).

Table 2: Vital parameters before and after endotracheal intubation

Variables	Before ETI	After ETI
ORi™	0.82 (0.64–1)	0.4 (0.29–0.61)
SpO_2 (%)	96 (95–98)	99 (98.5–100)
$EtCO_2$		36 (34–38.5)
MAP, (mmHg)	111 (101–124)	102 (89–118.5)
CPP	77 (67–86)	83 (72–92)

ETI:endotracheal intubation, IQR: Interquartile range, ORi: oxygen reserve index, MAP: mean arterial pressure, CPP: Cardiak peak pulse; Data is median (IQR)

Table 3: Univariate analysis of variables by group

Variables		0.24 ≤ ORi	ORi < 0.24	P-value
Age, (years)		51 (37–63)	52 (42–60)	0.944*
Gender	Female	26 (68.4)	19 (73.1)	0.689
	Male	12 (31.6)	7 (26.9)	
ASA	1	9 (23.7)	7 (26.9)	0.769
	2	29 (76.3)	19 (73.1)	
Allergy		4 (10.5)	6 (23.1)	0.174
Weight, (kg)		73 (67–83)	84 (74–98)	**0.01***
Height, (cm)		162 (157–165)	162 (160–171)	0.267*
BMI, (kg/m^2)		28.3 (25.1–31.9)	32.4 (29.3–34)	**0.015***
Operation time, (min)		47.5 (36–61)	57 (43–65)	0.155*
Intraabdominal pressure, (mmHg)		13 (12–13)	13 (12–14)	0.572*
Surgeons satisfaction		25 (65.8)	6 (23.1)	**0.001**
Sore throat		1 (2.6)	8 (30.8)	**0.001**
Laryngospasm		0 (0)	3 (11.5)	**0.032**

*Data presented as Median (IQR) or n (%); IQR: Interquartile range, ASA: American Society of Anesthesiologists, BMI: Body mass index, ORi™: oxygen reserve index, *Mann Whitney U test and chi-square test were performed; P < 0.05 considered statistically significant.*

Table 4: Receiver operating characteristic (ROC) analysis results

Variables	AUC (95% CI)	P-value
BMI (kg/m^2)	0.68 (0.542–0.818)	**0.015**
Weight (kg)	0.691 (0.557–0.825)	**0.01**

AUC: Area under curve, CI: Confidence interval, BMI: Body mass index

3. RESULTS

Among the patient population, 70.3% were female, and the median age was 52 years (IQR: 39–60). All patients were classified as ASA I (25%) or ASA II (75%). The median weight was 80 kg (IQR: 68.5–88.5), median height was 162 cm (IQR: 158–169), and median body mass index (BMI) was 29.7 kg/m^2 (IQR: 25.8–33.05).

Before endotracheal intubation, the median ORi™ was 0.82 (IQR: 0.64–1.0), oxygen saturation (SpO_2) was 96% (IQR: 95–98), mean arterial pressure (MAP) was 111 mmHg (IQR: 101–124), and heart rate was 77 bpm (IQR: 67–86). After intubation, median ORi™ decreased to 0.4 (IQR: 0.29–0.61), SpO_2 increased to 99% (IQR: 98.5–100), MAP was 102 mmHg (IQR: 89–118.5), heart rate

was 83 bpm (IQR: 72–92), and end-tidal CO_2 was 36 mmHg (IQR: 34–38.5) (Table 2). The median duration spent with ORi™ < 0.24 was 66 seconds (IQR: 31–79).

Patients were divided into two groups based on the ORi™ cut-off value of 0.24: ORi™ < 0.24 and ORi™ ≥ 0.24. In the ORi™ < 0.24 group, the median weight was 84 kg (IQR: 74–98) and the median BMI was 32.4 kg/m² (IQR: 29.3–34), whereas in the ORi™ ≥ 0.24 group, the median weight was 73 kg (IQR: 67–83) and the median BMI was 28.3 kg/m² (IQR: 25.1–31.9). There were statistically significant differences between the two groups in terms of weight (P = 0.01)

Postoperative sore throat (30.8% vs. 2.6%) and laryngospasm (11.5% vs. 0%) were significantly more common in the ORi™ < 0.24 group. Surgeon satisfaction was reported in 23.1% of cases in the ORi™ < 0.24 group compared to 65.8% in the ORi™ ≥ 0.24 group, indicating significantly lower satisfaction in the former (P = 0.001) (Table 3).

According to ROC analysis, based on the ORi™ < 0.24 threshold, the optimal cut-off values were identified as >80 kg for weight and ≥ 30 kg/m² for BMI. The area under the curve (AUC) for BMI was 0.68 (95% CI: 0.542–0.818, P = 0.015) and for weight was 0.691 (95% CI: 0.557–0.825, P = 0.01) (Table 4).

4. DISCUSSION

In our study, it was found that apneic ventilation can be safely performed in patients with a BMI ≤ 30 without the ORI value dropping below 0.24. In cases where the ORI remained above 0.24 until intubation—without the need for mask ventilation or orogastric tube placement—surgeon satisfaction was higher. Additionally, the incidence of laryngospasm and sore throat was significantly lower in these patients.

Postoperative laryngospasm occurred in three patients. All of them underwent NG ventilation and were switched to mask ventilation. Their BMIs were 30.7, 29.7, and 34. One of these patients also had a diagnosis of allergy. All four patients had postoperative sore throats and were also switched to mask ventilation and NG ventilation. Based on this information, we suspected that laryngospasm in these patients was triggered by NG exposure.

In 17 patients using this technique, NG was placed, but due to surgeon dissatisfaction, NG was performed in only 3 patients. In the 14 patients who received NG despite not masking and using this technique, surgical satisfaction was high, but NG was performed due to postoperative follow-up and routine clinical trends.

Consistent with previous studies in the literature that evaluated the efficiency of preoxygenation using ORI, our study also monitored preoxygenation and apneic ventilation through ORI.[1] Preoxygenation is typically used as a preventive measure against apnea. Baraka et al. (1999) reported that tidal volume breathing for 3–5 minutes is more effective than deep breathing for 30 seconds.[15]

Yoshida et al. (2018) demonstrated that monitoring ORI during apneic ventilation for rapid sequence induction (RSI) could predict a decline in oxygenation approximately 30 seconds before a drop in SpO_2 occurred.[16] Considering that apneic ventilation is a key component of RSI, the use of ORI monitoring may help reduce hypoxemia-related complications during RSI.

In our study, the ORI dropped below the 0.24 cutoff value at a median of 66 seconds (IQR: 31–79). Among patients whose ORI fell below this threshold, the median BMI was 32.4 (IQR: 29.3–34). In the literature, Tsymbal et al. (2021) reported that in obese patients, the time to drop below an ORI of 0.24 was significantly shorter than in patients with normal BMI—54.0 seconds (IQR: 38.0–74.0), P < 0.0001.[2]

It has been proposed that the use of ORI in the management of obese patients may help prevent complications associated with hypoxia, as ORI provides earlier warnings compared to conventional pulse oximetry.[2] In our study, we also observed that ORI offered early warning during apneic ventilation phases in the anesthetic management of obese patients, supplementing SpO_2.

According to regression analysis in our study, a BMI < 30 was identified as the safe threshold for apneic ventilation.

Based on these findings, we recommend the use of ORI monitoring to ensure safe apneic ventilation in non-obese patients (BMI < 30), which may reduce the incidence of laryngospasm and sore throat, improve patient satisfaction, and minimize gastric distension—thereby enhancing surgical comfort.

5. Strengths & Limitations

Our study is the first in the literature to define a safe BMI threshold for apneic ventilation and is also the first to recommend apneic ventilation to enhance patient and surgeon comfort during laparoscopic cholecystectomy—a common and frequently performed surgery. However, a major limitation of this study is the relatively small sample size. We recommend a multi-center study with a larfer sample size to further validate the findings.

6. CONCLUSION

In the critical management of anesthesia, particularly during apneic ventilation phases, the use of ORI in

addition to SpO_2 can enhance safety and monitoring effectiveness.

Our findings suggest that in patients with a BMI below 30, ORI-guided apneic ventilation is a safe approach. It reduces complications such as sore throat and laryngospasm, improves patient satisfaction, and prevents gastric distension—thereby contributing to greater surgical comfort.

7. Data availability

The numerical data generated during this research is available with the authors.

8. Conflict of interest

All authors declare that there was no conflict of interest.

9. Funding

The study utilized the hospital resources only, and no external or industry funding was involved.

10. Ethical considerations

This research was carried out following the principles of the Declaration of Helsinki and was ethically approved by the Ethics Committee 2 of Ankara Bilkent City Hospital (E2-22-2605),
Before joining the study, all participants provided written informed consent. They were fully briefed on the study's goals, risks, procedures, and benefits.

11. Authors' contribution

All authors took part in the concept, methodology, data collection, statistical analysis and manuscript preparation.
All authors have read the manuscript and approved the final draft.

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