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Early Oxygen Saturation Index Within the First 24 Hours and Subsequent Need for Invasive Respiratory Support in Infants ≥34 Weeks' Gestation

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Abstract

Aim: Early identification of late preterm and term infants with respiratory distress who will require invasive respiratory support (IRS) remains challenging. This study evaluated whether early oxygen saturation index (OSI) values, particularly the maximum value within the first 24 hours, were associated with the subsequent need for IRS in infants born at ≥34 weeks' gestation.

Study Design: This retrospective cohort study included 192 neonates admitted between January 2021 and December 2022. Admission OSI and maximum OSI within the first 24 hours were analyzed. The primary outcome was the need for the IRS.

Results: IRS was required in 22 of 192 infants (11.5%) at a median of 22 hours (interquartile range [IQR]: 10–39.5) after admission. Infants requiring IRS had higher admission and maximum OSI values than those managed non-invasively ($p=0.007$ and $p<0.001$, respectively). Receiver operating characteristic (ROC) analysis identified a cut-off value of 1.8 for admission OSI (area under the curve [AUC]: 0.673, 95% confidence interval [CI]: 0.544–0.821) and 2.84 for maximum OSI (AUC: 0.988, 95% CI: 0.975–1.000), with maximum OSI demonstrating greater discriminative performance.

Conclusions: Higher early OSI values, particularly the maximum value within the first 24 hours, were associated with the subsequent need for invasive respiratory support in late preterm and term infants with respiratory distress. However, given its temporal relationship to clinical deterioration, maximum OSI may reflect evolving respiratory compromise and should therefore be interpreted as a non-invasive marker of respiratory failure rather than an independent predictor of intubation. Prospective validation is warranted.

Keywords: Late preterm infant; non-invasive monitoring; oxygen saturation index; respiratory distress; term infant.

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Introduction

Late preterm and term infants account for a substantial proportion of neonatal intensive care unit (NICU) admissions, with respiratory distress being one of the leading causes of hospitalization.[1-3] These infants frequently require respiratory support because of various pulmonary and extrapulmonary conditions, including airway, cardiovascular, thoracic, and neuromuscular disorders.[3]

Respiratory failure is a common complication in this population[3] and is characterized by clinical signs of respiratory distress accompanied by hypoxemia, hypercarbia, and respiratory acidosis. Assessment relies on clinical evaluation, blood gas analysis, and imaging. Among objective measures, the oxygenation index (OI) is widely used to define and grade the severity of respiratory failure in NICUs.[4] However, OI requires arterial blood sampling, limiting its use for continuous or repeated monitoring.

The oxygen saturation index (OSI), calculated using mean airway pressure (MAP), fraction of inspired oxygen (FiO_2), and oxygen saturation (SpO_2), has been proposed as a non-invasive surrogate for OI.[5-8] Because these parameters are readily available at the bedside, OSI enables continuous assessment, although its accuracy may be affected by factors influencing SpO_2 measurements, such as motion artifacts or variations in perfusion.

Previous studies have demonstrated a strong correlation between OSI and OI in neonates receiving respiratory support.[6,7,9-11] However, most data are derived from mechanically ventilated populations, and evidence regarding the utility of OSI in infants managed with non-invasive respiratory support remains limited.

In clinical practice, escalation to invasive respiratory support is based on a combination of oxygen requirements, work of breathing, and the patient's overall clinical condition. In this context, OSI may provide a supportive, standardized parameter for early risk stratification. Therefore, this study aimed to evaluate whether early OSI values, particularly the maximum value within the first 24 hours, were associated with the subsequent need for invasive respiratory support (IRS) in late preterm and term infants with respiratory distress.

Materials and Methods

Study Design and Population

This retrospective cohort study included 192 neonates born at ≥34 weeks' gestation who were admitted to the tertiary NICU of a university hospital between January 2021 and December 2022 because of respiratory distress. Infants were categorized according to the type of respiratory support received into those managed with non-invasive respiratory support (NRS) and those who subsequently required IRS.

In this study, NRS was defined as non-invasive positive-pressure respiratory support, including nasal continuous positive airway pressure (nCPAP) and non-invasive positive-pressure ventilation (NIPPV).

The exclusion criteria were intubation within the first postnatal hour because of severe respiratory compromise, major congenital anomalies, intubation performed solely for surgical procedures, and oxygen therapy without applied positive pressure (e.g., oxygen delivered via an oxygen hood or nasal cannula without distending pressure).

Newborns were admitted to the NICU if they were unable to maintain oxygen saturation >94% without supplemental oxygen at two hours of life or exhibited clinical signs of respiratory distress (tachypnea, retractions, grunting, or cyanosis). Arterial or venous blood gas analysis was performed on admission and subsequently as clinically indicated rather than at fixed intervals.

Non-Invasive Respiratory Support and Devices

Non-invasive respiratory support was delivered according to the unit protocol using either nCPAP or NIPPV. nCPAP was provided using ventilators (Sophie, Stephan, Germany) or an Infant Flow Driver system (Viasys, CareFusion, USA). NIPPV was delivered using ventilators (Sophie, Stephan, Germany). The choice of modality and ventilator settings was at the discretion of the attending neonatologist based on the infant's clinical condition.

Calculation of OSI

OSI was calculated using the following formula:

$$OSI = (MAP \times FiO_2 \times 100) / SpO_2$$

For infants receiving nCPAP, the applied positive end-expiratory pressure (PEEP) was used as a surrogate for MAP. For those receiving NIPPV,

MAP was calculated using the standard equation: MAP = [(Inspiratory Time × Peak Inspiratory Pressure [PIP] + Expiratory Time × PEEP)] / (Inspiratory Time + Expiratory Time)

OSI values were calculated retrospectively using simultaneously recorded SpO_2, MAP, and FiO_2 data extracted from patient monitoring and ventilator records.

Criteria for Invasive Respiratory Support

The decision to initiate IRS was based on a combination of clinical assessment and blood gas parameters, including respiratory acidosis (pH <7.25 with $PaCO_2$ >60 mmHg), PaO_2 <50 mmHg despite FiO_2 >0.5, persistent or worsening respiratory distress requiring FiO_2 >0.5, and significant apnea requiring intervention.

All decisions regarding escalation to IRS were made by the attending neonatologists and were not guided by OSI values. Instead, OSI was evaluated retrospectively as a standardized composite parameter reflecting oxygenation status and respiratory support intensity.

In the study cohort, infants requiring IRS were intubated at a median of 22 hours (interquartile range [IQR]: 10–39.5) after admission. To ensure temporal relevance, only OSI values obtained within the first 24 postnatal hours were analyzed.

Data Collection

Demographic characteristics, antenatal and perinatal history, and clinical diagnoses were obtained from medical records. Admission OSI and maximum OSI were analyzed. Maximum OSI was defined as the highest OSI value recorded within the first 24 postnatal hours. For infants intubated during this period, only pre-intubation OSI values were considered; post-intubation measurements were excluded.

For infants who underwent arterial blood gas analysis, PaO_2, the PaO_2/FiO_2 ratio, OI, and the Score for Neonatal Acute Physiology with Perinatal Extension II (SNAPPE-II) [12] were recorded. OSI values corresponding to the time of blood gas sampling were used for correlation analyses.

Congenital pneumonia was diagnosed based on early-onset respiratory distress, radiographic findings consistent with pneumonia, and the clinical decision to initiate antibiotic therapy. Given the potential overlap with transient tachypnea of the newborn, this diagnosis was based on clinical judgment, which is acknowledged as a study limitation.

Statement of Ethics and Consent

The study was conducted in accordance with the Declaration of Helsinki and approved by Ankara University Human Research Ethics Committee (Approval Number: İ07-727-25, Date: 16.09.2025). The requirement for informed consent was waived by the ethics committee because of the retrospective study design.

Statistical Analysis

Data were analyzed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as means ± standard deviations or medians (IQRs), as appropriate, and categorical variables as counts and percentages. Group comparisons were performed using the chi-square test or Fisher's exact test for categorical variables and Student's t-test or the Mann–Whitney U test for continuous variables, depending on the distribution assessed using the Shapiro–Wilk test.

Receiver operating characteristic (ROC) curve analysis was used to evaluate the ability of OSI to discriminate between infants who required IRS and those who did not, and the area under the curve (AUC) was calculated. Optimal cut-off values were determined using the Youden index. In a subset of infants with arterial blood gas measurements, the relationships between OSI and both OI and the PaO_2/FiO_2 ratio were assessed using Spearman's correlation coefficient. A p-value <0.05 was considered statistically significant.

Results

Study Population

During the study period, 312 neonates born at ≥34 weeks' gestation were admitted to the NICU with respiratory distress. Of these, 120 were excluded: 33 were intubated within the first postnatal hour, 56 were intubated because of congenital anomalies or surgical interventions, and 31 had mild respiratory distress requiring only supplemental oxygen or heated, humidified high-flow nasal cannula support without measurable MAP (Fig. 1). The final cohort included 192 infants, of whom 170 (88.5%) were managed with non-invasive respiratory support and 22 (11.5%) required invasive respiratory support. Infants in the IRS group were intubated at a median of 22 hours after admission (IQR: 10–39.5). Of the total cohort, 68 infants (35%) were born at <37 weeks' gestation, 122 (63.5%) were male, and 152 (79%) were delivered by cesarean section. A complete course of antenatal corticosteroids was documented in 7% of infants.

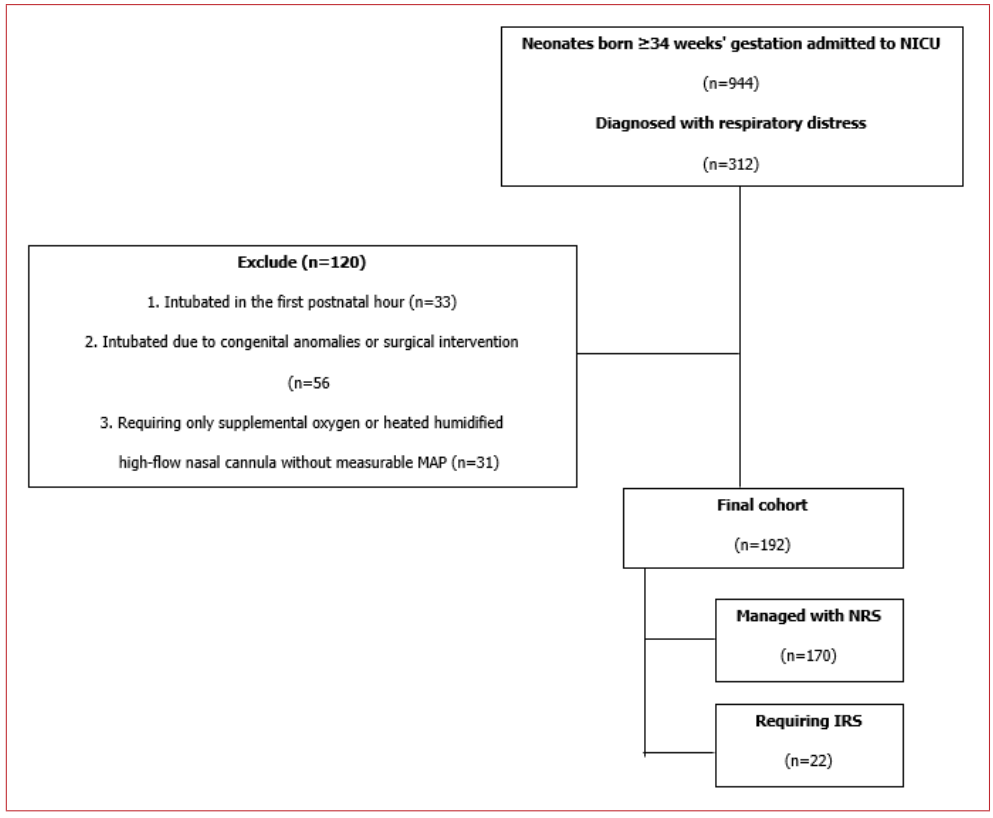


Figure 1. Study flowchart.

Diagnoses

Among infants managed with NRS, 79% were diagnosed with transient tachypnea of the newborn (TTN) and 21% with congenital pneumonia; three infants also had pneumothorax. In the IRS group, 91% were diagnosed with congenital pneumonia and 9% with TTN. One infant with congenital pneumonia received inhaled nitric oxide for persistent pulmonary hypertension of the newborn, and five developed pneumothorax. Some infants had more than one diagnosis. Baseline maternal and perinatal characteristics did not differ significantly between groups ($p>0.05$) (Table 1).

Oxygen Saturation Index and Outcomes

Infants requiring IRS had higher admission and maximum OSI values within the first 24 hours, as well as longer hospital stays, than those managed with NRS (all $p<0.01$) (Table 1).

Arterial Blood Gas Subset

Among the 49 infants who underwent arterial blood gas analysis, SNAPPE-II scores (median: 5, IQR: 5–25 vs. median: 5, IQR: 0–5; $p=0.032$) and mean oxygenation index values (8.93±3.47 vs. 2.63±1.22; $p<0.001$) were higher in the IRS group, whereas the PaO_2/FiO_2 ratio was lower (117±35 vs. 241±92; $p=0.001$) (Table 1). OSI showed a strong positive correlation with OI ($\rho=0.743$) and a moderate inverse correlation with the PaO_2/FiO_2 ratio ($\rho=-0.570$).

Discriminative Performance of OSI

Admission OSI showed limited discrimination for IRS at a cut-off value of 1.8 (AUC: 0.673, 95% confidence interval [CI]: 0.544–0.821; sensitivity: 64%; specificity: 66%). Maximum OSI demonstrated high discriminative performance at a cut-off value of 2.84 (AUC: 0.988, 95% CI: 0.975–1.000; sensitivity: 95.5%; specificity: 96.5%) (Table 2).

Discussion

In this study, maximum OSI within the first 24 postnatal hours demonstrated substantially greater discriminative performance for the subsequent invasive respiratory support than admission OSI in infants born at ≥34 weeks' gestation with respiratory distress. Although admission OSI showed modest discrimination, maximum OSI was more closely associated with the evolving clinical course, suggesting that the timing of OSI assessment is important when evaluating respiratory deterioration.

Table 1. Comparison of baseline characteristics between the noninvasive respiratory support (NRS) and invasive respiratory support (IRS) groups

	NRS (n=170, 88.5%)	IRS (n=22, 11.5%)	p
Gestational age of 34–37 weeks (n, %)[a]	62 (36.5)	6 (27.3)	0.396
Birth weight (g) (mean±SD)[b]	3011±620	3157±472	0.258
Male sex (n, %)[a]	105 (61.8)	17 (77.3)	0.155
Cesarean delivery (n, %)[a]	135 (79.4)	17 (77.3)	0.784
Complete course of antenatal corticosteroids (n, %)[a]	12 (7.1)	1 (4.5)	1.000
Maternal hypertension (n, %)[a]	8 (4.7)	2 (9.1)	0.321
Gestational diabetes mellitus (n, %)[a]	17 (10.0)	2 (9.1)	1.000
Congenital pneumonia (n, %)[a]	35 (20.6)	20 (90.9)	**<0.001**
Pneumothorax (n, %)[a]	3 (1.8)	5 (22.7)	**0.001**
OSI at admission (mean±SD)[b]	1.65±0.49	2.03±1.39	**0.007**
Maximum OSI[c] (mean±SD)[b]	1.68±0.52	4.93±2.19	**<0.001**
SNAPPE-II score (median, IQR)[b] (n=49)[d]	5 (0–5) (n=44)	5 (5–25) (n=5)	**0.032**
PaO_2/FiO_2 ratio (mmHg; mean±SD)[b] (n=49)[d]	241±92 (n=44)	117±35 (n=5)	**0.001**
OI (mean±SD)[b] (n=49)[d]	2.63±1.22 (n=44)	8.93±3.47 (n=5)	**<0.001**
Length of hospital stay (median, IQR)[b]	4 (2–7)	10 (8–13)	**<0.001**

[a] Chi-square test/Fisher's exact test; [b] Mann–Whitney U test/Student's t-test. [c] Maximum OSI was determined using measurements obtained before intubation or within the first 24 hours of hospitalization. [d] Assessed in the subset of 49 patients who underwent arterial blood gas analysis. NRS: Noninvasive respiratory support; IRS: Invasive respiratory support; TTN: Transient tachypnea of the newborn; OSI: Oxygen saturation index; SNAPPE-II: Score for Neonatal Acute Physiology with Perinatal Extension II; PaO_2/FiO_2: Ratio of arterial partial pressure of oxygen to fraction of inspired oxygen; OI: Oxygenation saturation index.

Table 2. Discriminative performance of oxygen saturation index (OSI) for the subsequent need for invasive respiratory support

	Cut-off value	Sensitivity	Specificity	AUC (95% CI)
Admission OSI	1.8	64%	66%	0.673 (0.544–0.821)
Maximum OSI[a]	2.84	95.5%	96.5%	0.988 (0.975–1.000)
SNAPPE-II score (n=49)[b]	14	40%	95.5%	0.759 (0.548–0.970)
PaO_2/FiO_2 ratio (mmHg; n=49)[b]	157.5	80%	91%	0.964 (0.908–1.000)
OI (n=49)[b]	5.195	100%	95.5%	0.986 (0.958–1.000)

[a] Maximum OSI was defined as the highest value recorded within the first 24 hours of hospitalization or before intubation, whichever occurred first. [b] Analyses were restricted to the 49 infants who underwent arterial blood gas analysis. AUC: Area under the receiver operating characteristic curve; CI: Confidence interval; OSI: Oxygen saturation index; SNAPPE-II: Score for Neonatal Acute Physiology with Perinatal Extension II; PaO_2/FiO_2: Ratio of arterial partial pressure of oxygen to fraction of inspired oxygen; OI: Oxygenation index.

Although transient tachypnea of the newborn typically resolves with supportive care,[13] a subset of infants may develop progressive respiratory failure requiring invasive respiratory support.[14] Established perinatal risk factors, such as late preterm birth, male sex, and cesarean delivery, are associated with respiratory morbidity but lack sufficient discriminatory power to guide real-time decisions regarding escalation of respiratory support.[15] Antenatal corticosteroid administration has been shown to reduce respiratory support requirements in late preterm infants.[16,17] In our cohort, baseline characteristics and antenatal corticosteroid exposure were comparable between the groups, underscoring the limited predictive value of demographic variables alone. Although congenital pneumonia was more frequently diagnosed in the IRS group, this may reflect diagnostic reassignment following clinical deterioration and the initiation of antibiotic therapy rather than a true early predictor.

Several invasive oxygenation indices, including OI, the alveolar–arterial oxygen gradient (A–aDO2), the arteri-

al-to-alveolar oxygen ratio (a/A ratio), and the PaO_2/FiO_2 ratio, have demonstrated predictive utility for respiratory failure.[4,18,19] However, their dependence on arterial blood sampling limits their applicability for continuous bedside monitoring. In contrast, OSI offers a non-invasive, continuously available surrogate measure of oxygenation derived from routinely monitored parameters.

Previous studies have consistently demonstrated strong correlations between OSI and OI in mechanically ventilated neonates.[6,7,9-11,19-21] Muniraman et al.[7] reported robust agreement across more than 1,400 paired measurements, and similar findings have been confirmed in both preterm and term populations. Nevertheless, most previous investigations evaluated OSI primarily as a surrogate for invasive oxygenation indices rather than as a marker of impending escalation from non-invasive to invasive respiratory support.

Our findings extend this evidence by evaluating OSI in late preterm and term infants initially managed with non-invasive respiratory support. We observed that maximum OSI within the first 24 postnatal hours demonstrated strong discrimination for subsequent intubation. Although admission OSI showed modest discriminative performance, the highest OSI value recorded within the first 24 hours provided substantially greater discrimination. These findings suggest that early oxygenation trends may better reflect evolving respiratory compromise than a single admission measurement.

The relatively high discriminative performance observed for maximum OSI should be interpreted in the context of its temporal proximity to clinical deterioration. Importantly, OSI measurements were restricted to the pre-intubation period. However, because maximum OSI was defined as the highest value recorded within the first 24 postnatal hours, with only pre-intubation measurements considered for infants intubated during this period, it may have been obtained shortly before escalation to invasive support. Thus, maximum OSI may partly reflect both physiological deterioration and clinically driven increases in FiO_2 and airway pressure. Accordingly, maximum OSI should be interpreted as a non-invasive marker of evolving respiratory failure rather than an independent or long-range predictor of intubation. Prospective validation in independent cohorts is needed to confirm the stability of the proposed cut-off value and evaluate its performance across diverse clinical settings.

This study has several limitations. Its retrospective, single-center design may limit generalizability, and the relatively small number of intubation events may reduce the precision of the estimated OSI cut-off value. The classifications of congenital pneumonia may have been influenced by post-intubation management decisions. When PEEP was used as a surrogate for MAP during nCPAP, minor discrepancies between set and delivered airway pressures may have occurred, particularly in the presence of mouth leaks. However, OSI values were calculated using contemporaneously recorded monitoring and ventilator parameters and were not used to guide clinical decision-making, reducing the risk of incorporation bias.

Conclusion

Maximum OSI within the first 24 postnatal hours demonstrated good discriminative ability for identifying late preterm and term infants with respiratory distress who subsequently required invasive ventilation. As a simple, non-invasive parameter that can be monitored continuously, OSI may complement clinical assessment and help identify evolving respiratory deterioration. Larger prospective multicenter studies are needed to determine whether OSI-guided monitoring strategies could improve the timing of escalation to invasive respiratory support.

Ethics Committee Approval: Ethics committee approval was obtained from Ankara University Human Research Ethics Committee (Approval Number: İ07-727-25, Date: 16.09.2025).

Informed Consent: The requirement for informed consent was waived by the ethics committee because of the retrospective study design.

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