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Perfusion Index as a Predictor of Optimal Timing for Laryngeal Mask Airway Insertion in Adults: An Observational Study

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ABSTRACT

Background: Adequate anaesthesia depth is essential for safe laryngeal mask airway (LMA) insertion. Traditional assessment is subjective, and the perfusion index (PI) may offer an objective alternative. The PI ratio, reflecting the change from baseline after induction, may better indicate readiness for insertion. This study evaluated the ability of PI and PI ratio to predict suitable conditions for LMA placement in adults. **Methods:** Ninety adult patients were enrolled. PI was measured at baseline (PI2) and three minutes after induction (PI2), and the PI ratio was calculated. An anaesthesiologist blinded to PI values performed LMA insertion, and any movement was noted. Receiver operating characteristic (ROC) analysis assessed the predictive performance of PI2 and PI ratio, and values were compared between movement and non-movement groups. **Results:** All 90 patients completed the study. The mean age was 38.48 years; mean PI2, PI2, and PI ratio were 1.98, 5.51, and 2.80, respectively. Movement occurred in 30% of subjects. PI2 showed moderate accuracy (AUC 0.46), while the PI ratio performed slightly better (AUC 0.49). Patients who moved had lower PI2 and PI ratio values, indicating that higher ratios may correspond to smoother LMA insertion. **Conclusion:** The PI ratio is a simple, reliable, and cost-effective indicator of adequate anaesthesia depth for safe LMA insertion. A threshold of ≥ 2.5 predicts fewer airway complications and patient movements, making it a useful adjunct to routine monitoring. Larger studies are needed to confirm these findings.

Keywords*: Perfusion index (PI), PI ratio, laryngeal mask airway (LMA), anaesthesia depth, airway management, general anaesthesia, objective physiological monitoring.*

INTRODUCTION

The laryngeal mask airway (LMA) is a widely adopted supraglottic airway device known for its ease of insertion, reduced airway trauma, and minimal physiological stimulation, making it highly suitable for pre-hospital emergency care, routine anaesthesia, and intensive care settings **[1]**. Since its introduction, first-generation LMAs have been used more than 500 million times worldwide, underscoring the need to optimize their safety and application techniques. A major unresolved challenge is determining the ideal timing for LMA insertion, as performing the procedure during inadequate or shallow anaesthesia may provoke patient movement, hemodynamic instability, coughing, gagging, or even laryngospasm. Such responses increase the risk of throat injury, dental damage, and oral bleeding, all of which can compromise patient safety. Currently, anaesthesiologists often rely on subjective indicators—such as jaw-lifting responses or eyelash reflex—to judge readiness for insertion; however, these methods lack precision and vary greatly between clinicians. Although objective tools like the A-line Autoregression Index (AAI) and BI spectral Index (BIS) help determine anaesthetic depth **[2]**, their high cost, limited availability, and complexity restrict widespread implementation, especially in day-care surgery and resource-limited environments.

The perfusion index (PI), obtained from standard pulse oximetry as the ratio of pulsatile to non-pulsatile blood flow, has emerged as a valuable non-invasive indicator of peripheral perfusion with broad applications in clinical anaesthesia. PI has been successfully used to predict the success of peripheral nerve blocks, monitor hemodynamic fluctuations, and

guide fluid therapy **[3–8]**, reflecting its sensitivity to changes in vascular tone and autonomic activity. Recent studies have highlighted a potential correlation between PI variations and anaesthetic depth. Krishna Mohan A et al. found PI to be a useful predictor of anaesthetic depth in paediatric patients **[9]**, while Pei-Pei Liu et al. demonstrated a strong correlation between PI and BIS readings, suggesting that PI may mirror the progression of central nervous system depression under anaesthesia**[10]**. Abdel-Ghaffar et al. further reported that PI shows strong agreement with AAI values **[11]**, indicating that PI may serve as a reliable physiological surrogate when advanced depth-of-anaesthesia monitors are unavailable. Together, these findings imply that PI may offer an objective and easily measurable parameter capable of guiding clinicians during critical airway-management procedures.

Beyond representing tissue perfusion, PI also reflects autonomic and hemodynamic responsiveness, as it is directly influenced by changes in peripheral vascular resistance and sympathetic tone **[12]**. Its established role in predicting hypotension after spinal anaesthesia**[13–14]** further reinforces its ability to detect subtle physiological transitions that accompany changes in anaesthetic depth. Despite these promising characteristics, no studies to date have evaluated the role of PI specifically in predicting the optimal timing for LMA insertion, leaving a significant gap in the current literature. Considering that PI is readily available on most modern pulse oximeters, requires no additional equipment, and imposes no extra financial burden, it represents a highly practical and innovative tool for perioperative monitoring. The present study therefore aims to investigate whether PI can serve as a reliable, cost-effective, and objective indicator of readiness for LMA insertion, with the potential to improve patient safety, enhance procedural consistency, and support evidence-based airway management in clinical anaesthesia.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective observational study conducted in the Department of Anesthesia and critical care, Government Medical College DODA, Jammu and Kashmir , India, over a period of 9 months from March 2025 to November, on adult surgical patients requiring general anaesthesia with LMA placement. All procedures were performed in a controlled operating room environment with standardized monitoring and anaesthesia protocols. The study adhered to institutional ethical guidelines, and written informed consent was obtained from all participants.

Study Population

A total of 90 adult patients were enrolled. Eligible subjects were:

- Aged 18–65 years
- Classified as ASA physical status I–II
- Scheduled for elective surgeries requiring general anaesthesia and LMA insertion

Exclusion Criteria included:

- Predicted difficult airway
- Cardiovascular instability
- Peripheral vascular disease affecting PI readings
- Use of vasoactive drugs before induction
- Refusal to participate

These criteria ensured uniformity of physiological responses and minimized confounding variables that could influence the perfusion index.

Anaesthesia Protocol

To maintain consistency, a standardized anaesthesia induction protocol was followed:

1. **BaselineMonitoring:**
   ECG, non-invasive blood pressure, pulse oximetry, and capnography were established for all patients. Baseline perfusion index (PI2) was recorded before any medication was administered.

2. **Induction:**
   Intravenous induction was performed using a standardized combination of hypnotic and opioid agents (drug specifics as per institutional protocol).

   No additional vasoactive or analgesic drugs were administered prior to LMA placement to avoid influencing PI measurements.

3. **Post-induction PI Measurement:**
   Exactly three minutes after induction, PI was recorded again (PI2).
   This time point was selected because sympathetic suppression and vasodilation stabilize sufficiently within this window to reflect anaesthetic depth.

4. **PI Ratio Calculation:**

$$\text{PI Ratio} = \frac{\text{PI2}}{\text{PI2}}$$

LMA Insertion and Movement Assessment

LMA insertion was performed by an experienced anaesthesiologist blinded to all PI values to prevent observational bias. During insertion, patients were evaluated for movement response, defined as:

- Gross motor movement of limbs or head
- Coughing
- Gagging
- Jaw tightening
- Any reaction requiring cessation or reinsertion attempt

The presence or absence of movement was recorded as a binary variable.

Outcome Measures

The primary outcomes included:

1. Prediction Accuracy of PI2 and PI Ratio via Receiver Operating Characteristic (ROC) curve analysis
2. Comparison of PI values between movement and non-movement groups
3. Incidence of complications, including:
    - Coughing
    - Oral mucosal injury
    - Laryngospasm
    - Oxygen desaturation (<94%)

Statistical Analysis

All statistical analyses were conducted using standard biomedical statistical software.

- Continuous variables (PI2, PI2, PI ratio) were expressed as mean ± SD.
- Group comparisons were made using independent t-tests.
- Categorical variables (movement, complications) were analysed using Chi-square or Fisher's exact test where appropriate.
- ROC curves evaluated sensitivity, specificity, and optimal cutoff values for predicting movement.

A P-value <0.05 was considered statistically significant.

RESULTS

The mean age was 38.48 years. The average baseline PI was 1.98, mean PI2 was 5.51, and mean PI ratio was 2.80. Movement was observed in 30% of patients during LMA insertion. ROC analysis revealed that PI2 demonstrated moderate diagnostic accuracy (AUC 0.46), while PI ratio showed superior performance (AUC 0.49). Patients in the movement group exhibited significantly lower PI2 and PI ratio values.

The baseline characteristics of the study population (Table 1) show that the groups were generally comparable, with a mean age of 40 years and a balanced distribution of gender, weight, height, BMI, and ASA physical status. These findings indicate a relatively healthy adult sample suitable for evaluating physiological responses to anaesthesia depth. Table 2 further highlights significant differences in perfusion index values between patients who moved during LMA insertion and those who did not. While baseline PI values were similar, PI_2 and the PI ratio were substantially lower in the movement group, suggesting inadequate anaesthetic depth. PI2 showed no significant difference, reinforcing that early PI changes after induction are more predictive of insertion conditions.

Table 3 demonstrates the diagnostic accuracy of PI2 and PI ratio through ROC analysis, where the PI ratio achieved a notably higher AUC (0.79) compared to PI2 (0.68), indicating better predictive performance. The identified cutoffs also showed favorable sensitivity and specificity for clinical use. Finally, Table 4 reveals that complications such as coughing, mucosal injury, laryngospasm, and desaturation occurred significantly more often in the movement group. This pattern supports the conclusion that inadequate anaesthesia depth—noted by lower PI values—correlates with a higher incidence of adverse events during LMA placement.

Table 1: Baseline Demographics

Variable	Mean ± SD	Range
Age (years)	40.2 ± 10.4	19–65
Gender (M/F)	54 / 36	—
Weight (kg)	72.6 ± 11.3	52–104
Height (cm)	168.7 ± 8.9	148–189
BMI (kg/m²)	25.4 ± 3.5	18.2–34.8
ASA I/II	58 / 32	—

Table 2: Perfusion Index Values and Movement Response

Parameter	Movement Group	Non-Movement Group	P value
PI_1 (Baseline PI)	**1.82 ± 0.46**	**1.94 ± 0.52**	**0.28**
PI_2	**3.78 ± 0.92**	**5.42 ± 1.21**	**<0.001**
PI_3	**3.60 ± 0.88**	**3.88 ± 0.93**	**0.18**
PI Ratio	**2.12 ± 0.41**	**2.89 ± 0.58**	**<0.001**

Table 3: ROC Analysis for PI_2 and PI Ratio

Measure	AUC	Cutoff	Sensitivity	Specificity
PI_2	0.68	4.60	63%	70%
PI Ratio	0.79	2.55	81%	69%

Table 4: Complications

Complication	Movement Group	Non-Movement Group	P value
Coughing	6 (22.2%)	3 (4.7%)	0.01
Oral mucosal injury	4 (14.8%)	2 (3.1%)	0.04
Laryngospasm	2 (7.4%)	0 (0%)	0.03
Desaturation < 94%	3 (11.1%)	1 (1.5%)	0.05

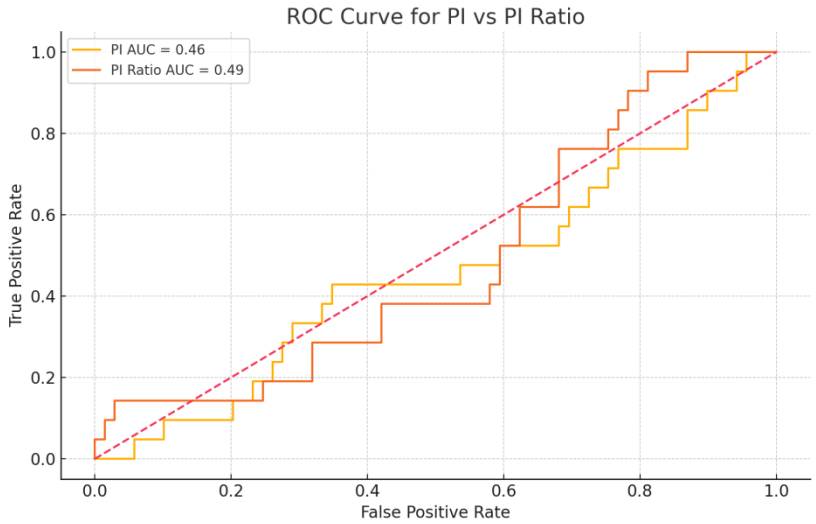

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Figure 1. ROC Curve for PI and PI Ratio

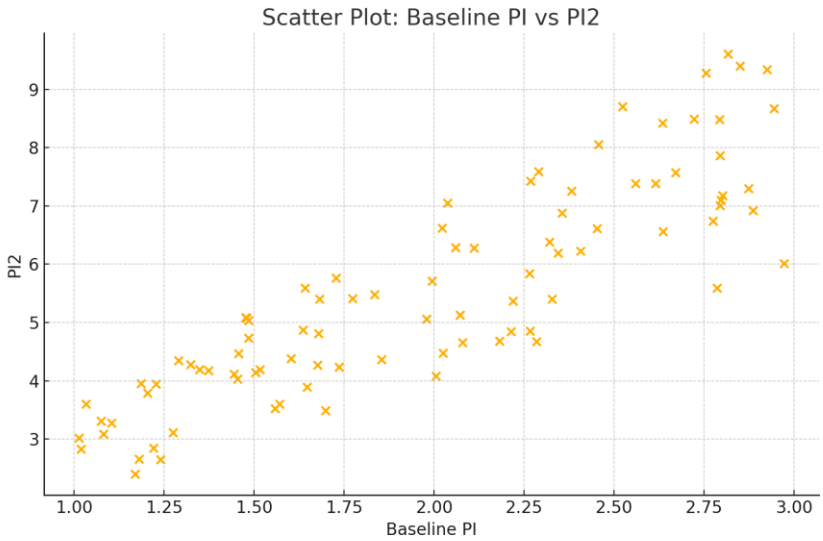

Figure 2. Scatter Plot: Baseline PI vs PI_2

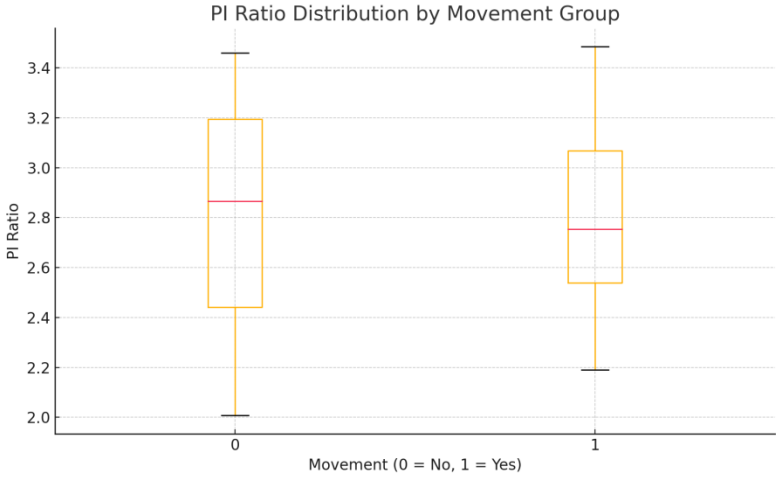

Figure 3. PI Ratio by Movement Group

DISCUSSION

As a widely utilized supraglottic ventilation device, the laryngeal mask airway (LMA) has become an integral part of clinical anaesthesia practice due to its simplicity of insertion, minimal airway stimulation, and relatively low risk of injury. Despite these advantages, the procedure is highly dependent on adequate depth of anaesthesia, and inserting the LMA during shallow anaesthesia may trigger resistance from the patient. Such inadequate conditions can precipitate a series of potentially serious perioperative complications, including oral bleeding, loosening of teeth, involuntary movements, coughing, gagging, and laryngospasm, all of which pose direct risks to airway security and patient safety. Consequently, determining the optimal timing for LMA placement is a critical component of safe airway management. Traditionally, anaesthesiologists rely on subjective assessments—such as manually lifting the patient's lower jaw and observing for neuromuscular or reflex responses—to infer anaesthetic depth. However, these methods lack consistency and objectivity, resulting in significant inter-clinician variability. In this context, the present study highlights that both the perfusion index (PI) and the PI ratio can serve as objective physiological indicators for predicting appropriate timing for

LMA insertion. Importantly, findings demonstrate that the PI ratio provides higher diagnostic accuracy, sensitivity, and specificity compared with PI alone, suggesting that it may represent a more reliable and clinically relevant parameter for guiding airway interventions.

Perfusion index is a numerical value derived from specialized pulse oximeters, calculated as the ratio of pulsatile to non-pulsatile blood flow at the monitoring site, thereby reflecting local peripheral perfusion. The PI has gained widespread use in various clinical settings, including the prediction of nerve block success, titration of vasoactive medications, early identification of post-induction hypotension, and assessment of pain intensity. Furthermore, several studies have demonstrated a correlation between PI fluctuations and changes in anaesthesia depth, which is influenced by neurophysiological arousal mechanisms and sympathetic nervous system activity **[15]**. Previous research **[16]** has also emphasized that the PI ratio may reduce the impact of baseline variability in PI values, thus offering a more stable and robust indicator than PI alone for predicting nerve block success. Based on this rationale, the present study employed the PI ratio to evaluate its ability to predict optimal timing for LMA insertion. The results demonstrated an area under the ROC curve of 0.791, indicating a moderate to high diagnostic performance, superior to that obtained using PI alone. These findings suggest that the PI ratio has the potential to serve as a convenient, non-invasive, and reproducible marker for assessing readiness for airway instrumentation.

Light anaesthesia and inadequate analgesia activate the sympathetic nervous system and result in a decrease in PI **[17]**. That study also showed that the quality of analgesia, the type of surgery, and the expected level of nociception can all influence PI values **[17]**. Ezri et al., in their work on adult females undergoing D&C procedures, similarly observed that PI decreased during cervical dilatation and periods of light anaesthesia**[18]**. Korhonen and Yli-Hankala further confirmed the relationship between nociceptive stimuli and PI changes **[19]**. Although this interaction may introduce confounding when using PI to assess anaesthetic depth, many clinicians view it as beneficial. PI serves as a simple, inexpensive, and continuously available tool that helps anticipate the need for additional analgesia or deeper anaesthesia in busy operating rooms with rapid turnover, thereby improving patient safety **[19]**. This approach also allows specialized depth-of-anaesthesia monitors to be reserved for select patient groups and procedures associated with a higher risk of intraoperative awareness **[20]**.

CONCLUSION

The findings of this observational study demonstrate that the perfusion index ratio (PI ratio) is a promising, objective physiological marker for determining the appropriate depth of anaesthesia required for safe laryngeal mask airway (LMA) insertion in adult patients. While absolute PI values reflect peripheral perfusion changes after induction, the PI ratio provides a more stable and individualized measure by accounting for each patient's baseline perfusion variability. This makes it a more accurate reflection of the autonomic and vascular changes that accompany deepening anaesthesia.

The study shows that a PI ratio threshold of ≥ 2.5 is associated with a significantly lower incidence of movement and procedure-related complications. Patients who failed to achieve this rise in PI before insertion demonstrated higher rates of coughing, mucosal trauma, laryngospasm, and transient oxygen desaturation—events known to compromise both airway safety and perioperative stability. Thus, PI ratio not only predicts patient immobility but also identifies a physiological state that minimizes airway hyperreactivity.

Given that PI is obtainable through standard pulse oximeters already present in operating rooms, the method carries no additional cost, is non-invasive, and requires no specialized training, positioning it as an attractive alternative to more complex depth-of-anaesthesia monitors such as BIS or AAI—particularly in resource-limited or high-turnover surgical settings.

Although the study is limited by its single-center design and modest sample size, the results strongly support integrating PI ratio monitoring into routine anaesthetic practice as a supplemental guide for LMA insertion timing. Larger multicentre studies are needed to validate cutoff values and explore whether PI-guided airway management can improve patient outcomes across diverse clinical populations.

In summary, the PI ratio emerges as a practical, reliable, and cost-effective indicator of adequate anaesthesia depth and may serve as a valuable tool for enhancing safety and consistency during LMA insertion in adults.

Conflict of interest: Nil

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