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Correlation Between Diaphragmatic Electrical Activity and Clinical Respiratory Distress in Premature Infants: A Prospective Observational Study

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Abstract

Background

The electrical activity of the diaphragm (EDi), measured via neurally adjusted ventilatory assist (NAVA), reflects neural respiratory drive and may provide an objective marker of respiratory distress in preterm infants. However, its relationship with clinically assessed respiratory distress remains uncertain, particularly across different levels of maturity.

Objective

To evaluate the correlation between EDi peak values and respiratory distress severity, as measured by the Silverman–Anderson Score (SAS), in premature infants with NAVA catheters in situ.

Methods

A prospective observational study was conducted at a tertiary neonatal unit between January 2024 and December 2025. Premature infants with a NAVA catheter were included. Infants with congenital diaphragmatic anomalies, neuromuscular disorders, significant congenital heart disease, or receiving palliative care were excluded. Respiratory distress was independently assessed by four experienced clinicians using SAS (≤ 3: minimal/no distress; >3: moderate/severe distress). Simultaneous EDi peak values (μV) were recorded and averaged across breaths. Correlation between EDi and SAS was assessed using Pearson's correlation coefficient. Subgroup analyses were performed by corrected gestational age (cGA < 32 vs ≥ 32 weeks) and weight at assessment (W < 1500 vs ≥ 1500 g).

Results

A total of 200 observations from 44 infants were analysed. Median cGA was 24 + 3 weeks (range 22 + 4–39 + 2) and median weight was 580 g (380–3850). Median SAS was 2 (0–7) and median EDi peak was 6.9 μV (0.5–43.6). EDi peak demonstrated a moderate positive correlation with SAS ($r = 0.405$, $p < 0.001$). Among infants with SAS > 3, 60% had EDi peak < 15 μV, whereas only 7% of those with SAS ≤ 3 had EDi peak > 15 μV. In infants with SAS > 3, more mature infants (cGA ≥ 32 weeks and W ≥ 1500 g) had significantly higher EDi peaks than less mature infants ($p = 0.001$).

Conclusions

EDi peak correlates moderately with clinical respiratory distress in preterm infants but demonstrates limited sensitivity in detecting severe distress, particularly in extremely preterm infants. Maturational

differences significantly influence EDi responses, suggesting that EDi should be used as an adjunct to, rather than a replacement for, clinical assessment when guiding respiratory support.

WHAT IS KNOWN • WHAT IS NEW

What is Known:

• EDi, measured via NAVA, reflects neural respiratory drive in neonates.

• Respiratory muscle strength and neural control mature with increasing gestational age.

What is New:

• EDi peak shows only moderate correlation with SAS; 60% of infants with moderate/severe distress had EDi <15 μV.

• Maturational stage significantly influences EDi response to distress; published 'normal' EDi thresholds should not be used in isolation to guide ventilatory support.

INTRODUCTION

Premature infants are particularly vulnerable to respiratory distress due to structural and functional immaturity of the lungs and diaphragm. The assessment of respiratory distress traditionally relies on clinical scoring systems, such as the Silverman–Anderson Score (SAS), which evaluates intercostal retractions, nasal flaring, grunting, and chest movement asymmetry to classify distress severity [1, 2].

Recent advances in neonatal ventilatory support, particularly neurally adjusted ventilatory assist (NAVA), allow direct measurement of diaphragmatic electrical activity (EDi). EDi reflects the neural respiratory drive originating from the medullary respiratory centres, transmitted via the phrenic nerve to the diaphragm, providing a physiological marker of inspiratory effort [3, 4]. Measuring EDi offers a non-invasive, continuous method to monitor respiratory effort and potentially guide ventilatory support titration [5].

Previous studies have suggested that EDi correlates with tidal volume and respiratory effort [6, 7]; however, the relationship between EDi peak values and clinically assessed respiratory distress in premature infants across varying gestational ages and birth weights remains poorly characterised. Understanding this relationship may enable more individualised ventilation strategies and prevent under- or over-assistance in vulnerable infants [8].

This study aimed to investigate whether EDi peak values correlate with the severity of respiratory distress, as measured by SAS, in a cohort of premature infants with NAVA catheters in situ.

METHODS

Study design and setting

A prospective observational study was conducted at St George's Hospital NHS Foundation Trust, London, between January 2024 and December 2025. No additional investigations or interventions beyond routine care were undertaken. The study was registered as a prospective audit with the Trust audit department (Audit registration number: AUDI004058).

Participants

Premature infants with a NAVA catheter in situ were eligible for inclusion. Exclusion criteria were: congenital diaphragmatic anomalies, neuromuscular disorders, severe congenital heart disease, or receipt of palliative care.

Study protocol

Study protocol
The observer liaised with the bedside nurse during routine nursing observations. EDi peak recording was initiated on the ventilator. Respiratory distress was assessed over a 30-second period during planned nursing assessment. EDi peak values for the preceding 30 seconds were recorded and averaged.

Clinical assessment

Four senior clinicians (RC, BM, AK, DT), each with over four years of neonatal intensive care experience, independently assessed respiratory distress using the Silverman–Anderson Score (Table 1). SAS was categorised as: ≤3 (minimal or no distress) and > 3 (moderate to severe distress) [1, 2].

Table 1
Silverman–Anderson Scoring System

Score	Upper Chest Movement	Lower Chest Retractions	Xiphoid Retractions	Nasal Flaring	Expiratory Grunt
0	Synchronised with abdomen	None	None	None	None
1	Lag on inspiration	Just visible	Just visible	Minimal	Audible with stethoscope only
2	See-saw (opposite to abdomen)	Marked retractions	Marked retractions	Marked	Audible without stethoscope

SAS ≤ 3: minimal/no distress; SAS > 3: moderate to severe distress.

EDi measurements

EDi peak values (μV) were recorded via the NAVA catheter simultaneously with clinical assessment to ensure temporal correlation. Averaged EDi values across multiple breaths were calculated.

Collected variables

Gestational age (GA, weeks), birth weight (BW, grams), current weight (g), day of life, corrected gestational age (cGA, weeks), arterial PCO_2 (kPa), fraction of inspired oxygen (FiO_2, %), EDi peak (μV), and SAS.

Statistical analysis

Continuous variables are presented as median (range). Pearson's correlation coefficient (r) was used to assess the relationship between EDi peak and SAS. Subgroup analyses were performed by cGA (< 32 vs ≥ 32 weeks) and weight (< 1500 vs ≥ 1500 g). A p-value < 0.05 was considered statistically significant.

RESULTS

Demographics and clinical characteristics

A total of 200 observations in 44 infants were included. Median GA was 24 + 3 weeks (22 + 4–39 + 2), median BW was 580 g (380–3850), and median day of life at assessment was 44.5 (16–150). Median cGA was 30 + 6 weeks (24–50 + 1) and median current weight was 1040 g (490–4100) at assessment. Median SAS was 2 (0–7) and median EDi peak was 6.9 μV (0.5–43.6). Twenty-six observations (13%) demonstrated SAS > 3, indicating moderate to severe respiratory distress (Table 2).

Table 2
Demographics and clinical characteristics (n = 200 observations, 44 infants)

Variable	N	Median (Range)
Gestational age (weeks)	200	24 + 3 (22 + 4–39 + 2)
Birth weight (g)	200	580 (380–3850)
Current weight (g)	200	1040 (490–4100)
Day of life	200	44.5 (16–150)
Corrected gestational age (weeks)	200	30 + 6 (24–50 + 1)
PCO_2 (kPa)	195	7.6 (4.6–13.5)
FiO_2 (%)	200	41 (21–75)
EDi peak (μV)	200	6.9 (0.5–43.6)
Silverman–Anderson Score	200	2 (0–7)

GA = gestational age; BW = birth weight; cGA = corrected gestational age; PCO_2 = partial pressure of carbon dioxide; FiO_2 = fraction of inspired oxygen; EDi = electrical activity of the diaphragm; SAS = Silverman–Anderson Score.

Correlation between EDi and respiratory distress

A positive correlation between EDi peak and SAS was observed (Pearson's r = 0.405, p < 0.001), indicating a weak-to-moderate association (Fig. 1). Notably, among infants with SAS > 3, 60% had EDi peak < 15 μV. Among infants with SAS ≤ 3, only 7% had EDi peak > 15 μV.

Subgroup analyses

In infants with minimal or no respiratory distress (SAS ≤ 3), EDi peak values were similar across cGA and weight subgroups, suggesting that baseline diaphragmatic electrical activity is relatively preserved across maturity levels under stable conditions. In contrast, among infants with SAS > 3, more mature infants (≥ 32 weeks cGA and ≥ 1500 g) demonstrated substantially higher EDi peak values than less mature infants (p = 0.001 for both comparisons) (Table 3, Fig. 2). Only 7% of infants with SAS ≤ 3 had EDi peak > 15 μV, confirming that high diaphragmatic activity is uncommon in infants without clinical distress.

Table 3
Averaged EDi peak (aEDIp) by SAS category and subgroup

SAS Category	Subgroup	aEDIp Median (Range) μV	p-value
SAS ≤ 3 (n = 174)	cGA < 32 weeks	6.1 (1.3–13.5)	0.56
	cGA ≥ 32 weeks	6.0 (1.0–23.5)	
	W < 1500 g	6.5 (1.0–23.5)	0.58
	W ≥ 1500 g	6.0 (1.0–19.6)	
SAS > 3 (n = 26)	cGA < 32 weeks	12.0 (2.5–16.5)	0.001
	cGA ≥ 32 weeks	19.0 (10.0–43.6)	
	W < 1500 g	12.3 (2.5–16.7)	0.001
	W ≥ 1500 g	18.6 (10.0–43.6)	

p-values refer to comparisons within each SAS category between maturity subgroups. cGA = corrected gestational age; W = weight at time of assessment; aEDIp = averaged electrical activity of the diaphragm peak.

DISCUSSION

This study demonstrates a moderate positive correlation between EDi peak values and clinically assessed respiratory distress in premature infants. While higher EDi peaks were generally associated with increased respiratory effort, this relationship was not uniform across gestational ages and birth weights. Our findings align with prior research suggesting that EDi reflects neural respiratory drive and correlates with inspiratory effort [3, 6, 7]. However, the moderate correlation strength (r = 0.405) indicates that EDi alone may underestimate distress in extremely preterm or lower-weight infants, likely reflecting immature diaphragmatic innervation and contractile capacity, which limits measurable electrical activity despite significant clinical signs of distress [4, 8].

The subgroup analysis highlights the critical influence of maturational stage. Infants < 32 weeks cGA or < 1500 g exhibited lower EDi peak values than more mature infants, even when SAS indicated moderate or severe distress. This is consistent with evidence that developmental immaturity of the diaphragm limits EDi amplitude, reducing its reliability as a sole marker of respiratory drive [5, 9, 12]. Conversely, extremely preterm infants may exhibit blunted EDi responses despite significant clinical distress, likely due to immature neuromuscular coupling and reduced diaphragmatic reserve [4, 8, 13]. This dissociation between clinical distress and EDi signal in the least mature infants underscores the need for combined clinical and physiological assessment in this population.

These findings have important implications for clinical practice. EDi measurements provide objective, real-time data on respiratory effort and may usefully complement NAVA titration. However, the commonly cited target EDi peak range of 5–15 μV — derived from studies of spontaneously breathing

neonates without respiratory support [12] — should not be applied in isolation to guide ventilatory adjustment in this population. Weight, corrected gestational age, and the degree of clinical respiratory distress all substantially influence EDi peaks, and a low EDi in a distressed extremely preterm infant does not indicate adequate support. Trend monitoring of EDi over time, rather than reliance on single peak values, may better reflect evolving respiratory effort and help anticipate changes in ventilatory support needs [6, 11]. Greater variability in EDi among lower GA and BW infants likely reflects intermittent diaphragmatic activation, sighs, and apnoea events, consistent with known instability of respiratory control in preterm neonates [3, 4, 7, 13]. This reinforces the need for multi-parameter monitoring that integrates EDi trends with clinical scores and conventional ventilatory parameters.

Strengths and limitations

Strengths of this study include its prospective design, the use of four experienced independent clinicians for SAS assessment, and simultaneous EDi recording, which minimises temporal bias. Limitations include single-centre recruitment, relatively small subgroup sizes, and potential residual observer bias in SAS scoring despite blinding. Variability in NAVA settings across infants may also have influenced EDi amplitudes [10, 11]. EDi averaging over 30-second windows may not fully capture breath-to-breath variability, and the study was not powered for subgroup comparisons. Larger multicentre studies are needed to validate these findings and to derive maturity-specific EDi reference ranges for use during respiratory distress.

CONCLUSIONS

EDi peak values exhibit a moderate correlation with clinically assessed respiratory distress in premature infants. Extremely preterm and low-birth-weight infants show lower EDi peaks and greater variability, suggesting limited reliability of EDi alone in this population. EDi peak may complement but cannot replace clinical assessment in guiding respiratory management and NAVA titration. Trend monitoring and integration with clinical scoring remain essential in this vulnerable population.

Declarations

Funding: No funding was received for this study.

Competing interests: SS participated in a one-off Medical Advisory Board meeting for Maquet Critical Care AB in 2024. He has received honoraria from Getinge for educational speaking engagements related to neonatal ventilation. RC, BM, AK, and DT declare no competing interests.

Ethics approval: This study was performed in line with the principles of the Declaration of Helsinki. The study was registered as a prospective audit with the St George's Hospital NHS Foundation Trust audit department (Audit registration number: AUDI004058). As a registered audit using routinely collected clinical data, formal ethics committee approval was not required under institutional policy.

Informed consent: As a prospective audit of routinely collected data, individual patient consent was not required per institutional policy.

Author contributions: All authors meet ICMJE criteria for authorship. AK conceived and designed the study. RC, BM, AK, and DT performed clinical assessments and data collection. AK drafted the manuscript. BM, AK, DT, and SS critically revised the manuscript for important intellectual content. All authors approved the final version and agree to be accountable for all aspects of the work.

Data availability: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Figures

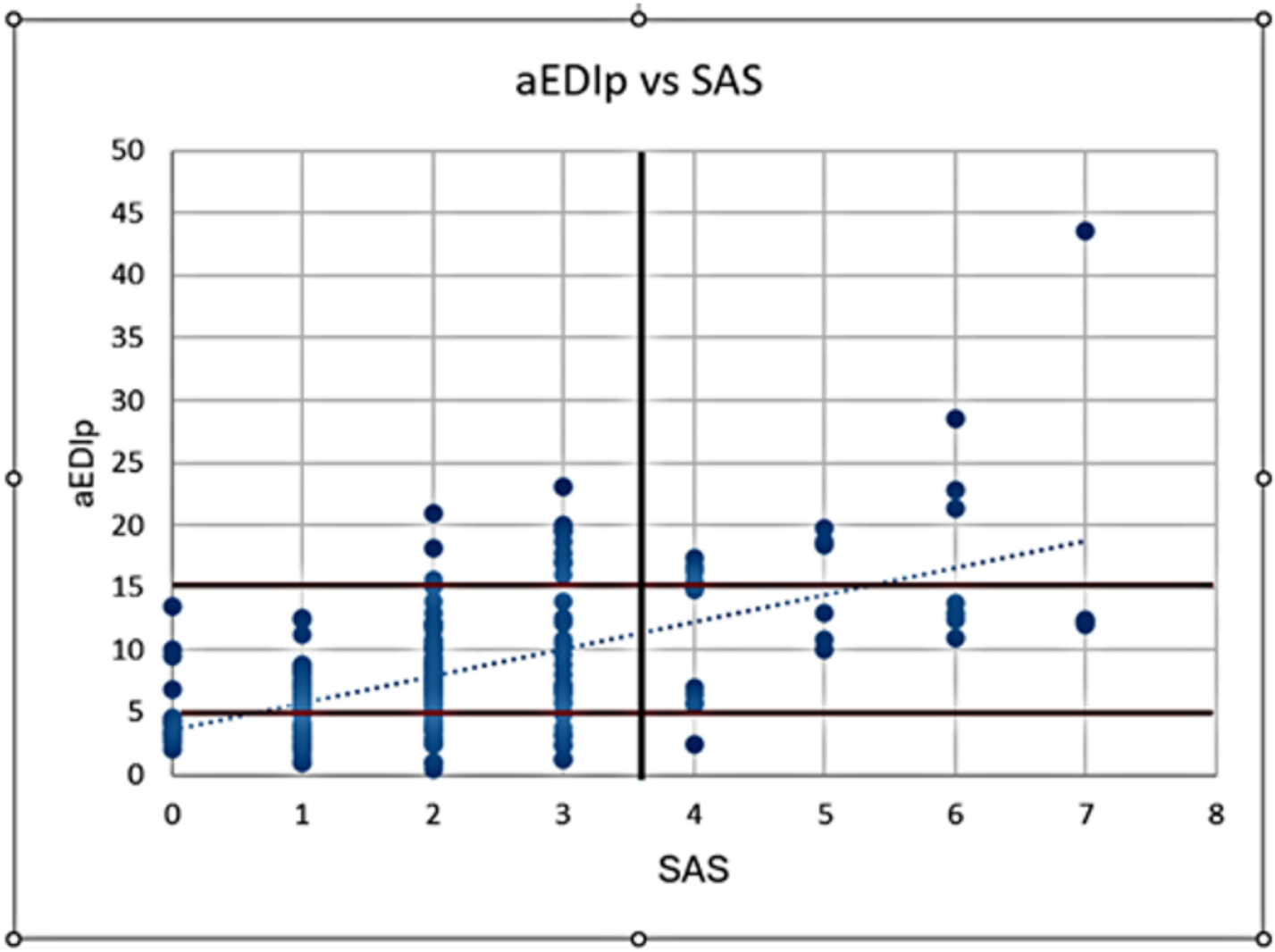


Figure 1

Scatter plot showing the correlation between averaged EDi peak (aEDIp, μV) and Silverman–Anderson Score (SAS) across all 200 observations. The regression line and 95% confidence interval are shown. Pearson's r = 0.405.

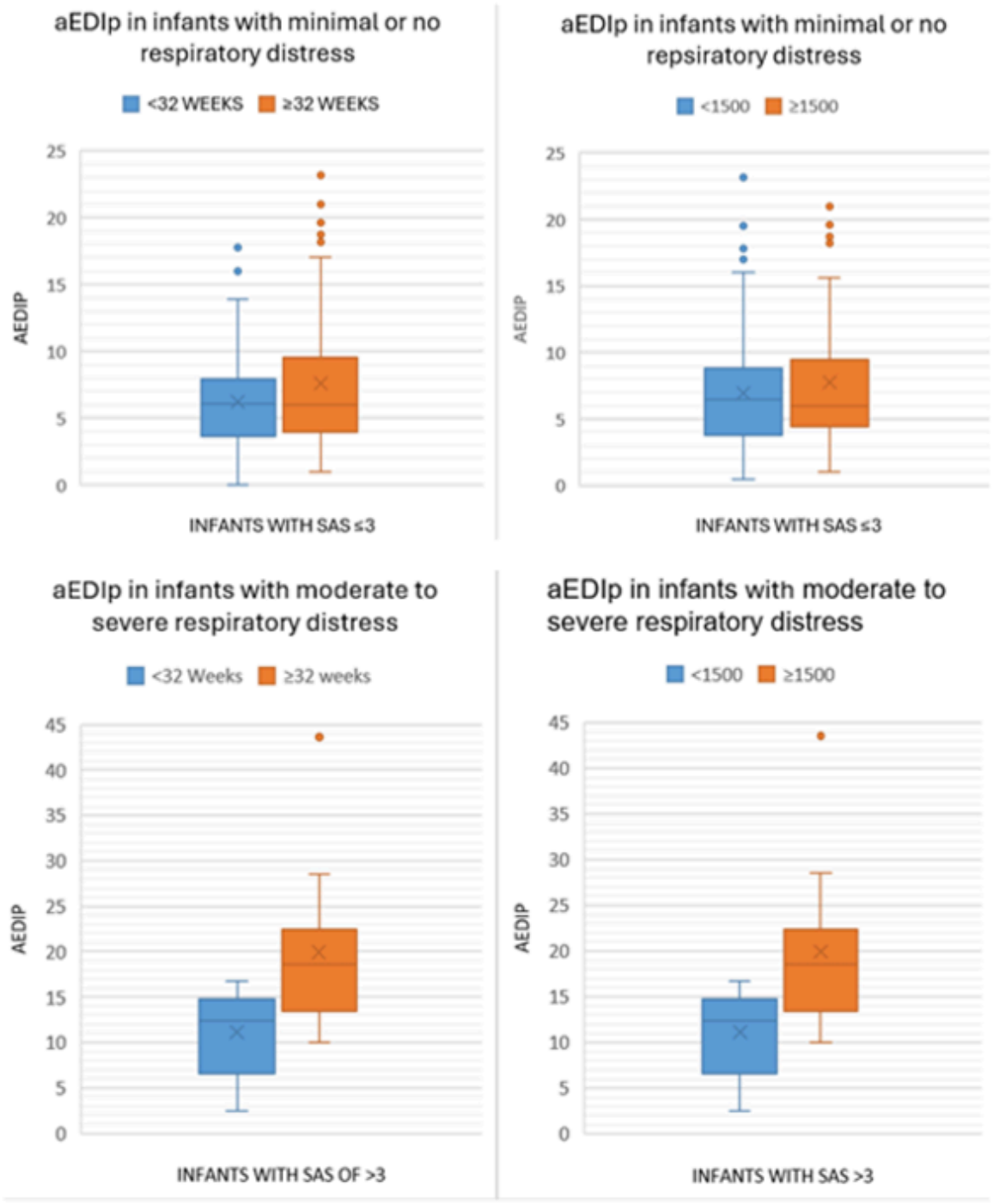


Figure 2

Figure 2

Box plots showing aEDIp values stratified by SAS category (SAS ≤3 vs SAS >3) and subgroup (corrected gestational age <32 vs ≥32 weeks; weight at assessment <1500 vs ≥1500 g). * p = 0.001.