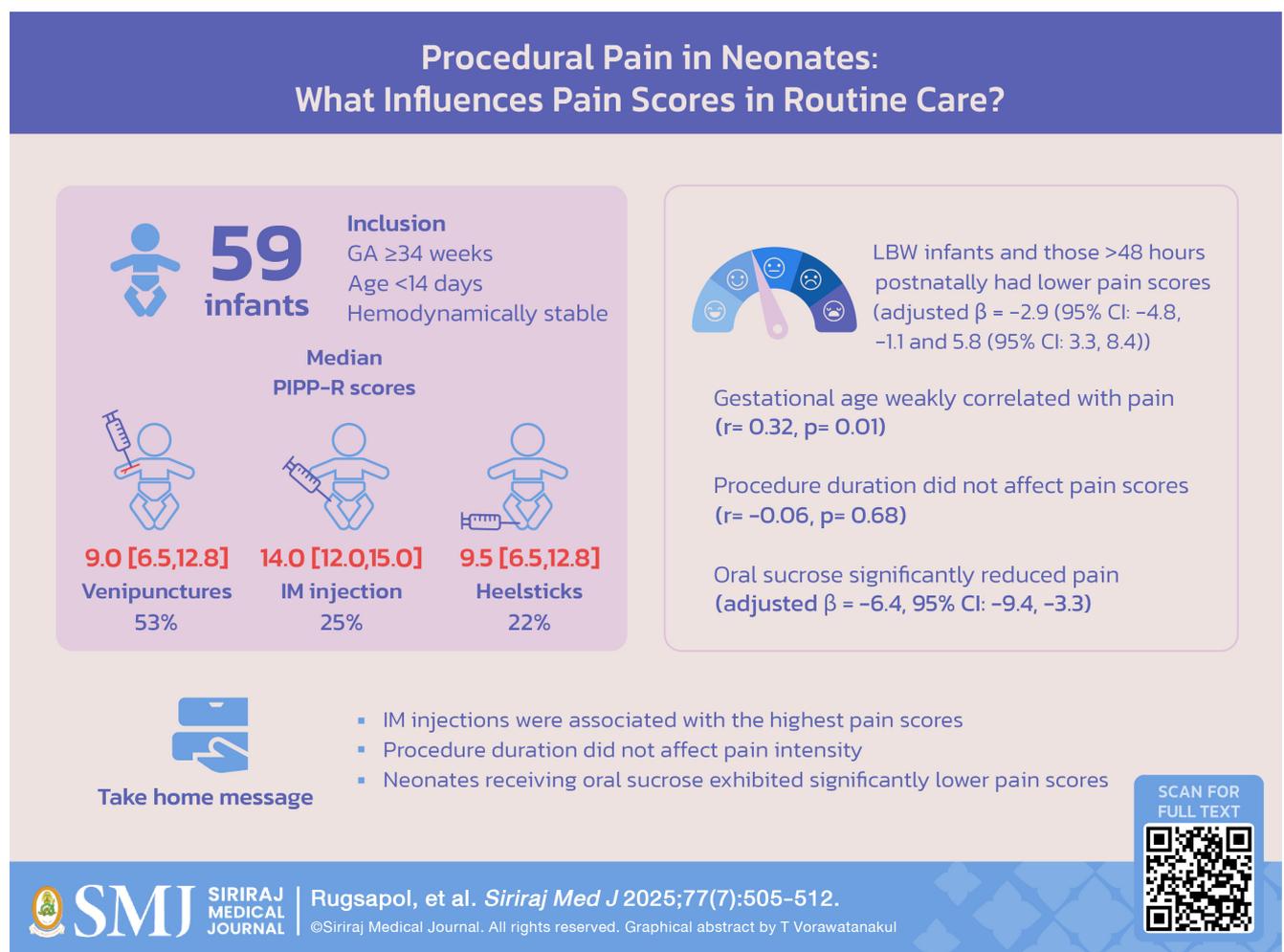# Factors Associated with Pain Scores in Late Preterm and Term Infants Undergoing Routine Procedures

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Procedural Pain in Neonates:
What Influences Pain Scores in Routine Care?

59 infants

Inclusion
GA ≥34 weeks
Age <14 days
Hemodynamically stable

Median PIPP–R scores

9.0 [6.5,12.8]
Venipunctures
53%

14.0 [12.0,15.0]
IM injection
25%

9.5 [6.5,12.8]
Heelsticks
22%

LBW infants and those >48 hours postnatally had lower pain scores (adjusted β = −2.9 (95% CI: −4.8, −1.1 and 5.8 (95% CI: 3.3, 8.4))

Gestational age weakly correlated with pain (r= 0.32, p= 0.01)

Procedure duration did not affect pain scores (r= −0.06, p= 0.68)

Oral sucrose significantly reduced pain (adjusted β = −6.4, 95% CI: −9.4, −3.3)

Take home message
- IM injections were associated with the highest pain scores
- Procedure duration did not affect pain intensity
- Neonates receiving oral sucrose exhibited significantly lower pain scores

SCAN FOR FULL TEXT

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ABSTRACT

Objective: To identify factors associated with Premature Infant Pain Profile-Revised (PIPP-R) scores in late preterm and term infants undergoing routine skin-puncture procedures.

Materials and Methods: A secondary analysis of a prospective cohort study was conducted in hemodynamically stable late preterm and term infants (gestational age [GA] 34–41 weeks) undergoing routine procedures. PIPP-R scores were evaluated through video recordings by a blinded assessor.

Results: Among 59 infants, 31 (52.5%) underwent venipuncture, 15 (25.4%) received intramuscular (IM) injections, and 13 (22%) underwent heelsticks. The median PIPP-R score was 11.0 [7.0, 14.0]. IM injections and heelsticks resulted in significantly higher pain scores compared to venipunctures (regression coefficient: 4.6, 95% CI: 2.3–6.8, and 2.8, 95% CI: 0.6–5.0, respectively). No correlation was observed between procedure duration and pain scores ($r = -0.06$, $p = 0.68$), but GA showed a weak positive correlation ($r = 0.32$, $p = 0.01$). After adjustment, low birthweight (<2500 g) was independently associated with lower PIPP-R scores (-2.9, 95% CI: -4.8, -1.1), while postnatal age <48 hours was linked to higher scores (5.8, 95% CI: 3.3–8.4). Oral sucrose solution significantly reduced pain scores (-6.4, 95% CI: -9.4, -3.3).

Conclusion: IM injections were associated with the highest pain scores, while procedure duration did not affect pain intensity. LBW infants and those >48 hours old exhibited lower pain scores, suggesting developmental factors. The demonstrated efficacy of oral sucrose underscores its importance in neonatal pain management, emphasizing the need for routine implementation of analgesic strategies.

Keywords: Heelstick; intramuscular; late-preterm; PIPP-R scores; venipuncture (Siriraj Med J 2025; 77: 505-512)

INTRODUCTION

Newborn infants are routinely subjected to painful procedures, including essential newborn screenings and vaccination injections. Higher-risk infants may require additional procedures. Research suggests that early pain exposure can influence both short-term and long-term nervous system development. Studies indicate a correlation between pain and abnormal brain development, as evidenced by dysmaturation in the brains of newborns.[1] Autopsy findings in infants with abnormal brain tissues reveal impaired preoligodendrocyte development, which is critical for myelin production and may result from brain injury repair processes during infancy.[2] Studies tracking early brain changes using MRI have shown an association between white matter abnormalities, altered diffusivity, and abnormal brain metabolites.[3] Additionally, research indicates that the number of painful procedures during infancy is linked to reduced intelligence and altered white matter development.[4,5] Furthermore, early pain experiences have been shown to influence pain perception later in life.[6-8] Consequently, caregivers should prioritize minimizing infant pain by reducing procedural interventions, mitigating factors that exacerbate pain, and assessing pain severity to determine the appropriate use of analgesic medications. Nevertheless, most studies focus on very preterm infants, a high-risk group undergoing multiple painful procedures due to severe illness.[3,9] While the impact of painful procedures in late preterm and term infants is acknowledged, it is less emphasized compared to very preterm infants. This discrepancy arises because procedures in late preterm and term infants are brief and less invasive, leading caregivers to underestimate the importance of pain assessment and management.

Due to infants' inability to directly communicate pain, assessments primarily rely on behavioral observations, such as changes in facial expressions, using tools like the neonatal facial coding system and the facial action coding system.[10] However, preterm infants may exhibit reduced facial pain expressions of pain.[11] Therefore, additional psychometric factors are incorporated, including the Premature Infant Pain Profile – revised (PIPP-R), Cry, Requires oxygen, Increased vital signs, Expression, Sleeplessness (CRIES), Neonatal Infant Pain Scale (NIPS), COMFORT, and COMFORTneo, as well as the Neonatal Pain, Agitation, and Sedation Scale (N-PASS).[12] Among these, NIPS and PIPP-R scores are widely used.[13] In our previous study, we found no significant changes in cerebral oxygenation in late preterm and term infants during painful procedures.[14] Consequently, pain score assessment remains the primary method for evaluating pain in this population. Since newborn infants may exhibit varying pain responses depending on gestational age, postnatal age, or other factors, as well as differing levels of pain depending on procedure type[15], this study hypothesizes that both infant characteristics and procedure

type influence pain scores. Therefore, the aim of this study was to identify factors associated with PIPP-R scores, one of the most widely used pain assessment tools, in late preterm and term infants undergoing blood sampling procedures.

MATERIALS AND METHODS

A secondary analysis was conducted using data from a previous prospective cohort study on pain response in late preterm and term infants.[14] The study protocol was approved by Siriraj Institutional Review Board (COA no. Si 435/2022), and written parental consent was obtained prior to infant recruitment. The study was carried out at the high-risk nursery at Siriraj Hospital, Mahidol University in Bangkok, Thailand. In accordance with institutional protocol, hemodynamically stable preterm infants (<37 weeks of gestation) who did not require positive-pressure ventilation for respiratory compromise were admitted to the high-risk nursery. Infants with very low birthweight, respiratory compromise or hemodynamic instability were admitted to either intermediate care or the neonatal intensive care unit. Gestational age (GA) was determined using maternal ultrasonographic data from the first trimester, or when available, through postnatal clinical examination.

The enrolled infants satisfied the following inclusion criteria: 1) born within the GA range of 34 to 41 weeks, 2) postnatal age less than 14 days, 3) exhibited respiratory stability without requiring positive-pressure ventilation, maintained hemodynamic stability without requiring vasoactive agents, and 4) had a physician's order for skin puncture procedures. The exclusion criteria included infants exhibiting signs of neonatal encephalopathy, such as abnormal movements, hypotonia, or apnea, as well as those with severe congenital anomalies. To ensure biological diversity and reduce potential biases, each infant was enrolled only once, and in cases of multiple pregnancies, only one twin was included to minimize the influence of genetic factors.

The care of neonates, including the choice of blood sampling, either heelstick or venipuncture, was determined at the clinical discretion of the attending physician. For procedures, a 25G needle was used for IM injections at the anterolateral thigh, a 24G needle for venipunctures or IV procedures, and a 28G needle for heelsticks. The institutional protocol for procedural pain control includes oral sucrose solution and non-pharmacologic measures such as swaddling and non-nutritive sucking. However, to allow for unobstructed assessment of facial expressions required for accurate pain scoring, non-nutritive sucking was not provided in this

cohort. The infant was placed supine on a radiant warmer during the procedure. Cerebral oxygenation ($CrSO_2$) was monitored using the INVOS 5100C device as part of the primary study, while oxygen saturation (SpO_2) and heart rate were concurrently evaluated using the Nellcor™ Bedside SpO_2 Patient Monitoring System with a MAXN sensor affixed to the infant's right hand. The procedure adhered to standard protocols and included simultaneous video documentation for subsequent pain evaluation. The video recordings focused on capturing the infant's facial expressions and monitoring heart rate and SpO_2, providing a comprehensive evaluation of responses to the procedures. Pain assessment was conducted using the Premature Infant Pain Profile-Revised (PIPP-R) score.[16] A single assessor (PT), blinded to the type and duration of each procedure, analyzed the recordings to ensure unbiased evaluation. The intraclass correlation coefficients for PIPP-R scores was 1.00. Another co-author (SR) independently extracted procedure-related variables from the same set of video recordings to minimize ascertainment bias.

Statistical analysis

This secondary analysis included all eligible infants from the parent cohort (n = 59) who underwent skin-puncture procedures including heelstick, venipuncture, or intramuscular injection during the study period.[14] Demographic characteristics were reported as numbers (percentages), mean ± standard deviation (SD), or median [25th, 75th percentile], depending on variable type and distribution. Correlations between gestational age or procedure duration and pain scores were assessed using Pearson correlation coefficients (*r*). Differences in PIPP-R scores across groups exposed to specific variables were analyzed using the Mann-Whitney U or Kruskal-Wallis tests. Potential factors associated with pain scores were identified through univariate linear regression, with variables showing *p* <0.2 further evaluated via backward multiple linear regression analysis. Results were reported as regression coefficients with 95% confidence intervals (CI). Statistical analyses were performed using SPSS version 29.0, with *p* <0.05 considered statistically significant.

RESULTS

This secondary analysis included 59 procedures from 59 infants, of whom 29 (49.2%) were born at a gestational age (GA) ≥ 37 weeks, and 22 (37.3%) were classified as low birthweight (LBW; birthweight <2,500 g). Maternal and infant demographic characteristics are detailed in Table 1. The median postnatal age at the time of the procedures was 5 [2, 18] hours. Among the procedures,

TABLE 1. Maternal and infant demographic characteristics.

Mothers (n = 59)	
Age (year)	30.9 ± 5.7
Gestational age (week)	36 [35,38]
Twin pregnancy	3 (5.1)
Hypertension related condition	6 (10.2)
Diabetes	18 (30.5)
Antenatal magnesium sulphate	3 (5.1)
Antenatal dexamethasone	24 (40.7)
Systemic intrapartum pain control	13 (22)
Cesarean section	30 (50.8)
Infants (n = 59)	
Birth weight (g)	2,690 ± 520
Male sex	34 (57.6)
1-minute Apgar score	8 [8,9]
5-minute Apgar score	10 [9,10]
Birth resuscitation	8 (13.6)
Small-for-gestational age	9 (15.3)
Large-for-gestational age	4 (6.8)
Postnatal age (hour)	5 [2,18]

Data are presented as mean ± SD, number (%), or median [P25, P75]. * p <0.05 indicates statistical significance.

31 (52.5%) were venipunctures for intravenous (IV) fluid administration, 15 (25.4%) were intramuscular (IM) injections, and 13 (22%) were heelsticks. Five infants (8.5%) received oral glucose solution for pain relief. The median procedure durations were 34 [5, 51] seconds for venipunctures, 11 [6, 12] seconds for IM injections, and 1 [1, 1] second for heelsticks. The median PIPP-R score across all procedures was 11.0 [7.0, 14.0]. A weak positive correlation was observed between GA and PIPP-R scores (r= 0.32, p= 0.01) but no significant correlation was found between procedure duration and PIPP-R scores (r= -0.06, p= 0.68).

Table 2 summarizes the associations between maternal and infant factors and PIPP-R scores, using both univariate and multiple regression analyses. Infants who received oral sucrose solution had significantly lower PIPP-R scores compared to those who did not, with an unadjusted regression coefficient of -6.8 (95% CI: -10.9, -2.7; p = 0.002). This association remained robust after adjustment, with an adjusted coefficient of -6.4 (95% CI: -9.4, -3.3; p < 0.001). LBW was associated with lower PIPP-R scores. In the univariate analysis, the regression coefficient was -5.3 (95% CI: -7.5, -3.2; p < 0.001), and this association persisted in the adjusted analysis, with a coefficient of -2.9 (95% CI: -4.8, -1.1; p = 0.002). Postnatal age <48 hours was significantly associated with higher PIPP-R scores. The univariate regression coefficient was 3.2 (95% CI: 0.0, 6.5; p = 0.05), and this association strengthened in the adjusted analysis, with a coefficient of 5.8 (95% CI: 3.3, 8.4; p < 0.001).

The type of procedure also significantly influenced pain scores. IM injections were associated with the highest PIPP-R scores compared to venipunctures, with an adjusted regression coefficient of 4.6 (95% CI: 2.3, 6.8; p < 0.001). Heelstick procedures had higher PIPP-R scores compared to venipunctures, with an adjusted coefficient of 2.8 (95% CI: 0.6, 5.0; p = 0.02).

TABLE 2. Factors associated with PIPP-R scores.

Factors	n	PIPP-R scores	p*	Univariate linear regression analysis Coefficient (95% CI)	p†	Multiple linear regression analysis Coefficient (95% CI)	p*
Mothers (n = 59)							
Systemic intrapartum pain control			0.50	-1.3 (-4.3,1.6)	0.37		
No	46	11.5 [7.0,14.0]					
Yes	13	10.0 [3.0,14.5]					
Antenatal magnesium sulphate			0.01*	-5.1 (-10.6,0.4)	0.07†	-2.7 (-6.5,1.1)	0.17
No	56	12.0 [7.0,14.0]					
Yes	3	5.0 [4.0,-]					
Antenatal dexamethasone			0.19	-1.5 (-4.0,1.0)	0.25		
No	35	12.0 [7.0,15.0]					
Yes	24	10.5 [4.3,13.0]					
Cesarean section			0.86	-0.3 (-2.8,2.2)	0.82		
No	29	12.0 [7.0,14.0]					
Yes	30	11.0 [4.8,14.0]					
Infants (n = 59)							
Birthweight <2,500 g			<0.001*	-5.3 (-7.5,-3.2)	<0.001†	-2.9 (-4.8,-1.1)	0.002*
No	37	13.0 [11.0,15.0]					
Yes	22	5.0 [3.0,10.3]					
Gestational age <37 weeks			0.06	-2.1 (-4.5,0.3)	0.09†		
No	29	12.0 [7.5,15.0]					
Yes	30	10.5 [4.0,13.0]					
Postnatal age <48h			0.03*	3.2 (0.0,6.5)	0.05†	5.8 (3.3,8.4)	<0.001*
No	49	11.0 [5.0,13.0]					
Yes	10	14.5 [9.5,15.3]					
Female sex			0.87	-0.1 (-2.6,2.4)	0.95		
No	34	12.0 [6.3,14.0]					
Yes	25	11.0 [6.0,14.5]					
Resuscitation			0.38	1.8 (-1.8,5.4)	0.33		
No	51	11.0 [5.0,14.0]					
Yes	8	13.0 [10.3,14.0]					
Size-for-gestational age			0.21				
Appropriate-for-gestational age	46	11.0 [6.5,15.0]		Reference			
Small-for-gestational age	9	7.0 [3.5,12.5]		-2.4 (-5.8,1.0)	0.17†		
Large-for-gestational age	4	13.5 [12.3,14.0]		2.9 (-2.0,7.8)	0.24		
Glucose oral solution			0.004*	-6.8 (-10.9,-2.7)	0.002†	-6.4 (-9.4,-3.3)	<0.001*
No	54	12.0 [7.0,14.3]					
Yes	5	4.0 [2.0,6.0]					
Procedure duration <1 minute			0.54	-1.0 (-4.3,2.4)	0.56		
No	10	12.5 [8.5,15.0]					
Yes	49	11.0 [6.0,14.0]					
Procedure type			0.007*				
Intravenous	31	9.0 [6.5,12.8]		Reference			
Intramuscular	15	14.0 [12.0,15.0]		4.4 (1.6,7.2)	0.002†	4.6 (2.3,6.8)	<0.001*
Heelstick	13	9.5 [6.5,12.8]		0.5 (-2.4,3.4)	0.74	2.8 (0.6,5.0)	0.02*

DISCUSSION

This study investigated factors influencing pain scores in late preterm and term infants undergoing routine procedures. By focusing on hemodynamically stable infants, the findings are broadly applicable to a low-risk neonatal population. Using the PIPP-R, a validated pain assessment tool that incorporates gestational age, behavioral, and physiological indicators, we observed that even brief procedures resulted in PIPP-R scores within the moderate to severe range (interquartile range: 7–14). These findings highlight the importance of implementing pain mitigation strategies during routine neonatal care, regardless of procedure duration.[17]

Interestingly, LBW infants were associated with lower PIPP-R scores, with a regression coefficient of -2.9 (95% CI: -4.8, -1.1). LBW infants are often preterm or experience fetal growth restriction, which can result in developmental immaturity that impacts their behavioral and physiological pain responses.[17] These infants may exhibit less pronounced facial expressions or movements, partly due to underdeveloped motor control and limited energy reserves.[8] Additionally, postnatal illnesses such as hypoglycemia, commonly seen in LBW infants, may further blunt their responses to painful stimuli.

Although not statistically significant, our findings showed lower pain scores in infants whose mothers received MgSO4. This may reflect a potential dampening effect of MgSO4 on the infant's ability to respond to painful stimuli or a direct neuromodulatory action. Given the small number of exposed infants in our study, this observation should be interpreted with caution and warrants further investigation.

While this study included infants with GA starting at 34 weeks, where late preterm infants receive an additional point on the PIPP-R score due to their GA indicator, our findings revealed that term infants had higher PIPP-R scores compared to late preterm infants. Despite this adjustment, term infants exhibited higher PIPP-R scores, and a weak positive correlation between GA and PIPP-R scores was observed. This correlation suggests that advancing GA might contribute to slightly heightened pain perception or expression. However, these findings indicate that the additional scoring point for late preterm infants did not significantly impact the overall pain score. This aligns with our previous findings showing no significant differences in cerebral oxygenation responses between late preterm and term infants,[14] emphasizing that factors other than GA likely play a more critical role in shaping pain perception in this population. Unexpectedly, postnatal age <48 hours was associated with higher PIPP-R scores, with a regression

coefficient of 5.8 (95% CI: 3.3, 8.4). The selection of 48 hours as a cutoff assumed that neonates beyond this age would have transitioned through the critical phase of postnatal adaptation. This finding may be explained by the reduced exposure to medical interventions in neonates under 48 hours old, as the intensity of acute postnatal care typically decreases after this period. The lower procedural frequency may result in reduced cumulative stress and less sensitization to painful stimuli, potentially explaining the lower pain scores. Additionally, neonates older than 48 hours may exhibit better behavioral regulation, further attenuating their pain responses.

The duration of the procedure did not significantly correlate with pain scores ($r = -0.06$, $p = 0.68$). However, the procedural route significantly influenced pain intensity, with IM punctures resulting in higher PIPP-R scores compared to IV and heelstick procedures. Factors such as the depth of needle insertion, muscle contractions, and localized tissue drug accumulation during IM injections likely contribute to more intense nociceptor activation compared to the more superficial nature of IV or heelstick procedures. In this study, the needle sizes used were 25G for IM injections, 24G for IV procedures, and 28G for heelsticks. Although the IM needle was slightly larger than the heelstick needle, it was not the primary factor contributing to the increased pain scores. Previous research in adults has shown no significant association between needle gauge and pain response.[18] Instead, the deeper tissue penetration and mechanical irritation of muscle fibers during IM injections may trigger stronger muscle contractions and nociceptor activation.[19] Additionally, the localized accumulation of injected substances in muscle tissue likely amplifies discomfort compared to the smaller, more superficial punctures of IV and heelstick procedures. Our findings indicate that PIPP-R scores for heelstick procedures were higher than those for IV procedures [regression coefficients 2.8 (95% CI: 0.6, 5.0), $p = 0.02$]. This trend aligns with findings from a meta-analysis conducted in term infants[20], which suggests that IV routes should be prioritized when feasible to reduce pain intensity. Given the necessity of IM injections for routine neonatal care, such as vitamin K administration and vaccinations, it is crucial to implement effective analgesic measures to minimize discomfort, even for brief procedures. Strategies such as oral sucrose solution, swaddling, or facilitated tucking should be considered to improve procedural comfort and reduce pain.[5,17]

Oral sucrose solution demonstrated significant efficacy in reducing pain, with neonates receiving sucrose exhibiting lower PIPP-R scores compared to those who did not [regression coefficients: -6.4 (95% CI: -9.4, -3.3);

$p < 0.001$]. Its analgesic effect, mediated through activation of endogenous opioid pathways, aligns with previous studies documenting reduced pain and distress during procedures such as heelsticks, venipunctures, and IM injections.[21,22] However, only 8.5% of neonates in this study received sucrose, highlighting gaps in protocol adherence. To address this, a quality improvement project has been initiated to promote consistent and efficient use of oral sucrose for procedural pain management.

This study has several strengths, including its focus on routine neonatal procedures and the use of PIPP-R, a widely accepted pain assessment tool. Blinding assessors to procedure type and duration minimized bias, enhancing validity. Nevertheless, certain limitations exist. The analyzed procedures were brief and may not fully reflect pain responses to longer or more invasive interventions. Additionally, all included late preterm and term infants were hemodynamically stable, which likely reduced variability in physiological responses. Critically ill neonates, such as very preterm infants or those with hemodynamic instability, may exhibit more pronounced differences in pain responses,[23] highlighting the need for further investigation. PIPP-R scores may partially capture anxiety rather than pain alone, suggesting the need for exploring complementary non-pharmacological interventions such as swaddling or facilitated tucking. Finally, our findings must be considered in light of the relatively small sample inherent to this secondary analysis. Because our cohort size was determined by the parent study, no pre-specified sample size calculation was possible, and we may have been underpowered to detect associations for less common variables or modest effect sizes. Although this limitation cannot be remedied retrospectively, the trends and confidence intervals we observed offer valuable insights and generate hypotheses for further investigation. Larger, prospectively powered studies in more diverse neonatal populations will be essential to validate and extend these results and to deepen our understanding of how infant characteristics and procedural factors influence pain responses.

CONCLUSION

IM injections were associated with higher pain scores compared to IV procedures or heelsticks. Gestational age demonstrated a weak correlation with pain scores, while procedure duration did not influence pain levels. Lower pain scores were observed in LBW infants, whereas higher scores were observed in those <48 hours postnatal. Oral sucrose solution was effective in reducing pain. These findings underscore the critical need for consistent pain mitigation strategies to enhance procedural comfort in neonates.

Data Availability Statement

The datasets generated and/or analysed during this study are available from the corresponding author upon reasonable request.

Conflict of Interest

All authors declare no conflicts of interest.

Registration Number of Clinical Trial

This study is not a registered clinical trial. Ethical approval was obtained from the Siriraj Institutional Review Board, Faculty of Medicine Siriraj Hospital, Mahidol University (COA no. Si 435/2022).

Use of Artificial Intelligence

Artificial intelligence was used solely to assist with English language editing during the preparation of the initial draft of this manuscript. All study concepts, analysis, interpretation, and writing were initiated and carried out by the authors. The final version of the manuscript, prior to submission, was further reviewed and edited by a professional English-language editor to ensure clarity and accuracy.

Author Contributions

The authors confirm their contribution to the paper as follows: study conception and design: RK and SR; data collection: SR and PT; analysis and interpretation of results: RK, SR and IA; draft manuscript preparation and critical revision: RK, SR, and IA. All authors reviewed the results and approved the final version of the manuscript.

REFERENCES

1. McPherson C, Miller SP, El-Dib M, Massaro AN, Inder TE. The influence of pain, agitation, and their management on the immature brain. Pediatr Res. 2020;88(2):168-75.
2. Buser JR, Maire J, Riddle A, Gong X, Nguyen T, Nelson K, et al. Arrested preoligodendrocyte maturation contributes to myelination failure in premature infants. Ann Neurol. 2012;71(1):93-109.
3. Brummelte S, Grunau RE, Chau V, Poskitt KJ, Brant R, Vinall J, et al. Procedural pain and brain development in premature newborns. Ann Neurol. 2012;71(3):385-96.
4. Vinall J, Miller SP, Bjornson BH, Fitzpatrick KP, Poskitt KJ, Brant R, et al. Invasive procedures in preterm children: brain

and cognitive development at school age. Pediatrics. 2014;133(3): 412-21.

5. Johnston CC, Fernandes AM, Campbell-Yeo M. Pain in neonates is different. Pain. 2011;152(3 Suppl):S65-s73.

6. Walker SM, Melbourne A, O'Reilly H, Beckmann J, Eaton-Rosen Z, Ourselin S, et al. Somatosensory function and pain in extremely preterm young adults from the UK EPICure cohort: sex-dependent differences and impact of neonatal surgery. Br J Anaesth. 2018;121(3):623-35.

7. Hermann C, Hohmeister J, Demirakça S, Zohsel K, Flor H. Long-term alteration of pain sensitivity in school-aged children with early pain experiences. Pain. 2006;125(3):278-85.

8. Williams MD, Lascelles BDX. Early neonatal pain—a review of clinical and experimental implications on painful conditions later in life. Front Pediatr. 2020;8:30.

9. Slater R, Fabrizi L, Worley A, Meek J, Boyd S, Fitzgerald M. Premature infants display increased noxious-evoked neuronal activity in the brain compared to healthy age-matched term-born infants. Neuroimage. 2010;52(2):583-9.

10. Craig KD, Hadjistavropoulos HD, Grunau RV, Whitfield MF. A comparison of two measures of facial activity during pain in the newborn child. J Pediatr Psychol. 1994;19(3):305-18.

11. Gibbins S, Stevens B, McGrath PJ, Yamada J, Beyene J, Breau L, et al. Comparison of pain responses in infants of different gestational ages. Neonatology. 2008;93(1):10-8.

12. Maxwell LG, Fraga MV, Malavolta CP. Assessment of pain in the newborn: an update. Clin Perinatol. 2019;46(4):693-707.

13. Olsson E, Ahl H, Bengtsson K, Vejayaram DN, Norman E, Bruschettini M, et al. The use and reporting of neonatal pain scales: a systematic review of randomized trials. Pain. 2021; 162(2):353-60.

14. Amornjiraporn I, Rugsapol S, Thanasarnpaiboon P, Paes B, Kitsommart R. A comparison of the effect of procedural pain on cerebral oxygen saturation between late preterm and term infants. J Perinatol. 2024; doi: 10.1038/s41372-024-01978-4.

15. Wilson-Smith EM. Procedural pain management in neonates, infants and children. Rev Pain. 2011;5(3):4-12.

16. Gibbins S, Stevens BJ, Yamada J, Dionne K, Campbell-Yeo M, Lee G, et al. Validation of the Premature Infant Pain Profile-Revised (PIPP-R). Early Hum Dev. 2014;90(4):189-93.

17. Good practice in postoperative and procedural pain management, 2nd edition. Paediatr Anaesth. 2012;22 Suppl 1:1-79.

18. Yoon SH, Rah UW, Sheen SS, Cho KH. Comparison of 3 needle sizes for trigger point injection in myofascial pain syndrome of upper- and middle-trapezius muscle: a randomized controlled trial. Arch Phys Med Rehabil. 2009;90(8):1332-9.

19. Tucker MH, Tiwari P, Carter BS. The physiology, assessment, and treatment of neonatal pain. Semin Fetal Neonatal Med. 2023; 28(4):101465.

20. Shah VS, Ohlsson A. Venepuncture versus heel lance for blood sampling in term neonates. Cochrane Database Syst Rev. 2011; doi: 10.1002/14651858.CD001452.pub4(10).

21. Stevens B, Yamada J, Ohlsson A, Haliburton S, Shorkey A. Sucrose for analgesia in newborn infants undergoing painful procedures. Cochrane Database Syst Rev. 2016;7(7):Cd001069.

22. Witt N, Coynor S, Edwards C, Bradshaw H. A guide to pain assessment and management in the neonate. Curr Emerg Hosp Med Rep. 2016;4(1):1-10.

23. Moolmai P, Rattanachamnongk P, Yangthara B, Wutthigate P. Factors influencing bronchopulmonary dysplasia: an eight-year study in a single tertiary care unit in Thailand. Siriraj Med J. 2025;77(2):158-67.