Donna Dowling, PhD, RN ○ Section Editor

CE 2.5 HOURS Continuing Education

Effect of Vibration on Pain Response to Heel Lance

A Pilot Randomized Control Trial

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ABSTRACT

Background: Applied mechanical vibration in pediatric and adult populations has been shown to be an effective analgesic for acute and chronic pain, including needle pain. Studies among the neonatal population are lacking. According to the Gate Control Theory, it is expected that applied mechanical vibration will have a summative effect with standard nonpharmacologic pain control strategies, reducing behavioral and physiologic pain responses to heel lancing.

Purpose: To determine the safety and efficacy of mechanical vibration for relief of heel lance pain among neonates.

Methods: In this parallel design randomized controlled trial, eligible enrolled term or term-corrected neonates (n = 56) in a level IV neonatal intensive care unit were randomized to receive either sucrose and swaddling or sucrose, swaddling, and vibration for heel lance analgesia. Vibration was applied using a handheld battery-powered vibrator (Norco MiniVibrator, Hz = 92) to the lateral aspect of the lower leg along the sural dermatome throughout the heel lance procedure. Neonatal Pain, Agitation, and Sedation Scale (N-PASS) scores, heart rate, and oxygen saturations were collected at defined intervals surrounding heel lancing.

Results: Infants in the vibration group (n = 30) had significantly lower N-PASS scores and more stable heart rates during heel stick ($P = .006$, $P = .037$) and 2 minutes after heel lance ($P = .002$, $P = .016$) than those in the nonvibration group. There were no adverse behavioral or physiologic responses to applied vibration in the sample.

Implications for Practice and Research: Applied mechanical vibration is a safe and effective method for managing heel lance pain. This pilot study suggests that mechanical vibration warrants further exploration as a nonpharmacologic pain management tool among the neonatal population.

Key Words: analgesia, heel lance, heel stick, infant, neonatology, newborn, pain management, sucrose, vibration

Infants hospitalized in the neonatal intensive care unit (NICU) are often exposed to repeated, painful procedures that are medically necessary, yet carry adverse short- and long-term effects.[1] Neonates born extremely premature have intact nociception, but are limited in their ability to communicate pain.[2] Pain thresholds of neonates are lower when compared with children and adults because of immature descending inhibitory pathways and lower tactile thresholds prone to further sensitization,[3-6] making neonates uniquely vulnerable to the detrimental effects of pain. Infants who are born very premature often experience more than 100 skin-breaking procedures during their NICU hospitalization.[7] Pain exposure, even after controlling for acuity and clinical factors, is associated with abnormalities in brain development with effects persisting into school age.[7-10] In light of continued emerging evidence linking pain exposure to poorer outcomes, it is the responsibility of neonatal professionals to decrease pain exposure while continually striving to manage pain more effectively.

Heel lances to obtain laboratory specimens are the most common invasive procedure in the NICU.[11] Although common and less invasive than other methods of blood sampling, heel lances are not without risk. Adverse effects have diminished since the introduction of automated devices that slice with a blade to a defined depth rather than puncture, yet the risks of nerve damage, bone damage, osteomyelitis, infection, and scarring remain.[12] Heel lancing is more painful than venous needle sticks[13,14] and may be increasingly painful with repeated heel lances. Evidence has demonstrated central and peripheral sensitization from repeated heel sticks in animal models: wounding of the hindpaw skin of newborn rats causes a localized increase of nerve growth factor and subsequent proliferation of local nerve terminals resulting in increased sensitivity to pain.[15] This hypersensitivity persists after wounds have healed for 6 weeks or more after tissue injury.[16]

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Supported by a grant from the Dudley L. Moore Nursing and Allied Health Fund.

The authors declare no conflicts of interest.

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DOI: 10.1097/ANC.0000000000000315

The pain experienced by repeated heel lances may lead to lasting negative effects on pain processing and stress response. In a study to investigate the effects of repetitive neonatal pain, rat pups that received 4 heel lances per day for the first 7 days of life were compared with rat pups that received a nonpainful tactile stimulation to their hindpaws with a cotton swab at the same intervals. The heel lance group experienced decreased pain thresholds through adulthood as well as defensive-withdrawal behaviors and anxiety/hypervigilance behaviors, increased glucocorticoid response to emotional stressors, and an increased preference for alcohol.[17] These findings suggest that infants in intensive care may be at increased risk for similar long-term effects of pain exposure because they experience frequent painful procedures coupled with maternal separation, nonsocial handling, and noxious environmental stimuli.

Pharmacologic pain management for heel lance pain is ineffective and not often considered because of associated risks related to sedation, respiratory depression, and potential toxicity. Studies have shown that topical local anesthetics (eutectic mixture of local anesthetic [EMLA], amethocaine) and acetaminophen are not effective for heel lance pain.[18,19] Even morphine has proven ineffective at mitigating heel lance pain.[20,21]

Numerous studies have investigated nonpharmacologic interventions to mitigate heel stick pain. Of these, sucrose administration has received the most scientific attention prompting wide clinical use for procedural pain management.[22] The latest meta-analysis of the analgesic effects of sucrose continues to support its use for heel lance pain management; however, the long-term effects of sucrose are unknown.[11] Therefore, sucrose may not be the optimal solution for minor procedural pain. Limitations of sucrose include that it is not recommended in extremely premature infants, and its use in unstable, ventilated infants has not been studied. Sucrose consistently decreases neonatal behavioral pain response, but has not been shown to attenuate the tachycardia response to acute pain.[23] Other research has shown that sucrose does not alter nociceptive brain activity and reflexive withdrawal to pain, suggesting that it may only mute behavioral responses.[24] Recently, Asmerom and colleagues[25] demonstrated that oral sucrose administration increases adenosine triphosphate usage and higher markers of oxidative stress were found in infants given sucrose versus controls. This suggests further investigation into sucrose alternatives is warranted.

Swaddling or gentle containment has been shown to have an analgesic effect during a heel lance.[26,27] Other literature-supported methods of nonpharmacologic pain management for heel sticks that are less commonly used in the NICU include skin-to-skin parental holding[28] and breastfeeding[29] during the procedure. In accordance with current evidence,[11,19,22] swaddling and sucrose with offered nonnutritive sucking (ie, pacifier) remain the current standard of care for heel stick pain management. Because of growing debate over the safety and efficacy of sucrose, new methods for managing the procedural pain associated with heel sticks are needed.

What This Study Adds

- Evidence that applied vibration with sucrose versus sucrose alone results in lower behavioral and physiologic pain response to heel stick in term and term-corrected neonates.
- Investigation of novel nonpharmacologic method of pain management in the neonatal population.
- Further scientific inquiry regarding vibration for neonatal analgesia is warranted.

Vibratory stimulation for pain alleviation is used in adult and pediatric populations[30-32]; however, there is a paucity of research evaluating vibration analgesia among the neonatal population. The analgesic effect of vibration is understood through the Gate Control Theory of Pain, first proposed by Melzack and Wall in 1965,[33] which theorized that stimuli transmitted by various afferent fibers compete at the dorsal horn so that only the predominant stimulus is transmitted to secondary neurons that ascend the spinothalamic tract. Therefore, a threshold of stimuli is required to "open the gate" and competing impulses have the potential to "close the gate." Since the Gate Control Theory was originally proposed, our understanding of pain and pain processing has continued to evolve, acknowledging that pain is a dynamic process that is individually influenced by previous experience and genetics.[34,35] Although the Gate Theory has since been replaced by more complex pain theory, its concept of modulating peripheral and spinal afferent impulses remains clinically relevant today.[36] Animal studies first demonstrated that nociceptive neurons are depressed by vibration.[37] It was later found through human research that higher pain thresholds and prolonged reaction times with applied vibration are apparent.[38] Similar to the practice of "rubbing away the pain," vibration applied during a painful stimulus can blunt or block afferent pain impulses with large fiber signals that "close the gate" so that less pain signals ever reach the brain.

Despite the lack of research surrounding neonatal use of vibration, infants are regularly exposed to mechanical vibration. In both hospital and home settings, vibration is often used for soothing infants (vibrating infant seats/swings). Mechanical vibration has been shown to have some benefit on calming colicky babies[39] and may even have a future use in the NICU for stabilizing preterm respiratory patterns through stochastic mechanosensory stimulation.[40] Applied vibration with a mechanical handheld vibrator is one method of chest physiotherapy in the NICU.[41] Mechanical vibration, however, also has the potential to reduce pain in the neonatal population.

A literature search revealed only one study that has investigated the effect of vibration on heel stick pain in infants.[42] This study used a random-crossover design where infants received 5 seconds of applied vibration using a handheld vibrator immediately before heel lancing on either their first or second heel lance. Heel lance pain was scored by a blinded observer using the Neonatal Infant Pain Scale (NIPS). They found that the crossover design led to order effects of habituation as experiential differences can affect responses to subsequent painful stimuli.[43,44] Although the results did not show a statistically significant reduction in NIPS scores, the group that received vibration before the second heel stick approached statistical significance and there were no negative effects observed. This suggested that further study was warranted and led to the hypothesis that continuing the applied vibration throughout the duration of the heel stick procedure might further reduce pain.

PURPOSE

The primary purpose of this study was to measure the effect of applied mechanical vibration on pain response (Neonatal Pain, Agitation, and Sedation Scale [N-PASS] scores, change in heart rate and oxygen saturation from baseline) to heel lance. The secondary purpose of this pilot study was to assess the safety and risks of applied mechanical vibration (92 Hz, 0.6-mm amplitude) for neonatal analgesia. We hypothesized that applied mechanical vibration would result in decreased pain response with heel stick with no adverse effects.

METHODS

Design

This prospective randomized controlled trial investigated the effect of vibration on pain response to a heel stick among term infants. The current standard of care for heel stick pain management is swaddling and oral sucrose. This study compares vibration in addition to standard of care (experimental group) versus standard care alone (control group). Because of the nature of the intervention, the study was not blinded. To minimize variation in technique, all heel lances were performed by the primary investigator. N-PASS scores were consistently scored by the hospital's pain management nurse coordinator. She is an expert in neonatal and pediatric pain and was responsible for the implementation of the N-PASS tool months before the start of this study. To minimize bias in the absence of blinding, the bedside nurse served as a secondary independent rater of pain.

The study protocol and all informed consent documents were approved by the institutional review board. Hospitalized infants were screened for eligibility biweekly by the primary investigator, and eligible babies with parents present were approached for study enrollment.

Sample

This study was conducted in a 43-bed level IV[45] regional NICU. All patients in this children's hospital NICU were transferred from referring hospitals because of the need for specialty services. Eligibility criteria for inclusion in this study are listed in Box 1. All patients enrolled were either term or term-corrected and were required to be off of respiratory support. Conditions that could potentially alter pain perception or response were excluded from this study. Likewise, conditions that would require alteration of the procedure (eg, clubfeet and severe osteopenia) were excluded. Data were collected from September 2014 through May 2015.

Instruments

Vibrator Device Information

The Norco MiniVibrator (North Coast Medical Inc, NC70209, Gilroy, California) operates at 92 Hz and an amplitude of 0.6 mm. There is evidence to support this frequency being within the therapeutic range for analgesia,[32,46] and this device is comparable to the vibrator used in the previous study investigating vibration for relief of heel stick pain.[42] The MiniVibrator was chosen over other commercially available devices marketed for vibration analgesia for our study because it was readily available for use in our NICU for vibratory chest physiotherapy. The device was considered a nonsignificant risk device by the institutional review board.

The Neonatal Pain, Agitation, and Sedation Scale

Pain was measured using the N-PASS, the neonatal pain assessment tool used in our NICU s. Using a combination of physiologic and behavioral indices, the N-PASS pain assessment tool is a valid and reliable tool for assessing acute heel stick pain in neonates.[47,48] This instrument was validated in infants 0 to 30 days of age (23-40 weeks' gestation) and resulted in excellent internal consistency (Cronbach

Box 1. Eligibility and Exclusion Criteria

Eligibility Criteria	Exclusion Criteria
• ≥38 wk CGA • In RA (no supplemental flow/oxygen in previous 24 h) • ≥1 wk postoperative *or* no surgical history • No narcotics or sedatives in previous 24 h	• Neurological injury/ impairment[a] • Major chromosomal anomalies • Inborn errors of metabolism • Presence of pacemaker • Lower limb deformity • Fragile bones precautions • Thrombolytic therapy

Abbreviations: CGA, corrected gestational age; RA, room air.
[a]Defined as severe intraventricular hemorrhage (grade III or IV), periventricular leukomalacia, hypoxic-ischemic encephalopathy, hydrocephalus, brain malformation, spina bifida, or history of seizures.

α = 0.84-0.89). Interrater agreement was excellent (intraclass correlation coefficient = 0.86-0.93) and correlation of the N-PASS with Premature Infant Pain Profile scores showed good construct validity (r_s= 0.75). The N-PASS was also chosen over other neonatal pain assessment tools because it was already in routine use in the unit where this study took place. Therefore, the staff already had a comfort level with the tool and interrater testing had taken place on the unit several months before the start of this pilot study.

Study Procedure

Written parental consent was obtained for all patients enrolled in our study. Enrolled patients were scheduled to have their next laboratory values drawn by the study team. All heel sticks performed were clinically necessary. Immediately before the heel stick procedure, participants were randomized using a block randomization schema to either the control or experimental group at a 1:1 ratio. To ensure equal distribution of previous experiences with pain, surgical and nonsurgical participants were randomized separately. Demographic and contextual data were collected before heel stick.

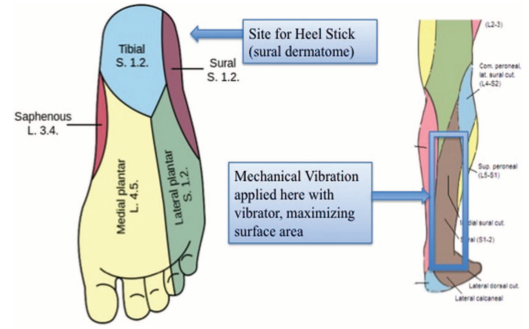
Control Group

Patients randomized to the control group were first swaddled with 1 leg exposed and a heel warmer placed on the exposed heel 3 to 5 minutes before the lance. Two minutes before the heel stick, the patient was given 0.1 to 0.2 mL of oral 24% sucrose with pacifier offered. Before the lance, the heel warmer was removed and site prepared with alcohol. Using the appropriate-sized Tenderfoot lancet, the outer edge of the lateral plantar surface was lanced, along the sural dermatome. A period of 10 seconds without squeezing was observed to estimate the response to the heel stick alone. After this undisturbed phase, blood was collected with intermittent squeezing and allowing for capillary refill. After 0.4 to 1 mL of capillary blood was collected, a small adhesive bandage was applied to the heel and the infant was reswaddled in a flexed, midline posture.

Experimental Group

The experimental group procedure was identical to the control except for the following: approximately 30 seconds before the heel stick, the vibrator was applied over the mid/lateral calf, just below the knee in accordance with the sural dermatome (see Figures 1 and 2) for a 30-second "test" vibration. During this period, the infant was observed carefully for any adverse responses. If the infant had any apnea, bradycardia, or desaturation, the vibrator was immediately removed and reaction documented. Similarly, if the infant demonstrated sustained heart rate elevation 20% above baseline or persistent crying, the mechanical vibration was immediately removed and not reapplied. If there were no adverse responses observed during the 30-second trial, the vibration was continued throughout the duration of the heel lance procedure and was stopped immediately before the application of the adhesive bandage. Adverse responses were recorded. The site of applied vibration was monitored for any redness, swelling, bruising, or alteration in skin integrity.

FIGURE 1

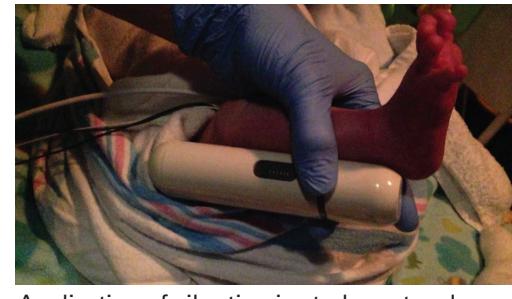


Dermatomes of leg and plantar surface of the foot.[49]

Data Collection

Study data were entered into REDCap, a secure electronic research database hosted by our institution. The following variables were collected at defined intervals during the heel stick procedure: heart rate, oxygen saturation, and N-PASS pain score. The first data collection time point, defined as baseline, was immediately following swaddling and heel-warmer application. These data were again collected immediately after the heel stick to estimate pain response to the heel stick and at 2-minute and at 5-minute postheel stick to reflect recovery. Two independent raters assigned the N-PASS scores. The hospital's pain management nurse coordinator was present for all heel sticks and consistently rated N-PASS scores at the defined time points. The second rater was the infant's bedside nurse who independently entered N-PASS scores at the defined time points. All nurses who served as the second rater had received previous training in N-PASS scoring.

FIGURE 2



Application of vibration in study protocol.

In addition to the above data collection, a retrospective chart review was performed on all study participants to review degree of hemolysis of samples collected via control procedure versus vibration procedure to determine whether there was a significant difference between groups.

Statistical Power

Before starting the study it was determined that 60 subjects (30 per group) would be required to detect a 2-point difference in the change in N-PASS scores between the experimental and control groups. Specifically, the sample size and power were calculated to compare the relative change in N-PASS scores and vital signs compared between treatment groups. A sample size of 60 patients (30 per group) achieves 80% power to detect a 2-point difference in the average increase in pain between treatment groups. Power was calculated assuming the standard deviation of 2.6[48] using a 2-sided Mann-Whitney test with a .05 level of significance.

Statistical Analysis

Descriptive statistics were calculated for all variables of interest and compared between treatment groups. Means and standard deviations or median and interquartile ranges were calculated for continuous variables and compared using 2-sample *t* tests or Wilcoxon rank-sum tests, as appropriate. Counts and frequencies were calculated for categorical variables and compared using χ^2 tests. When expected cell counts were less than 5, exact tests were used. Outcomes of interest included N-PASS score, heart rate, and Spo_2. Means and standard deviations were calculated for each outcome at each study time point (Baseline, Heel Stick, 2 minutes poststick, and 5 minutes poststick). Before modeling, baseline measurements were subtracted from each time point to assess the change in outcome relative to baseline. Repeated-measures analysis of variance was used to model the change from baseline for each outcome at each time point after their initial assessment. A Tukey-Kramer multiple comparisons procedure was used to account for multiple comparisons. A subanalysis of very low birth-weight (VLBW) infants weighing less than 1500 g at birth and extremely low birth-weight (ELBW) infants weighing less than 1000 g at birth was also performed using similar methods. To verify that vibration alone did not change outcomes, outcomes at baseline and test vibration were compared using paired *t* tests. Interrater agreement was assessed using a weighted κ statistic Spearman correlation coefficient, and paired *t* tests. Statistical significance was assessed at the .05 level and SAS version 9.3 (Cary, North Carolina) was used for analysis.

RESULTS

A total of 76 families were approached: 62 consented and 14 refused. Of the 62 who consented, 4 patients were transported or discharged from hospital before intervention completion and 2 were no longer eligible at time of scheduled intervention. A total of 56 patients were included in this pilot study (Table 1). There were no losses or exclusions after randomization as this was done immediately before heel stick procedure. In addition to demographic data, contextual clinical data were recorded for each participant before the heel stick (Table 2). Both the demographic and contextual clinical data collected were variables that had the potential to alter pain response.[20,43] No significant differences in demographic or clinical characteristics were found between the vibration and control groups. Of note, there were 4 infants in the experimental group and

TABLE 1. Demographics

Characteristics	Vibration (n = 30) n (%) or Median (25th-75th)	Control (n = 26) n (%) or Median (25th-75th)	*P* Value
Gender			.832
Female	13 (43.3)	12 (46.2)	
Male	17 (56.7)	14 (46.2)	
Race			.350
White	11 (36.7)	12 (46.2)	
Black	17 (56.7)	10 (38.5)	
Other	2 (6.7)	4 (15.4)	
Patient weight, kg	3.20 (2.72-3.61)	2.84 (2.56-3.19)	.052
Birth weight, kg	2.67 (1.30-3.17)	2.27 (1.30-2.67)	.192
Gestational age, wk	38 (30-39)	36 (20-38)	.192
Postconceptual age, wk	41 (39-43)	40 (39-41)	.131
Length of stay, d (n = 53)	22 (14-37)	28 (13-55)	.581

TABLE 2. Clinical Characteristics

Characteristics	Vibration Group (N = 30) n (%) or Median (25th-75th)	Control Group (N = 26) n (%) or Median (25th-75th)	*P*
Surgical status			
Surgical	22 (73.3)	20 (76.9)	.757
Nonsurgical	8 (26.7)	6 (23.1)	
Number of painful procedures in previous 24 h			
0	27 (90.0)	21 (80.8)	.549
1	3 (10.0)	4 (15.4)	
2	0 (0.0)	0 (0.0)	
≥3	0 (0.0)	1 (3.9)	
Time since last pain exposure			
0-11 h	1 (3.3)	82 (7.7)	.613
12-23 h	2 (6.7)	3 (11.5)	
≥24 h	27 (90.0)	21 (80.8)	
Handling before heel stick			
Yes	4 (13.3)	6 (23.1)	.487
No	26 (86.7)	20 (76.9)	
Sleep state before heel stick			
Awake	9 (30.0)	8 (30.8)	1.00
Crying	1 (3.3)	0 (0.0)	
Deep	13 (43.3)	11 (42.3)	
Light	7 (23.3)	7 (26.9)	
Time since last feeding			
Nothing by mouth	2 (6.7)	4 (15.4)	.771
0-2	3 (10.0)	3 (11.5)	
3	18 (60.0)	13 (50.0)	
Continuous	7 (23.3)	6 (23.1)	
Parental support during procedure			
Yes	1 (3.3)	0 (0.0)	1.00
No	29 (96.7)	26 (100.0)	
Amount of blood obtained	0.8 (0.8-0.9)	0.8 (0.6-0.9)	.192

2 infants in the control group who did not want the offered pacifier, and the sucrose was administered directly to the anterior tongue.

To address the question of safety and tolerance, all infants in the experimental group (n = 30) received the test vibration before to heel lancing. There were no adverse behavioral or physiological responses to applied vibration (Table 3). All infants randomized to the vibration group received the vibration throughout the heel stick procedure.

Figures 3 and 4 represent the actual clinical outcomes measures presented graphically. Table 4 demonstrates the differences within groups for each outcome measure and also provides *P* values to compare differences between control and experimental groups at each time point. Changes in heart rate and N-PASS pain score from baseline were significantly lower in the vibration group than in the nonvibration group. Although both groups had elevated pain scores at the time of heel lance, the change in pain score from baseline in the vibration group was significantly less at the time of the heel lance (1.03 [0.07 to 2.00] vs 3.65 [2.62 to 4.69], $P = .006$) and 2 minutes after the lance (0.23 [−0.57 to 1.03] vs 2.04 [1.18 to 2.90], $P = .037$) compared with the nonvibration group. At 2 minutes after heel lancing, the vibration group's mean pain score was no longer significantly different from the mean baseline pain score whereas the control group's mean pain score remained significantly elevated ($P < .001$). The vibration group had significantly lower elevations in heart rate at the time of the heel lance (8.67 [4.59 to 12.74] vs 21.11 [16.74 to 25.49], $P = .002$) and 2 minutes after the lance (1.23 [−3.81 to 6.28] vs 13.73 [8.31 to 19.15], $P = .016$)

TABLE 3. Safety Evaluation[a]

Measure	Group	Mean (95% CI)	*P* Value
Heart rate	Baseline	158.1 (153.2 to 163.0)	.056
	Test vibration	160.9 (156.2 to 165.6)	
Spo_2	Baseline	98.5 (97.5 to 99.5)	.116
	Test vibration	99.1 (98.5 to 99.7)	

Abbreviation: CI, confidence interval.
[a]*Difference between test vibration and baseline in experimental group (n = 30).*

compared with the control group. Again, at 2 minutes after lancing, the vibration group's mean heart rate was no longer significantly different from baseline whereas the control group's mean heart rate remained significantly elevated above baseline ($P <$ .001). The oxygen saturation did not change significantly in either group at any of the time points.

Interrater Reliability

The data presented in Figure 3 and Table 4 use the N-PASS scores of the primary expert rater. To validate the findings, these N-PASS scores were compared with those scored simultaneously by a secondary independent rater. There was moderate to good agreement between the 2 raters. The weighted κ value for baseline N-PASS scores was 0.34. The weighted κ values for the other time points ranged from 0.60 to 0.61. There was moderate correlation between raters at each time point (r = 0.33-0.86). A sensitivity analysis was performed using the second rater's N-PASS scores, and similar results were seen when compared with the primary expert rater scores (see Table 5).

Hemolysis Data

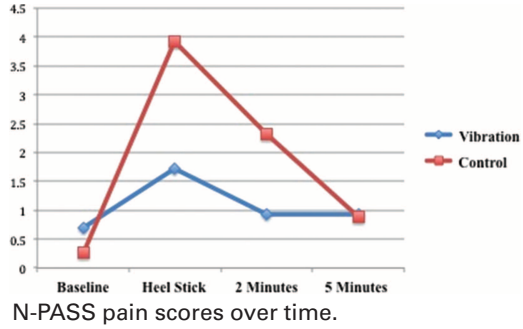
Post-hoc data collection and analysis were performed on all blood specimens to determine the degree of hemolysis subsequent to vibration. No significant difference between the vibration group and the control group in degree of hemolysis of sample was observed (P = .580).

Subgroup Analyses

During the process of data collection, the study team repeatedly observed that vibration seemed to be particularly effective for the infants born very premature who were very sensitive to tactile stimulation. Anecdotally, this subgroup of patients would already be quite agitated at baseline and with the application of vibration would soothe with sometimes no discernable physiologic or behavioral response to the heel stick. To investigate this perceived phenomenon, post-hoc subgroup analyses were performed to determine whether there were gestational age effects on vibration analgesia. The VLBW subgroup is composed of study patients who weighed less than 1500 g at birth, remembering that for inclusion in this study they were at least 38 weeks' corrected gestational age at the time of intervention.

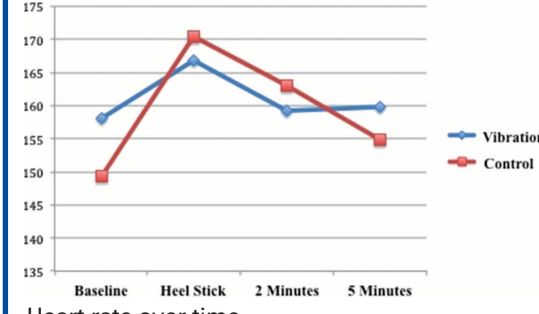
The VLBW subgroup analysis is shown in Table 6. N-PASS scores in the VLBW control group were significantly elevated from baseline at heel stick and 2 minutes (4.44 [2.25 to 6.64], P = .001, 1.56 [0.30 to 2.81], P = .019), but the VLBW vibration group N-PASS scores were never significantly different from baseline at any of the time points (0.75 [−1.58 to 3.09], P = .504, 0.13 [−1.21 to 1.46], P = .845). A subgroup analysis on ELBW infants, defined as less than 1000 g at birth, revealed similar findings as the VLBW subgroup. Although inadequately powered (n = 10) to show significant difference between vibration and control groups, there were significant findings within ELBW groups. The N-PASS scores in the ELBW vibration group were not significantly elevated from baseline at any time point (−0.40 [−3.59 to 2.79], P = .780, 0.00 [−1.58 to 1.58], P = 1.000,

FIGURE 3



N-PASS pain scores over time.

FIGURE 4



Heart rate over time.

TABLE 4. Change in Mean Measures From Baseline With Comparison Between Groups (Δ, 95% CI)

Measure	Group	Heel Stick	2 min	5 min
N-PASS	Vibration	1.03 (0.07 to 2.00)[a]	0.23 (−0.57 to 1.03)	0.23 (−0.54 to 1.00)
	Control	3.65 (2.62 to 4.69)[a]	2.04 (1.18 to 2.90)[a]	0.62 (−0.21 to 1.44)
	P value[b]	.006	.037	.984
Heart Rate	Vibration	8.67 (4.59 to 12.74)[a]	1.23 (−3.81 to 6.28)	1.70 (−3.56 to 6.96)
	Control	21.11 (16.74 to 25.49)[a]	13.73 (8.31 to 19.15)[a]	5.58 (−0.08 to 11.23)
	P value[b]	.002	.016	.914
Spo2	Vibration	0.80 (−1.91 to 3.51)	0.77 (−1.98 to 3.52)	0.70 (−2.92 to 4.32)
	Control	1.85 (−1.06 to 4.76)	1.58 (−1.38 to 4.53)	−0.73 (−4.61 to 3.15)
	P value[b]	.996	.999	.994

Abbreviation: N-PASS, Neonatal Pain, Agitation, and Sedation Scale.
[a]*Significant difference from baseline score (P < .05).*
[b]*P value compares between groups within time point.*

−0.40 [−1.43 to 0.63], $P = .397$). The ELBW control group, unlike any other group, had significantly elevated N-PASS scores at all of the time points including 5 minutes after the heel stick (4.40 [1.21 to 7.59], 1.80 [0.22 to 3.38], 1.20 [0.17 to 2.23]).

DISCUSSION

Nonpharmacologic pain management is of utmost importance in our patient population that is not only subjected to repetitive and acutely painful procedures such as heel lances, but also highly vulnerable to developmental injury because of repeated pain exposure. The significant findings of this study were that vibration for relief of heel lance pain was both effective (reduced N-PASS pain scores and heart rate elevation) and safe. There were no adverse effects from applied vibration and the method was well tolerated.

Some of the most fascinating findings were those of the term-corrected VLBW and ELBW subgroups. These subgroup analyses suggested, although inadequately powered for statistical significance between groups, that vibration analgesia may be most effective in these subgroups of patients. Despite the small sample size, there does seem to be a gestational age effect where vibration yielded increased pain relief in the VLBW and ELBW experimental groups: N-PASS scores were never significantly elevated from baseline in contrast to the larger sample where N-PASS scores were elevated at heel stick in both groups although significantly less in the experimental group. Future research to investigate this potential correlation is certainly warranted.

This study, building on the work of Baba et al[42] and using the principles of the Gate Control Theory, demonstrates that applied mechanical vibration during heel lance significantly decreases physiologic and behavioral pain response in neonates. Perhaps the biggest difference between the study of Baba et al and ours was the method of vibration application. Infants in their study received only 5 seconds of vibration directly to the heel before the heel stick, whereas participants in our study received 30 seconds of vibration before the heel stick and continued application throughout the capillary sample collection. Application of the stimulus throughout the heel lancing procedure may account for the significance of findings in this study.

The limitation of this design, however, was the inability to blind to intervention. When vibration is applied before and throughout the duration of the heel lance procedure (lance and blood collection), blinding would require a sham vibrator or perhaps

TABLE 5. Change in Secondary Rater's Mean N-PASS Scores From Baseline With Comparison Between Groups (Δ, 95% CI)

Measure	Group	Heel Stick	2 min	5 min
N-PASS	Vibration	0.83 (0.11 to 1.55)[a]	0.20 (−0.44 to 0.84)	0.20 (−0.38 to 0.78)
	Control	3.00 (2.23 to 3.77)[a]	1.92 (1.24 to 2.61)[a]	0.62 (−0.02 to 1.24)
	P value[b]	.002	.006	.335

Abbreviation: N-PASS, Neonatal Pain, Agitation, and Sedation Scale.
[a]*Significant difference from baseline score (P < .05).*
[b]*P value compares between groups within time point.*

TABLE 6. Change in Mean Measures From Baseline in VLBW Patients With Comparison Between Groups (N = 17) (Δ, 95% CI)

Measure	Group	Heel Stick	2 min	5 min
N-PASS	Vibration	0.75 (−1.58 to 3.08)	0.13 (−1.21 to 1.46)	−0.25 (−1.27 to 0.77)
	Control	4.44 (2.25 to 6.64)[a]	1.56 (0.30 to 2.81)[a]	0.56 (−0.41 to 1.52)
	P value[b]	.202	.576	.821
Heart rate	Vibration	9.13 (2.46 to 15.79)[a]	1.63 (−8.31 to 11.56)	1.63 (−9.48 to 12.73)
	Control	22.33 (16.05 to 28.62)[a]	9.89 (0.52 to 19.26)[a]	5.44 (−5.03 to 15.92)
	P value[b]	.072	.786	.994
Spo_2	Vibration	2.00 (−8.07 to 12.07)	2.13 (−8.07 to 12.32)	1.63 (−8.59 to 11.84)
	Control	5.78 (−3.71 to 15.27)	5.33 (−4.28 to 14.94)	5.22 (−4.41 to 14.86)
	P value[b]	.991	.996	.593

Abbreviation: N-PASS, Neonatal Pain, Agitation, and Sedation Scale.
[a]*Significant difference from baseline score (P < .05).*
[b]*P value compares between groups within time point.*

limiting those scoring pain to not be able to view the lower extremities and turning on the vibrator for each intervention (whether or not it was actually applied to the patient). Methods to blind this particular intervention were not feasible for this pilot study but should be considered in future trials.

There is a multitude of implications for future research regarding the use of vibration for pain relief in the neonatal population. There are a myriad of other potential uses for vibration analgesia in the NICU: intramuscular/subcutaneous injections, minor incisions, suture/staple removal, and venipuncture. There are many questions that are unanswered about the best use of vibration analgesia in this population from the best method of application to the ideal frequency of vibration for pain relief. There are commercial devices[50-52] specifically marketed for vibrational analgesia, although none has been tested on neonates. For needle stick pain, these device manufacturers recommend the device be used over the site of injection and moved slightly proximal before the needle stick. In our procedure, we did not apply vibration directly to the infant's heel because we were concerned that this would be noxious or irritating to our patients. It is possible, however, that vibrating directly over the heel before the stick would be beneficial. Also, investigation of the effect of applied vibration on nociceptive brain activity using near-infrared spectroscopy or electroencephalography instrumentation may offer the most objective, quantitative method as these applications become more readily used in neonatal pain research.[53]

We conducted this study on term and term-corrected neonates. Although preterm infants are often exposed to mechanical vibration during transport, high-frequency ventilation, and occasionally during chest physiotherapy, the long-term effect of vibration exposure in preterm infants is unknown. Introducing applied vibration for analgesia to this population should be done cautiously with consultation of experts.

CONCLUSIONS

Our findings suggest that infants who received both sucrose and applied mechanical vibration had lower

Summary of Recommendations for Practice and Research

What we know	• Painful procedures experienced during the neonatal period result in both short-term and long-term adverse effects. • Heel sticks are the most common painful procedure in the neonatal population. • Applied vibration along with oral sucrose during heel stick resulted in better analgesia compared with oral sucrose alone.
What needs to be studied	• Safety and efficacy of applied vibration in preterm population. • Investigate possible gestational age effects. • Define optimal "dose" (frequency/amplitude) and method of application for vibrational analgesia. • Investigate other applications for vibration analgesia in neonatal population (eg, intramuscular/subcutaneous injections and venipuncture).
What can we do today	• In term or term-corrected neonates, applied vibration can be used as an adjunct or alternative to oral sucrose for heel stick pain management.

pain response compared with infants who received sucrose alone. Vibration, achieved with an inexpensive handheld vibrator, offers an effective adjunct or alternative to oral sucrose for heel stick pain management.

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