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ORIGINAL ARTICLE

Prior leg massage decreases pain responses to heel stick in preterm babies

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Aim: Leg massage could inhibit the transmission of pain by 'closing the gate' or by activating the endogenous opioid pathway to decrease nociceptive transmission of pain associated with heel stick. The aim of this study is to determine the effects of massage therapy prior to heel stick on responses assessed by the Neonatal Infant Pain Scale (NIPS) (primary outcome), heart rate, respiratory rate and oxygen saturation (secondary outcomes) in infants who required a heel stick for blood sampling.

Methods: This randomised, double-blind, crossover trial with infants from 1 to 7 days post birth excluded those with prior surgery, septicaemia, current assisted ventilation or an analgesic within 48 h. After informed consent, 13 infants received a 2-min massage of the ipsilateral leg prior to heel stick on the first study sampling and no massage on the next sampling 2–7 days later and 10 infants had the reverse order. The bedside nurse, blinded to the intervention, measured NIPS, heart rate, respiratory rate, and oxygen saturation prior to massage, after massage, and 5 min after heel stick. Serum cortisol was measured with the blood sampling.

Results: In 23 infants (birthweight 795–2507 g), there were no adverse physiologic effects of massage. After heel stick, NIPS ($P < 0.001$) and heart rate ($P = 0.03$) were increased in the no-massage group compared with the massage group. Respiratory rate, oxygen saturation and serum cortisol were not significantly different.

Conclusion: Gentle massage of the leg prior to heel stick is safe and decreases pain responses in preterm infants.

Key words: clinical trial; infant newborn; massage; pain; technique.

Infants admitted to the neonatal intensive care unit (NICU) are repeatedly subjected to painful diagnostic and interventional procedures during their hospital stay.[1,2] Verbal expression of pain is the gold standard for interpreting pain but neonates are incapable of self-reporting. Although infants do not verbalise, they reveal their vulnerability to pain through specific pain behaviours and physiologic changes.[3] Pain has long been undermanaged in infants because of beliefs that neural immaturity does not allow perception of pain. However, there is no doubt that newborns (term and preterm) perceive pain.[4] The need for better management of pain in newborns is emphasised in a joint statement of the Canadian Paediatric Society and the American Academy of Pediatrics.[5]

Afferent fibres transmit pain impulses to the spinal cord where modulation by a spinal gating mechanism in the dorsal horn occurs. The gating mechanism is influenced by the activity in the large diameter nerve fibres. Gentle massage may inhibit the transmission of pain along the ascending fibres by closing the gate[6] or by activating the descending endogenous opioid and non-opioid pathways to decrease nociceptive transmission and reduce pain.[7]

Pain assessment in premature infants is a challenge and several scales have been developed.[8] Lawrence *et al*. developed the Neonatal Infant Pain Scale (NIPS) for assessing acute procedural pain in term and preterm infants.[9] It has high inter-rater reliability and internal consistency before, during and after the painful procedure. We used NIPS because the bedside nurses were using this pain scale routinely in the Neonatal Intensive Care Unit (NICU).

We conducted a trial in preterm infants (<37 weeks gestation) to determine the effects of gentle massage of the ipsilateral leg to heel stick on the pain responses assessed by NIPS, heart rate (HR), respiratory rate (RR) and oxygen saturation (SpO_2). Infants of this gestation were chosen because of the anticipated availability for the second (crossover) portion of this trial.

Key Points

1 Heel sticks in newborn babies are painful.
2 Pain with heel sticks is lessened with prior leg massage.
3 Utilisation of massage with other pain reduction techniques should be further studied.

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Methods

Patients

This was a crossover, double-blind, randomised, controlled trial approved by the Clinical Research Ethics Committee of the University of Calgary, Calgary, Alberta, Canada. Written informed consent was obtained from one of the parents of the infant. Preterm infants (<37 weeks gestation) 1–7 days of age admitted to the NICU

in Foothills Medical Centre were included if they were not currently requiring assisted ventilation and were anticipated to require two or more heel sticks prior to 14 days of age. Infants who received analgesics in the previous 48 h, had a surgical procedure in the preceding 2 weeks, or had prior sepsis were excluded. Massage was not used for babies in our nursery except in this study.

Randomisation

Infants were randomised into two groups (massage first or massage second) by opening sequential sealed opaque envelopes. Twenty-five such envelopes had been prepared with the help of computer-generated random numbers. In this crossover study, infants who received massage intervention on the first occasion received no massage on the second occasion (2–7 days later) and *vice versa*. Each infant served as his/her own control with the crossover design.

Massage intervention

Prior to the heel stick, the infant was wrapped and bundled in accordance with prevailing practice. Other measures (e.g. sucrose) to minimise pain responses to heel sticks were not in use in our NICU at this time. The bedside nurse chose the heel for blood collection. Five minutes before the heel stick, one of the investigators (SJ or PK) slowly massaged the outer aspect of the leg chosen for the heel stick from toes to mid thigh by using a firm but gentle pressure by fingers and thumbs. The massage pressure was adjusted to keep the baby comfortable. The investigator remained at the bedside for an equivalent time, behind the curtains when no-massage intervention was given. At the end of the massage intervention (2 min), the heel was wrapped with a warm cloth for 2–3 min. A bedside nurse performed the heel stick using a Tenderfoots Preemie lancet (0.85 mm depth, 1.75 mm length). The blood sample was collected as ordered with an extra 0.5 mL blood collected for serum cortisol measurement.

Blinding of the caretakers to the massage or no-massage intervention was ensured by pulling the curtains around the bed until the intervention was completed. Nursing staff were aware of the importance of maintaining the blinding.

Sample size

No prior data were available for a traditional sample size calculation. No specific formula could calculate sample size for a non-parametric variable such as NIPS, which includes assessment of facial expression, cry, breathing patterns, position of the arms and legs and state of arousal.[9] Norman and Streiner have suggested that sample size calculation from a parametric test could be used and 10% added to the sample size to allow for the slight degree of conservatism built into the test.[10] Assuming an alpha of 1.96 power of 80% standard deviation 2.5, and mean difference between pre- and post-test scores of 1.5, we calculated a sample size of 22. Adding 10% to the sample size and rounding up to an even number, we planned a sample size of 26.

Measurements

Heart rate and RR, highest SpO_2 and NIPS were recorded similarly within 5 min prior to the intervention (massage or no massage), after completion of intervention (massage or no massage) and 5 min after heel stick. All participating nurses were experienced with use of NIPS. The maximum HR and RR and minimum SpO_2 were recorded over a 1-min period. All the parameters were recorded by the bedside nurse who was blinded to the intervention.

Statistical analysis

Data sheets were reviewed manually for consistency and appropriate codes prior to data entry. Data were entered into Microsoft Excel and checked for outliers and the normality of distribution of continuous variables (e.g. weight, gestational age). Analysis of variance was used to look for effects of order of intervention. Paired two-tailed *t*-test was used to compare the two interventions.

Results

Twenty-three infants with complete data (measurements under both massage and no-massage treatment conditions) were included for the analyses (Table 1). Data of three infants could not be included because two were transferred to other hospitals before completion of the study and one was later discovered to have received morphine within 24 h prior to initiation of the study. All calculations were performed on the 23 babies who completed the study. At the time of the first intervention, 13 infants were 3.8 days of age (massage first) and 10 infants (massage second) were 4.0 days of age. The second intervention occurred the next day for 16 babies, in 2 days for six babies and in 3 days for one baby.

An analysis of variance was first performed to determine whether there was statistically significant effect of the order of treatment (i.e. Was there a difference between the massage and no-massage treatments dependent on which treatment was received first?). The test indicated that there was no effect of order ($P = 0.95$). Data from the two groups were, therefore, pooled and paired *t*-tests were performed to compare the effects of massage and no-massage intervention.

Assessment results with massage and with no massage are shown in Table 2. NIPS scores prior to heel stick were low indicating that the infants were not in pain prior to the heel stick. Massage (A vs. B) was not associated with a significant change in NIPS, RR or SpO_2. Following heel stick NIPS increased in both the groups but no-massage was associated with a significantly higher increase in the score (3.5 ± 1.6 vs. 1.5 ± 0.9, $P < 0.001$). HR increased in both groups but significantly more in the no-massage group ($P = 0.03$). RR increased in both groups after heel stick but was not significantly different. SpO_2 decreased significantly after heel stick in the no-massage group although the difference between the groups was

Table 1 Patient demography

Gestational age (weeks)†	31.1 ± 1.9	(28–35)
Birthweight (g)†	1693 ± 396	(795–2507)
Apgar score‡ (1 min)	6 (1–9)	
Apgar score (5 min)	8 (7–9)	
Cord arterial pH†	7.33	(7.20–7.39)

†Mean ± standard deviation (range); ‡median (range).

Table 2 Response with heel stick

	Massage Mean (SD)	No massage Mean (SD)	*P*-value Massage versus no massage
NIPS (A)	1.3 (1.2)	0.8 (0.8)	0.10
NIPS (B)	0.8 (0.6)[1]	0.9 (0.9)[a]	0.68
NIPS (C)	1.5 (0.9)[2]	3.5 (1.6)[b]	<0.001
HR (A)	143.8 (12.3)	144.0 (12.1)	0.96
HR (B)	142.2 (10.4)[3]	144.6 (12.3)[c]	0.53
HR (C)	149.2 (13.6)[4]	159.2 (13.4)[d]	0.03
RR (A)	52.9 (14.8)	46.5 (16.3)	0.17
RR (B)	48.5 (14.7)[5]	51.5 (15.0)[e]	0.51
RR (C)	53.6 (14.7)[6]	55.3 (13.6)[f]	0.69
SpO_2 (A)	96.0 (2.1)	95.8 (2.2)	0.85
SpO_2 (B)	96.3 (2.8)[7]	96.0 (2.6)[g]	0.34
SpO_2 (C)	96.4 (1.8)[8]	94.2 (3.6)[h]	0.67

Patient assessment Neonatal Infant Pain Scale (NIPS), heart rate (HR), respiratory rate (RR) and oxygen saturation (SpO_2) prior to massage (A), after massage (B) and after heel prick (C). Values are mean ± standard deviation (SD). 1 versus 2, $P = 0.001$; 3 versus 4, $P = 0.002$; 5 versus 6, $P = 0.003$; 7 versus 8, $P = 0.39$. a versus b, $P \leq 0.001$; c versus d, $P \leq 0.002$; e versus f, $P = 0.06$; g versus h, $P = 0.001$.

not significant. The mean post-heel-stick serum cortisol was 243 ± 146 umol/L in the no-massage group and 177 ± 80 umol/L in the massage group ($P = 0.62$).

Discussion

Pain is a common occurrence for babies in NICUs[1,2] and has physiologic effects.[8] The developing brain is vulnerable[11] and there is increasing evidence that repetitive pain maybe associated with adverse neurodevelopmental consequences.[12] Preterm infants may beat decreased risk because of lack of inhibitory control development and increased ability to modulate pain.[3,13–16] We have documented that pain responses in premature infants due to heel stick (assessed by NIPS and HR) are reduced by gentle massage of the ipsilateral leg for 2 min prior to heel stick. The prior massage had no demonstrable adverse effects. Lawrence *et al*. developed the NIPS for assessing acute procedural pain in preterm and term neonates.[9] It is possible that other scales that have been used in preterm babies may have shown a different response.

There have been various studies on the physiologic responses in neonates to heel prick, intravenous initiation, circumcision, injections and lumbar puncture. HR increases in response to an acute painful stimulus.[3] The range of increase in HR in response to procedural pain varies but generally it is at least 10 beats per minute. In our study, the HR increased by 15 beats per minute (from 144/min to 159/min) in no-massage group but increased only five beats per minute (144/min to 149/min) in massage group. This supports that gentle massages of the leg prior to heel prick decreased pain as seen with the difference in NIPS. Some authors have found a decrease in SpO_2 in response to procedural pain.[17] We saw a small (1.8%) decrease in SpO_2 with no prior massage. We did not use continuous trend recording and it is possible that greater changes occurred prior to the 5 min post heel stick assessment. This limitation is similar with assessment of HR, RR and NIPS.

Stress hormones, particularly cortisol and catecholamines increase in response to post-cardiac surgery pain in preterm infants.[18] These may also be related to stress rather than to pain. Gunnar *et al*. found that there was no difference in cortisol levels in response to circumcision.[19] In our current study, we found that the plasma cortisol levels with heel stick (5 min after massage) were not different between massage and no-massage groups supporting that massage was not associated with measurable stress. It is possible that there was not enough time for serum cortisol to change with massage and later measurements of plasma cortisol may have shown different results. Massage in infants has been associated with a decrease in plasma cortisol levels 1 h later.[20]

Epitomised by Hippocrates in 400 BC as 'Medicine being the art of rubbing',[21] body massage has been reported to increase growth in term and preterm babies[22] and to assist colicky babies.[23] Local massage may benefit babies receiving vaccinations,[24] although may also increase site swelling.[25] The transmission of painful impulses is modulated by a 'spinal gating mechanism' in the dorsal horn of the spinal cord, which is influenced by the activity in the large-diameter nerve fibres.[6] The gating mechanism is influenced by the activity in the large-diameter nerve fibre; stimulation of these fibres inhibits the transmission of pain along ascending fibres by 'closing the gate'.[26] Acupressure has been shown to reduce labour pain.[27] Massage may activate descending endogenous opioid and non-opioid pathways to decrease nocioceptive transmission and reduce pain[7] and/or alter other natural pain killers such as serotonin and substance P.[7,21] It may also be that massage contributes to a soothing environment similar to studies of multisensory stimulation potentiating the analegesic effects of oral sugar in newborns undergoing heel sticks.[28]

There are a number of non-pharmacologic strategies that have been used to prevent and manage neonatal pain.[29] Although not in use in our NICU at the time of this study, oral sucrose has been shown to be effective[30] and is often administered by nurses for short-term painful procedures.[31] Massage has been studied in relation to growth and development of preterm infants (without clear benefit).[32] There are no known prior studies related to the effect on pain in neonates. Massage for pain relief is not included in a recent nursing review of best practices in neonates.[33]

Additional information on mechanisms of action would be beneficial and further clinical studies including term babies are needed. Comparison studies with oral sucrose and non-pharmacologic analgesic methods of pain reduction are also required. We have not studied massage in term neonates, for modulation of pain other than with heel stick, or to see if massage of the contralateral leg would have similar effect. However, this study demonstrates that leg massage, a simple non-invasive technique, prior to heel sticks is free of apparent adverse responses and reduces the manifestations of pain in preterm neonates.

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