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Original Article

# Assessment and Management of Procedural Pain During the Entire Neonatal Intensive Care Unit Hospitalization

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ABSTRACT

*Background:* Despite strong evidence that repeated pain exposure in neonates is associated with adverse outcomes, pain assessment and management continues to be less than optimal in most neonatal intensive care units (NICUs).
*Aims:* To evaluate current pain assessment and management practices, and identify factors associated with optimal treatment throughout a cohort of preterm neonates over the entire hospital stay.
*Design:* A secondary analysis of study data collected from 2012 to 2016 as part of a larger clinical trial and supplemental chart review.
*Settings:* Tertiary level neonatal intensive care unit.
*Participants/Subjects:* 242 stable preterm neonates born at less than 37 weeks gestational age.
*Methods:* Data were analyzed quantitatively using R for statistics.
*Results:* The 242 neonates underwent a total of 10,469 painful procedures (4,801 tissue breaking and 5,667 non–tissue breaking, with only 56.6% and 12.2% having a documented pain score using the Premature Infant Pain Profile, respectively). Average pain exposure was 43 with a median of 32(10-576) per entire hospital stay. Documented pain score and greater postnatal age were associated with higher use of a pain reducing intervention and lower gestational age, first day, first week, higher illness severity, non tissue breaking and night time procedures were associated with lower. Use of a pain relieving intervention was documented in 58.5% of procedures. Sucrose was most commonly used pharmacologic and non nutritive sucking the most common non pharmacologic interventions.
*Conclusions:* Increased efforts are needed to promote consistent pain assessment and management to ensure optimal outcomes for vulnerable at risk neonates.


## Introduction

Neonates requiring intensive care undergo on average between 7.5 to 17.3 painful procedures per day during their hospital stay (Cruz, Fernandes, & Oliveira, 2016), with the most common procedures being heel lancing, suctioning, and venipuncture (Cruz et al., 2016). Since the adverse effects of untreated early pain were first identified in the mid-1980s (Anand, 1985), considerable effort has been dedicated to reducing pain exposure and optimizing its assessment and treatment.

Exposure to untreated procedural pain has been linked to immediate and long-term adverse effects on neonatal outcomes, most notably brain development, neurodevelopment, regulation of stress systems, and, later, pain perception and sensitivity (Brummelte et al., 2015; Duerden et al., 2017; Ranger & Grunau, 2014; Vinall et al., 2015). The Canadian Pediatric Society and the American Association of Pediatrics recommend that neonatal care include a combination of pharmacologic and nonpharmacologic pain reduction methods for minor procedures, as well as minimization of the total number of painful procedures (AAP Committee on Fetus and Newborn and Section on Anesthesiology and Pain

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Medicine, 2016). Nonpharmacologic interventions are generally preferred for the most common repeated painful procedures as a result of their apparently superior efficacy and favorable safety profile (Badr, 2012). The most effective nonpharmacologic interventions include breastfeeding (Benoit, Martin-Misener, Latimer, & Campbell-Yeo, 2017), skin-to-skin contact (C. Johnston et al., 2017), sucrose (Stevens, Yamada, Gy, & Ohlsson, 2016), and glucose (Bueno et al., 2013).

Because of the extent of published knowledge on exposure and adverse outcomes associated with procedural pain, we would expect assessment and management in the neonatal population to have improved over the years. Despite the known consequences and readily available pain-relieving strategies and clinical practice recommendations, procedural pain remains poorly assessed and often goes untreated, with previous studies reporting less than half of painful procedures receiving an intervention (Carbajal et al., 2008; Cruz et al., 2016). Roofthooft, Simons, Anand, Tibboel, & Van Dijk (2014) found that the mean number of procedures per neonate per day in the Netherlands was reduced from 14.3 in 2001 to 11.4 in 2009. Appropriate pain assessment however, continues to be a significant problem, with infants being significantly less likely to have their pain assessed with an age-appropriate validated measure (Stevens, Harrison, Rashotte, Yamada, & Abbott, 2012). Pain assessment practices are highly variable, and there is a need for more effective assessment and management of pediatric pain (Stevens et al., 2012). Additionally, Andersen et al. (2018) found that pain was more frequently assessed and documented when there was a specific pain measurement scale in use. Thus, despite our current knowledge, the assessment and management of painful procedures does not meet the recommended guidelines of the Canadian and American pediatric governing bodies (AAP Committee on Fetus and Newborn and Section on Anesthesiology and Pain Medicine, 2016).

To the best of our knowledge, there has been a paucity of recent studies documenting the frequency of pain scores and pain relieving interventions in the preterm infant population, with most larger epidemiologic studies conducted more than a decade ago. Additionally, these studies typically have been conducted over a short period (Carbajal et al., 2008; Johnston, Barrington, Taddio, Carbajal, & Filion, 2011); no published studies have reported on these factors during the entire neonatal intensive care unit (NICU) hospitalization.

## Methods

### Aim

Our aim was to report and present data on neonatal pain exposure, pain management, and pain assessment and documentation throughout a cohort of preterm infant's entire hospitalization in a Canadian NICU. Additionally, we sought to determine which factors are associated with increased use of pain-relieving interventions.

### Design

We conducted a secondary analysis of data collected on a cohort of 242 hospitalized medically stable preterm infants delivered at less than 37 weeks' gestational age and admitted to a tertiary NICU in the eastern part of Canada as part of a larger randomized controlled trial titled the Trial of Analgesia and Kangaroo Mother Care (TRAKC) (Campbell-Yeo et al., 2013). The primary and secondary outcomes of interest in the TRAKC trial were primarily related to pain intensity scores and neurodevelopment across three groups randomly assigned to receive kangaroo care (KC) alone or in combination with sucrose compared with sucrose alone provided during a medically required heel lance procedure. Pain scores were collected by the research nurse at three time points during the neonate's hospitalization using video recording and simultaneous physiological recordings. Participants maintained group allocation for all remaining needle-related procedures, and data were collected through a standardized bedside form and daily maternal diary, which contained entries regarding pain exposure associated with specific frequently performed needle-related procedures. Information regarding associated pain assessment and pain scores for all other painful procedures were not collected as part of the larger trial.

### Data Collection

For this study, we conducted a retrospective chart review to augment the original study data and to include all exposure to pain throughout the neonate's hospitalization. Data collected from the chart review included procedure date and time, procedure type, pain scores, pharmacologic and nonpharmacologic interventions used, and need for repeat attempts made.

Nursing staff at the bedside recorded all procedures on a standardized form and in the neonate's hospital chart. The study coordinator ensured all procedures were recorded and verified the hospital chart against the form. The form listed 17 common painful procedures and included an option to list any other procedure that the staff considered painful. Two types of procedures were differentiated in the analysis: tissue breaking (e.g., heel lance or venipuncture) and non–tissue breaking (e.g., nasogastric tube insertion or suctioning). Nurses were asked to assess and record pain associated with each procedure using a composite pain tool, the Premature Infant Pain Profile (PIPP), which is a well-validated assessment tool in this population (Stevens, Johnston, Petryshen, & Taddio, 1996; Stevens, Johnston, Taddio, Gibbins, & Yamada, 2010a).

Pharmacologic pain-relieving interventions included 24% sucrose, fentanyl, morphine, and acetaminophen; nonpharmacologic pain-relieving interventions included skin-to-skin contact, breastfeeding, non-nutritive sucking, facilitated tucking, and bundling.

### Ethical Considerations

Institutional ethics approval was obtained as part of the larger study (Campbell-Yeo, 2013).

### Data Analysis

Data were analyzed with R for statistics (R Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics are presented as mean and standard deviation when outcomes are approximately normally distributed and as median and interquartile range otherwise.

To identify factors that are associated with the use of procedural pain–relieving interventions, a Bayesian generalized linear mixed model with a binomial likelihood and log link was developed using the rstanarm package (Stan Development Team, 2016). This method accounted for potential correlation created by nesting of observations within babies, and twins within pregnancies. Variables for inclusion were selected based on consultation with experienced clinicians, none of whom took part in the analysis of data. Additional target variables were identified based on similar projects conducted in Canada and elsewhere (Carbajal et al., 2008). If procedures occurred between 7 a.m. and 7 p.m., they were coded as “daytime.” Because the clinical trial that provided data for this analysis took place over 4 years, a term for year randomized was included to capture potential changes over time. A term was

included indicating infants were randomly assigned to a KC group for the same reasons. The rationale for this decision was that being randomly assigned to receive KC during all painful procedures may increase the likelihood that parents are present for procedures, which has been found by others to influence the provision of preprocedural pain interventions (Carbajal et al., 2008).

The rate at which infants received painful procedures was modeled with a Bayesian generalized linear mixed model with Poisson likelihood and log link. As in the model for preprocedural pain interventions, variables were included based on clinical consultation, although interaction effects were modeled post hoc. Infants were coded as "ever intubated" if they had a record of at least one endotracheal tube insertion.

## Results

Between July 2012 and March 2016, 242 preterm infants were enrolled in the larger trial, with primary results under review for publication elsewhere (Campbell-Yeo et al., 2013). The research nurse enrolled 43% of eligible NICU neonates (Fig. 1) during the study period. Of eligible neonates, 113 were not approached because of pending transfer to a referral hospital or unavailability of parents. The mean (standard deviation) length of stay in the NICU was 26.74 (17.26) calendar days, and the observation period represented 6,470 patient-days. Table 1 lists the characteristics of the cohort.

### *Pain Exposure*

The 242 neonates included in the study underwent a total of 11,191 procedures, of which 722 were repeat attempts. Most of the repeated procedures (63.7%) were intravenous needle insertions. Given the lack of documentation regarding pain intensity scores and pain-relieving interventions associated with repeated attempts, only initial attempts were included in the final analysis. The total number of first attempt procedures was 10,469. The mean (standard deviation) number of procedures per neonate was 43 (50) for the entire stay. The median number of procedures per neonate was 32 (range = 10-576) for the entire stay. The median number of procedures per day per neonate was 1.46.

The most common painful procedures were heel lance (36%), suctioning (21.9%), and tape removals (18.4%). The least common procedures were umbilical arterial line insertions (0.4%), eye examinations (0.6%), and endotracheal tube insertions (0.6%).

As seen in Table 2, analysis using a Bayesian generalized linear mixed model revealed that having a higher Score for Neonatal Acute Physiology with Perinatal Extension II and ever being intubated were associated with increased likelihood of a procedure. Additionally, being in week 2 or more of the NICU hospitalization and weekend days were associated with decreased likelihood of having a procedure. There was a significant negative effect between gestational age and week 2, gestational age and week 3, as well as ever being intubated and week 2.

### *Pain Management*

Table 3 shows the percentage of time common procedures received different interventions, as well as the total percentage of procedures that received a pharmacologic intervention alone, a nonpharmacologic intervention alone, or a combination of the two. Approximately 58% of procedures were performed without any procedural pain–relieving intervention.

When used, pharmacologic interventions included administering 24% sucrose 3,589 times (34.2%), fentanyl 101 times (1.0%), and acetaminophen 4 times (0%). Nonpharmacologic interventions included non-nutritive sucking 1,963 times (18.8%), facilitated tucking 1,695 times (16.2%), skin-to-skin contact 1,031 times (9.8%), bundling 271 times (2.6%), and breastfeeding 15 times (0.1%). Nonpharmacologic interventions were sometimes combined with another nonpharmacologic intervention or a pharmacologic intervention.

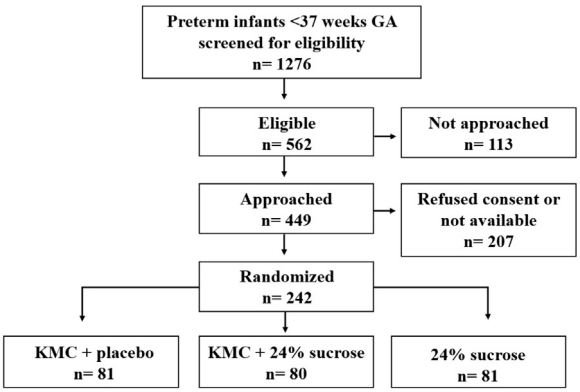


**Figure 1.** Consort flow diagram. GA = gestational age; KMC = kangaroo mother care.

Table 4 shows the pain relieving interventions received during common procedures in the three gestational age groups. Extremely preterm infants received the least number of interventions, followed by very preterm infants; late preterm infants received the most pain-relieving interventions. Use of both a pharmacologic and nonpharmacologic intervention together was the most popular pain-relieving intervention, followed by a pharmacologic intervention alone. Nonpharmacologic interventions were rarely used.

The adjusted odds ratios with 95% credible intervals derived from the generalized linear mixed models for the use of procedural interventions are shown in Table 5. Analysis indicated that having a PIPP score charted, having a tissue-breaking procedure, and having a procedure during the daytime (7 a.m.-7 p.m.) were associated with greater odds of receiving procedural interventions. Our model suggests that sicker infants (0.81, 0.71-0.94) receiving procedures in the first week (0.55, 0.41-0.75) were less likely to receive a pain-relieving intervention. Additionally, being randomly allocated in the year 2015 (0.59, 0.36-0.95) was linked to a decreased likelihood of receiving a pain-relieving intervention, which most likely was due to the ongoing practices in the NICU.

**Table 1**
Characteristics of Study Neonates

| | *n* = 242 |
|---|---|
| Gestational age, week* | 32 weeks 4 days (2 weeks) |
| Birth weight, g* | 1869.2 (513.8) |
| Male, n (%) | 136 (56.2) |
| Apgar at 1 minute* | 6.9 (2.3) |
| Apgar at 5 minutes* | 8.2 (1.4) |
| SNAPPE-II score* | 5.5 (10.7) |
| Days old at randomization* | 3.8 (1.7) |
| Length of stay, days* | 26.7 (17.3) |
| Twins, n | 82 |
| Mother's age, years* | 30.4 (5.8) |
| Primigravida, n (%) | 108 (44.6) |
| Mother's race, n (%) | |
| Caucasian | 220 (90.9) |
| African American/African | 8 (3.3) |
| Asian | 6 (2.5) |
| Other | 8 (3.3) |
| Two-parent family, n (%) | 237 (97.9) |
| Prenatal steroids, n (%) | 195 (80.6) |

SNAPPE-II = Score for Neonatal Acute Physiology with Perinatal Extension II.
* Expressed as mean (standard deviation).

**Table 2**
Factors Associated with the Likelihood of Receiving a Painful Procedure

| | B* | 95% CrI |
|---|---|---|
| Gestational age (scaled)† | 1.03 | 0.93-1.14 |
| SNAPPE-II score (scaled)† | 1.13 | 1.07-1.20‡ |
| Received caffeine | 1.08 | 0.92-1.27 |
| Weekend (yes) | 0.87 | 0.81-0.94‡ |
| Week 2 of NICU stay | 0.32 | 0.29-0.35‡ |
| Week 3 or greater of NICU stay | 0.13 | 0.12-0.15‡ |
| Birthweight (scaled)† | 0.94 | 0.88-1.02 |
| Ever intubated | 1.26 | 1.06-1.49‡ |
| GA × week 2 | 0.80 | 0.73-0.88‡ |
| GA × week 3 or greater | 0.71 | 0.65-0.79‡ |
| Ever intubated × week 2 | 0.77 | 0.62-0.96‡ |
| Ever intubated × week 3 or greater | 0.93 | 0.76-1.14 |
| (Intercept) | 2.81 | 2.35-3.38‡ |
| Random allocation 2013 | 1.06 | 0.86-1.28 |
| Random allocation 2014 | 1.02 | 0.85-1.23 |
| Random allocation 2015 | 1.10 | 0.91-1.33 |
| Random allocation 2016 | 1.01 | 0.77-1.31 |

CrI = credible interval; SNAPPE-II = Score for Neonatal Acute Physiology with Perinatal Extension II; NICU = neonatal intensive care unit; GA = gestational age.
* B coefficient refers to the change in rate ratio when changing the dependent variable 1 standard deviation above its mean.
† Scaled = mean centered and divided by 1 standard deviation.
‡ Credible interval excludes 1.

### *Pain Assessment*

A documented pain score using the PIPP was found with 56.6% of tissue-breaking procedures and 12.2% of non–tissue-breaking procedures. Overall, 32.6% of procedures had a documented pain score. Only 8.6% of painful procedures performed during the neonates' first day after birth and 31.1% of procedures performed during the first week of age had an associated pain score. Figure 2 shows the percentage of assigned PIPP scores for different procedures and which were the most and least likely to receive a pain assessment.

There were 7,060 procedures not assigned a PIPP score; 14.5% of the patients undergoing these procedures received a pain-relieving intervention. In contrast, of the 3,408 procedures with a documented PIPP score, 97.3% patients received a pain-relieving intervention.

### *The First Day and Week of Age*

There were 5,756 (55%) procedures performed in the first week of age. Of these, 43.4% were heel lances and 16.8% were suctions. The average number of procedures per baby in the first week of age was 24 (range = 9-74). The average number of procedures per day in the first week of age was 3.43. In the first 24 hours of age, the average number of procedures was 8.

Procedural pain relief was provided 26.2% of the time during the first 24 hours after birth and 42.6% of the time in the next 24 hours of age. We found that increased number of postnatal days led to increase odds of intervention. The procedures performed during the initial 24 hours after birth were associated with the use of a pharmacologic intervention alone 18.1% of the time, a nonpharmacologic intervention alone 1.2%, and in combination 6.9% of the time. In the first postnatal week, a pharmacologic intervention was used for 769 procedures (13.4%), a nonpharmacologic intervention for 77 procedures (1.3%), and in combination for 1,645 procedures (28.6%). This left 3,266 procedures (59.3%) being done without procedural pain interventions in the first week.

### *After the First Week*

The remaining 4,712 procedures were conducted after the first week of age. Table 2 shows that the likelihood of receiving a procedure decreased after 1 week of hospitalization, and this trend continued past the third week of hospitalization, as seen in Figure 3. When separated by gestational age, infants who were born extremely preterm underwent a greater number of painful procedures throughout their hospitalization. Of the procedures conducted after the first week of age, 10.2% received a pharmacologic intervention, 1.1% received a nonpharmacologic intervention, and 29.4% received a combination. This left 2,793 procedures (59.3%) being performed without any procedural pain–relieving intervention. As per Table 5, the likelihood of receiving a pain-relieving intervention increased slightly with postnatal age. Use of pain-relieving interventions increased slightly with increasing postnatal days in infants born before 32 weeks' gestation but plateaued if born after 32 weeks' gestation, as seen in Figure 4. Additionally, infants born after 29 weeks' gestation were more likely to receive some form of pain relief. A total of 31.1% of infants undergoing procedures received a pain score after the first week of hospitalization.

## Discussion

### *Pain Exposure*

In our study we aimed to examine the frequency of painful procedures throughout a cohort of preterm neonates' entire hospitalization. Not surprisingly, we found that exposures to

**Table 3**
Pain-Relieving Interventions for the Most Commonly Performed Procedures

| Procedure | Procedure No. (%) | Pain-Relieving Intervention (%) | Nonpharmacologic Only (%) | Pharmacologic Only (%) | Both (%) |
|---|---|---|---|---|---|
| PICC line insertion | 74 (0.7) | 83.8 | 0 | 33.8 | 50 |
| Venipuncture | 89 (0.9) | 80.9 | 0 | 25.8 | 55.1 |
| Heel lance | 3,769 (36) | 75.8 | 2.4 | 17.2 | 56.2 |
| Intravenous line insertion | 584 (5.6) | 68.3 | 0.5 | 19.7 | 48.1 |
| NG/OG tube insertion | 1,129 (10.8) | 56.7 | 1.2 | 22.8 | 32.7 |
| Other | 67 (0.6) | 56.7 | 3.0 | 22.4 | 31.3 |
| Intramuscular Injection | 285 (2.7) | 37.2 | 0 | 27.4 | 9.8 |
| Eye exam | 65 (0.6) | 24.6 | 1.5 | 4.6 | 18.5 |
| UVL | 74 (0.7) | 14.9 | 0 | 4.1 | 10.8 |
| ETT insertion | 68 (0.6) | 13.2 | 0 | 13.2 | 0 |
| Tape removal | 1,928 (18.4) | 8.3 | 0.8 | 2.2 | 5.3 |
| UAL | 40 (0.4) | 7.5 | 0 | 2.5 | 5 |
| Suction | 2,296 (21.9) | 0.2 | 0.1 | 0 | 0 |
| **Total** | **10,468 (100)** | **42** | **1.2** | **11.9** | **28.9** |

PICC = peripherally inserted central catheter; NG = nasogastric; OG = orogastric; UVL = umbilical venous line; ETT = endotracheal tube; UAL = umbilical arterial line.

**Table 4**
Pain-Relieving Interventions for the Most Commonly Performed Procedures by GA

| GA | <29 Weeks | | | | | 29-31 6/7 Weeks | | | | | 32-36 6/7 Weeks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Procedure Count | No Intervention | Non-pharm Only | Pharm Only | Both | Procedure Count | No Intervention | Nonpharmacologic Only | Pharmacologic Only | Both | Procedure Count | No Intervention | Nonpharmacologic Only | Pharmacologic Only | Both |
| Heel lance | 303 | 59 | 0 | 74 | 170 | 1,012 | 234 | 15 | 159 | 604 | 2,454 | 612 | 76 | 420 | 1,346 |
| Intravenous line insertion | 29 | 8 | 1 | 11 | 9 | 150 | 60 | 0 | 25 | 65 | 405 | 117 | 2 | 79 | 207 |
| NG/OG insertion | 142 | 73 | 3 | 26 | 40 | 473 | 196 | 2 | 124 | 151 | 514 | 220 | 9 | 107 | 178 |
| Intramuscular injection | 25 | 13 | 0 | 5 | 7 | 90 | 50 | 0 | 22 | 18 | 170 | 115 | 0 | 52 | 3 |
| Tape removal | 249 | 223 | 2 | 8 | 16 | 732 | 665 | 6 | 16 | 45 | 947 | 879 | 8 | 19 | 41 |
| Suction | 1,074 | 1,072 | 2 | 0 | 0 | 959 | 958 | 1 | 0 | 0 | 263 | 262 | 0 | 1 | 0 |
| Total | 1,822 | 1,448 (79.5%) | 8 (0.4%) | 124 (6.8%) | 242 (13.3%) | 3,416 | 2,163 (63.3%) | 24 (0.7%) | 346 (10.1%) | 883 (25.9%) | 4,753 | 2,205 (46.4%) | 95 (2.0%) | 678 (14.3%) | 1,775 (37.3%) |

GA = gestational age; NG = nasogastric; OG = orogastric.

**Table 5**
Factors Associated with the Use of Procedural Pain–Relieving Interventions

| | Odds Ratio | 95% CrI |
|---|---|---|
| PIPP Charted | 236.22 | 175.11-324.43* |
| Gestational age (scaled)† | 0.91 | 0.75-1.10 |
| SNAPPE-2 score (scaled)† | 0.81 | 0.71-0.94* |
| Birthweight (scaled)† | 1.05 | 0.87-1.27 |
| Postnatal days | 1.01 | 1.00-1.02 |
| Tissue breaking (yes) | 10.56 | 8.60-13.03* |
| Randomly allocation to KMC group‡ | 0.87 | 0.67-1.14 |
| Procedure in the first week (yes) | 0.55 | 0.41-0.75* |
| Daytime (yes) | 1.37 | 1.16-1.63* |
| Weekend (yes) | 1.05 | 0.87-1.27 |
| SD (id:mother) | 0.31 | 0.06-0.71* |
| SD (mother) | 0.35 | 0.01-0.68* |
| (Intercept) | 0.11 | 0.06-0.18* |
| Random allocation in 2013 | 1.44 | 0.87-2.42 |
| Random allocation in 2014 | 0.98 | 0.59-1.58 |
| Random allocation in 2015 | 0.59 | 0.36-0.95* |
| Random allocation in 2016 | 0.68 | 0.34-1.36 |

CrI = credible interval; SNAPPE-II = Score for Neonatal Acute Physiology with Perinatal Extension II; PIPP = Premature Infant Pain Profile; KMC = kangaroo mother care; SD = standard deviation.
SD (id:mother)/SD (mother): standard deviation of the interaction of baby and mother/standard deviation of mother.
95% CI: a credible interval that demonstrates the range of values within which an observation value falls within a 95% probability.
* Credible interval excludes 1.
† Scaled = mean centered and divided by 1 standard deviation.
‡ Randomly allocated to receive kangaroo care during procedures while on study.

procedures was greatest in the first week of age, with a mean of 24 procedures in the first week and 8 in the first 24 hours of age. Our findings are consistent with those of Stevens et al. (2011) (6.3 per child who had any painful procedure) and indicate an improvement over those of Johnston et al. (2011) (33 per child in 1 week). A previous study by Britto et al. (2014) reported a mean number of procedures per day of 8.1 (5.5) and a mean number of procedures for 2 weeks of 68.3 (64.8). Compared with these findings, our results indicate a decrease in the number of painful procedures that preterm neonates underwent during their NICU stay. This may be due to the relatively shorter study periods of the previously mentioned studies.

We also determined that heel lance and suctioning were the two most commonly performed procedures in our study. Our findings are in keeping with others reporting on the most common painful procedures in the NICU (Cruz et al., 2016). Alternatively, some

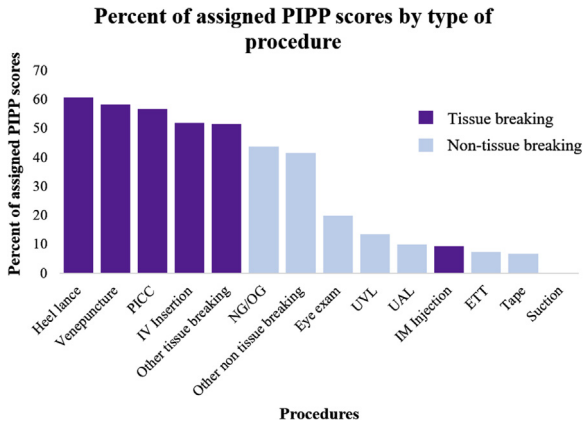


**Figure 2.** Percentage of assigned PIPP scores per type of procedure. Dark gray represents tissue-breaking procedures and light gray represents non–tissue-breaking procedures. PIPP = Premature Infant Pain Profile; PICC = peripherally inserted central catheter; IV = intravenous line; NG = nasogastric; OG = orogastric; UVL = umbilical venous line; UAL = umbilical arterial line; IM = intramuscular; ETT = endotracheal tube.

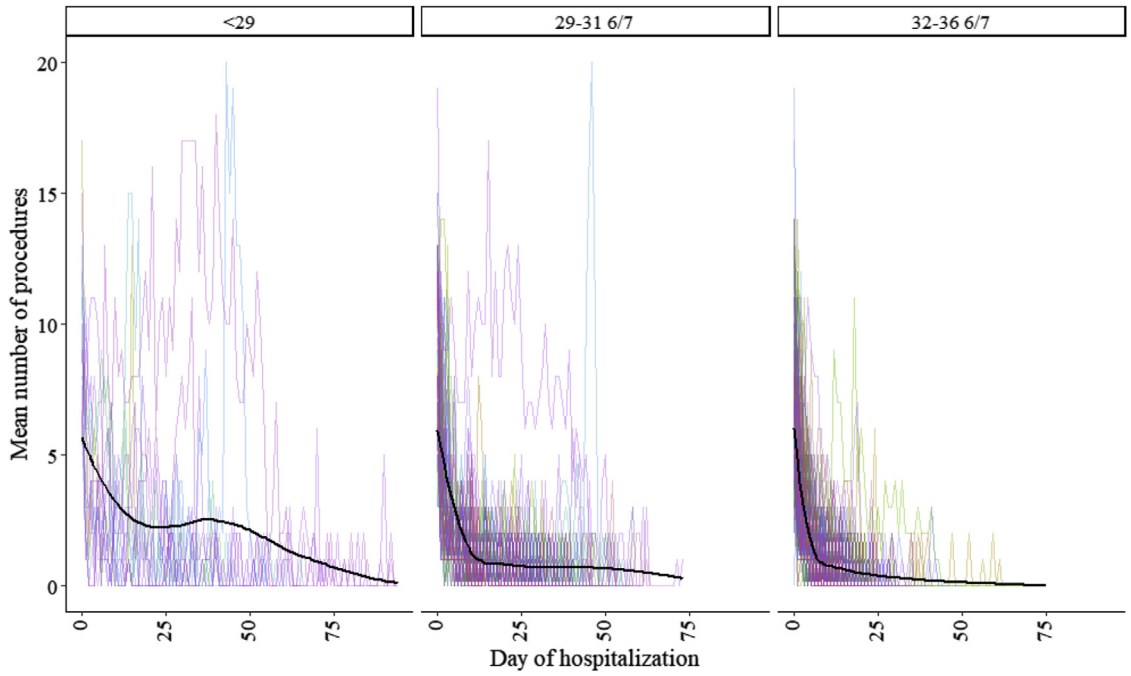


**Figure 3.** Trends in the average number of procedures per day throughout the entire hospitalization, separated by gestational age groups. Each colored line represents one infant and the solid line is a trend line fit using local regression (loess).

studies have found suctioning to be the most common painful procedure performed in the NICU (Roofthooft et al., 2014). The differences in these findings could be due to the change in nonroutine suction protocols and trends toward greater noninvasive ventilation (Mukerji et al., 2017).

When looking at factors associated with the likelihood of receiving a painful procedure, the model has some differences from previous findings. Specifically, one study found that the number of painful procedures did not markedly decrease throughout the hospitalization, but we found the opposite (Carbajal et al., 2008).

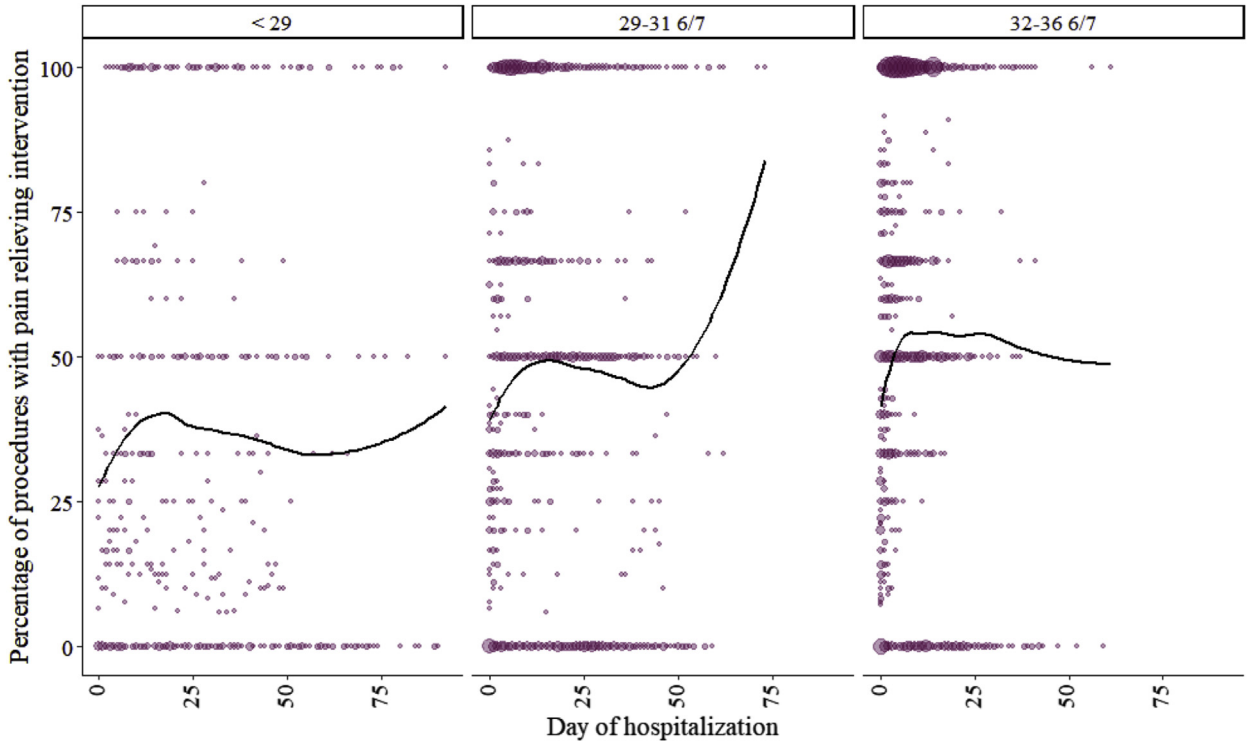


**Figure 4.** Trends in likelihood of receiving a procedural pain intervention throughout the entire hospitalization, separated by gestational age groups. Colored dots represent an individual's percentage of pain-relieving interventions on a given day and the solid black line is a trend line fit using local regression (loess).

Additionally, a recent study found that gestational age had an influence on the amount of tissue-breaking procedures an infant received (Finn, Butler, Sheehan, Livingstone, & Dempsey, 2018). Further analysis is needed to determine if this was the case in our cohort.

*Pain Management*

We sought to determine the frequency of use of different pharmacologic and nonpharmacologic interventions during painful procedures and what factors influences their use. In our study we found the use of specific procedural analgesia to be 48.1%. Our use of sucrose, which is just greater than 40%, was comparable to that found in an Australian NICU by Harrison et al. (2009). When comparing our data to the most recent Canadian data, there seems to have been an increase in the use of sucrose as a specific procedural pain–relieving intervention, from 2% in 2010 (Stevens et al., 2010b) to 14.3% in 2011 (Johnston et al., 2011) and now up to 40.6% in the present study. A study by Stevens et al, (2010b) found that nonpharmacologic interventions were used for 84% of procedures. However, these interventions were mainly physical interventions such as bundling and pacifier use. Because nonpharmacologic interventions are not as commonly documented in a medical chart, they may be less often attributed to pain management in retrospective chart reviews (Stevens et al., 2010b). Still, we found similar documentation of physical interventions, as well as increased documentation of other nonpharmacologic interventions such as breastfeeding and skin-to-skin contact. In 2008, published results from a prospective observational study found the use of some form of analgesia to be 50.9% for the top 20 painful procedures performed in 430 neonates (Carbajal et al., 2008). These results are comparable to those of our present study. However, Carbajal et al. (2008) found the use of nonpharmacologic, pharmacologic, or a combination to be 20.8%, whereas the use of nonspecific concurrent analgesia was 30.1%. Our study did not look at the use of concurrent analgesia during acute procedural pain because it has been found to be ineffective (Badr, 2012). The use of specific pain management should not be eliminated in infants receiving concurrent pain management because the use of continuous opiate infusions has been found to be ineffective for procedural pain. Our results indicate an increase in the use of procedural pain–relieving interventions compared with this European study.

Our study found that many factors influence the use of specific procedural pain interventions. Notably, we found that daytime performance of a procedure increased the likelihood of receiving some procedural interventions, which is consistent with the results from Carbajal et al. (2008). Additionally, we found that a higher clinical acuity score was associated with less frequent use of procedural pain interventions, again in keeping with previous findings (Carbajal et al., 2008). Furthermore, undergoing a tissue-breaking procedure and having a pain score charted were both associated with the use of procedural pain–relieving interventions. Our significant association of having a pain score charted and provision of pain care needs further exploration because it appears to clearly suggest that increased pain assessment is associated with greater pain management.

*Pain Assessment*

We aimed to determine the frequency of pain assessment using a validated pain tool. Based on documented pain intensity scores, our study found an overall pain assessment rate of 32.6% of all procedures, with tissue-breaking procedures being more than four times more likely to be associated with a documented pain score. Unfortunately, to our knowledge, no previous studies have examined overall pain assessment rates for all painful procedures during the NICU stay; thus, comparing our findings to the literature becomes a challenge. Nonetheless, previous studies in the pediatric population have found that 27% of children had a pain score documented in the 24 hours preceding data collection (Taylor et al., 2008). Another study found that 68.4% of children had a pain assessment documented in the 24 hours preceding data collection, 28% of which were done with a validated measure (Stevens et al., 2012). Additionally, when looking specifically at venipuncture, one study found the rate of pain assessment to be 94.8%, compared with our study, which found just less than 60% (Courtois et al., 2016). Therefore it seems that pain assessment remains infrequent and highly variable across NICUs, and there appears to be a greater association with tissue-breaking procedures.

We found that almost all patients with a documented pain score undergoing procedures received a pain-relieving intervention, which supports the importance of consistent pain assessment and documentation practices for neonatal patients. Several studies report that pain assessment is the cornerstone of pain management (Cox, 2010; Drendel, 2006; Stevens et al., 2010a), particularly in nonverbal populations such as neonates.

The procedures that were most likely to be accompanied by a documented pain assessment and treatment were generally needle related, findings in keeping with Courtois et al. (2016), who reported almost 95% of patients undergoing venipuncture having a documented pain score. Although there has been extensive research on needle-related pain and possible interventions in all age populations (Cong, 2015; Taddio et al., 2015), there is much less focus on non–needle-related painful procedures. We found that the procedures least likely to be accompanied by a pain assessment were non–needle related, such as suctioning, tape removals, and endotracheal tube insertions. Findings from several studies have identified these procedures as moderately to severely painful for preterm neonates (Cignacco et al., 2008; Välitalo et al., 2016), and thus the lack of pain assessment and treatment associated with these types of procedures require further attention. A focus on the development and implementation of guidelines for non–needle-related procedures is needed.

*The First Day and Week of Age*

We found that almost one quarter of all painful procedures done during the study were completed during an infant's first 24 hours after birth. Contrary to our findings, Carbajal et al. (2008) reported that 10% of painful procedures were completed in the first day of age; however, they considered both painful and stressful procedures (Carbajal et al., 2008). Nevertheless, a large proportion of painful procedures are done in the early age of a hospitalized neonate, which represents a critical period in their development (Duerden et al., 2017). Furthermore, only about 25% of procedures performed on the first day of age were accompanied by a pain-relieving intervention, and only 9% of patients received a pain assessment. This may be due in part to the perceived urgency of the procedures and the unstable condition of the neonate. Alternatively, at least one study has suggested that health care practitioners may be properly assessing pain and providing pain relief but are simply not documenting their actions in the medical chart (Simons, 2012).

*After the First Week*

We found the mean number of procedures per day to be 1.75 with a standard deviation of 0.94, and the median was 1.46 procedures per day. Limited studies have looked at the entirety of a

preterm infant's hospitalization. Most were performed before 2001, and none to our knowledge have been done in Canada. Practice changes have brought about improvements in pain assessment and management, and our study identified a decrease in the number of painful procedures compared with other studies (Porter & Anand, 1998). Additionally, there has been a large increase in the use of nonpharmacologic interventions. However, there is still room for improvement in these areas. As seen in Figure 4, there are differences between gestational age groups in the likelihood of receiving a pain-relieving intervention, and further research is needed in this area. Still, pain-relieving interventions are lacking at all points throughout hospitalization.

### *Limitations*

Despite numerous strengths, there are some limitations of our study. One concern, common to many secondary analyses and clinical chart review, is the lack of complete documentation regarding pain intensity scores and pain-relieving interventions. We found that procedure documentation often lacked a notation of the time it was performed, and we cannot exclude that repeat attempts and pain-relieving interventions went unrecorded. Thus it is difficult to confirm whether lack of documentation equated to lack of provision of treatment across all painful events. As a single-center study, generalizability of these results is limited.

### *Implications for Nursing Education, Practice, and Research*

The assessment of pain in the NICU continues to be a problem, and thus further research should examine strategies for implementing and establishing systematic use of a pain assessment tool by means of a prospective study. Furthermore, education is needed for health care providers on the assessment of non–tissue-breaking procedures. Finally, because it seems that documentation of pain assessment leads to better pain management (Habich et al., 2012; Manworren & Stinson, 2016), there is a need for focused knowledge translation strategies to increase documentation of pain assessment as well as examine the clinical utility of existing pain assessment tools. We recommend that large neonatal consortiums such as the Canadian Neonatal Network and the Vermont Oxford Network, which do not currently collect data on the assessment and management of painful procedures, consider collection of these data so that benchmarking and evidence-based standards for assessment and management of infant pain can be created.

It has been reported that health care providers are inconsistent in the documentation of pain assessment and management (Costa et al., 2017), and our results seem to reflect the same. This inconsistent documentation creates problems when evaluating the quality of pain management practices in the NICU and presents another worry when considering the legal implications of “what is not written does not exist” (Silvestre, Santos, de Oliveira-Filho, & de Lyra, 2017). There are many barriers to proper documentation of pain assessment and management (Zisk-Rony, Lev, & Haviv, 2015). Therefore a tailored knowledge translation intervention may be needed to promote optimal pain practices (Stevens et al., 2014) and to reduce the resistance to change practice. Implementation and consistent use of scales is an imperative contribution to better pain management and reduced suffering of the neonate (Andersen et al., 2018).

## Conclusions

Although the assessment and management of some needle-related pain has improved, it remains less than optimal. Moreover, non–needle-related pain remains significantly undertreated. The use of nonpharmacologic pain-relieving interventions has increased, but methods to increase and sustain their use are needed, specifically with respect of parent-led interventions, which remain underused. Documentation of pain assessment appears to be linked to the provision of pain management strategies. Continued emphasis on practice change strategies to improve consistent use of pain assessment is warranted.

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