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Research paper

Sensorial saturation improves infants' procedure-related pain behaviour in the cardiac intensive care unit: A quasi-experimental study

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ABSTRACT

Background: Painful procedures are unavoidable when providing critical care to infants in intensive care units. These adverse experiences during infancy can lead to later hyperalgesia and poor neurodevelopmental outcomes. Thus, appropriate interventions are required to relieve infant pain during these procedures.

Objectives: This study evaluated the effectiveness of sensorial saturation in reducing pain for infants during jugular central venous catheter removal procedures in intensive care units.

Methods: This study involved a quasi-experimental, repeated-measures design. Data were collected from participants sequentially recruited from April to June 2019 (control period) and July to September 2019 (experimental period). Participants included 78 infants younger than 1 year with congenital heart disease. The control group ($n = 38$) received a general nursing intervention using swaddling, a common child-care practice that consists of wrapping infants to restrict movements, whereas the experimental group ($n = 40$) received sensorial saturation using oral sugar, body massage, and verbal interaction. Infants' physiological reactions to procedural pain were measured by changes in heart rate, oxygen saturation, and respiratory rate. Infants' procedural pain and behavioural indicators were measured using the Modified Behavioural Pain Scale. Data were analysed using descriptive statistics, independent *t*-tests, χ^2 tests, and repeated-measures analysis of variance.

Results: Compared with the control group, the experimental group had lower heart rates ($F = 53.15$, $p < .001$), respiratory rates ($F = 15.19$, $p < .001$), and behavioural pain scores ($F = 45.21$, $p < .001$), both during and after the procedure.

Conclusions: Sensorial saturation can be used as a nursing intervention in infants. Given the many invasive procedures that are part of infant clinical care, sensorial saturation may be a safe analgesic alternative. The findings of this study could lead to the development of evidence-based clinical practice guidelines for the nonpharmacological management of acute pain in infants.

1. Introduction

Preventing and treating pain in infants is necessary owing to the short- and long-term effects of pain in this population.[1] Possible short-term effects of pain include physiological instability, such as increases or decreases in blood pressure, heart rate, respiratory rate, or haemodynamic stability and oxygenation;[2] long-term consequences include psychological and behavioural disorders, learning disabilities, and negative effects on psychosocial development.[2]

Infants in the cardiac intensive care unit (CICU) are often subjected to invasive procedures that cause pain, distress, and anxiety, such as jugular central venous catheter (CVC) removal.[3] Consequently, infants may experience interrupted sleep, agitation, and

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physiological and behavioural instability, which can also result in negligence or delayed treatment.[3] However, the pain management administered to infants prior to invasive procedures is not routine;[1] the overall incidence of infantile analgesia administration during invasive procedures is 27.4%.[4] Thus, it is important to establish pain management strategies for infants undergoing prolonged invasive procedures. Optimal infant pain management requires a proactive approach to invasive procedures evaluated by assessments that incorporate physiological and behavioural responses.[5]

Pharmacological and nonpharmacological approaches are used to relieve distress in infants. Opioid analgesia is widely used for pharmacological pain management in infants; however, recent studies indicate that repeated opioid exposure can have potentially detrimental neurodevelopmental effects.[6] Furthermore, receiving higher accumulative doses of morphine in infancy has been associated with internalising behaviours in school-aged children.[6] Therefore, because of the excessive chemical effects of medications, pharmacological therapies are not suitable for acute pain management in infants, and nonpharmacological interventions are recommended, particularly as the first choice.[1] Many nonpharmacological pain methods such as oral sucrose with and without non-nutritive sucking, kangaroo care, swaddling, music therapy, and sensorial saturation[7] are useful for treating mild to moderate pain in infants.[7]

Oral sucrose, the most well-known nonpharmacological analgesic therapy, is commonly used in hospitals for minor procedures.[8] More than 100 studies have investigated the impact of sucrose on pain in infants, and findings indicate that it can minimise the acute pain response induced by minor procedures.[8] Furthermore, although sucrose administration can reduce behavioural and physiological responses, it does not reduce the electroencephalographic response to pain.[9] Owing to the limitations of these single interventions, two or more interventions—oral sucrose, swaddling, and non-nutritive sucking—have been combined since the mid-2010s to reduce pain-related behaviours (e.g., squirming, grimacing, and limb and trunk extensions).[10] Hence, compared with oral sucrose alone or a combination of interventions (oral sucrose combined with non-nutritive sucking or swaddling), non-nutritive sucking and swaddling were synergistic in pain relief when used with oral sucrose and provided the best pain relief.[10] Oral sucrose used in conjunction with other sensory stimuli, defined as sensorial saturation, are reportedly more effective than other previously described methods.[11] Therefore, a combination of several nonpharmacological interventions may improve the pain reduction effectiveness. We investigated whether sensory stimulation combined with oral glucose administration provided more effective analgesia than swaddling alone.

Compared with oral sucrose alone or combination interventions (oral sucrose combined with sucking, sensorial saturation with and without oral sucrose), the combined use of sensorial saturation with oral sucrose was found to be synergistic and provide the best pain relief.[11] Therefore, the combined use of several nonpharmacological interventions may improve the effectiveness of pain reduction.[11] Sensorial saturation is easily learned and can be used by any caregiver (e.g., mother, paediatrician, or nurse).[11] Moreover, it is considered effective, safe, and simple for pain reduction.[11]

Sensorial saturation involves gustatory, visual, tactile, auditory, and olfactory stimulation, which can be used alone or in combination.[12] A combination of two or three stimuli is reportedly more effective than one alone. Recently, the '3Ts', a method of sensorial saturation that combines taste (oral sugar), touch (massage), and speech (attracting the baby's attention with words), has been reported as more effective than using one or two stimuli.[12] It was posited that along with oral sucrose's sweet taste, a more considerable analgesic impact might be achieved by offering infants various combined stimuli. The 3Ts may work via two mechanisms: reduced pain owing to gentle stimulation (massage and oral sugar) that activates inhibitory pathways and endorphin release[12] and inhibition of pain stimuli in the spinal cord through intermediate interneurons acting as pain gateways, known as 'gate control'.[13] Besides effectively reducing pain behaviour, the simultaneous application of multiple stimuli using the 3Ts also moderates increased intracranial blood pressure during medical procedures more than oral sucrose alone.[12]

In intensive care units (ICUs), CVC removal is a painful invasive procedure;[13] however, to our knowledge, no studies have reported the pain-relieving effects of sensorial saturation during CVC removal in infants. Without effective pain management, CVC removal is one of many painful procedures that can impact an infant's future pain responses,[14] and frequent pain exposure could lead to a decreased pain threshold and trigger hyperalgesia.[15] Therefore, better pain management methods, such as the 3Ts, should be implemented for this procedure as well as general care. Additionally, evidence-based nursing can be refined if the effects of sensorial saturation on procedural pain for infants are proven superior to routine nursing care. Hence, we aimed to determine the effectiveness of sensorial saturation in reducing pain during jugular CVC removal in infants in the CICU.

2. Methods

A quasi-experimental, repeated-measures design[16] was used to compare the effects of sensorial saturation and swaddling on physiological and behavioural pain responses before, during, and after CVC removal. Because sensorial saturation includes touching and talking, it was easily learned when providing interventions in the control group. Therefore, sequential recruitment was conducted to prevent possible cross-group contamination by nurses. Control group data were collected from April to June 2019; experimental group data were collected from June to September 2019.

2.1. Setting and sample

Participants were recruited through convenience sampling from the CICU of Severance Hospital, Yonsei University. To solicit participation, we explained the study's purpose and procedures to parents. Infants meeting the following criteria were included: (i) received a jugular CVC after undergoing thoracotomy for congenital heart disease, (ii) no neurological and sensorial injuries, (iii) gestational age of 32 weeks or more, (iv) birth weight more than 2.5 kg, (v) 0–12 months old, (vi) provision of parental informed consent, (vii) oral feeding in progress after extubation (removal of an endotracheal tube), and (viii) planned transfer to the general ward. Exclusion criteria were as follows: (i) received emergency measures such as cardiopulmonary resuscitation, (ii) intubation on the day of data collection, or (iii) sedatives administered within 12 h of data collection.

The infants were divided into two groups: experimental and control. The estimated sample size was 82, calculated using G*Power (version 3.1),[17] with 80% statistical power of repeated measures, an alpha level of 0.05, and an effect size of 0.25. Initially, we recruited 92 participants (46 per group) and considered a 10% dropout rate for infant intervention studies.[18] Participating infants were assigned to the control and experimental groups from April to June 2019 and from July to September 2019, respectively.

2.2. Outcome measures

Infants in both groups were wrapped in the same type of blankets, placed in beds in a supine position, and were actively

awake, not crying, and calmly remained undisturbed for 1 min before catheter removal. Therefore, the conditions at the start of the procedure and 1 min before the start of the procedure were the same. The CVC removal procedure was conducted by an intern and physician as per the removal procedure instructions. Upon procedure initiation, swaddling, the general care provided by the CICU nurse for infant pain management, was administered to the control group; the experimental group received sensorial saturation.

Controlled clinical trials have demonstrated the efficacy of swaddling as an analgesic and that it may improve stress self-regulation and reduce pain.[18] This technique allows the infant to be placed in the foetal position, preserving an asymmetrical rolled shape.[19] The procedure team minimised sound, touch, and sight stimuli for the control group by not talking during the procedure, holding the baby only to secure the removal site, and avoiding eye contact with the infant. Swaddling, which consists of wrapping an infant to restrict movement, is a traditional child-care practice that may promote physiological stability and self-regulatory capacity.[18] We provided appropriate emotional support through swaddling without talking or making eye contact with the control group infants.

Experimental group infants received sensorial saturation during the procedure. This method comprised synchronised steps (Fig. 1): (i) laying the infant on their side, wrapped in a blanket; (ii) looking at the infant's face to attract their attention; (iii) massaging the infant's face and back; (iv) speaking to the infant gently, but firmly; (v) placing 20% sucrose (1 mL) in the buccal cavity with a 1-mL needleless syringe within 1 min of catheter removal;[18] and (vi) providing a standard silicone pacifier to induce sucking before the recovery process (the removal of the catheter and haemostasis). Here, the induction of sucking in infants makes it easier to achieve haemostasis while reducing crying behaviour. One research registered nurse (with 5 years of CICU experience) provided sensorial saturation. Swaddling and sensorial saturation began 1 min before jugular CVC removal and were maintained until procedure completion and dressing application.

Pulmonary blood flow is increased in infants with congenital heart disease who have ventricular or atrial defects and an abnormal connection between the aorta and the pulmonary artery.[20,21] This secondarily raises pulmonary artery pressure and reduces oxygen saturation during severe crying; in severe cases, it is likely to cause anoxia.[20,21] Therefore, if the infant cries during an invasive procedure, oxygen saturation is reduced. Accordingly, we prophylactically provided oxygen administration by holding an oxygen source near the infant's faces in both groups. Considering the dilutional effects of ambient air and low oxygen dependence, this kind of oxygen administration is widely used for short periods.[22]

2.3. Data collection tools and methods

General participant characteristics—sex, age (months), delivery type, feeding type, gestational age (weeks), birth weight (kg), birth height (cm), birth head circumference (cm), Apgar score at 1-min intervals, and type of congenital heart disease—were collected from electronic medical records. Outcome variables included infants' physiological and behavioural responses. Infants' physiological reactions to procedural pain during catheter removal were monitored continuously and measured by recording changes in heart rate, oxygen saturation, and respiratory rate using bedside electrocardiographic instruments (Philips, Cambridge, MA, USA) and custom computer software. Electrocardiograph leads were attached to the chest, and the oxygen saturation probe was attached to the foot. Physiological parameters were digitally sampled at 1-min intervals, and each phase of each procedure was recorded through the baseline, catheter removal, and recovery phases.

Infants' procedural pain and behavioural indicators were measured with the Modified Behavioural Pain Scale (MBPS), designed to evaluate the specificity of pain responses in infants,[23] after receiving consent from the developer. Using the standard forward–backward procedure, two qualified translators first independently translated the MBPS (English to Korean) and prepared a provisional version, which was back-translated into English by a native English interpreter unfamiliar with the original instrument. The back-translator and a committee or experts reviewed the back-translated MBPS to create the final version.

The MBPS assesses three behaviours: facial expressions, crying, and body movements. Each behaviour is measured, and the scores are combined to produce a pain intensity score ranging from 0 to 10. Higher total scores indicate a greater pain response. MBPS scores were assessed during the catheter removal and recovery phase of each procedure by two trained evaluators (the first author and a research nurse with 10 years of CICU experience) who were aware of the study's purpose. To ensure appropriate inter-rater agreement, both evaluators assessed MBPS scores for each infant during the CVC removal process; inter-rater reliability was 91.3%.

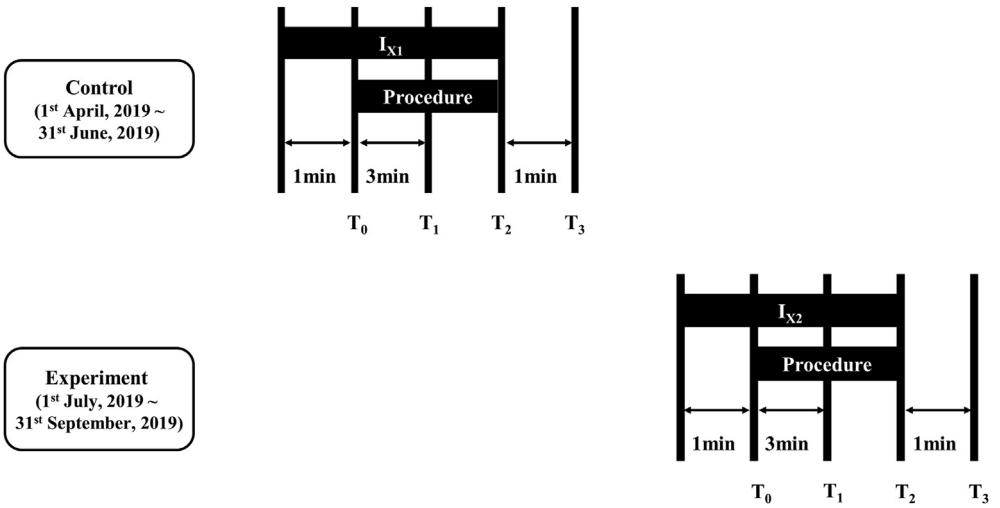

Fig. 1. Design of the study. I_{X1}: General nursing intervention (swaddling), I_{X2}: sensorial saturation, Procedure: jugular central venous catheter removal, T0: immediately before, T1: three minutes after the start, T2: immediately after, T3: one minute after the end.

The pain score was assessed after enveloping infants in the experimental and control groups in the same blanket so that the procedure could commence under identical conditions in each group. One research nurse conducted the intervention according to the assigned condition, and the physician then removed the catheter using a standardised procedure. Two research nurses (the first author and a registered nurse with 10 years of CICU experience) measured each infant's physiological and behavioural indicators during four phases: (i) baseline (data were collected after 1 min without stimulation just prior to catheter removal); (ii) catheter removal (including dressing removal and disinfection, data were collected immediately after catheter removal); (iii) catheter removal site haemostasis (including removal site compression and dressing application, data were collected after approximately 3 min); and (iv) recovery (data were collected 1 min after haemostasis). During the four phases of each procedure, the infant's heart rate, oxygen saturation, and respiratory rate were displayed via an electrocardiographic bedside monitor (Philips) and assessed by the MBPS. The first author trained all participating staff members separately.

2.4. Data analysis

All analyses were performed using SPSS for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). Data were calculated as means and standard deviations for continuous variables and as frequencies for categorical variables. The Kolmogorov–Smirnov test was used to test the normal distribution of variables. The level of significance was set at $p < .05$. For participant characteristics, independent *t*-tests and chi-square tests were used to determine any significant between-group differences. Measurement parameters (MBPS score, heart rate, oxygen saturation, and respiratory rate) were averaged separately for comparing different phases among patients. The results were analysed using Mauchly's sphericity testing and a repeated-measures analysis of variance, followed by a Bonferroni's multiple comparison test.

2.5. Ethical and research approvals

This study was approved by the Institutional Review Board of Yonsei University Health System (approval number: 4-2019-0142) and conforms to the principles outlined in the Declaration of Helsinki. The study aim and methods were outlined for the participants' parents, who were informed that the collected data would be used only for research purposes. We guaranteed voluntary participation, confidentiality, and anonymity. We further explained that the parents had the right to decline participation at any point, without any disadvantages. Verbal assent and written consent were collected from one parent or guardian per infant.

3. Results

3.1. Participant flow

Throughout the data collection period, 105 infants were screened and found to be eligible for the study. Of those, the parents of 92 infants provided consent. Fourteen infants dropped out because they had either been released from the unit prior to catheter removal ($n = 6$) or experienced cardiac arrest or displayed unstable vital signs ($n = 8$). The final analysis included 40 infants in the experimental group and 38 infants in the control group (Fig. 2).

3.2. Baseline participant characteristics and measures

The sample included 78 infants with a mean gestational age of 39.31 ± 0.82 weeks. The majority of infants were male (55.05%) and born by normal spontaneous delivery (57.75%). Infants had a mean age of 3.45 ± 3.10 months, and 84.45% had noncyanotic congenital heart disease. The infants' mean heart rate was 140.66 ± 8.83 beats/min, oxygen saturation was 96.9%, respiratory rate was 38.88 ± 6.9 breaths/min, and MBPS was 1.66 ± 2.03. There were no significant differences at baseline between the experimental and control groups for any sociodemographic variables, clinical characteristics, or physiological and behavioural indicators, including diagnoses (Table 1).

3.3. Comparison of physiological response to pain between the two groups

The comparison of physiological pain responses between the experimental and control groups is shown in Table 2. The experimental group's mean heart rate decreased to 143.48 ± 10.86 beats/min, whereas the mean respiratory rate decreased to 41.3 ± 6.14 breaths/min, after CVC removal. By contrast, the control group's

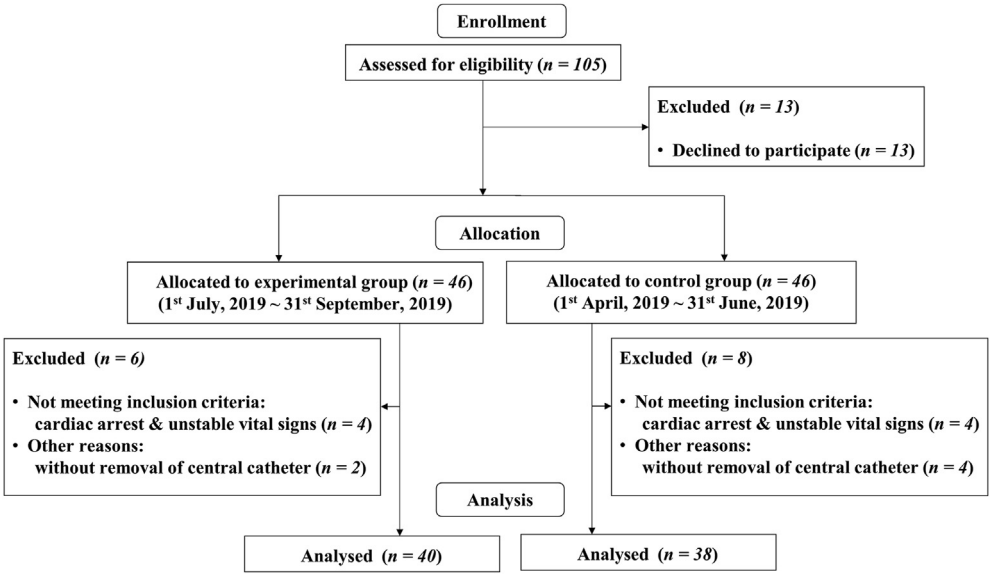

Fig. 2. Flowchart of participant recruitment.

Table 1
Baseline characteristics and pain responses for the two groups.

Variables		Experiment ($n = 40$)	Control ($n = 38$)	t or χ^2	p
		n (%) or $M \pm SD$	n (%) or $M \pm SD$		
Gender	Male	23 (57.5)	20 (52.6)	.19	.82
	Female	17 (42.5)	18 (47.4)		
Age (months)		3.45 ± 3.13	3.45 ± 3.06	6.40	.90
Delivery type	N/D	22 (55.0)	23 (60.5)	.24	.65
	C/S	18 (45.0)	15 (39.5)		
Feeding type	Human milk	15 (37.5)	10 (26.3)	.69	.75
	Milk	14 (35.0)	16 (42.1)		
	Mix	11 (27.5)	12 (31.6)		
Gestational age (weeks)		39.28 ± .82	39.34 ± .82	1.84	.62
Birth weight (kg)		3.59 ± .12	3.60 ± .17	8.64	.20
Birth height (cm)		48.95 ± .23	49.12 ± .37	13.13	.14
Birth head circumference (cm)		34.95 ± .09	34.97 ± .07	2.13	.69
Apgar score		7.65 ± .48	7.61 ± .50	.17	.82
Type of CHD	Non-cyanotic	36 (90.0)	30 (78.9)	1.83	.22
	Cyanotic	4 (10.0)	8 (21.1)		
Heart rate (beats/min)		142.10 ± 9.27	139.21 ± 8.39	1.44	.15
SpO_2 (%)[a]		97 ± 5.33	96.82 ± 5.27	.15	.88
Respiratory rate (breaths/min)		40.15 ± 6.88	37.61 ± 6.92	1.63	.11
MBPS (scores)		1.53 ± 1.95	1.79 ± 2.10	.58	.57

Note. M: mean; SD: standard deviation; N/D: normal spontaneous delivery; C/S: caesarean section; CHD: congenital heart disease; SpO_2: oxygen saturation.
[a] Peripheral capillary oxygen saturation, MBPS: Modified Behavioral Pain Scale.

mean heart rate increased to 152.11 ± 9.89 beats/min and the mean respiratory rate increased to 47.34 ± 8.33 breaths/min. Compared with the control group, the sensorial saturation experimental group had a lower heart rate ($F = 53.15$, $p < .001$) and respiration rate ($F = 15.19$, $p < .001$) both during and after procedures. No significant difference was observed in oxygen saturation between the experimental and control group ($F = .52$, $p = .47$). Additionally, multiple time points were given, and post hoc tests were conducted to identify which time points were different (Table 2).

3.4. Comparison of behavioural pain response between the two groups

The comparison of behavioural pain responses between the experimental and control groups is shown in Table 2. Compared with the control group, the experimental group had a lower mean MBPS total score (1.42 ± 1.67 vs. 5.59 ± 1.85; $F = 45.21$, $p < .001$), facial expressions (0.57 ± 0.68 vs 2.03 ± 0.55; $F = 36.55$, $p < .001$), crying (0.48 ± 0.56 vs. 1.85 ± 0.69; $F = 54$, $p < .001$), and body movements (0.37 ± 0.57 vs 1.71 ± 0.92; $F = 16.89$, $p < .001$), both during and after procedures (Table 2).

4. Discussion

For infants in the CICU, jugular CVC removal is a common procedure performed prior to transfer to a general ward. Our results showed that based on physiological and behavioural responses, pain behaviours were reduced more effectively in infants who were administered sensorial saturation than in the control group infants. Notably, infants who received sensorial saturation during the procedure had lower heart rates, respiratory rates, and MBPS scores. Because infants are particularly sensitive to pain, they can be negatively affected by even relatively low pain levels.[15] Healthcare providers aim to eliminate procedural distress, and our results suggest that this can be accomplished by sensorial saturation, without the use of pharmacological interventions. Previous studies report that multisensory stimulation reduces pain more effectively than unistimulation.[11] Different sensory components increase the analgesic effect of glucose because another stimulus can activate the gate control mechanism to prevent nociceptive transmission, in addition to the sweet stimulus opioid mechanism.[11] The role of sensory stimulation in pain reduction was also documented via cross-modal shaping, which refers to a situation where a stimulus to one sensory modality affects perceptions, behavioural responses, or neural stimulus processing in another sensory modality.[24]

Here, there was no significant difference in oxygen saturation between the experimental and control groups; however, increases

Table 2
Comparison of physiological and behavioral pain responses between the two groups.

Variable	Groups	Baseline	During	Immediately after	After 1 min	Sources	F	p
		$M \pm SD$	$M \pm SD$	$M \pm SD$	$M \pm SD$			
Physiological pain responses								
Heart rate (beats/min)	Cont.	139.21 ± 8.39	153.79 ± 10.87	151.97 ± 9.47	150.58 ± 9.34	Group	6.46	.013
	Exp.	142.10 ± 9.27	146.38 ± 11.20	143.03 ± 10.45	141.03 ± 10.94	Time	87.22	<.001
						Group*Time	53.15	<.001
SpO_2 (%)[a]	Cont.	96.82 ± 5.27	95.50 ± 6.82	95.58 ± 6.34	96.00 ± 6.09	Group	0.52	.47
	Exp.	97.00 ± 5.33	96.43 ± 5.52	96.70 ± 4.66	97.38 ± 4.42	Time	13.53	.27
						Group*Time	4.46	<.001
Respiratory rate (breaths/min)	Cont.	37.61 ± 6.92	49.74 ± 8.91	46.55 ± 7.73	45.74 ± 8.35	Group	8.12	<.001
	Exp.	40.15 ± 6.88	44.38 ± 6.67	41.43 ± 5.33	38.07 ± 6.44	Time	26.20	<.001
						Group*Time	15.19	<.001
Behavioral pain responses								
Total	Cont.	1.79 ± 2.10	7.43 ± 2.05	5.11 ± 1.94	4.24 ± 1.58	Group	92.06	<.001
	Exp.	1.53 ± 1.95	2.58 ± 2.52	1.25 ± 1.58	0.43 ± 0.91	Time	92.35	<.001
						Group*Time	45.21	<.001
Facial expression	Cont.	0.8 ± 0.83	2.46 ± 0.50	1.93 ± 0.64	1.71 ± 0.52	Group	88.19	<.001
	Exp.	0.68 ± 0.80	0.91 ± 0.88	0.58 ± 0.68	0.23 ± 0.48	Time	53.87	<.001
						Group*Time	36.55	<.001
Crying	Cont.	0.47 ± 0.51	2.67 ± 0.90	1.58 ± 0.68	1.29 ± 0.50	Group	93.72	<.001
	Exp.	0.45 ± 0.50	0.78 ± 0.77	0.48 ± 0.51	0.19 ± 0.42	Time	107.29	<.001
						Group*Time	54.00	<.001
Body movements		0.5 ± 0.83	2.29 ± 0.83	1.59 ± 0.92	1.24 ± 1.02	Group	64.21	<.001
		0.4 ± 0.81	0.89 ± 1.01	0.20 ± 0.61	0.01 ± 0.08	Time	43.33	<.001
						Group*Time	16.89	<.001

Note. Cont.: control group ($n = 38$); Exp.: experimental group ($n = 40$); M: mean; SD: standard deviation; SpO_2: oxygen saturation.
[a] Peripheral capillary oxygen saturation.

in heart and respiratory rates were lower in the experimental group during and after the procedure, in line with previous studies. When performing an invasive procedure such as a heel stick, there were significant differences with regard to heart rate in non-pharmacological pain management such as kangaroo care,[25] non-nutritive sucking,[26,27] and swaddling,[26,27] but none for oxygen saturation.[26,27]

Sensorial saturation works through competition between non-painful and painful stimuli and does not suggest that nonpainful stimuli cause saturation of the sensory pathways.[12] Bellieni et al.[11] found that in blood sampling from the heel, there were no differences in the pain scores of a control group receiving glucose and an experimental group receiving multisensory stimulation without glucose. Among other pain management methods, multisensory stimulation showed the most pain reduction. In this study, MBPS scores were significantly lower in the experimental group during and after the procedure. We found that infants quickly recovered to the state before pain stimulation through this intervention. Furthermore, 27 of the 40 infants in the experimental group fell asleep within 1 min after procedure completion. However, these results were observed in infants who were 3–4 months of age and may have been related to the sleep characteristics of this age group. Therefore, a covariate analysis with age was performed. Subsequently, MBPS scores were significant in the experimental group; the effect size was also significant, indicating that age did not affect behavioural pain responses. These findings are consistent with studies reporting reduced intravascular injection pain in infants[28] during heel lancing[29] with multisensory stimulation.[7] When infants' pain and stress were alleviated during painful procedures, changes in their physiological condition were minimised.[30] Thus, we conclude that the onset of sleep observed in infants receiving sensorial saturation indicates a greater reduction in their pain and stress, relative to the control group.

5. Limitations

This study had several limitations. First, the infants were recruited from a CICU at a single university hospital in [blinded for peer review], which may limit the generalisability of the results. Second, infants' temperamental characteristics could not be controlled. Furthermore, it was not possible to fully control environmental factors in the ICU (e.g., light, noise, and crying of other infants) or the medical staff's proficiency in performing jugular CVC removal; although the same protocol was used consistently, these factors may affect pain responses. Third, facial expressions in infants below 3 months of age could not be accurately observed when pacifiers were provided. Fourth, swaddling limited the observation of an infant's movement to the upper limbs. We cannot rule out the possibility that this affected MBPS measurement. Fifth, this study explored only jugular CVC removal. Therefore, it cannot be generalised to all CVC removals. Finally, owing to the quasi-experimental repeated-measures design of the study, participants were not randomised or blinded. A study supervisor served as an evaluator and selection bias could not be eliminated, which might have limited the accuracy and generalisability of the results.

6. Conclusion

The use of sensorial saturation effectively reduced the frequency of pain behaviours in infants. Our results provide evidence supporting clinicians' incorporation of sensorial saturation into clinical practice when infants undergo painful procedures and clinical guidelines for nonpharmacological management of procedure-related pain. Our study findings and the factors influencing infant pain suggest that atraumatic CVC removal could be developed by timing the procedure when infants are stable and quiet, comforting them, positioning them appropriately, stabilising them, offering sensorial saturation, orally administering sucrose in the buccal cavity, providing non-nutritive sucking, and then gently removing the catheter and applying compression.

Conflict of interest

No conflicts of interest to declare.

Informed consent

The parents of all participating infants provided written informed consent for their children's participation.

Data availability statement

All data generated or analysed during this study are included in this article.

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CRediT authorship contribution statement

Yuri Choi: Term, Conceptualisation, Methodology, Validation, Data curation, Formal analysis, Investigation, Writing - Original Draft, Visualisation. **Professor Eun Kyoung Choi:** Conceptualisation, Methodology, Validation, Supervision, Project administration, Writing-Reviewing and Editing. **Professor Hyejung Lee:** Conceptualisation, Methodology, Supervision, Project administration, Writing-Reviewing and Editing. **Dr. Yoonjeong Shin:** Conceptualisation, Methodology, Supervision, Project administration, Writing-Reviewing and Editing. All authors have given final approval of the final version of the manuscript to be published, agree to be accountable for all aspects of the work, and acknowledge that those who are entitled to authorship are listed as authors.

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