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Cardiorespiratory Stability of Premature and Term Infants Carried in Infant Slings

Waltraud Stening, MD*; Patrizia Nitsch, MD*; Gernot Wassmer, PhD‡; and Bernhard Roth, MD*

ABSTRACT. *Objective.* **Parents in industrialized societies make increasing use of infant slings to carry their infants. This study was conducted to determine whether infants who are carried in slings are at risk of experiencing clinically relevant changes in cardiorespiratory measurements.**

Methods. **In a 3-period crossover trial, 24 preterm and 12 term newborns were continually monitored while being carried horizontally or vertically in a sling or lying in a pram. Oxygen saturation, heart rate, nasal airflow, abdominal breathing, and movements were recorded.**

Results. **Infants who were carried in slings were not at risk of clinically relevant changes of oxygen saturation or heart rate. The 90% confidence interval of oxygen saturation in both infant sling positions remained within a ±2% interval around the average oxygen saturation in the pram. However, a significant decrease of oxygen saturation was observed while infants were carried in a sling with a mean oxygen saturation of 96.3% (standard deviation [SD]: 1.8) in the vertical and 96.1% (SD: 2.0) in the horizontal sling position compared with the mean oxygen saturation in the pram (97.1%; SD: 1.5). The degree and the incidence of desaturations and bradycardia did not change while the infants were carried. Both types of episodes were seen only in preterm infants.**

Conclusion. **The use of carrying slings is not associated with an increased risk of clinically relevant cardiorespiratory changes in term and preterm infants.** *Pediatrics* **2002;110:879–883;** ***infant, preterm, carrying, cardiorespiratory stability, desaturation, bradycardia.***

ABBREVIATION. bpm, beats per minute.

In many cultures, the use of infant slings is a longstanding tradition. For psychosocial reasons, an increasing number of parents in industrialized societies are also carrying their infants in infant slings for several hours a day. It is hoped that carrying children in slings will enhance the parent–child relationship.[1] The tactile/kinesthetic stimulation has been shown to have a positive effect on the infant's development.[2–6] A controlled, randomized study revealed that the frequency of crying decreases with additional carrying of infants.[7] However, this conclusion remains controversial.[8,9] Little is known about the physiologic or potentially harmful cardiorespiratory effects of infant slings.[10]

At the University of Cologne Children's Hospital, parents are encouraged to use such slings to carry their infants and premature infants around the wards and hospital grounds. Our study was designed to assess whether the use of infant slings is associated with clinically relevant changes of cardiorespiratory parameters. We were particularly interested in episodes of oxygen desaturation and bradycardia.

METHODS

Patients

Twenty-four preterm newborns (average postnatal age: 47 days; range: 6–113) with stable cardiorespiratory measurements and 12 term infants (average postnatal age: 20 days; range: 6–42) were enrolled in the study. Infants were classified as cardiorespiratorily stable when no apnea or bradycardia was seen and no medical intervention was required for at least 4 days. Two infants were already discharged on the day of the study. Patient characteristics are summarized in Table 1.

Design

In a 3-period crossover trial, subjects were continually monitored in 3 conditions: 1) carried vertically in a sling, face turned to the mother/father; 2) carried horizontally in a sling, in the supine position; and 3) positioned laterally in a pram. Subjects were monitored for 20 minutes in each carrying method. The infants were randomly subdivided into 6 groups with different sequences of the 3 carrying methods. The study conditions were intended to match those of a normal stroll. The infants were carried in infant slings outdoors by their mother or father.

Measurement Methods

Pulsoximetric oxygen saturation and signal quality were recorded using an Oxycount Mini device (Weinmann, Stuttgart, Germany). This apparatus uses a split-pulse-wave algorithm. For each pulse wave, up to 50 oxygen saturation values are determined. The signal quality is derived from the number of values recorded during a pulse wave (range: 1–10, with 10 indicating the highest quality). For avoiding measurement errors as a result of external light contamination, the sensor was shielded with a lightproof bandage.

The measurements made with the Oxycount Mini device were saved online using a Vitaport system. The Vitaport system is a device designed for the evaluation of physiologic variables (developed by the Institute of Psychology, University of Cologne, and Becker Meditec, Karlsruhe, Germany). The Vitaport system was also used to register abdominal breathing (Respitrace sensor), movements of the infant (Piezo movement sensor), and nasal airflow (thermistor). Abdominal expansion was monitored to assess the presence or absence of apnea during desaturations or bradycardia. All physiologic measures were recorded every 2 seconds. The recorded data were stored on compact flash cards and transferred to a laptop computer with a card slot for additional processing.

The physiologic data were related to the infants' behavior, which was continuously assessed by an investigator and classified

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TABLE 1. Characteristics of the Study Group

Characteristics	Premature Infants	Term Newborns
N	24	12
Male/female	9/15	8/4
Mean birth weight (g; range)	1386 (500–2000)	3411 (2690–3870)
Mean gestational age (wk; range)	30 (23–35)	40 (38–42)
Mean weight at time of study (g; range)	1910 (1310–2560)	3490 (3360–4600)
Mean postnatal age (d; range)	47 (6–113)	20 (6–42)
Infants with CNS pathology*	3	1
Ventilated after birth	15†	0
Apnea-bradycardia syndrome after birth	14	0
Caffeine/theophylline‡	0	0
Hemoglobin (g/dL)‡	10.6 (8–16.1)	17.8 (11.8–20)

CNS indicates central nervous system.
* One term infant with thrombosis of middle cerebral artery, 3 premature infants with intraventricular hemorrhage (I to IV°).
† Mean duration of ventilation 3.1 days (range: 19 h–18 d).
‡ At time of study.

as follows: 0, asleep; 1, awake quiet; 2, awake fussing; 3, crying.[11] Electrode placement and positioning the infant slings (Didymos, Ludwigsburg, Germany) were standardized and always performed by the same investigator.

Data were evaluated using Vitagraph, a program developed for the Vitaport System. The data were screened for artifactual oxygen saturation and measurements according to the recommendations of the manufacturer of the Oxycount Mini device. For instance, data associated with a very rapid decrease of registered signal quality or data recorded with a signal quality value of <3 were excluded from additional analysis. In addition to the analysis by the device's internal data quality control system, data were checked manually and excluded when other sensors, eg, the movement sensor, or the observations of the investigator suggested possible recording errors.

Desaturation was defined as a decline in oxygen saturation to <88% for at least 10 seconds, bradycardia as <100 beats per minute (bpm) for a minimum of 10 seconds, and apnea as a suspension of respiration for a minimum of 20 seconds. Clinically relevant changes during sling usage were defined as a 2% decrease or increase of oxygen saturation or a 10% change of heart rate compared with the average value recorded in the lateral position in the pram. All parents gave written informed consent. They were present throughout the study.

Statistical Analysis

Paired 2-tailed *t* tests were used to assess the treatment effect. Special attention was paid to the contrasts between infant sling vertical versus pram and infant sling horizontal versus pram measurements. $P < .05$ was considered statistically significant. Equivalence for oxygen saturation was claimed when the 90% confidence interval remained completely within a ±2% interval around the average saturation during the control condition (lying in a pram). This interval was defined in the study protocol.

RESULTS

The use of infant slings was not associated with a clinically relevant drop of oxygen saturation. The 90% confidence interval of oxygen saturation in the 2 infant sling positions remained within a ±2% interval around the average oxygen saturation in the pram. However, the average oxygen saturation dropped slightly when infants were carried in an infant sling rather than pushed in a pram across the whole study group (Table 2). A clinically irrelevant but statistically significant decrease of oxygen saturation was observed in both the horizontal ($P = .0006$) and vertical ($P = .0045$) positions. In term infants, this trend was seen only in the horizontal position.

The results of the oxygen saturation measurements were not significantly influenced by actual hemoglobin value, history of apnea-bradycardia syndrome, history of mechanical ventilation, birth weight, current weight, corrected age, or recorded infant behavior. Graphical data representation did not suggest a relevant carryover effect between carrying conditions. Hence, we were able to ignore a possible period effect in our calculation of the variance.[12]

Episodes of desaturation were seen in 4 (11%) of 36 infants. Desaturation occurred only in preterm infants. One of the infants affected (infant 1) had intracranial pathology (intraventricular hemorrhage II). From a total of 12 desaturation episodes, 6 were observed with infants in the vertical sling position, 4 in the horizontal sling position, and 2 in the pram. Only 1 infant experienced desaturation while in the pram. Desaturation episodes were not associated with apnea. The longest and deepest desaturation continued for 112 seconds with values between 83% and 87%. The affected child (infant 1) was born 13 weeks prematurely and was 100 days old at the time of the study. Three episodes of desaturation were recorded while the infant was in the vertical sling position. Although not accompanied by bradycardia (<100 bpm), a clear decrease of mean heart rate was seen at the time of these episodes.

A closer look at the clinical characteristics of the infants affected by desaturation episodes (excluding infant 1 on account of the neurologic impairments) revealed that they were much younger on the day of the study (19.7 days vs 47 days) than the other preterm infants, although they had a higher mean gestational age (32 weeks), birth weight (1733 g), and current weight (1987 g).

Mean heart rate did not differ significantly among the 3 conditions across the whole study group. In total, 3 episodes of bradycardia (<100 bpm) were seen in 2 of the infants (6%; Table 3). As with desaturation episodes, only preterm infants were affected. The longest period of bradycardia lasted for 22 seconds with a minimum heart rate of 85 bpm.

Our behavioral observations (Table 3) revealed that infants in the horizontal infant sling position had lower activity scores than infants in a pram.

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TABLE 2. Oxygen Saturation and Desaturation in the 3 Study Conditions With Observation for 20 Minutes in Each Position

	Oxygen Saturation* (%; $n = 36$)	Oxygen Saturation* (% Premature Infants; $n = 24$)	Oxygen Saturation* (% Term Infants; $n = 12$)	Oxygen Saturation* (% Infants With CNS Pathology; $n = 4$)	Lowest Recorded Oxygen Saturation (%; $n = 36$)	Duration of Longest Desaturation Episode (Spo_2 <88%) (Sec; $n = 36$)†	Total No. of Desaturation Episodes in Each Condition (Spo_2 <88%) ($n = 36$)†	Quality of Oxygen Saturation Measurement ($n = 36$)
Infant sling vertical	96.3 (1.8)‡	96.1 (2.0)‖	96.7 (1.3) NS	94.8 (2.1)	83	112	6	8.4 (1.0)
Infant sling horizontal	96.1 (2.0)§	96.1 (2.1)¶	96.1 (1.8)#	95.3 (2.3)	84	78	4	8.8 (0.8)
Pram	97.1 (1.5)‡§	97.1 (1.4)‖¶	97.1 (1.6)#	95.8 (2.0)	86	54	2	8.7 (0.9)

CNS indicates central nervous system; NS, not significant.
* Data given are arithmetic mean values with standard deviations in parentheses.
† Desaturations were seen exclusively in preterm infants.
‡ $P = .0045$ always compared with observations in the pram.
§ $P = .0006$.
‖ $P = .0078$.
¶ $P = .0077$.
# $P = .042$.

DISCUSSION

The use of infant slings for preterm and term infants has been an integral part of the psychosocial care of infants for many years. The current study was designed to address whether infants who are carried in infant slings are at risk of clinically relevant decreases of oxygen saturation or critical changes of heart rate. Although mean oxygen saturation was slightly (but significantly) lower in both sling positions, this cannot be considered clinically relevant. The 90% confidence interval of oxygen saturation in the 2 infant sling positions remained within a ±2% interval around the average oxygen saturation in the pram.

Despite that our analysis used a very wide definition of desaturation (Spo_2 <88% for at least 10 seconds), only a small number of desaturation episodes were seen and the risk of such episodes was not significantly increased while using a infant sling. Only on 1 occasion was desaturation accompanied by bradycardia. No infants had apnea, cyanosis, or any other clinical sign of distress during episodes of desaturation. No desaturation episodes observed in this study reached the desaturation levels defined in previous studies of respiration in preterm infants. Poets et al[13–16] published several reports documenting the risk of episodic hypoxemia (defined in this study as Spo_2 <80% for a minimum of 4 seconds) in preterm infants. Desaturation episodes were seen in 71% of 160 preterm infants in his 1993 study. Desaturation was not accompanied by apnea in 17% of cases. The infants described in Poets's study were considered fit for discharge; they had a mean gestational age of 32.8 weeks at birth and a mean postconceptional age of 36.3 weeks at the time of the study. The characteristics and rate of the episodes of desaturation were comparable to those seen in term infants of the same postconceptional age.[16] The author, as well as other investigators,[17,18] considered these hypoxic episodes to be physiologic events, although their prognostic significance remains unclear. Apart from airway obstruction,[19] hypoxic events have been thought to be caused by intrapulmonary right-to-left shunts through persisting fetal blood vasculature.[13,20,21]

Although we did not observe any clinically relevant effects of infant slings on desaturation risk across our whole study group, some of the episodes of desaturation observed deserve closer analysis. The longest and deepest episode of desaturation was recorded while an infant (infant 1) was fussing (behavioral state 2). Several studies have shown that agitation or fussing is associated with apnea and desaturation in preterm infants.[22,23] Furthermore, infant 1 may have been at particular risk of desaturation because of a structural cerebral lesion. Subgroup analysis focusing on infants with cerebral morphologic changes showed that these infants had reduced mean oxygen saturation in all conditions studied (Table 2) although only infant 1 had an episode of desaturation. However, the group was so small that this result should be interpreted only as a trend.

The other 3 infants who experienced desaturation

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TABLE 3. Heart Rate, Bradycardia, and Motor Activity in the 3 Study Conditions With Observation for 20 Minutes in Each Position

	Heart Rate (bpm;* $n = 36$)	Heart Rate (bpm;* Premature Infants; $n = 24$)	Heart Rate (bpm;* Term Infants; $n = 12$)	Lowest Heart Rate (bpm)	Duration of Longest Bradycardia Episode (Hf <100 bpm; sec)	Total No. of Bradycardia Episodes in Each Condition (Hf <100 bpm)	Mean Activity Level
Infant sling vertical	140.4 (10.9) NS	143.3 (11.7)	134.4 (5.4)	85	22	3	0.69†
Infant sling horizontal	139.1 (9.0) NS	142.0 (8.5)	133.1 (7.1)	>100	0	0	0.47†‡
Pram	139.5 (11.6)	142.3 (12.2)	134.0 (7.7)	>100	0	0	1.06†‡

NS indicates not significant.
* Data given are arithmetic mean values with standard deviations in parentheses.
† Range: 0–3.
‡ $P = .017$ compared with observations in the pram.

had a postconceptional age that was 2 weeks below the mean of the whole group. One study by Schluter et al[19] showed that the rate of episodes of apnea, usually caused by obstruction, is negatively correlated with postconceptional age in preterm infants. Right-to-left shunts are also found more commonly in younger infants.[20] Furthermore, it is known that preterm infants are at particular risk for apnea and periodic breathing when placed on their back.[24] In our study, the infants were examined only while they were lying horizontally on their back while being carried in a sling. This may explain some of the results. One should also note that our monitoring, which was intended not to disrupt normal sling usage more than absolutely necessary, did not differentiate between different sleep phases or between periods of regular and irregular respiration, all of which could have had an influence on oxygen saturation and desaturation.[21]

Critics of infant slings maintain that small infants who are unable to sit are at risk of hypoxia and hypoxemia as a result of limitations of thoracic motility. However, we were unable to detect a statistically significant difference in oxygen saturation between the horizontal and vertical carrying conditions. It should be made clear that our results apply only to infant slings and not to other carrying aids, which may offer less support to the infant. The frequently made observation that carried infants are calmer was supported by our documentation of a mean activity score of 0.47 in the horizontal infant sling condition compared with 1.06 in the pram.

CONCLUSION

We did not observe any clinically relevant systematic changes in oxygen saturation or heart rate across the whole group of preterm and mature infants. Although some episodes of desaturation were seen, they were considered clinically irrelevant. There was no statistically significant difference between the rate of desaturation and bradycardia episodes observed in the 2 sling carrying positions and the pram.

Desaturation episodes were observed only in preterm infants with low postconceptional age. Therefore the slings should be used with caution for carrying preterm infants before they reach term postconceptional age. In mature infants, there was a trend toward higher oxygen saturation in the vertical carrying position compared with the horizontal position. On the whole, however, there was no clinically relevant systematic effect of carrying position on the cardiorespiratory parameters studied. However, it must be borne in mind that this was a short-term study and may not be applicable to long-term situations.

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