Respiratory Instability of Term and Near-Term Healthy Newborn Infants in Car Safety Seats

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ABSTRACT. *Objective.* **Premature infants who are discharged from intensive care nurseries are known to be at increased risk for apnea, bradycardia, and oxygen desaturation while in the upright position. These small infants also do not fit securely in standard infant car seats. Because of these problems, the American Academy of Pediatrics recommends a period of observation in a car seat for all infants who are born at <37 weeks' gestation. It is not clear whether this recommendation should apply to the minimally preterm infants (born at 35–36 weeks' gestation) who are healthy at birth and are hospitalized in the normal newborn nursery. The objective of this study was to evaluate the respiratory stability and safety requirements of healthy, minimally preterm infants in car seats compared with term infants.**

Methods. **Fifty healthy, nonmonitored, preterm infants (mean gestational age: 35.8 ± 0.6 weeks) and 50 term infants (mean gestational age: 39.5 ± 1.4 weeks) were recruited from a level I newborn nursery in a community hospital. Appropriateness of car seat fit was documented for each infant. Heart rate, respiratory rate, and pulse oximetry were evaluated while infants were supine and in their car seats. Apneic and bradycardic events were recorded in addition to a continuous recording of oxygen saturation values.**

Results. **Twenty-four percent of preterm and 4% of term newborn infants did not fit securely into suitable car seats despite the use of blanket rolls. Mean oxygen saturation values declined significantly in both preterm and term infants from 97% in the supine position (range: 92%–100%) to 94% after 60 minutes in their car seats (range: 87%–100%). Seven infants (3 preterm and 4 term) had oxygen saturation values of <90% for longer than 20 minutes in their car seats. Twelve percent of the preterm infants (95% confidence interval: 4.5%–24.3%) but no term infants had apneic or bradycardic events in their car seats.**

Conclusions. **Our data support the current American Academy of Pediatrics recommendations that all infants who are born at <37 weeks' gestation, including those who are admitted to level I community hospitals, be observed for respiratory instability and secure fit in their car seats before hospital discharge. Because lowering of oxygen saturation values was seen uniformly in all newborn infants, car seats should be used only for travel, and travel should be minimized during the first months of life. *Pediatrics* 2001;108:647–652; *car seat, newborn, prematurity, apnea, bradycardia, oxygen desaturation.***

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PEDIATRICS (ISSN 0031 4005).

ABBREVIATIONS. NICU, neonatal intensive care unit; AAP, American Academy of Pediatrics; HR, heart rate; bpm, beats per minute.

Infant car safety seats play an important role in protecting young infants from injury and death in motor vehicle accidents. However, very young infants who cannot sit and who have immature head-righting reflexes require special support in car seats to hold their body securely during movement of the car, to protect them from injury during crashes,[1,2] and to maintain respiratory stability.

Respiratory stability in the upright position is a particular problem for premature infants. Willett et al[3] demonstrated that convalescent premature infants from an neonatal intensive are unit (NICU) had more frequent apneic and bradycardic episodes as well as decreased oxygen saturation values in the upright position, compared with prone positioning, regardless of whether they had a history of apnea. These findings have been confirmed in subsequent studies.[4,5] Because of this, the American Academy of Pediatrics (AAP) recommends that premature infants <37 weeks' gestation have a period of observation in a car safety seat before hospital discharge to monitor for episodes of apnea, bradycardia, or oxygen desaturation.[1,2] Adherence to this recommendation is not universal among NICUs within our community (Minneapolis, St Paul, MN), and not all hospitals may be familiar with the AAP's recommendations. There is even less adherence in level I newborn nurseries that care for healthy premature infants who do not require special care (typically, infants who are born at 35 and 36 weeks' gestation). It is not clear from the available evidence that these otherwise healthy infants require observation in their car seats. Premature infants who do not require special newborn care were included in one study.[5] However, these infants' data were not analyzed separately from the data of the infants who were hospitalized in the level II nursery. Estimation of the risk of an adverse physiologic event in a car seat is important because 4% to 6% of all newborns are born at 35 or 36 weeks' gestation.[6] These infants are at minimal risk for apnea of prematurity[7] and often are admitted directly to the newborn nursery and discharged from the hospital with their mothers. Adding a car seat observation period to the short hospital stay may be difficult to implement, time-consuming, and expensive. Unless this population is specifically

at risk for respiratory instability in their car seats, the test should not be performed routinely.

The purpose of this study was to evaluate the incidence of car seat–associated respiratory instability (apnea, bradycardia, and/or oxygen desaturation) in healthy, minimally preterm infants who required only basic newborn care in a normal newborn nursery compared with healthy full-term infants. Because car seat designs have changed considerably since car seat suitability for preterm infants was first reported,[8] the second purpose of the study was to evaluate minimally preterm infants' ability to fit securely in recent models of standard infant car seats, compared with full-term infants.

METHODS

The study was approved by the Institutional Review Board of Children's Hospital–St Paul. Informed consent was obtained from the parents of each participating infant. Fifty preterm and fifty full-term infants were recruited from the newborn nursery. Preterm infants were born at 35 to 36 weeks' gestation; full-term infants were born at ≥37 weeks using best obstetrical criteria. All newborns were eligible, provided that they had never required intensive or convalescent care in the NICU. Preterm infants were enrolled sequentially. Because transient complications of pregnancy, labor, and delivery may have an impact on physiologic stability in the immediate newborn period, an effort was made to recruit healthy term infants with normal perinatal histories, as well as infants who experienced difficulties during labor or delivery. Because car seat dimensions may not be suited to newborn infants of all sizes, an effort was made to recruit term infants who were small, average, and large for gestational age.

Parents' car seats were assessed to determine whether the seat met current safety standards and whether the infant could be positioned securely within the seat. Parents' car seats were not used when they were designed for use in the forward-facing position only, more than 6 years old, purchased second-hand without knowledge of previous crashes, or had been recalled.[1,9] Secure positioning in the car seat was achieved by placing the infant in the car seat with the buttocks against the back of the seat and tightening the harnesses to allow only 1 finger-width distance between the infant and the harness.[9] In addition, blanket rolls were placed on either side of the infant and around the head to maintain midline position of the head and neck. When necessary, an additional blanket roll was placed between the infant and the crotch belt to prevent sliding forward in the seat (Fig 1).[1] When the parents' car seat met current standards but the infant could not be positioned securely using the harnesses and blanket rolls, an alternative car seat (Century Smartfit Plus with a 5-point restraint; Century Products Co, Macedonia, OH; or Evenflo Dynomite; Evenflo Juvenile Furniture Products, Inc, Piqua, OH) was provided. (The Evenflo Dynomite car seat is a small car seat suitable for premature infants. It is no longer manufactured but was available through the hospital car seat rental program.) An alternative car seat also was used for infants who did not have a car seat. All 100 infants were positioned securely and their car seats were angled appropriately according to the manufacturers' recommendations at the time of the physiologic recordings.

Infants were tested 30 to 60 minutes after a feeding. They were tested on the day of planned discharge or the day before dis-

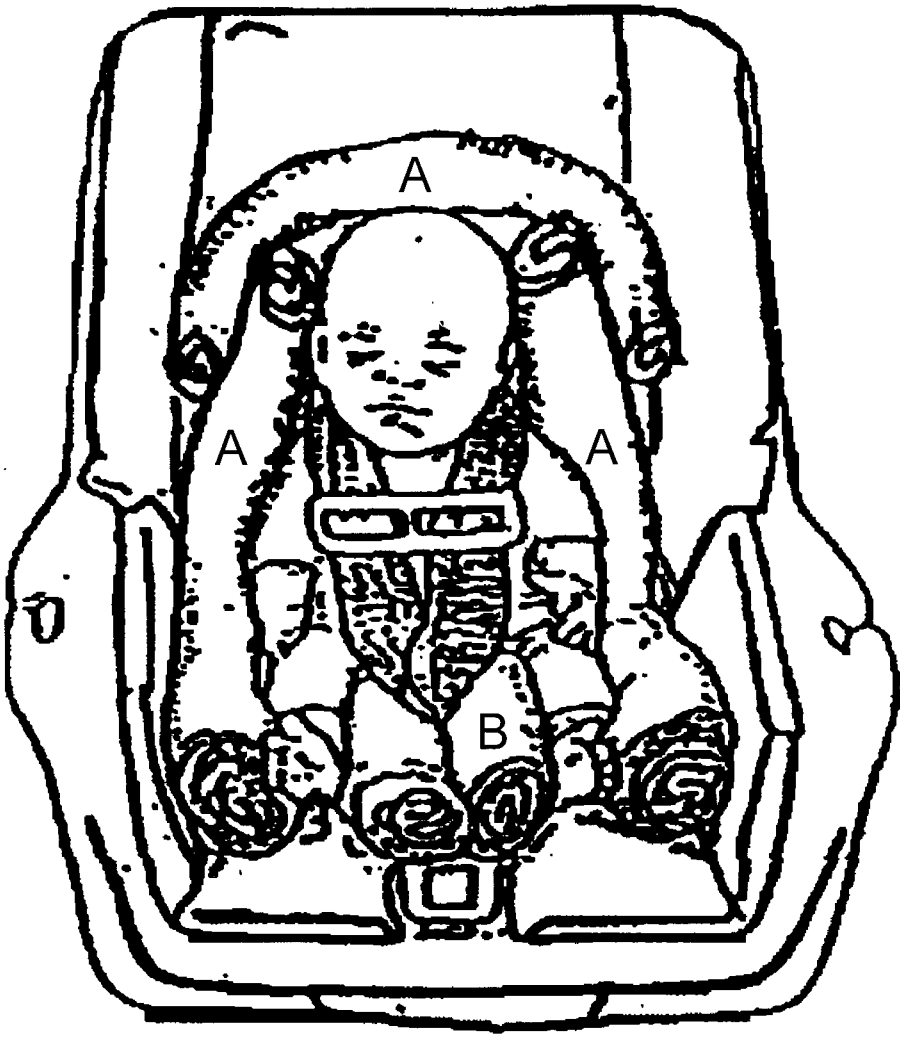

Fig 1. Use of blanket rolls for positioning infants in car safety seats. A, Indicates blanket rolls supporting the head neck and body position. All preterm and term infants required these for secure positioning. B, Indicates blanket rolls between the legs. Thirty-six percent of preterm and 16% of term infants required blanket rolls between the legs ($P = .0226$) for secure positioning.

charge, depending on the parents' preference. Heart rate (HR), respiration, and pulse oximetry were evaluated in the supine position for 30 minutes and then while infants were placed in the car seat for an additional 90 minutes. Blanket rolls were placed as needed for both preterm and full-term infants, as described above. The placement and number of blanket rolls required for secure positioning were recorded for each infant.

A technician observed the infant continuously during the recording. Two monitors were used. The Nellcor N3000 pulse oximeter with memory (Malinkrodt; Pleasanton, CA) was used to monitor oxygen saturation values. Oxygen saturation values (averaged over 10 seconds) were recorded continuously and saved. The oximeter also was linked to the Edentech Assurance 2000 apnea monitor with memory (Malinkrodt; Plymouth, MN). This monitor calculates HR by using a moving average time of 8 seconds and measures respiratory rate using chest wall impedance. The monitor records HR, thoracic impedance, and oximetry data continuously but saves the data only for predefined events. For this study, events were defined as follows: HR <80 beats per minute (bpm), respiratory pause >20 seconds, or oxygen saturation value <85% (see Fig 2 for an example). The 30 seconds before the event is saved as the baseline, and the recording continues for 60 seconds after the event or until the end of the event, whichever is longer. Thus, each infant had a monitor recording for each event that occurred during the study as well as a continuous recording of oximeter readings.

Monitor and oximeter recordings were inspected manually, and those with artifact were discarded as follows: artifactual bradycardia was detected by inspection of the QRS complexes during an event, artifactual apnea was detected when chest wall impedance was low without accompanying HR deceleration or oxygen desaturation, and pulse oximetry artifacts were detected when there was a discrepancy between the HR detected by the pulse oximeter and the cardiac monitor.

Transient alterations in HR, respiration, and oxygenation may occur in healthy infants. The following types of events have been described in healthy infants and are not considered to be pathologic: brief episodes of apnea ≤20 seconds,[10,11] transient episodes of bradycardia without oxygen desaturation,[12] and brief episodes of oxygen desaturation below 80% with spontaneous recovery.[13–16] For this study, significant events were defined as follows: HR <80 bpm for >4 seconds with oxygen desaturation (<80%), HR <80 bpm for >10 seconds without oxygen desaturation, apnea >20 seconds with oxygen desaturation (<80%), or HR <80 bpm. Isolated, acute drops in oxygen saturation values below 80% for >10 seconds also were scored as events. In addition to acute decreases in oxygen saturation values, a study was abnormal when the oxygen saturation value steadily dropped while the infant was in the car seat and fell below 85%. When an infant had a significant event that did not resolve spontaneously, stimulation was administered and the infant was removed from the seat.

Perinatal complications were recorded from the mothers' and infants' charts, including fetal distress (defined as having 1 or more of the following: late decelerations during labor, loss of HR variability, meconium-stained amniotic fluid, or Apgar score <6 at 1 or 5 minutes) and mode of delivery. One month after delivery, medical records were reviewed to determine the incidence of emergency department visits or hospital admissions related to dusky spells, apparent life-threatening events, or apnea.

Clinical characteristics of the preterm and full-term infants were compared using t tests. χ^2 tests or Fisher's exact tests were used to compare the incidence of car seat suitability and fit, use of blanket rolls, apnea and bradycardia, and oxygen desaturation episodes in the preterm and term groups. Oxygen saturation values, recorded at 15-minute intervals, were compared between the preterm and full-term infants over time using repeated measures analysis of variance, with Student-Newman-Keuls post hoc tests.

RESULTS

Clinical characteristics of the 2 groups of infants are shown in Table 1. The annual cesarean section rate at the hospital was 17.3% in 1998. The cesarean section rate was higher in both groups than the hospital average because of the large number of twins and triplets and because the longer hospital stays facilitated enrollment into the study.

For 13 infants (6 preterm and 7 term), the car seat supplied by the parents did not meet current safety standards, as previously defined. Eight infants (4 preterm and 4 term) had no car seat. Twelve preterm infants (24%) and 2 full-term infants (4%; both with birth weight of <2500 g) could not be positioned securely in their home car seats, despite properly positioned blanket rolls ($P = .0064$). These 35 infants were tested in the alternative car seat provided by the study.

All infants, both preterm and term, required blanket rolls at the sides and head for secure positioning

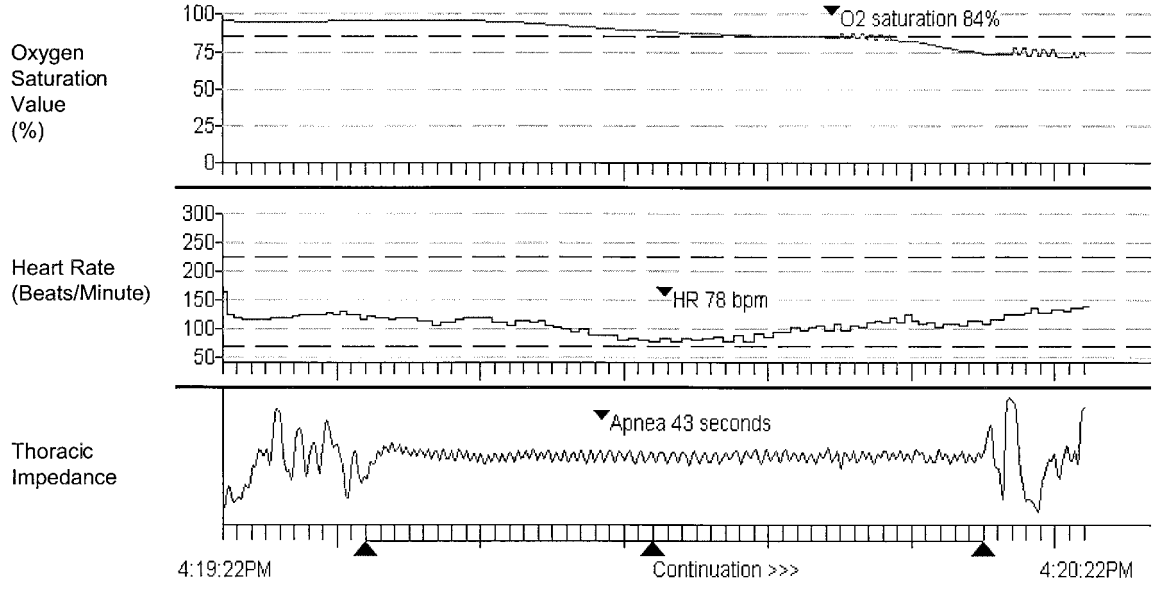

Fig 2. Example of an event recording, capturing an episode of apnea with a transient drop in HR and oxygen saturation values in a premature infant. Lack of pulse correlation of the pulse oximeter and cardiac monitor is denoted by a sawtooth pattern on the oximetry recording. This infant had a normal pneumogram and no history of apnea of prematurity.

TABLE 1. Participant Characteristics

Characteristic	Preterm Infants (n = 50)	Term Infants (n = 50)
Male	22 (44%)	27 (54%)
Gestational age (wk) (range)	35.8 ± 0.6 (34.7–36.7)	39.5 ± 1.4 (37.0–42.0)
Birth weight (g) (range)	2442 ± 356 (1810–3784)	3323 ± 768 (1889–5216)
Small for gestational age	2 (4%)	6 (12%)
Large for gestational age	1 (2%)	11 (22%)
Age at test (days) (range)	3.6 ± 1.9 (1–8)	2.2 ± 1.0 (1–7)
Multiple gestation	28 (56%)	2 (4%)
C-section rate	32 (64%)	20 (40%)
Fetal distress	6 (12%)	19 (38%)

Data presented as the number (percentage) of infants or as the mean ± 1 standard deviation.

in their car seats. In addition, 36% of preterm and 16% of term infants required a blanket roll between the legs for secure positioning (P = .0226; Fig 1).

Preterm and term infants did not differ in their oxygen saturation values recorded in the supine position and in the car seat (P = .68). Mean oxygen saturation values declined during the 90 minutes in the car seat (analysis of variance, $P < .0001$). Oxygen saturation values recorded in the car seat were significantly lower than those recorded in the supine position by 15 minutes in the car seat (Fig 3). Oxygen saturation values continued to fall until 60 minutes in the car seat and then became stable. Seven infants (4 term and 3 preterm) spent more than 20 minutes in the car seat with oxygen saturation values between 85% and 90%; no infant had a steady state oxygen saturation value <85%.

Six preterm infants (12%; 95% confidence interval: 4.5%–24.3%) and no term infants had significant apnea or bradycardia in their car seats (P = .0267; Example, Fig 2). Of the 6 preterm infants who had apnea or bradycardia, 3 required stimulation or removal from the car seat to terminate the event; the other events resolved spontaneously. There was no difference in the incidence of apnea or bradycardia between infants who were born at 35 (3 of 25) and 36 (3 of 25) weeks' gestation. One preterm and 2 term infants had isolated episodes of oxygen desaturation <80% that lasted longer than 10 seconds (without central apnea or bradycardia) in their car seats. One of the full-term infants experienced oxygen desaturation from a baseline saturation value of 85% to 90%; the other infants had a normal baseline oxygen saturation value at the time of the events. All isolated drops in oxygen saturation values resolved spontaneously.

One preterm infant was readmitted to the hospital after a dusky episode at 2 weeks of age, not occurring in a car seat. The infant had respiratory syncytial virus and continued to have persistent episodes of bradycardia. Home monitoring was prescribed, and bradycardic episodes persisted for several months. This infant had experienced prolonged bradycardia during the predischarge car seat evaluation, and the family declined additional evaluation. No other infants, preterm or term, were readmitted with dusky spells or apnea.

DISCUSSION

Nearly 4 million infants are born each year in the United States, and 4% to 6% are born at 35 to 36 weeks' gestation.[6] Many of these infants are healthy after birth and receive only basic newborn care in the nursery, but our study showed that 12% of these infants experienced apnea and/or bradycardia in their car seats. These findings confirm the recom-

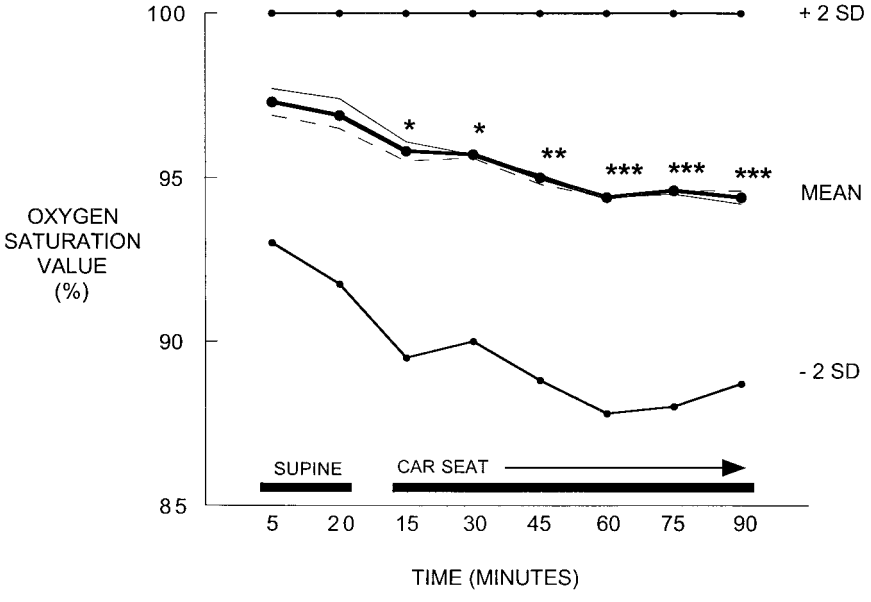

Fig 3. Mean oxygen saturation values ± 2 standard deviations at 5 and 20 minutes in the supine position and over time spent in the car seat for the preterm and term infants combined (thick lines). There were no significant differences between mean saturation values for the term (thin solid line) and preterm (thin dashed line) groups. For the groups combined, *mean oxygen saturation value was significantly lower after 15 minutes in the car seat than at either time in the supine position (P < .05). **Mean oxygen saturation value was significantly lower at 30 minutes in the car seat than at either time during supine positioning and at 15 minutes in the car seat (P < .05). ***Mean oxygen saturation values were significantly lower at 60, 75, and 90 minutes in the car seat than at either time in the supine position and at 15 and 30 minutes in the car seat (P < .05).

mendation of the AAP that all infants who are born at <37 weeks' gestation receive an individualized car seat evaluation,[1] regardless of whether the infant requires special care after birth. At the initiation of this study, no nurseries in our community were routinely following this recommendation for preterm infants who were hospitalized in the level I newborn nursery. We were concerned that the evaluation may not be warranted in this group of otherwise healthy infants and that the time and expense of doing the evaluation might be burdensome to families and to the nursery staff. However, the results of the study did affirm the need for car seat evaluations in this population, and the process has been accepted as a routine part of care for these patients. Additional difficulties in implementing the policy may apply to nurseries that are not associated with NICUs. For example, hospitals must have expertise with cardiac-apnea monitoring as artifactual tracings are common, and minor events may not be pathologic.

Although only preterm infants experienced apnea and/or bradycardia while in their car seats, the oxygen saturation values of both term and preterm infants declined over the first hour spent in the car seat. As also noted by Willett et al,[3] most of the infants maintained oxygen saturation values of >90% throughout the study. However, 7% of infants spent more than 20 minutes in the car seat with oxygen saturation values between 85% and 90%. Steady-state oxygen saturation values below 90% are not normally seen in healthy infants,[15,16] indicating suboptimal oxygenation in the upright position. This degree of hypoxia is not thought to be harmful, but even healthy full-term infants may be vulnerable to more significant hypoxia with prolonged upright positioning, frequent gastroesophageal reflux, or intercurrent respiratory illnesses.

This study was not designed to evaluate the cause of the abnormal events that occurred while infants were seated in their car seats, as this issue has been explored in other studies. Although these events seem to be related to a combination of immature control of breathing and decreased tidal volume in the upright position,[4] they are not limited to infants with a clinical history of apnea of prematurity.[3] All of the infants in our study were admitted to a normal newborn nursery and cared for without apnea monitors. No infant was clinically suspected to have apnea before the study. However, after significant events in their car seats, 1 infant was found to have apnea of prematurity and another was found to have significant gastroesophageal reflux. This circumstantial evidence is consistent with previous findings that infants with apnea of prematurity may experience further problems in their car seats, but infants without clinically detected apnea of prematurity still are at risk.[3]

The AAP recommends prone or supine positioning in a car bed for an infant with documented oxygen desaturation, apnea, or bradycardia while seated in a car safety seat.[1] Recommendation of a car bed poses problems for families with twins, triplets, or other children, as the Cosco Dream Ride (Cosco, Inc, Columbus, IN) requires >1 space in the car, and the Cherish Car Bed (Graco, Elverson, PA) fits infants who weigh only up to 9 pounds. Families that travel in trucks also may have difficulties using the car bed. When a car bed was not a viable option for families, we retested the infant in a seat of a different design or with the seat at the most reclined angle permitted by the manufacturer, as this was noted to improve oxygen saturation values in a previous study.[4] Before recommending a car bed, it also is important to consider that the car seat evaluation may unmask an underlying condition that was not suspected previously (eg, apnea of prematurity in a near-term infant, gastroesophageal reflux).[5] Furthermore, moving the infant to a car bed usually abolishes the events, but this is not always the case.[17] Our current policy is that premature infants from the newborn nursery who fail their car seat evaluations are moved to a car bed and monitoring is continued for an additional hour. Infants who have events either during the baseline supine period or in the car bed typically are admitted to the NICU for additional evaluation.

In addition to the issues of respiratory stability, this study showed that 24% of preterm and 4% of term infants in this study were unable to be positioned securely in modern car seats supplied by their families, despite the use of blanket rolls. This was attributable, in part, to a large variation in the design of many standard infant car seats. Some do not have belt dimensions that currently are recommended for premature infants.[2] Others have a steep angle of incline that makes it difficult to stabilize the infant's head. In previous studies, the size of the belt dimensions and the use of blanket rolls to stabilize the head and neck of the infant were important in maintaining proper alignment and thus optimizing safety in a crash situation.[3,4,8] Proper size of the car seat and positioning of the infant within the car seat also may aid in maintaining a patent upper airway and thus better respiratory stability in these infants.

The AAP recommends that at discharge, every newborn be restrained properly in a car safety seat.[18] Our study results indicate that there are a number of barriers to accomplishing this goal. In our study, 35% of families had no car seat or brought car seats that were unsafe or did not fit despite the use of blanket rolls. Even with modern car seat designs, no newborn infant in our study could be positioned securely without additional padding at the sides, and even full-term infants occasionally required padding at the crotch strap to ensure a secure fit. For preterm infants, parents often are unprepared for the specific car safety seat issues with which they will have to contend, making it difficult to select an appropriate car seat before birth. Most nurseries do not have standard policies to evaluate car seats and to teach parents how to use blanket rolls to position newborn infants properly, but this should be part of the discharge process. Pre- and postnatal education of families, as recommended in the current AAP guidelines,[18] will help families to ensure the safety of their children while traveling in cars. During the course of the study, it became clear that new parents are overwhelmed with information about their newborn and

that parents need simple instructions that can be recalled and used easily later. With this in mind, it may be more effective to make car seat manufacturers aware of the issues of positioning and physiologic stability in newborn infants who use their products. Additional studies to define an optimal design for infant car seats would be helpful in ensuring a uniformly secure fit and physiologic stability, thus making it easier for families to use car seats properly without the need for a complicated set of instructions.

Infant car safety seats play an important role in protecting young infants from injury and death in motor vehicle accidents. However, data in this study show that term and preterm infants are equally susceptible to declining baseline oxygen saturation values in car seats. Although car seats often are used as carriers for newborn infants, our data indicate that preterm and term newborns should not remain in car seats for extended periods of time when they are not traveling. The AAP recommends that travel be minimized for premature infants,[1] and our data suggest that full-term newborns also would benefit from this recommendation. In addition, the use of swings and other types of upright seating devices should be uniformly discouraged during the first months of life.

ACKNOWLEDGMENTS

This study was funded by a grant from the Children's Hospital Association. Preliminary results of this study were presented at the September 1999 meeting of the American Academy of Pediatrics (Washington, DC) and at the February 2000 meeting of the Western Society for Pediatric Research (Carmel, CA).

We thank the physicians and nursing staff in the newborn nursery, who identified potential candidates for the study as they were admitted. We also thank the staff in the Special Diagnostics Laboratory, who conducted the car seat evaluations with us and have been instrumental in developing policies to ensure the safe transportation of all newborn infants who are discharged from our hospital.

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THE LIMITS OF DOCTORS' FREEDOM TO ACT

Doctors must have the freedom to act against standard practice, but only when they do so as part of a properly supervised trial, in a way that is controlled and observed, and provided the patient is offered orthodox opinion and can take part in the decision.

Ross N. Skill before politeness. *BMA News Review.* December 2000

Submitted by Student