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Postanesthetic Apnea and Periodic Breathing in Infants

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Premature infants undergoing general anesthesia for surgery within the first year of life may develop respiratory and cardiovascular complications in the perioperative period.[1-4] Apnea and/or bradycardia with cyanosis are by far the most common and potentially lethal complications.

We designed this prospective study to determine the incidence of perioperative apnea and/or periodic breathing in infants undergoing general anesthesia for inguinal herriorrhaphy in the first year of life. We also attempted to define the age at which a prematurely born infant "outgrows" possible apneic episodes.

METHODS

Infants less than 12 months postnatal age undergoing general anesthesia for herriorrhaphy were studied. They were divided into two groups: 1) premature infants (Group 1) birth weight ≤ 2,500 g and/or gestational age ≤ 37 weeks, and 2) full-term infants (Group 2) gestational age > 37 weeks. Infants with cardiac, neurologic, endocrine, or metabolic diseases were excluded from the study.

Patients with past or present history of apneic spells or other risk factors such as history of sudden infant death syndrome among siblings, bronchopulmonary dysplasia,

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present history of respiratory distress syndrome, and coexisting complications such as history of pneumonia, upper respiratory tract infection, and anemia were admitted to the hospital on the night before surgery and placed on a Healthdyne 16000® monitor with a Holter® recorder for at least 12 h prior to anesthesia. Infants who were free of risk factors had surgery performed as outpatients and were therefore only monitored postoperatively. The monitor used in this study detects respiration through the use of impedance pneumography, whereby the change in impedance or resistance in the chest is measured as respiration occurs. The electrocardiogram is detected and amplified, and from this signal, the patient's heart rate is determined. The monitor incorporates the use of standard skin electrodes as transducers for detecting both the ECG and impedance changes.[5] The recorded data were sent out for scanning and then analyzed by the pulmonologists (N.R. and R.F.) for evidence of apnea, periodic breathing, and bradycardia. Because several days were required to complete the analysis, the results were not available to the anesthesiologist before induction of anesthesia.

Changes in respiratory pattern and/or heart rate were reported as follows: 1) prolonged apnea, defined as a respiratory pause 15 s or longer,[6] that may be accompanied by bradycardia; and 2) apnea, defined as a respiratory pause less than 15 s. Periodic breathing was defined as three or more periods of apnea of 3–15 s separated by less than 20 s of normal respiration. The significance of periodic breathing was interpreted by relating its duration to the total sleep time. To report the amount of periodic breathing (PB), the duration of all such episodes (in min) was totaled. The total min of PB was then divided by the total sleep time (min) in the recording to determine the per cent of PB. PB less than 0.5% of the recording was considered normal.[7] Bradycardia was defined as a heart rate slower than 100 beats/min for at least 5 s in neonates under 1 month of age, 90 beats/min in infants 1 to 3 months of age, and 80 beats/min in infants 3 months or older.

Patients were not premedicated with sedatives or narcotics. Atropine 0.02 mg/kg (iv or im) was given during induction of anesthesia. General endotracheal anesthesia

TABLE 1. Comparison of Age, Incidence of Apnea, Periodic Breathing (PB) and Postoperative Ventilation in Groups 1 and 2

	Group 1: Premature Infants (gestational age ≤ 37 weeks) n = 38		Group 2: Full-term Infants (gestational age > 37 weeks) n = 48	
Conceptual age (wk) (range)	≤44 (34–44)	>44 (45–77)	≤44 (41–44)	>44 (46–88)
Gestational age range (wk)	26–37	26–36	38–40	38–42
Number of patients:	22	16	7	41
With history of apnea	18	12	0	0
Postoperative PB	14*	0	0	0
Postoperative intubation or ventilation	0	0	0	0

* $P < 0.001$ Fisher's exact test.

was administered using a variety of techniques selected by the participating anesthesiologists. This usually included nitrous oxide/oxygen and halothane with or without muscle relaxants, with ventilation controlled. No narcotics were used. Patients were monitored appropriately with no less than indirect blood pressure, electrocardiogram, temperature, and precordial stethoscope.

In the recovery room the postoperative patterns of respiration and heart rate were monitored and recorded. The inpatients were discharged to a monitored hospital bed when the recovery room discharge criteria were met and monitored for at least 12 h postoperatively. Monitoring was discontinued the morning after surgery when the patient was ready for discharge. In the event that life-threatening complications occurred or were anticipated, the patient was to be monitored in the intensive care unit. The outpatients were managed in the same manner in the recovery room. If no complications occurred, patients were transported to the adjacent short stay recovery unit and monitoring continued for at least 4 h until they were discharged home.

The difference in the incidence of prolonged apnea and/or periodic breathing in premature infants ≤44 weeks conceptual age (gestational age + postnatal age) versus those >44 weeks was tested for statistical significance by Fisher's exact test.

RESULTS

Eighty-six patients were studied. Thirty-eight infants were premature and 48 infants were full term.

Seven of the full-term infants were ≤44 weeks conceptual age, and 41 were >44 weeks conceptual age at the time of surgery (table 1). None of the full-term infants had a preoperative history of apnea or any other risk factors, and none developed postoperative prolonged apnea or PB.

Sixteen of 38 premature infants were >44 weeks conceptual age at the time of surgery. Twelve had a preoperative history of apnea, but none showed preoperative or postoperative prolonged apnea or PB on pneumogram. None required postoperative endotracheal intubation or

mechanical ventilation. Twenty-two of the premature infants were ≤44 weeks conceptual age. Eighteen had a history of apnea, but none showed preoperative prolonged apnea and/or PB. There were no episodes of postoperative prolonged apnea in this group. Periodic breathing was noted only in 14 ex-prematures with a conceptual age less than or equal to 44 weeks compared with those with a conceptual age greater than 44 weeks ($P < 0.001$ Fisher's exact test). These 14 (63.6%) had postoperative PB greater than 0.5% without bradycardia on pneumogram (fig. 1). Two of these patients showed PB as late as 5 h postoperatively. None of the patients in either group required endotracheal intubation or controlled ventilation postoperatively.

DISCUSSION

Premature infants represent a significant operative risk mainly related to the presence of many immature organ systems.[3] The incidence of apneic episodes in the premature infant is inversely correlated with gestational age and weight.[6] Henderson-Smart et al.[8] recently demonstrated that the auditory brain stem conduction time increased as gestational age decreased. The increase in conduction time correlated with the frequency of apneic ep-
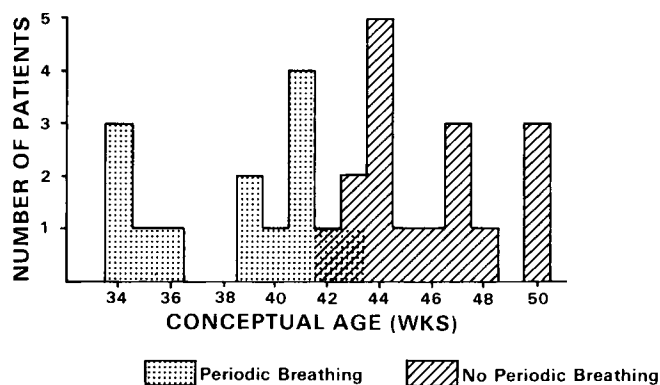

FIG. 1. Distribution of conceptual age, number of patients and incidence of postoperative periodic breathing.

isodes. He concluded that apnea is probably related to immature brain stem function.

Unlike prolonged apnea, which is always pathologic, PB has been observed to occur in 30–95% of otherwise healthy premature infants during sleep and reflects inadequate development of ventilatory control.[7] Some premature infants who breathe periodically demonstrate hypoventilation, a shift to the right of the CO_2 response curve, and a paradoxic response to hypoxia. During PB, there is a gradual reduction in ventilation and oxygenation that can result in prolonged apnea.[9] Kelly and Shannon[7] found a definite increase in PB in infants with near-miss sudden infant death syndrome.

In a retrospective chart review of healthy infants undergoing herniorrhaphy, Steward[4] reported that preterm infants who require surgery in the first months of life are more likely to develop respiratory complications during and following anesthesia as compared with full-term infants. He found that 12% of preterm infants were observed to have prolonged apnea during and up to 12 h following anesthesia. None required mechanical ventilation postoperatively.[10] In the prospective study by Liu et al.,[1] six infants with a history of apnea and a conceptual age below 46 weeks were observed to have prolonged apnea after anesthesia and surgery. Seven infants who had a preoperative history of apnea, but a conceptual age of 46–80 weeks, were not observed to have apnea postoperatively. A large number of patients in this study required mechanical ventilation for other preexisting conditions, such as brain damage, and therefore the incidence of apnea in this subgroup remains unknown. In a prospective study, using pneumography Kurth et al.[11] observed a 37% incidence of postanesthetic prolonged apnea limited to 47 former preterm infants whose conceptual age varied from 32 weeks to as old as 55 weeks. He also demonstrated that the initial episode of apnea may occur as late as 12 h following anesthesia.

In our study none of the infants developed prolonged apnea or PB with bradycardia on pneumogram, even though some patients had a history of preanesthetic apnea and were receiving apnea monitoring at home. None of the patients required prolonged endotracheal intubation or artificial ventilation, and all trachea were extubated in the operating room. Periodic breathing without bradycardia, however, was found in 14 of 38 preterm infants in the postoperative period. In four of these, there was no preoperative history of apnea. The PB was frequent and occurred as late as 5 h postoperatively. Theoretically, frequent PB in a given patient may result in hypoxemia and bradycardia.[7,9] To our knowledge this did not occur in our study. Consistent with previous studies, PB was more frequent the more immature the baby.[8,12] It did not occur in former premature infants greater than 44 weeks

conceptual age who were without any major systemic disease.

The absence of prolonged apnea in our group of patients is at odds with other studies.[1,4,11] It was difficult for us to interpret much of the existing literature, especially when the data were derived from retrospective review of complications and/or when patients with preexisting disease who underwent complex surgical procedures were included. In addition, there are many other predisposing factors in the development of prolonged apnea in premature infants. These include hypoglycemia, hypoxia, hyperoxia, sepsis, anemia, hypocalcemia, and environmental temperature changes.[13] Institutional differences regarding patient selection, caring of the premature infant, assignment of gestational age, type of surgery, type of anesthetic management, number of patients studied, and the method and duration of recording and monitoring apnea may also influence the results and conclusions in this type of study. We attempted to control as many of these variables as possible by prospectively studying infants without systemic disease for herniorrhaphy using a pneumogram. In the only other study using preoperative and postoperative pneumography, Kurth et al.[11] included patients undergoing laparotomy and neurologic surgical procedures, while ours was limited to herniorrhaphy. Their study included patients with preexisting disease, while in ours, these patients were excluded. In their study, the absence of a statistical correlation of these factors with outcome may have been related to the limited number of patients studied.

One of the most controversial aspects of the diagnostic evaluation of apnea of infancy is the significance of the recording of cardiorespiratory patterns.[14] There are two major difficulties in the interpretation of such recordings. First, there is the problem of obtaining a representative sample of the infant's respiratory patterns.[15] There may be some differences between nap time and nighttime sleep. Steinschneider[16] has demonstrated a correlation between the frequency of short apnea and the occurrence of prolonged apnea, thus providing some evidence that shorter recording periods may be able to detect abnormalities, but Guilleminault et al.[15] question the value of short recording sessions. Second, there is a problem in defining normal versus abnormal and in determining what measurements are most practical for analysis and discriminatory for distinction between normal and abnormal.

In conclusion, premature infants less than 44 weeks conceptual age are at high risk for developing postoperative ventilatory dysfunction. We agree that it is probably best to delay nonessential surgery for preterm infants until they are beyond 44 weeks conceptual age.[10] Patients whose surgery cannot be delayed and who otherwise have identified risk factors should be admitted to a hospital

and monitored with an apnea monitor for at least 12 h postoperatively. In our institution we found that herniorrhaphy can be safely performed in infants greater than 44 weeks conceptual age who do not have major cardiac, neurologic, endocrine, or metabolic diseases. Until more information is available, the care of a high-risk infant should be individualized and should remain conservative. Should any questions arise, postoperative monitoring and observation in a hospital setting are recommended.

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A Cause of Breathing System Leak during Closed Circuit Anesthesia

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Closed-circuit anesthesia requires meticulous attention to the anesthetic system. We recently observed a complication of closed-circuit anesthesia related to the injection of liquid anesthetic that resulted in equipment failure.

REPORT OF A CASE

A Draeger Narkomed® anesthesia machine with a standard circle absorber system was prepared for closed-circuit use by inserting an injection port coupler (Anesthesia Associates, Inc., San Marcos, CA)

into the breathing circuit. This coupler was equipped with a stopcock, a female Luer® connector, and a 25-gauge needle allowing for injection of liquid anesthetic agents into the lumen. The coupler was attached to the machine end of the expiratory limb hose. The flow-sensing cartridge of an electronic volume monitor (Ohmeda, Madison, WI, Model 5400) was attached to the other end of the coupler, and the flow cartridge was then attached to the inlet to the expiratory valve. A calibrated polarographic oxygen analyzer (Instrumentation Laboratories, Lexington, MA, Model 402) was used with the sensor placed in the dome of the expiratory valve. The entire system was checked for leakage of gases, and fresh gas flowmeters were properly calibrated prior to the induction of anesthesia.

A healthy, 35-yr-old, 96-kg man presented for elective ankle exploration and removal of fractured bone fragments. Medical and surgical history as well as physical examination, vital signs, review of systems, chest radiograph, ECG, and routine laboratory studies were within normal limits.

Following breathing of 100% oxygen for 5 min and use of conventional monitoring, anesthesia was induced with d-tubocurarine, 3 mg iv, and thiopental, 700 mg iv. Endotracheal intubation was facilitated by succinylcholine, 100 mg iv. Correct location of the endotracheal tube was confirmed by auscultation.