

using a cumulative dose method. This has been explained on the basis of the relatively short action of vecuronium, particularly in small doses, in relation to the time it takes to administer further increments in a cumulative dose technique.¹ Similar considerations perhaps apply to atracurium, an agent with a short half-life¹⁰ and which begins to be metabolized from the time of administration via the Hoffman elimination reaction.

An obvious disadvantage of the single dose method is the larger number of patients required to establish potency of a drug. It is, however, clear that the results with relatively shorter acting agents like atracurium and vecuronium are influenced by the technique of evaluation, although this does not seem to matter when longer acting agents like pancuronium and tubocurarine are evaluated. It is perhaps preferable to determine potency of such agents by a single-dose technique, since this is the way in which anesthesiologists administer the muscle relaxants, particularly the initial dose.

In conclusion, our results show the potency of atracurium to be significantly greater ($P < 0.005$) when assessed using a single-dose method. The ED₅₀ and ED₉₅ were determined to be 162 and 305 $\mu\text{g}/\text{kg}$, respectively, using the cumulative dose technique, and 126 and 226 $\mu\text{g}/\text{kg}$, respectively, using the single-dose technique.

Anesthesiology
62:659-661, 1985

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Emergency Management of the Infant with an Obstructed Airway at Birth

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Congenital subglottic stenosis is the third most common obstructive airway lesion in infancy and childhood¹ and the most common congenital laryngeal lesion requiring tracheotomy.² Such infants usually present with stridor and/or repeated respiratory infections in the first few months of life. We describe a neonate with total subglottic obstruction, symptomatic from birth. Differential diagnosis of the newborn with an apparently

obstructed airway along with suggestions for acute airway management of such infants is discussed.

REPORT OF A CASE

This 2,780-g female infant was born at 37 weeks' gestation to a 33-year-old gravida 8 para 3 mother. Four spontaneous first-trimester abortions had occurred between the last live birth and the current pregnancy. Ultrasound at 24 weeks' gestation performed for evaluation of polyhydramnios revealed fetal ascites but no other anomalies. Antibody screen of mother's blood was negative. Fetal heart rate was noted to be 180 bpm. With the presumption that the ascites represented congestive heart failure secondary to supraventricular tachycardia,³ digitalis was administered to the mother. Follow-up sonograms showed resolution of ascites, but polyhydramnios remained.

Delivery was accomplished by repeat Cesarean section in labor under general anesthesia. The infant had good tone and made two or three attempts at inspiration, then became apneic. Efforts to ventilate her lungs with help of a bag and mask were unsuccessful; the infant's chest did not expand, nor did her bradycardia or cyanosis improve. During an attempt by an experienced neonatologist to intubate the trachea, first with a 3.0 and then with a 2.5 endotracheal tube, the cords were easily visualized, but the endotracheal tube

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Received from the Departments of Neonatology, Anesthesia, and Surgery of Memorial Medical Center, Savannah, Georgia, and the Medical College of Georgia, Augusta, Georgia. Accepted for publication November 29, 1984.

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Key words: Airway; obstruction. Tracheal agenesis. Tracheotomy.

would not pass beyond them. In retrospect, no pulmonary fluid was seen flowing out through the cords, as is commonly observed at Cesarean section delivery. The anesthesiologist in attendance also attempted tracheal intubation but was unsuccessful. Since both bag and mask aided ventilation and endotracheal intubation had failed, the child apparently had some form of critical airway obstruction. Because the Apgar score at 3 min remained at 1, the decision to perform an emergency tracheotomy was made. A delay of 10–20 min was anticipated while preparations for the surgery, including arrival of a surgeon, were made. Because of the child's critical condition, a 16-gauge Teflon® iv catheter attached to a 10-ml syringe was inserted into the trachea in the midline, below the thyroid cartilage. Thirty milliliters of straw-colored fluid, presumably representing normal complement of lung fluid, immediately was aspirated. After the needle was withdrawn, a standard endotracheal tube adapter was attached to the proximal metal tip of the iv catheter, and the infant was ventilated with a self-inflating infant resuscitation bag. Ventilation with 100% oxygen at a rate of 50–60 breath/min through this "catheter-tracheotomy" produced an immediate improvement in heart rate, color, tone, and perfusion. At about 10 min of age, blood withdrawn through an umbilical arterial catheter showed pH of 6.83, $p\text{CO}_2$ 97 mmHg, $p\text{O}_2$ 47 mmHg, base deficit 10 mEq/l. Five milliequivalents of sodium bicarbonate were given through an umbilical venous catheter, and the rate of ventilation increased. Periodically, copious amounts of fluid that bubbled out of the intratracheal catheter were suctioned. At 30 min of age, a tracheotomy was performed with insertion of a 2.5 endotracheal tube in lieu of a tracheotomy tube, as the smallest size immediately available was too large. The external portion of the trachea, visualized directly during the procedure, appeared to be normal in caliber. At 90 min of life, a blood-gas in 23% oxygen using a ventilator at an inflating pressure of 25 cmH₂O and rate of 100 breaths/min showed $p\text{H}_a$ of 7.39, PaCO_2 36 mmHg, PaO_2 58 mmHg, base deficit 2 mEq/l.

Physical examination of the infant at this time was consistent with 36–37 weeks gestation. The liver edge was palpable 3 cm below the right costal margin. The abdominal skin was slightly redundant, but no ascites was appreciated. Heart rate was 150 bpm, and heart sounds were normal. ECG and M-mode echocardiogram were within normal limits. Chest roentgenogram showed mild ground glass appearance, consistent with hyaline membrane disease. Over the next 4 days the infant's requirement for additional oxygen decreased and she was maintained on 2 cm continuous positive airway pressure in room air.

At 5 days of age, the tracheotomy was revised and a 00 silastic infant tracheotomy tube, internal diameter 3.0 mm, inserted. The following day the baby developed bilateral pneumothoraces. Chest tubes were placed. She required marked increase in ventilatory support for several days. By the twenty-first day of life ventilatory support, including continuous positive airway pressure was discontinued successfully.

Feeding proved to be very difficult because the infant would not suck from a bottle. Esophagram to rule out tracheoesophageal fistula was negative. Feeding gastrostomy was performed at 3 months of age. Nissen fundoplication was performed prior to discharge because of significant vomiting and failure to gain weight secondary to gastrointestinal reflux not responsive to medical management. At 4 months bronchoscopy revealed total subglottic occlusion. The child was discharged on gastrostomy feedings at 5 months of age. At 8 months she takes only occasional "spoon feedings" by mouth and weighs 4.4 kg. Developmentally she is age-appropriate, except for vocalization. Definitive repair of the tracheal stenosis is planned for a later date.⁴

DISCUSSION

It is not unusual to encounter an infant in the delivery room or in the nursery soon after birth with labored respirations and/or apnea. Primary lung disease, diaphragmatic hernia, pneumothorax, and sepsis are common causes of respiratory distress. These entities, in addition to central nervous system abnormalities also can evoke the nonspecific symptom of apnea in neonates, probably through common pathways of hypoxemia and/or central depression of respiratory centers. Congenital tracheal obstruction or total agenesis of the trachea as an etiology of neonatal respiratory distress or apnea is rare. Agenesis of the trachea is not compatible with life unless a large (2–4 mm) fistula exists between the esophagus and carina. Periods of survival ranging from a few hours to several weeks have been reported in neonates with tracheal agenesis and tracheoesophageal fistula after esophageal intubation or administration of intragastric oxygen followed by corrective surgery.^{5–9} Tracheal agenesis usually is accompanied by multiple congenital anomalies, especially those affecting the gastrointestinal and genitourinary tracts, heart, and skeleton.^{5,7,9–14} A history of polyhydramnios is common.

On the other hand, neonates with tracheal or subglottic stenosis normally present at a few weeks or months of age, with stridor or repeated respiratory infections. Tracheal stenosis usually is not associated with multiple congenital anomalies, although an occasional association with hemivertebrae, thumb hypoplasia, duodenal atresia, congenital heart disease, and unilateral pulmonary agenesis has been reported.^{15–18}

Three types of stenosis are recognized: generalized hypoplasia, funnel-like stenosis, and segmental stenosis. Subglottic stenosis is the most prevalent form of segmental stenosis. The point of greatest obstruction generally is found 2–3 mm below the level of the superior surface of the true cords.² The clinical condition of infants with symptomatic congenital subglottic stenosis generally permits radiographic and/or bronchoscopic evaluation and elective intubation prior to tracheotomy, although such was not the case in our patient.

Several previously reported studies performed in adults¹⁹ and small animals^{20,21} have shown the feasibility of providing oxygenation and ventilation by needle tracheotomy, at least in a controlled situation. We believe we did not achieve initial relief of hypercapnia and hypoxemia in our patient for several reasons: 1) acute cardiopulmonary failure; 2) no gaseous functional residual capacity; and 3) inadequate minute ventilation. All experimental studies of needle tracheotomy began with subjects who were normoxic, normocarbic, nonacidotic, with normal functional residual capacity. Before

insertion of the catheter-tracheotomy, our patient was hypoxic, hypercarbic, and acidotic, conditions in the newborn that very frequently lead to persistent pulmonary hypertension and consequent persistence of right-to-left shunting through the foramen ovale and ductus arteriosus,²² further compromising cardiopulmonary resuscitation. In addition, the resuscitation of our infant began with essentially no gaseous functional residual capacity. The baby ultimately proved to have mild hyaline membrane disease, requiring higher than normal minute ventilation to achieve normalization of blood gases. Given the child's moribund condition soon after birth, however, the emergency catheter-tracheotomy enhanced oxygenation and ventilation, albeit not optimally, prior to tracheotomy, preventing further deterioration and probable death.

When unexpected difficulty in ventilation and/or endotracheal intubation unrelated to inexperience of the operators is encountered during resuscitation at birth, the possibility of tracheal agenesis or critical tracheal stenosis should be considered. An obstructed airway, rather than complete atresia with tracheoesophageal fistula, should be suspected if ventilation with bag and mask is unsuccessful, if no pulmonary secretions are observed with direct visualization of the cords and when the smallest size endotracheal tube cannot be advanced beyond the cords.

The authors thank Dr. H. Biemann Othersen, Department of Surgery, Medical University of South Carolina, Charleston, South Carolina, for his help in management of the patient, and Evelyn Mann for assistance in preparation of the manuscript.

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