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Bronchodilator responsiveness in a ventilator-dependent infant with severe tracheobronchomalacia

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Abstract A neonatal case of severe, ventilator-dependent tracheobronchomalacia (TBM) is described. The extent of the malacic segment was determined by endoscopy and tracheobronchography. Additionally, relevant and ever increasing reversible peripheral airway obstruction was documented by measuring the mechanical properties of the respiratory system before and after salbutamol. With the combination of endoscopically guided aortopexy and salbutamol infusion, the infant was eventually weaned from mechanical ventilation at the age of 86 days. We speculate that in ventilator-dependent infants with severe TBM the determination of bronchodilator responsiveness may have clinical consequences.

Key words Tracheobronchomalacia · Infant · Bronchodilation · Peripheral airway obstruction · Aortopexy

Introduction

Standard treatment for severe tracheobronchomalacia (TBM) remains tracheostomy and prolonged mechanical ventilation (MV) [1–3]. This approach is justified by the fact that most infants will outgrow TBM requiring ventilation by the age of 1–2 years. The high complication rate of prolonged tracheostomy and MV (laryngeal or tracheal stenosis, infections, neurodevelopmental delay) requires careful consideration of alternative therapies such as aortopexy [4], tracheal resection [5], or other treatment modalities [6]. However, the efficacy of alternative therapies may be limited by concomitant airway problems. The case reported here illustrates such an additional airway problem, recognizable only by measuring the mechanical properties of the respiratory system and determining bronchodilator responsiveness.

Case report

A female newborn (gestational age 36 weeks, birthweight 2880 g) required endotracheal intubation at 2 h of life for respiratory distress after premature rupture of membranes. Chest radiography showed bilateral patchy infiltrates and pulmonary overinflation, suggesting amniotic fluid aspiration. After stabilization on a mechanical ventilator, she was rapidly weaned off respiratory support and extubation was performed on day 2. However, respiratory distress with severe hypercapnia (pH 7.17, arterial carbondioxide tension 83 mmHg) required reintubation and MV on day 4, and the response to bronchodilators was tested because of prolonged expiration and wheezing [7]. The mechanical properties of the respirato-

Table 1 Effect of salbutamol on respiratory system compliance and resistance. Mean of 4–9 measurements

Days of life	Intervention	Compliance (mean ± SD)	Resistance (mean ± SD)
5	None	0.85 ± 0.03	0.135 ± 0.003
	After salbutamol	1.03 ± 0.03[c]	0.127 ± 0.008[a]
20	None	0.48 ± 0.05	0.595 ± 0.093
	After salbutamol	0.72 ± 0.03[c]	0.281 ± 0.114[b]
41	None	0.44 ± 0.02	0.358 ± 0.027
	After Salbutamol	0.42 ± 0.01	0.291 ± 0.032[a]
82 (preop.)	None	0.63 ± 0.03	0.353 ± 0.04
83 (postop.)	None	0.49 ± 0.04	0.578 ± 0.038
	After salbutamol	0.79 ± 0.03[c]	0.134 ± 0.006[c]

Changes in coefficient of variation (CV) after i.v. salbutamol when compared before intervention: [a] > 2 CV, [b] > 3 CV, [c] > 4 CV
Normal values for Crs = 0.96 (0.06 SE) ml/cmH_2O per kg and Rrs = 0.06 (0.01 SE) cmH_2O/ml per s [8]

ry system [respiratory compliance (Crs) and resistance (Rrs)] were determined, using the single-breath occlusion method (SensorMedics 2600 Pediatric Pulmonary System, Yorba Linda, Calif., USA), before and after a dose of intravenous salbutamol of 10 μg/kg. Abnormal Crs and Rrs were noted at baseline with some improvement after salbutamol (see Table 1, day 5). Due to persistence of obstructive signs, flexible bronchoscopy (Olympus N 20) was performed through the endotracheal tube during spontaneous breathing. It demonstrated a moderate, dynamic but not pulsatile stenosis of the carina and the left main bronchus, compatible with the diagnosis of malacia. The cartilage of the trachea as well as bronchi had a normal horseshoe configuration. A tracheal stenting effect was observed by application of positive end-expiratory pressure (PEEP). In this situation, it was decided to try conservative management with high PEEP (8–15 cmH_2O), moderate positive inspiratory pressure (24–28 cmH_2O), and flow-triggered patient-synchronized ventilation (Babylog 8000, Drägerwerke Lübeck, Germany) with low positioning of the endotracheal tube. Unfortunately, there was no evidence of airway stabilization, and the patient remained ventilator-dependent with recurrent cyanotic spells due to gas trapping and pulmonary overinflation. Repeated testing of mechanical properties of the respiratory system showed severe decreases in Crs and increases in Rrs with inconsistent responses to salbutamol (see Table 1, days 20 and 41). Further work-up of TBM included bronchography with an iso-osmolar nonionic contrast medium in order to confirm the bronchoscopic findings and to exclude distal bronchomalacia. Severe expiratory collapse of the distal trachea and of a 1.5-cm long segment of the left main bronchus during spontaneous respiration was documented, as well as a stenting effect by PEEP (see Figs. 1, 2, 3). Echocardiography was normal. Barium swallow showed a normal esophagus but gastroesophageal reflux (GER) without aspiration into the tracheobronchial tree. Analysis of bronchoalveolar lavage fluid was negative for lipid-laden macrophages. Repeated bronchoscopy at age 82 days confirmed failure of conventional therapy and worsening of TBM with almost total collapse of the distal trachea and left main bronchus, explaining hypercapnia and hyperinflation with herniation of the left lung into the right hemithorax.

Since TBM was severe and GER mild (no lipid-laden macrophages, there were no signs of esophageal inflammation on endoscopy, and there was normal infant growth), we gave priority to aortopexy and not to fundoplication. In our patient, after sternotomy, partial thymectomy and duct ligation, the aortic arch and pulmonary bifurcation were lifted and fixed toward the inner surface of the sternum under endoscopic control. Immediate postoperative bronchoscopy showed minimal residual malacia mainly in the main bronchus. Postoperative testing of Crs and Rrs showed worsening mechanical properties (see Table 1, day 83). However, marked bronchodilator responsiveness was again observed. Therefore, a continuous infusion of salbutamol (1 μg/kg per min) was started which allowed successful extubation 3 days after surgery. Residual bronchial obstruction with pulmonary hyperinflation was treated with inhalation of beta-agonists, steroids, and ipratropium. GER failed to improve postoperatively despite conservative treatment. Therefore, a fundoplication and gastrostomy were performed on day 103 of life. Unfortunately, chronic lung disease was diagnosed with pulmonary overinflation and hyperreactive airways, necessitating supplemental oxygen up to 18 months of age and continued use of bronchodilator therapy. A neurological follow-up examination at 18 months gave normal results.

Discussion

This case demonstrates how a thorough and repeated functional evaluation of central (endoscopy, tracheobronchography) and peripheral airways (single-breath occlusion method) not only helped to diagnose severe TBM, but also revealed an increasingly relevant component of airway obstruction reactive to salbutamol. Combined aortopexy and salbutamol eventually allowed successful weaning from the ventilator, avoiding tracheostomy and long-term MV.

Severe TBM may be manifested by respiratory distress at birth, requiring intubation and MV within the first hours of life. In such a situation, TBM cannot be distinguished from the more common aspiration syndromes. Suspicion of TBM usually arises only after repeated failures of weaning from the respirator [1]. Diagnosis is easily confirmed by flexible bronchoscopy. In a clinical context, it is often difficult to separate primary (immaturity of the tracheobronchial cartilages, etc.) from secondary forms (external compression of the airways, etc.) of TBM [3], or to adequately measure the cartilage to posterior membrane ratio [9], nor is it crucial for determining the best treatment modality. The reason for a thorough examination is to try to avoid long-term MV and tracheostomy by alternative treatment modalities. Bronchoscopic and bronchographic examinations of the airways are performed to determine extent and severity of malacia as well as to exclude other airway anomalies. A careful search for external airway compression (including high speed computed tomography or magnetic resonance angiography, if suspected), congenital syndromes, neurological impairment and GER is added. Whenever possible, treatment is directed toward the underlying cause of TBM [6]. In localized forms of TBM, surgical options are resection of the malacic segment with reanastomosis [5], external splinting [6], or endoscopic placement of expandable stents in the malacic segment [10]. Aortopexy/tracheo-

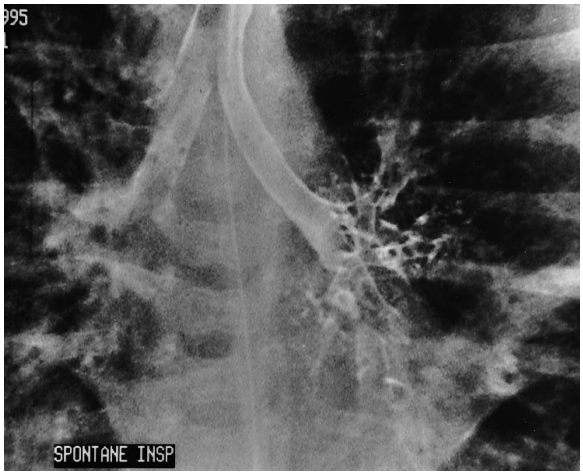

Fig. 1 Bronchography of central airways during spontaneous inspiration

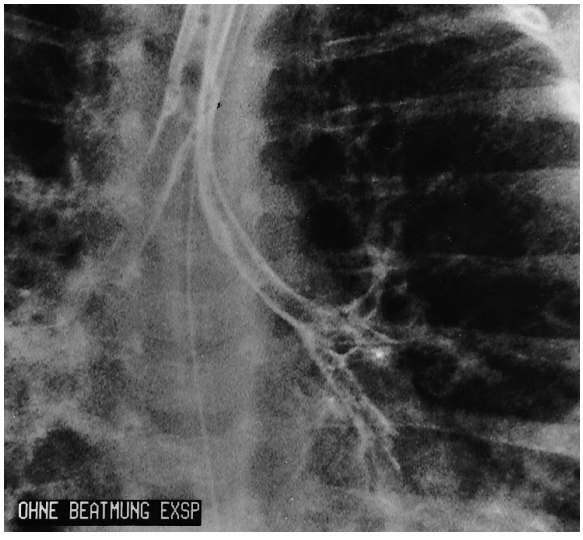

Fig. 2 Bronchography of central airways during spontaneous expiration without PEEP, showing a marked collapse of the lower trachea and left main stem bronchus

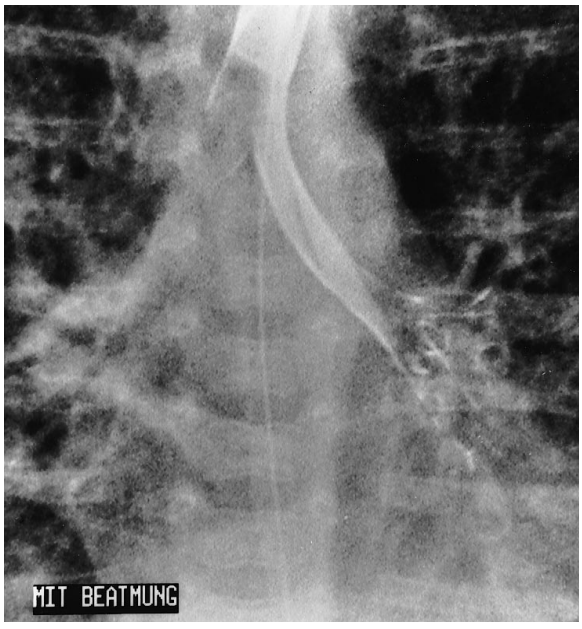

Fig. 3 Bronchography of central airways during spontaneous expiration and PEEP application documenting the stenting effect of PEEP on central airways

pexy has been shown to be successful in patients with more extended forms of primary TBM without signs of external compression [4]. In some patients, however, aortopexy fails to improve TBM [1, 4, 11], particularly in the case of GER [4]. The contribution of GER to respiratory difficulties and, vice versa, respiratory problems contributing to GER are well recognized. GER-induced respiratory abnormalities include reactive airway disease. Our case reveals such additional peripheral and reversible airway obstruction, which might be the reason for surgical failure of aortopexy in patients with concomitant TBM and GER [4]. To our knowledge, bronchodilator responsiveness in a ventilator-dependent patient with severe TBM has not been described so far in the literature. In some nonventilator-dependent infants with primary bronchomalacia, Finder [11] very recently described additional reactive airway disease suspected by clinical observation and by shape interpretation of flow-volume loops. However, the objective and quantitative determination of salbutamol response by measuring lung mechanics not only allows the recognition of such a complex airway pathology, but allows also the delineation of the benefit of bronchodilator therapy in the presence of severe TBM. For determination of bronchodilator responsiveness, we measured Crs and Rrs by the single-breath occlusion and passive deflation flow-volume technique because of its clinical simplicity [7].

Panitch et al. [12] documented decreased forced expiratory flows after relaxation of airway smooth muscle by bronchodilation in three infants with tracheomalacia without the need for MV. Relaxation of central airway smooth muscle leads to air trapping and to worsening Crs and Rrs. In our ventilator-dependent patient, we observed the opposite effect, namely improvement of lung mechanics after bronchodilation with salbutamol. This discrepancy may be due to different techniques used, but is probably due to the well described stenting effect of the endotracheal tube [2, 13], overriding most of the central airways smooth muscle relaxation after salbutamol and at the same time demonstrating improvement of Crs and Rrs in the presence of peripheral airway obstruction. We speculate that bronchodilator

responsiveness in a patient with severe TBM might only be detectable after optimal tracheal stenting with an endotracheal tube and PEEP. Determining bronchodilator responsiveness in ventilator-dependent infants with TBM may be of clinical importance, especially in those infants failing surgical treatments of TBM or in those with chronic lung disease and persistent ventilatory requirements [1].

References

1. Doull IJM, Mok Q, Tasker RC (1997) Tracheobronchomalacia in preterm infants with chronic lung disease. Arch Dis Child 76:F203–F205
2. Panitch HBP, Allen JL, Alpert BE, Schidlow DV (1994) Effects of CPAP on lung mechanics in infants with acquired tracheobronchomalacia. Am J Respir Crit Care Med 150: 1341–1346
3. Jacobs IA, Wetmore RF, Tom LWC, Handler SD, Potsic WP (1994) Tracheobronchomalacia in children. Arch Otolaryngol Head Neck Surg 120: 154–158
4. Malone PS, Kiely EM (1990) Role of aortopexy in the management of primary tracheomalacia and tracheobronchomalacia. Arch Dis Child 65: 438–440
5. Pfenninger J, Leijala M, Mauderli M (1993) Case 22. In: Rogers MC, Helfaer MA (eds) Case studies in pediatric intensive care. Williams & Wilkins, Baltimore, pp 129–136
6. Vinograd I, Klin B, Efrati Y, Barr J, Behar M, Eshel G (1994) Airway obstruction in neonates and children: surgical treatment. J Cardiovasc Surg 35: 7–12
7. Pfenninger J, Aebi C (1993) Respiratory response to salbutamol in ventilator-dependent infants with chronic lung disease: pressurized aerosol delivery versus intravenous injection. Intensive Care Med 19: 251–255
8. Hammer J, Numa A, Newth CJL (1995) Albuterol responsiveness in infants with respiratory failure caused by respiratory syncytial virus infection. J Pediatr 127: 485–490
9. Mair EA, Parsons DS (1992) Pediatric tracheobronchomalacia and major airway collapse. Ann Otol Rhinol Laryngol 101: 300–309
10. Filler RM, Forte V, Fraga JC, Matute J (1995) The use of expandable metallic airway stents for tracheobronchial obstruction in children. J Pediatr Surg 30: 1050–1056
11. Finder JD (1997) Primary bronchomalacia in infants and children. J Pediatr 130: 59–66
12. Panitch HB, Keklikian EN, Motley RA, Wolfson MR, Schidlow DV (1990) Effect of altering smooth muscle tone on maximal expiratory flows in patients with tracheomalacia. Pediatr Pulmonol 9: 170–176
13. Zinman R (1995) Tracheal stenting improves airway mechanics in infants with tracheobronchomalacia. Pediatr Pulmonol 19: 275–281