Acute Hypoxemia in a Child With Neurologic Impairment Associated With High-Frequency Chest-Wall Compression

Leah Denise Willis RRT-NPS and Robert Hughes Warren MD

An 11-year-old child with cerebral palsy required hospital admission for respiratory distress following administration of high-frequency chest wall compression (HFCWC). The child had severe neurologic impairment and an ineffective cough effort. HFCWC is effective in treating cystic fibrosis, but its use has not been widely studied in other diagnoses. Although highly effective in mobilizing mucus, HFCWC does not assist in removing airway secretions. In the absence of an effective cough, additional devices or techniques may be required. *Key words: high-frequency chest wall compression, HFCWC, vest, cerebral palsy, cough.* [Respir Care 2007;52(8):1027–1029. © 2007 Daedalus Enterprises]

Introduction

High-frequency chest-wall compression (HFCWC) is an airway clearance method that has proven to be effective in the management of recurrent pulmonary infections in cystic fibrosis.[1–5] HFCWC loosens and mobilizes airway secretions by rapidly inflating and deflating a vest to produce chest compressions and generate airflow in the lungs.[1,2] Its use in other conditions, such as cerebral palsy, has been practiced but not extensively studied.[6]

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Comparison studies of airway clearance techniques in cystic fibrosis have shown HFCWC to be as effective as other modalities, but not superior.[3–5] Evaluations of manual chest physical therapy, intrapulmonary percussive ventilation, HFCWC, and vibratory positive expiratory pressure devices have produced similar results.[3–5] Patient adherence to prescribed treatment is better with HFCWC than with other airway clearance techniques, such as manual chest physical therapy, because of the ease of administration with HFCWC. HFCWC does not require special positioning or depend on caregiver technique to provide an effective treatment.

In our practice, HFCWC is recommended twice daily for maintenance, and increased to 3–4 times a day during acute illness. We report the case of a child with severe neurologic impairment and ineffective cough who experienced respiratory distress following HFCWC therapy.

Case Summary

An 11-year-old male with severe cerebral palsy was evaluated in the pediatric pulmonary clinic for pulmonary risk assessment of spinal fusion surgery. He was a normal infant up until 6 weeks of age, at which time he suffered an anoxic episode as the result of an apparent life-threatening event. He had a history of recurrent pneumonia and upper respiratory infections.

His daily respiratory care plan prior to the pulmonary visit consisted of nebulized albuterol 3 times daily, and budesonide twice daily. He also received glycopyrrolate for oral secretions. Manual chest physical therapy was administered twice a day for 5 min. It was difficult for caregivers to turn and position him correctly for manual

Leah Denise Willis RRT-NPS and Robert Hughes Warren MD are affiliated with Respiratory Care Services, Arkansas Children's Hospital, Little Rock, Arkansas, and with the Pulmonary Medicine Section, Department of Pediatrics, University of Arkansas for Medical Sciences, Little Rock, Arkansas.

Leah Denise Willis RRT-NPS presented a version of this paper at the Open Forum at the 51st International Respiratory Congress of the American Association for Respiratory Care, held December 3–6, 2005, in San Antonio, Texas.

The authors report no conflicts of interest related to the content of this paper.

Correspondence: Leah Denise Willis RRT-NPS, Pulmonary Medicine Section, Arkansas Children's Hospital, 800 Marshall Street, Slot 512–17, Little Rock AR 72202. E-mail: willisdenisel@uams.edu.

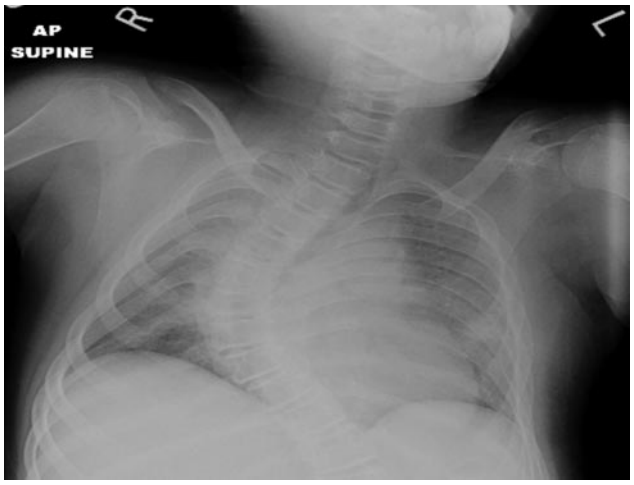

Fig. 1. Chest radiograph at initial pulmonary clinic visit, showing substantial scoliosis.

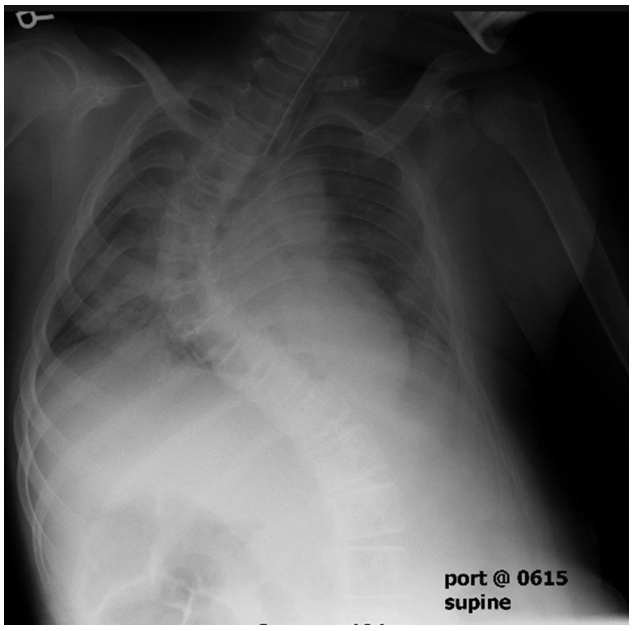

Fig. 2. Chest radiograph on admission to the pediatric intensive care unit, showing bilateral infiltrates.

chest physical therapy because of his size and thoracic deformity secondary to scoliosis.

A chest radiograph revealed substantial scoliosis, with an 80° thoracic curve and 70° lumbar curve (Fig. 1). A weak cough effort was observed on examination and evidenced by inability to effectively clear airway secretions. His resting tidal volume was 3.6 mL/kg, which indicates a hypopneic breathing pattern. Capillary blood gas analysis revealed pH 7.47, P_{aCO_2} 42 mm Hg, and an elevated HCO_3^- 29.7 mmol/L, which suggested intermittent hypoventilation during sleep, with a renal response.

Because of severe neurologic impairment he was incapable of performing routine spirometry or other diagnostic measurements such as maximum inspiratory or expiratory pressure. Nutrition was administered exclusively via gastrostomy tube, because a swallowing study from the previous year showed severe dysphagia and an increased risk of aspiration.

He was deemed an acceptable risk for surgery, and it was anticipated that reduction of the spinal curvature would contribute to improvement of overall pulmonary function. Based on the history of recurrent pneumonia and lack of success with chest physical therapy, HFCWC (The Vest, Hill-Rom Services, St Paul, Minnesota), was prescribed for home use.

Our protocol for HFCWC administration is a pressure control setting of 4–6, with 3 separate compression frequencies, for 8–10 min each, for a total time of 24–30 min. The first compression frequency is between 5 Hz and 10 Hz, the second between 10 Hz and 15 Hz, and the third between 15 Hz and 20 Hz. Updraft aerosol therapy with a bronchodilator and/or normal saline is administered simultaneously during the entire treatment.

The child's caregivers were instructed to use HFCWC twice a day in conjunction with 2.5 mg nebulized albuterol, followed by normal saline for the duration of the treatment. Settings used at home were reported to be a pressure control setting of 5 and compression frequencies of 10 Hz, 15 Hz, and 19 Hz, for 10 min each.

Two months after beginning HFCWC, the child was admitted to the pediatric intensive care unit for acute respiratory failure presumed secondary to aspiration. There were no reports of difficulty tolerating the HFCWC device prior to this event. His caregivers stated that he "felt poorly" after his treatment, and sustained coughing progressed to difficulty breathing. Because of progressive respiratory distress, emergency medical services were requested.

Marked respiratory distress and desaturation (approximately 80%, via pulse oximetry) were recorded by the emergency medical technician on initial assessment. The child was transported to the local hospital, where arterial blood gas values were pH 7.15, P_{aCO_2} 52 mm Hg, P_{aO_2} 57 mm Hg, HCO_3^- 30 mmol/L, and base excess 2 mmol/L. He was intubated, mechanically ventilated, and transferred to a children's hospital, where he remained for 12 weeks.

Chest radiograph (Fig. 2) on admission to the pediatric intensive care unit showed bilateral pulmonary infiltrates. Venous blood gas analysis showed improvement in respiratory status, with pH 7.48, P_{CO_2} 38 mm Hg, mixed venous partial pressure of oxygen 62 mm Hg, HCO_3 26.8 mmol/L, and base excess 3.6 mmol/L.

He failed 2 extubation attempts within the first month of hospitalization, and a tracheostomy was considered but not performed. Once he reached a state of respiratory stability, the decision was made to proceed with spinal fusion surgery. He tolerated the procedure well and there were no

major postoperative complications. He was able to wean to noninvasive nocturnal ventilatory support, which was continued after discharge. HFCWC therapy was resumed, and no additional respiratory events related to HFCWC use have been reported.

Discussion

This case describes a child with cerebral palsy who had a respiratory event following use of HFCWC. We also follow 3 other children with cerebral palsy in our clinic who reportedly experienced respiratory distress associated with HFCWC in the home setting. Those children also had severe neurologic impairment and an ineffective cough.

Cerebral palsy can present with the same sequence of events as is seen in primary neuromuscular disease.[7] Respiratory muscle weakness, generalized hypotonia, hypoventilation, and scoliosis all contribute to pulmonary involvement in children with severe neurologic impairment. These factors also play a role in the diminished cough effort.

Pulmonary complications are a common occurrence in children with neurologic disorders. Multiple factors, including aspiration, weak or absent cough effort, respiratory muscle weakness, and scoliosis, may concurrently contribute to respiratory symptoms.[8] Children with severe cerebral palsy often have compromised airway clearance because of ineffective cough. Though a stimulus to cough may exist, the child may be unable to produce an effective cough because of the neurologic impairment.[9]

Excessive accumulation of normal oral and pharyngeal secretions due to dysphagia create the potential for chronic and intermittent aspiration.[9] Airway hyposensitivity can occur as a result of prolonged exposure to upper airway secretions when cough effort is weak and ineffective. Thus, the child becomes accustomed to the presence of excessive airway mucus. This phenomenon may be the result of airway receptor desensitization from chronic aspiration.[8,9]

Another potential cause of aspiration is gastroesophageal reflux. Caregivers should be cautioned against administering HFCWC or any secretion mobilization method immediately following a meal. Instead, treatments should be given beforehand or 1–2 hours afterwards. It is unknown whether the child described above had been fed prior to HFCWC at the time of his hypoxemic event.

Children with severe cerebral palsy are limited to airway clearance methods that do not require active participation. Because manual chest physical therapy is labor intensive when done correctly, deficient technique is commonly observed. Many caregivers prefer the simplicity of HFCWC, and it is often easily obtained for home use.

We do not think HFCWC is entirely inappropriate for these children. However, assisted coughing devices or techniques may be required in addition to secretion mobilization methods in the presence of an ineffective cough. Cough effort can be evaluated by direct observation in this group of children, since they usually are unable to cough on command. Airway secretions not cleared after a cough attempt manifest as audible large-airway noise and represent an ineffective cough effort.

Determination of the adequacy of cough effort is critical in any situation where respiratory techniques are required for secretion mobilization. This case report raises issues regarding secretion mobilization methods in the presence of an ineffective cough. Future research is needed on HFCWC use in children with neurologic impairment who are unable to clear airway secretions effectively.

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