Postoperative use of a cough-assist device in avoiding prolonged intubation

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Postoperative management following major surgery in patients with neuromuscular disorders associated with scoliosis is frequently complicated by sputum retention and ventilatory failure. This report demonstrates the successful perioperative management of an 11-yr-old boy with type II spinal muscular atrophy undergoing a single-stage posterior spinal fusion procedure. Use of an MI-E device was able to successfully treat sputum retention and avoid a tracheostomy.

Keywords: airway, reflexes; complications, muscular atrophy; complications, respiratory; cough; infections, pulmonary; lung, mucus; scoliosis; ventilation, postoperative

Accepted for publication: May 31, 2002

Patients with neuromuscular disorders associated with scoliosis often present when restrictive respiratory failure is developing. Postoperative management following major surgery is frequently complicated by sputum retention and ventilatory failure, which may lead to prolonged intensive care episodes, tracheostomy formation with attendant complications, and death.

Ventilatory failure can now be easily managed with the use of non-invasive ventilation. This case report shows that the treatment of postoperative sputum retention, and avoidance of tracheostomy, can also be aided by using mechanical insufflation-exsufflation.

Case report

An 11-yr-old boy with type II spinal muscular atrophy (SMA) presented for assessment before corrective spinal scoliosis surgery. He had been wheelchair-bound since infancy because of his disease. He required help with feeding and personal hygiene, which was made more complicated by his obesity (BMI 34.7). His last chest infection requiring hospital admission was at the age of 7 yr, for which he did not require mechanical ventilation. Subsequent chest infections were managed at home, and the year preceding surgery he had been relatively free of them.

His cough reflex was intact but very poor. Parental reports stated that coughing episodes often interrupted his sleep, sometimes requiring assisted coughing by his mother to aid clearance of secretions. He snored at night but did not suffer from early morning headaches, daytime somnolence, or apnoeas. His school progress was considered normal.

On clinical examination, he weighed 76 kg. Cardiovascular and respiratory examinations were unremarkable. A transthoracic echocardiogram was normal. His forced expiratory volume in 1 s (FEV₁) was 0.92 litres, and forced vital capacity (FVC) was 0.97 litres (35% predicted). He had a short neck and poor mouth opening. Radiographic examination revealed a thoracic scoliosis with a Cobb angle of 101°.

A sleep study performed using transcutaneous carbon dioxide and oxygen electrodes combined with pulse oximetry, showed a baseline partial pressure of oxygen of 68 torr (9.0 kPa), intermittently dipping to 38 torr (5.0 kPa), and a baseline partial pressure of carbon dioxide of 49 torr (6.5 kPa), intermittently rising to 68 torr (9.0 kPa). On the basis of this study he was sent for a respiratory opinion, from where he was established on nocturnal non-invasive ventilation. Five months later, he represented for posterior fusion and instrumentation surgery for his scoliosis. This was to aid in his posture maintenance whilst sitting in his wheelchair, and for pain control. Repeat lung function tests at this time, showed a minimal improvement with an FEV₁ of 1.18 litres, and an FVC of 1.26 litres. It was decided not to repeat the sleep study as the patient was now established on nocturnal non-invasive ventilation, and it was felt that no useful information would be gained.

A gaseous induction was performed using sevoflurane, as venous access was predicted to be difficult. Vecuronium was given to aid tracheal intubation. He was a grade III Cormack and Lehane direct laryngoscopy view. A laryngeal mask airway was inserted and his trachea was subsequently intubated through it using a fiberoptic laryngoscope. Anaesthesia was maintained using oxygen, nitrous oxide,
and isoflurane. Intermittent positive pressure ventilation was used throughout the procedure. His spinal column was fused from the fourth thoracic vertebra down to the sacrum. Estimated blood loss was 3 litres. The operating surgeon sited an epidural between the seventh and eighth thoracic vertebrae before wound closure.

After surgery, the patient was electively ventilated on the intensive care unit for 24 h so that the neuromuscular blocking agent could wear off, haemostasis could be ensured, and good analgesia via the epidural achieved. A continuous infusion of 0.125% bupivacaine was run through the epidural catheter at a rate of 4 ml h⁻¹. Regular acetaminophen suppositories were also used for analgesia. The tracheal tube was removed and the patient was placed immediately on to his own non-invasive ventilator (Nippy). His ventilatory frequency was 18 bpm with adequate chest expansion and arterial oxygen saturations of 98% on 35% oxygen.

The following day, his arterial partial pressure of oxygen was 86 torr (11.4 kPa) on 35% oxygen, and he had moderate amounts of loose secretions on his chest. He remained on non-invasive ventilation, with his pain well controlled. His cough remained very poor and he required manual assistance with coughing, although sputum clearance was inadequate. He had clinical and radiological evidence of left lower lobe collapse and consolidation. The epidural infusion was discontinued on the third postoperative day and regular acetaminophen continued.

During the following 3 days his chest continued to deteriorate. He desaturated intermittently and became very dependent on his non-invasive ventilator, desaturating down to 82% when removing the mask to eat. By this time, his secretions had become very thick. He was being treated with saline nebulizers, antibiotics (cefuroxime), and intensive physiotherapy. The patient remained free from pain.

The following day, his chest radiograph (Fig. 1) showed a small right-sided pleural effusion and almost whiteout on the left side. Clinically, he remained on a non-invasive ventilator maintaining saturations greater than 95% on about 40% oxygen. At this stage he was to undergo an elective tracheostomy the next day. The cough-assist device was then tried. The patient tolerated it very well and it was able to assist him bringing thick secretions into his mouth from his chest.

As he was now able to clear secretions from his chest, the tracheostomy was delayed. The cough-assist device was used every 4 h and his condition continued to improve, as did the appearance of his chest radiograph (Fig. 2). Six days after first using the cough-assist machine, he progressed from requiring continuous non-invasive ventilation, to only needing nocturnal respiratory support, as in the preoperative phase. Three days later, he was able to return to the ward (17 days after surgery) and was discharged home well, 27 days later.

**Discussion**

SMA type II is an inherited disorder affecting the peripheral motor neurones without upper motor neurone involvement. The disease tends to be hereditary, usually autosomal recessive. Children with SMA type II usually survive into adolescence or even early adulthood. Patients with severe neuromuscular disorders, such as SMA and Duchenne muscular dystrophy, present for surgical repair of scoliosis for a variety of reasons. Often the patient is unable to maintain a sitting position in their wheelchair, and the surgery is performed with the aim of improving the child’s posture, general management, and discomfort. This patient population also may suffer with pain, often alleviated by surgical correction of their scoliosis. Poor respiratory function secondary to respiratory muscle weakness, a hallmark of these children, is not reversible by correcting the scoliosis but aids in slowing its progress. These children are therefore at a high risk of developing postoperative complications.
Both inspiratory and expiratory muscle weakness is largely dependent on the magnitude of flows on glottic opening, and the effectiveness of abdominal pressures are needed to generate effective cough clearance is found to be ineffective in clearing secretions. During periods of respiratory tract infection (RTI) or respiratory musculature weakening, and mucous plugging. The vital capacity (VC), FVC, and PCEFs are decreased during RTIs because of fatigue, pulmonary complications. The vital capacity (VC), FVC, and PCEFs are decreased during RTIs because of fatigue, respiratory musculature weakening, and mucus plugging. Both inspiratory and expiratory muscle weakness can cause cough flows to decrease. This can be further decreased by bulbar problems with incomplete or weak glottic closure. Cough flows less than 2.7 litre s$^{-1}$ have been found to be ineffective in clearing secretions. Adequate expiratory muscle function is critical for clearing airway secretions and bronchial mucus plugs. During periods of respiratory tract infection (RTI) or profuse airway secretion, peak cough expiratory flows (PCEFs) must be adequate to prevent mucus plugging and pulmonary complications. The vital capacity (VC), FVC, and PCEF are decreased during RTIs because of fatigue, respiratory musculature weakening, and mucus plugging. During a normal adult cough, just over 2 litres of air is expelled at flows of up to 20 litre s$^{-1}$. High thoracoabdominal pressures are needed to generate effective cough flows on glottic opening, and the effectiveness of mucus clearance is largely dependent on the magnitude of the PCEF. Both inspiratory and expiratory muscle weakness can cause cough flows to decrease. This can be further decreased by bulbar problems with incomplete or weak glottic closure. Cough flows less than 2.7 litre s$^{-1}$ have been found to be ineffective in clearing secretions.

Postural drainage and chest percussion are used routinely to mobilize airway secretions, although they are not always possible to use and are effort-intensive. They were used in the case of our patient but were not effective, because of his size, in aiding mucus clearance. Using deep lung insufflations, the maximum inspiratory capacity in patients with neuromuscular disease can be achieved. The insufflations may be delivered via a mouthpiece or nasal interface from a ventilator or manual resuscitator. The increase to maximum inspiratory capacity leads to a significant increase in the assisted PCEF. There are many techniques of manually assisted coughing. For patients with less than 1.5 litre of VC (as in the case of our patient) efficacy is enhanced by preceding an assisted exsufflation with a deep insufflation. Manually assisted coughing requires a cooperative patient, good coordination between the patient and caregiver, and adequate physical effort by the caregiver. When inadequate, the most effective alternative for generating optimal PCEF and clearing deep airway secretions is the use of mechanical insufflation-exsufflation (MI-E).

As early as 1953, portable devices for delivering MI-E directly to the airway via a mouthpiece, mask, or tracheal tube were being manufactured. The efficacy of MI-E was demonstrated both clinically and on animal models in the expulsion of bronchoscopically inserted foreign bodies. The volume of air and PCEF exsufflated during MI-E are comparable with those expelled during normal adult coughing. In one study of 46 neuromuscular ventilator users, PCEFs of more than 7.5 litre s$^{-1}$ were obtained using MI-E, as compared with 4.3 litre s$^{-1}$ using a maximum inspiratory capacity manoeuvre followed by manual assistance with abdominal compression. Early work has shown that in addition to the clearing of pulmonary infiltrates and atelectasis, MI-E can increase FVC by up to 55% in patients with paralytic restrictive pulmonary conditions. The use of MI-E through a tracheostomy tube has been demonstrated to be effective in reversing acute atelectasis associated with airway secretions, although PCEF were shown to be greater when MI-E was applied via a mask. A recent study has confirmed the value of MI-E in decreasing hospitalization rates for respiratory complications of neuromuscular disease.

The MI-E that we used is the Emerson CoughAssist™ Mechanical In-Exsufflator (J.H. Emerson Co., Cambridge, MA, USA) (Fig. 3). It has both a manual and an automatic mode, such that cycling from insufflation to exsufflation may be manually controlled or automatic. One treatment consists of about five cycles followed by a period of normal breathing or ventilator use for about 30 s to avoid hyperventilation. Each cycle comprises insufflation, then exsufflation, followed by a pause, at which the machine returns to atmospheric pressure. The pressures are generated by a two-stage centrifugal blower. The positive and negative pressures may be set for insufflation and exsufflation, up to a maximum of 60 cm H$_2$O. Each insufflation and exsufflation is usually 2–3 s.

Use of the MI-E has been found to be safe. One study found no adverse effects encountered in more than 2000
courses of MI-E, the majority of which were in patients with intrinsic lung disease. Transient appearance of blood-streaked sputum, probably originating from the bronchial wall sites of detachment of mucous plugs, may occur. Animal studies have revealed no evidence of parenchymal damage, haemorrhage, alveolar tears, or emphysematous blebs in the lungs of animals treated with MI-E. Borborygmus and abdominal distension are infrequent and eliminated by decreasing insufflation pressures, and aspiration of gastric contents has not been reported.

In summary, this case report demonstrates the successful perioperative management of a child with SMA undergoing a single-stage posterior spinal fusion procedure. Use of an MI-E device was able to successfully treat sputum retention and avoid a tracheostomy.

References