Resolution of Left Lower Lobe Collapse Postesophagectomy Using the Medivent RTX Respirator, a Novel Noninvasive Respiratory Support System

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THIS IS THE FIRST case report describing the use of a novel noninvasive respiratory support device, the RTX respirator (Medivent Ltd, London, UK) (Fig 1), for clearance of intractable secretions postesophagectomy. The patient had left lower lobe collapse and incipient respiratory failure. Routine postoperative physiotherapy techniques, combined with continuous positive airway pressure (CPAP) via a surgical tracheostomy, failed to clear retained sputum. The RTX respirator provided chest physiotherapy in the form of high-frequency oscillation interrupted by a “cough” phase to loosen and expel secretions (secretion clearance mode). These maneuvers allowed reflation of the lobe, and the patient recovered. The mode of operation of the RTX respirator, and the properties of the device that may have contributed to the patient’s recovery, are discussed.

CASE REPORT

A 61-year-old woman was admitted for surgical resection of a squamous cell carcinoma of the middle third of the esophagus. She had been operated on for a benign spinal tumor the previous year and was now wheelchair bound as a result of persistent back pain. There was no neurologic deficit resulting from this surgery. The patient was obese, with a body mass index of 30 (weight 76.3 kg, height 1.61 m). She had a history of hypertension, controlled with ramipril and bendrofluazide, and insulin-dependent diabetes mellitus. Preoperative respiratory function tests showed a forced expiratory volume in 1 second of 2.4 L with a forced vital capacity of 3.1 L (both 100% of predicted values1), giving a forced expiratory volume in 1 second/forced vital capacity ratio of 0.77 (FEV<FVC).

Anesthesia was induced with fentanyl, 250 μg, propofol, 150 mg, and rocuronium, 50 mg. A small right-sided Robertshaw endobronchial tube was placed without difficulty. Anesthesia was maintained with oxygen (50%), air (50%), and isoflurane. Intraoperative analgesia was provided by intravenous morphine to a total of 30 mg over the course of the 6-hour operation. In view of her recent spinal surgery, an epidural catheter, rather than a thoracic epidural, was chosen for postoperative analgesia. She underwent a subtotal esophagectomy via a left-sided thoracodorsal approach on 1 lung anesthesia, with esophageagastric anastomosis via a neck incision. Arterial blood gases were satisfactory throughout the operative period. In view of the prolonged period of surgery and the patient’s high body mass index, a minitracheostomy was placed at the end of surgery to facilitate secretion clearance. The patient’s paralysis was reversed with glycopyrrolate/neostigmine, and when respirations were satisfactory, the patient was extubated. Signs of respiratory obstruction were immediately apparent, and arterial blood gases deteriorated rapidly. The patient was reanesthetized, and an urgent rigid bronchoscopy was performed. This showed moderate mucoid secretions and gross tracheal and bronchial edema. A 6.5-cm single-lumen tube was placed, and the patient was admitted to the ICU.

After 1 failed attempt at extubation in the ICU, the patient underwent a surgical tracheostomy (Portex 7.5-mm diameter tracheostomy tube) to assist weaning. This was successful, and she went on to have supplemental oxygen through a tracheostomy mask. The patient returned to the thoracic high-dependency unit 7 days after surgery. Five days later, oxygenation declined because of retained secretions. The patient required intermittent CPAP (5 cmH2O) via the tracheostomy to maintain saturation; 24 hours later she had a further setback due to herniation of the tracheal cuff. The tracheostomy tube was replaced (8.0-mm diameter). During the next 4 days, the patient suffered increasing dyspnea and effort of breathing. No secretions could be expectorated despite aggressive physiotherapy. Augmentin (1.2 g 3 times daily intravenously) was prescribed but was changed to oxofloxacin (400 mg twice daily intravenously) on microbiology advice, when methicillin-resistant Staphylococcus aureus was detected in swabs taken from the tracheostomy site. CPAP via the tracheostomy was increased to 7.5 cmH2O and changed from intermittent to continuous therapy. A chest x-ray showed left lower lobe collapse and a loculated pleural effusion (Fig 2A). A barium meal confirmed that there was no anastomotic leak. Conventional treatment produced no improvement in respiratory function, and she became extremely tired. A computed tomography scan confirmed a persistent left lower lobe collapse and a loculated pleural effusion. Repeat rigid and flexible bronchoscopy failed to clear secretions in the left lung, and the patient’s respiratory function continued to deteriorate, despite continuing use of CPAP via the tracheostomy.

Because conventional noninvasive therapy had failed to improve respiratory function and because neither the clinical team nor the patient wished her to return to positive-pressure ventilation in the ICU, it was decided to attempt to improve secretion clearance in the collapsed lower lobe using the RTX respirator. The respirator was used in the physiotherapy (“secretion-clearance”) mode. Each cycle of physiotherapy lasted for 35 minutes, and treatment was applied 3 to 4 times per day. The respirator delivered the following physiotherapy regimen:

1. Continuous chest vibration for 5 minutes (active inspiration followed by active expiration) at a frequency of 800 cycles/min, with the inspiratory pressure generated during each cycle being −7 cmH2O and expiratory pressure 7 cmH2O.

2. At the end of 5 minutes, the respirator generated a cough cycle for 2 minutes, at a cough frequency of 50 cycles per minute. During this phase, the inspiratory phase/expiratory phase ratio was 6:1. The inspiratory pressure was −20 cmH2O and the active expiratory phase generated a positive pressure of +10 cmH2O.

3. Therefore, the total cycle time, including the vibration phase and cough, was 7 minutes. The complete cycle was repeated 5 times, resulting in a total treatment time of 35 minutes.

Each vibration phase was designed to loosen impacted bronchial secretions, and the cough cycle forced the secretions upward to the tracheostomy tube. The patient tolerated the cuirass well and was able to continue normal respirations and talk without difficulty during the period of physiotherapy.

Because the respirator was programmed to follow a specific cycle, the nurse applying the cuirass simply had to press one button to begin the treatment session, which would then terminate automatically. The cuirass was removed between treatments. The patient was able to sit upright in an ordinary chair or on her bed during therapy. After the first
Fig 1. The Medivent RTX respirator showing the manner in which the cuirass is fitted to the chest and the power unit controlling pressure within the cuirass. (Color version of figure is available online.)

Fig 2. Chest x-rays of the patient taken just before the first physiotherapy treatment with the respirator (A) and after 7 days of physiotherapy (B).
24 hours, the patient began to expectorate copious secretions, at first during the treatment sessions themselves and then subsequently between sessions. The respirator was used for 7 days. There was a dramatic improvement in the clinical status of the patient, with a rapid return to normoxia. A chest x-ray showed complete resolution of lung pathology, with reinfation of the collapsed lower lobe (Fig 2B). The tracheostomy was removed, and the patient was discharged from hospital shortly thereafter (31 days postsurgery). She remains well at 1-year follow-up.

**DISCUSSION**

Pneumonia is the most frequent postoperative complication of thoracic surgery. This includes transthoracic esophagectomy. Retention of secretions is the usual etiology. Many patients can be managed by aggressive physiotherapy, the insertion of a minitracheostomy, and the use of noninvasive respiratory support in the form of continuous positive airways pressure by facial or nasal mask (CPAP). These measures may fail for several reasons. First, the post-thoracotomy patient, who may also have chronic obstructive pulmonary disease, may be unable to expectorate adequately even with the best physiotherapy. Second, insertion of the minitracheostomy itself carries some risk. In addition, the bore of the minitracheostomy may be too narrow to allow removal of thick secretions. Third, CPAP masks are uncomfortable to wear and may cause skin and corneal abrasions. Intolerance of the CPAP mask may make its use impossible in some patients. If these measures fail, the usual next step is sedation and intermittent positive-pressure ventilation in the ICU, where mortality is recognized to be approximately 80% for post-thoracotomy patients.

Despite her obesity and generally poor mobility, this patient had excellent respiratory function as determined by spirometry and so was considered a good anesthetic and operative risk. She underwent esophagectomy with no surgical complications but developed respiratory obstruction immediately postextubation, secondary to intractable mucoid secretions and airway edema. The airway edema persisted for the first 48 hours of her ICU admission, resulting in one failed attempt at extubation before the decision to proceed to a formal tracheostomy was made. The reason for the airway edema is not clear, but the patient had a small diameter trachea, necessitating the placement of a small right-sided double-lumen tube (Robertshaw). The stated outside diameter of this tube is 35F gauge (11.7 mm), but when the diameter of the cuff is included, the final outside diameter is 39F gauge (13 mm), even before the cuff is inflated (A. Seymour, Birmingham Heartlands Hospital, UK, personal communication, December 2002). In this instance, care is always taken to inflate the tracheal and bronchial cuffs only to the point in which a leak is no longer detectable. Nevertheless, pressure of the endobronchial tube on the airway mucosa for more than 6 hours may well have been the source of this patient’s mucosal edema and inflammation.

The patient was weaned to spontaneous ventilation after formal tracheostomy. Retained secretions, which accumulated during the prolonged weaning process, continued to be a major problem, which ultimately resulted in left lower lobe collapse. Routine clinical interventions, including rigid and flexible bronchoscopy, failed to resolve the problem, and type II respiratory failure ensued. By contrast, the RTX respirator was a highly successful means of reversing lower lobe collapse and preventing readmission to the ICU.

The RTX respirator is a biphasic cuirass-style noninvasive ventilator. It supports both the inspiratory and expiratory phase of the respiratory cycle. The cuirass is a chest-mounted plastic shell that encloses the chest and upper abdomen. Such cuirass-style ventilators were developed to overcome the problems associated with the “iron-lung” style negative-pressure ventilator. The iron lung not only made patient access difficult but also carried the risk of shock (so-called “tank shock”) secondary to venous pooling in the lower abdomen during the application of negative pressure.11 The iron lung and early negative-pressure cuirass ventilators did not generate positive pressure, so expiration was passive. An additional and potentially serious problem of early cuirass ventilators was that the negative-pressure ventilation was controlled, so that the spontaneously breathing patient could struggle against the mechanically set respiratory rate.12 Recognition that the application of positive pressure during expiration improved secretion removal and aided alveolar recruitment led to the development of noninvasive positive-pressure devices.13,14 These devices have dramatically improved the care of patients with acute exacerbations of chronic obstructive pulmonary disease, but there are frequent complications and patient tolerance of these devices remains a problem.

The RTX respirator is an external biphasic cuirass ventilator. It consists of a cuirass, a clear, flexible plastic chest and abdominal enclosure bordered by soft foam rubber that creates an airtight seal around the patient, and a power unit (Fig 1). The cuirass is connected to the computerized power unit by a wide-bore tube, and the respiratory parameters are controlled by a feedback mechanism between the 2. The power unit works by creating cyclic pressure changes inside the cuirass. The negative pressure ( vacuum) creates chest expansion—inhalation. The positive pressure creates chest compression—exhalation. Thus, both phases of the respiratory cycle are controlled. The design of the RTX respirator seeks to overcome the problems associated with the early cuirass ventilators and noninvasive positive pressure. First, the respirator contains a novel sensor system that allows the computer to detect the patient’s respiratory effort and adjust the computer’s own programmed respiratory cycle accordingly, in a manner very similar to modern intermittent positive-pressure ventilators used in ICU. Second, positive pressure generated during the expiratory phase aids secretion clearance. Third, there is no facial component to the device, allowing the patient to eat, talk, and sleep normally.

The RTX has 7 modes of operation: monitor, continuous negative, controlled, triggered, synchronized, ECG triggered, and secretion clearance. These allow the RTX to be used to give respiratory support, full ventilation, or to aid physiotherapy. This case report focuses on the physiotherapy (“secretion clearance”) mode.

There are 2 components to the secretion clearance cycle. The first is a vibration mode, in which the I:E ratio is set as 1:1, but the vibration frequency may be varied from 240 to 1,200 cycles per minute. This is effectively high-frequency oscillation of the chest wall, which reduces the viscosity of the secretions, improving clearance. The cough mode, which interrupts each
vibration cycle, allows the setting of a high I:E ratio (up to 6:1), which allows maximum chest expansion, followed by a powerful expiration to expel secretions. It is likely that the key to the success of the respirator in this patient was the positive pressure that can be generated by the device during expiration, allowing thick secretions to be propelled toward the trachea in a more efficient manner than a normal cough. The fact that the patient could communicate and eat while treatment was in progress considerably improved patient compliance.

The RTX respirator may have considerable potential in the management of patients with postoperative sputum retention. It is well tolerated by the patient, and nurse training in the use of the device is straightforward. There may also be a role in preoperative respiratory physiotherapy, reducing the likelihood of postoperative pneumonia. More detailed clinical trials will be required to assess these possible roles.

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