Respiratory training for a person with C3-C4 tetraplegia

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Persons with high tetraplegic spinal cord injuries commonly have respiratory complications that may negatively impact their health and quality of life. Treatment of these respiratory problems often requires significant health care dollars. This case report describes and evaluates the effect of a year-long respiratory intervention, which included inspiratory muscle training and positive expiratory pressure therapy, for a person with C3-C4 tetraplegia. The intervention improved both inspiratory muscle force and pulmonary function values. Respiratory infections, frequency of suctioning and physiotherapy treatment time decreased progressively throughout the intervention. There were no admissions to the acute care hospital after the interventions began. This intervention improved the participant’s health and wellbeing and reduced costs to the health care system. [Ehrlich M, Manns PJ and Poulin C (1999): Case Report: Respiratory training for a person with C3-C4 tetraplegia. Australian Journal of Physiotherapy 45: 301-307]

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Introduction

Respiratory complications are one of the most common secondary problems for a person with a high tetraplegic injury (Zupan et al 1997) as more than 80 per cent of persons with tetraplegic injuries, C5 or above, report respiratory complications either acutely or long term (Jackson and Groomes 1994, Spungen et al 1997). Injuries to the spinal cord above the level of C5 may involve the phrenic nerve and thus cause partial or complete paralysis of the diaphragm (Zupan et al 1997). Because of diaphragmatic involvement, in addition to the paralysis of abdominal muscles, these individuals are very limited in their ability to cough and clear secretions and thus are at high risk for the development of respiratory tract infections (Kelly and Luce 1991). In addition, the position of the tetraplegic patient is noted to have a significant effect on pulmonary volumes and respiratory function (Lamig and Lammertse 1992). In supine, the effect of gravity is eliminated and the abdominal contents are more easily displaced, allowing greater diaphragmatic excursion. Consequently, vital capacity is generally greater in supine than in sitting for persons with high tetraplegic injuries, which may lead to increased difficulty in tolerating the sitting position.

Previous researchers have reported that an eight-week inspiratory muscle training program improved respiratory parameters in persons with high tetraplegia (Rutchik et al 1998). Though the authors suggest that these improvements may reduce the risk of chronic respiratory complaints, they did not measure the longer term effects of a training program. Additionally, another intervention, positive expiratory pressure (PEP) therapy, which has been shown to improve secretion clearance (McIlwaine et al 1997), has not previously been evaluated for effectiveness in persons with high tetraplegia.

Therefore, the purpose of this clinical case study was to document the longer term effects of a one-year respiratory training program, which included both inspiratory muscle training and PEP, on respiratory parameters and indicators of respiratory health for one person with high tetraplegia.

Method

Subject RL is a 27-year-old man who suffered a C3-C4 spinal cord injury in January 1993, complicated by marked respiratory impairment including right phrenic nerve paralysis. A tracheostomy was done three days later and he was ventilated for 105 days until April 16 when he was completely weaned from the ventilator. The tracheostomy was maintained but RL remained off the ventilator for almost three years. Functionally, RL
has complete C3-C4 tetraplegia and is totally dependent for all his care. He has full antigravity neck movement and strength. He operates a tilt recline power wheelchair with a head control attachment.

During the time in the rehabilitation and long term care facilities, RL had frequent admissions to an acute care hospital with respiratory complications. In March 1996, his respiratory status worsened and he was admitted to the hospital in respiratory failure. At that time, RL was ventilated again, for the first time since ventilation in acute care. Initially, five hours of night time ventilation was required. In September 1996, RL was transferred to the long term care facility (PRC) where this investigation took place. Soon after admission to PRC, RL developed pneumonia and night time ventilation was increased to eight hours. In addition, RL required supplemental oxygen at night, and as needed during the day, in order to keep his oxygen saturation levels above 88 per cent. During the first five months at PRC, chest physiotherapy was done daily, and occasionally twice daily, with treatment consisting of postural drainage, percussions and vibrations, assisted cough and tracheal suctioning as necessary. After four months of this treatment, a thorough re-evaluation of RL’s respiratory status was completed. Inspiratory muscle force was found to be extremely low (-10cm H₂O). Normal value for a man aged 27 is -128cm H₂O, with the lower limit of normal being -75cm H₂O (Black and Hyatt 1969).

RL also had chronic retention of secretions, denoted by the need for frequent daily secretion clearance including tracheal suctioning. Therefore, a different physiotherapy intervention was trialled - one that was designed to improve inspiratory muscle strength and assist with secretion clearance.

**Intervention** The treatment program included inspiratory muscle training and PEP therapy, a secretion clearance technique that has been used extensively with persons with cystic fibrosis (McIlwaine et al 1997). The PEP valve is a device with a variable resistance one way expiratory valve. The resistance generated by the expiratory valve provides positive pressure within the airways. The pressure induced acts to stabilise the smaller airways and prevents their collapse, thus enhancing mobilisation and removal of secretions (Humberstone and Tecklin 1995). The PEP valve used in this study was a Paripep.

The other intervention initiated was inspiratory muscle training (IMT) with a threshold trainer. The threshold trainer provides a consistent inspiratory load, independent of air flow rate, after the inspiratory pressure generated is great enough to open the one way valve (Larson et al 1988). The inspiratory muscle trainer used in this study was a Threshold Inspiratory Muscle Trainer. Progressive training against resistance increases the strength and endurance of the respiratory muscles and thereby may improve ventilation and delay the onset of respiratory muscle fatigue (Shekleton et al 1996).

**Procedure** The treatment program began in February 1997, six months after RL had been admitted to PRC. Initially, PEP alone was started so that the impact of that intervention could be evaluated. RL continued to perform daily postural drainage in supine prior to using the PEP device. The expiratory pressure he created while using the PEP device was measured with a manometer to ensure that 15cm H₂O expiratory pressure was generated. Throughout the intervention, the pressure was re-checked and re-calibrated as necessary, as strength improved. RL started out doing four sets of six expirations with the PEP, progressed to three sets of 10 expirations by the second month and gradually worked up to one set of 20 expirations after four months.

After the first three weeks of PEP alone, IMT with the threshold trainer was added to the program. Training was started at a resistance of 7cm H₂O, the lowest setting available on the trainer, with three or four sets of five breaths daily. Initially, repetitions were increased every one to two days. For example, one day RL would do three sets of 10 breaths, the next three or four sets of 20, then 30, then 40 breaths until he could do five minutes of continuous work on the muscle trainer. Once five minutes of continuous work was achieved, progressions were in sets of five minutes until he was able to do 15 minutes continuously. This process took four months until June 1997. After that time, IMT resistance was increased progressively so that RL’s level of exertion was maintained in the range of 6 or 7 on the category-ratio (1-10) rating of perceived exertion scale (American College of Sports Medicine 1995) Following 12 months of progressive IMT, RL was working at a resistance of 39cm H₂O.

Once both interventions were in place, they were performed five times weekly in supine under the
supervision of the physiotherapist, to monitor progress and adjust resistance as required. After October (following eight months of physiotherapy-directed treatment), RL was given responsibility for his own respiratory program. He was encouraged to initiate treatment by attending at the physiotherapy gymnasium or doing his respiratory therapy with the assistance of nursing staff. Once RL was given responsibility for his program, the exercises were done in sitting, which was a progression in itself.

**Outcome measures** The outcome measures that were used to evaluate the effectiveness of the treatment program with RL were: 1) inspiratory and expiratory muscle force; 2) pulmonary function tests (forced vital capacity [FVC] and forced expiratory volume within the first second of expiration) [FEV1]; 3) number of respiratory infections; 4) frequency of suctioning; and 5) amount of physical therapy treatment time. The number of trips out of the institution made by RL was also considered an important outcome measure and a behavioural indicator of the effectiveness of the program.

**Inspiratory and expiratory muscle force** Both inspiratory force and expiratory force were measured using a manometer and force was reported in cm H2O. For inspiratory muscle force, measurement was done at approximately monthly intervals throughout the intervention. (Values for the months of April, July and September 1997 were not taken, as testing equipment was not always available on site). The manometer was calibrated prior to every test and the same two physiotherapists performed all the testing. A mouthpiece attached to the manometer tubing was used. The patient was asked to exhale fully (tracheostomy was plugged and noseclip in place) prior to inhaling as forcefully as possible to obtain a reading for inspiratory force. The best result of three trials was used to represent inspiratory force. All testing was done in the supine position. The manometer was also used to measure expiratory force and the same procedures (except the opposite, ie inhale fully) were followed. Expiratory muscle force
was measured monthly for the first three months.

**Pulmonary function testing** Pulmonary function testing was done prior to the intervention and following 11 months of the intervention. A pocket monitor was used to establish the pre- and post-intervention values for FVC and FEV\(_1\). Both values were represented in litres. Again, the best value (with the tracheostomy plugged and noseclip in place) of three trials was used to represent FVC and FEV\(_1\).

**Number of respiratory infections** Prior to September 1996, because RL was in a different long term care facility, it was difficult to objectively quantify the frequency of respiratory infections. Therefore, the number of respiratory infections as an outcome, which was defined as infections that involved the lower respiratory tract, was reported only during the time that he was at PRC. The number of respiratory infections pre- (September 1996 - February 1997) and post- (March 1997 - April 1998) intervention were then compared. In addition, any differences pre- and post-intervention in the number of admissions to acute care hospital for respiratory reasons were reported. Information about the number of acute respiratory infections and hospital admissions was obtained from a chart review carried out jointly by the principal investigator and the co-investigator.

**Frequency of suctioning** Reduction in the amount of suctioning required was important, not only because it would decrease the amount of staff time required but also because frequent tracheal suctioning can potentially increase the risk of infection (Mendelson 1996). For the entire period that RL was at PRC, every time he was suctioned it was recorded in the respiratory progress notes. From a chart review, the number of times that RL was suctioned each day was recorded. The information was then compiled and the mean number of times suctioned each day was determined for each month. It should be noted that the number of times suctioned refers to the number of sessions of suctioning (at each session he was suctioned approximately three or four times).

**Physiotherapy treatment** Physiotherapy direct care statistics are kept individually for each patient at PRC. Total monthly treatment time for both the therapist and the attendant was determined by reviewing all the physiotherapy statistics for RL.
Treatment time was reported in weighted units with one unit equal to five minutes.

**Number of trips out of the institution** An increase in the number of trips out of the institution should be a strong indicator of better health and wellbeing. Trips were operationalised to represent any time that RL volitionally left the institution on either an evening or day pass. All trips were recorded by the staff in the chart and a retrospective chart review was used to determine frequency of trips. They were then compiled and the number of passes issued monthly was determined.

**Results**

Inspiratory muscle force improved from -10cm H\(_2\)O prior to the intervention to -42cm H\(_2\)O following one year of the intervention (Figure 1). Expiratory muscle force improved from 30cm H\(_2\)O pre-intervention to greater than 60cm H\(_2\)O after three months of the intervention. After that time, expiratory muscle force was no longer measured as the manometer did not record force greater than 60cm H\(_2\)O. In addition, pre- and post-intervention pulmonary function measures, FVC and FEV\(_1\), improved from 0.42L to 0.97L and from 0.36L to 0.83L respectively.

Prior to the interventions, RL had three respiratory infections, two of which required hospitalisation. Since the interventions began in February 1997, RL has had only two respiratory infections (both in May, 1997) that could be managed by the long term care facility and has had no admissions to an acute care hospital related to respiratory complications. Since the end of May 1997, he has not had any respiratory infections. It should also be noted that six months after the interventions began, RL's oxygen saturation levels were maintained on room air and he no longer required supplemental oxygen.

RL required tracheal suctioning approximately five times daily pre-intervention. The chart review revealed that the amount of suctioning required decreased progressively throughout the intervention and at 11 months post-intervention, he no longer required daily suctioning (Figure 2).

Physiotherapy time was subdivided into direct time of the physiotherapist and direct time of the attendant. Physiotherapy treatment time peaked around the time just prior to, and in the month following, the initiation of the intervention and then steadily decreased until the point where RL was reviewed only monthly by the physiotherapist. (Note: an increase in physiotherapist time from July to September 1997 was due to a six-week student placement who spent additional time with the client as part of her own learning experience). Attendant time remained fairly constant over the period of the intervention, as the attendants performed regular passive range of motion exercises with RL. However, attendant time increased slightly in January and February, 1998 (11 months into the intervention) when RL independently resumed his program of IMT with the attendants assisting by setting him up (Figure 3).

The number of trips outside the institution increased progressively throughout the intervention and are displayed graphically in Figure 4.

**Discussion**

This case report outlines a respiratory treatment program, including IMT and PEP, and documents the impact of those interventions on a person with a C3-C4 complete tetraplegic injury. Though the interventions improved respiratory parameters and decreased the number of respiratory infections and the amount of suctioning, perhaps the more important results were the effects that those improvements had on aspects of the subject’s life. Within two months of the initiation of the intervention, RL was able to sit up for longer periods in his wheelchair and was therefore better able to access his environment. This increased time out of bed facilitated regular trips outside the institution with family. In addition, RL felt that over the course of the intervention, his voice volume and quality improved. Other persons also commented on those improvements.

In addition to the positive changes related to RL’s health and wellbeing, significant cost savings were realised. The most obvious savings to the system were incurred primarily through a decrease in the number of admissions to an acute care setting (no admissions) and the savings in the cost of suctioning equipment. Physiotherapy time decreased progressively during the intervention but this was not necessarily a cost saving, as no extra staff had been hired to handle the workload. However, as a result of the intervention it was possible to more equitably distribute physiotherapist time. With RL’s condition
frequently acute, his treatment was often prioritised over other residents’ treatment, which of course negatively affected others’ therapy time.

This program also unintentionally demonstrated the effect of adherence to the program. After RL was given responsibility for his own respiratory program in October, he followed the program fairly diligently for the first month but in parts of November and all of December, stopped doing the IMT. Nevertheless, in spite of these problems with adherence, giving RL responsibility for his program was an important step. In the two-month period when training was stopped, inspiratory muscle force dropped from -37cm H₂O to -29cm H₂O. However, the amount of suctioning remained low and there were no respiratory infections reported. In January, RL was strongly encouraged to resume the respiratory training program (which he did) and inspiratory muscle force improved to a value higher than what it had been prior to cessation of regular training. It was encouraging that the short-term resumption of the training program led to a relatively rapid improvement in inspiratory muscle force even following a two-month lay off. It was also encouraging that the amount of suctioning and number of respiratory infections did not change during the time when the intervention was not done, which suggests that the respiratory training program and concomitant increase in inspiratory muscle strength may have had a protective effect. However, if there is a protective effect, it is unclear what the minimum threshold for inspiratory muscle force might be, if indeed there is one, after which RL would begin to experience respiratory symptoms. Long-term follow-up will perhaps provide more information about this issue. Follow-up will also give us more information about the intensity and frequency of training necessary to maintain respiratory health. Currently, RL continues to do IMT exercises an average of three times weekly. In addition, he uses the PEP device any time he feels secretions are present. He also continues to perform postural drainage in the mornings after coming off the ventilator, to assist in clearing any secretions present. At present, this regime appears to be maintaining his respiratory health.

The literature suggests that persons with a C3-C4 tetraplegic injury have the potential to be weaned from the ventilator (Peterson et al 1994, Viroslav et al 1996). Switching from invasive ventilatory methods with a tracheostomy to non-invasive ventilation methods when feasible has been found to improve patients’ perceptions of quality of life issues like speech, appearance and comfort (Bach 1993). Removal from the ventilator is the long-term goal for RL and, because he was not ventilated for a period of three years, it appears that this may be a reasonable goal. At the time of writing this report, he had just completed his first full year since the spinal cord injury during which he had no acute hospital admissions for respiratory complications, and progression towards weaning off night time ventilation was ongoing.

This investigation illustrated one case where there were benefits to the health and wellbeing of a person with tetraplegia, as well as significant cost savings to the health care system, with improved respiratory function. Continued monitoring of this subject’s training program will provide important information about training frequencies and intensities required to maintain respiratory health.

Footnotes 1)Pari Respiratory Equipment Incorporated, 3120 Glen Erin Drive, Unit 10, Mississauga, Ontario, Canada, L57 1R6. 2) Healthscan Products Incorporated, 908 Pompton Avenue, Unit B2, Cedar Grove, New Jersey, U.S.A. 07009-1292. 3) Micro Medical Limited, PO Box 6, Rochester, Kent ME1 2AZ, UK.

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References


