High Frequency Chest Wall Oscillation as a Prophylactic to Upper Respiratory Infections for a Patient in a Long Term Care Setting

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Abstract

Background and Purpose. Upper respiratory infections (URIs) continue to impact individuals with neurologic or neuromuscular compromise often residing in long term care settings. Chest physical therapy (CPT) has continued to be an integral part of the management of these complications, however, its proper usage and effectiveness has been debated for years. This case report describes the prophylactic use of high frequency chest wall oscillation (HFCWO) in an effort to control recurrent URIs and hospitalizations in an individual living in a long-term care facility. **Case Description.** The patient was a 45-year-old non-ambulatory male with mental retardation that received prophylactic HFCWO for 3 years. Prior to the HFCWO treatment, the patient was treated with standard medical interventions, which included medications, suctioning, and manual (CPT). Health outcome measures were compared prior to and during the 3 year HFCWO therapy. **Outcomes.** Health outcome measures related to URIs worsened during the prophylactic HFCWO. There was a 45% increase in the number of URIs, a 33% increase in hospital admissions, and an 81% increase in days of hospitalization. Seizure activity was reduced by 50% during the same time frame. **Discussion.** Prophylactic HFCWO did not reduce recurrent bouts of URIs or hospitalizations due to respiratory infections but may have had an unexpected impact on the frequency of seizures. Age and a sedentary lifestyle may limit HFCWO effectiveness when used long term for respiratory conditions but the vibratory and deep pressure components of the treatment may have a positive effect on seizure reduction.

Key Words: Chest physical therapy, High frequency chest wall oscillation, Deep pressure, Mental retardation, Vibration, Sensory stimulation

Introduction

Respiratory complications and upper respiratory infections (URIs) continue to impact the health of individuals, particularly the elderly and those with neurologic or neuromuscular compromise.[1] Maintaining respiratory health is vital across the scope of medical practice, from post surgical settings to long term care facilities. Each treatment setting provides unique concerns and challenges. Some of these challenges include advancing skeletal deformities such as kyphosis or scoliosis, aspiration due to increased seizure activity, diminished activity levels, inability to tolerate upright positioning, increased exposure to infectious agents, and/or medications that have the potential to weaken the immune system.[1] Any of the above problems can become greater liabilities with surgical interventions, advancing age and/or pre-existing neuromuscular disorders. The ribcage, which is distensible when young, has a tendency to become more rigid with age and a sedentary lifestyle often seen with patients living in long term care facilities.[2] This can have a negative impact on vital lung capacity, particularly in an individual with kyphoscoliotic deformities.[3] Patients residing in long term care facilities often pose a difficult challenge in promoting bronchial health. Under normal conditions, mucociliary actions and cough are very efficient in clearing secretions, but if these systems are compromised due to medical conditions, musculoskeletal deformities, and/or a sedentary lifestyle such as those observed in this patient population, complications such as infection, increased work of breathing, and hypoxia may occur.[4] Therefore it is critical to maintain bronchial hygiene in this population.

Pulmonary therapy is often used to maintain bronchial hygiene. It spans a broad spectrum of terms and procedures. According to the American Association for Respiratory Care (AARC)

clinical practice guidelines,[5] terms such as chest physical therapy (CPT), postural drainage, percussion, and vibration therapy have all been used to describe techniques used in conjunction with nebulizer treatments, turning and positioning, and other respiratory care procedures to promote bronchial hygiene and pulmonary health. These pulmonary therapies are designed to improve the mobilization of bronchial secretions, match ventilation and perfusion, and normalize functional residual capacity based upon the effects of gravity and external manipulation of the thorax. External manipulation includes both percussion and vibration. Percussion is accomplished by rhythmically tapping the thorax with a cupped hand or mechanical device. Vibration involves the application of a fine tremorous action that is manually performed by pressing in the direction of the ribs and soft tissue of the chest during the expiratory phase of the breathing cycle. The technique is often used in conjunction with percussion, or as a substitute for percussion in children or individuals diagnosed with osteoporosis that may not tolerate the more aggressive percussive techniques.[5] However, these manual CPT techniques have their limitations. The AARC guidelines list numerous relative contraindications including pulmonary edema, patients that are aged, confused or anxious who do not tolerate position changes or those on vasoactive medications or uncontrolled hypertension.

More recently, various mechanical devices, which generate a compressive and vibratory force, have been designed and advocated as an alternative to manual CPT. High frequency chest wall oscillation (HFCWO), sometimes referred to as external chest wall oscillation, high frequency chest compression or high frequency transthoracic ventilation has been shown to be equally effective as manual CPT in generating sputum production when used in disorders in which respiratory failure and secretion accumulation are a primary

concern such as cystic fibrosis and amyotrophic lateral sclerosis.[6-10] The device is based on the principle that high frequency oscillation applied to the chest wall transmits rapidly reversing oscillatory pressures through the chest wall and into the airways, creating forces that dramatically increase mucous clearance.[11] These devices have been available since the late 1980s for use as an alternative to and in conjunction with traditional manual chest percussive techniques to treat a variety of upper respiratory conditions. In addition to its reported effectiveness in generating sputum production, it has also been reported to be well tolerated. Anderson et al[12] notes that the HFCWO was safe and well tolerated when utilized with acute lung and chest wall injuries. A total of 25 patients diagnosed with blunt thoracic trauma were provided HFCWO for two 15 minute periods per day to assist in airway clearance. Physiological parameters of heart rate, heart rhythm, respiratory rate, O_2 saturation and mean arterial pressure were recorded before, during and after treatment. None of the parameters were significantly different pre and post treatment. Patients were also followed up 30 days after the intervention to determine health status, incidence of re-intubation, mechanical ventilation, number of hospital days required as well as any hospital re-admissions. No deaths or hospital re-admissions were reported. Two patients did require re-intubation during the treatment. A patient assessment of comfort and tolerance was also conducted at that time. The authors reported that 75% of the subjects reported experiencing mild or no pain due to the HFCWO and 70% reported that they would recommend the treatment to others. An earlier study by Whitman et al[13] reported similar results when comparing HFCWO to manual CPT techniques. A study of 10 patients who received artificial ventilation for more than 30 days and required external manipulation of the thorax

to enhance secretion clearance tolerated the HFCWO as assessed by blood pressure, heart rate and comfort levels.

Many patients in long-term care facilities suffering from musculoskeletal conditions such as scoliosis, kyphosis, and osteoporosis, are prohibited from the normal positioning required for the postural drainage which has often been a large component of the traditional pulmonary therapy treatment protocol.[14] Patients diagnosed with GERD or a hiatal hernia may also not tolerate the reverse Trendelenburg positioning required for adequate postural drainage of the lower lobes as these positions may cause pain or additional reflux.[15] This may contribute to additional aspiration, further impacting the patients respiratory status. The risk of fracture may also prevent some clinicians from applying percussion techniques to those individuals diagnosed with osteoporosis . Unlike traditional manual CPT, some important benefits of the HFCWO treatment include its ability to be performed while a patient is positioned in his wheelchair or recliner and may be somewhat less labor intensive than traditional manual CPT. Furthermore, in individuals with mentally disabilities, HFCWO may serve as an alternative to the traditional CPT techniques such as pursed lip breathing, huffing and coughing, and early mobility due to the difficulty in teaching the latter techniques to these individuals. HFCWO could also be more efficient than the traditional CPT techniques. Supporting this belief, Whitman et al[13] point out that 80% of the respiratory care staff in their study believed that there were time savings associated with the use of HFCWO in almost all cases. HFCWO does not require additional time to be spent repositioning or a therapist to provide percussion or vibration.[6] In addition to a time saving advantage, some patients, such as those diagnosed with cystic fibrosis may be able to perform the treatment independently.

This may allow substantial cost reductions to the patient requiring long duration and frequent CPT treatments .

In spite of the perceived advantages of respiratory physical therapy and its usage by respiratory and physical therapists across a wide range of patient populations and conditions, there continues to be inconsistencies in the literature regarding its effectiveness and appropriateness, particularly as a prophylactic measure.[17,18] Pasquina et al[17,18] concluded in his systematic reviews that "the usefulness of respiratory physiotherapy for the prevention of pulmonary complications after cardiac surgery remains unproved," and that "the routine use of respiratory physical therapy after abdominal surgery does not seem to be justified." These reviews included studies of respiratory interventions ranging from incentive spirometry and continuous positive airway pressure devices to the traditional physical therapy interventions discussed earlier in patients following cardiac or abdominal surgery. Outcome measures in these studies ranged from clinical parameters such as vital capacity assessments to radiographic and bacteriologic findings. [17, 18] Other studies have also questioned the overall effectiveness and potential for harm caused by some of the CPT techniques. [19-21] Chatburn [21] concluded from his review of high frequency assisted airway clearance systems that "despite 20 years of research, clinical evidence of efficacy for them is still lacking," and that "there is insufficient evidence to support the use of any single airway clearance technique, let alone judge any one of them superior." Additionally, there continues to be a paucity of evidence supporting the long term use of either manual CPT or HFCWO to prevent or decrease the incidence rate of URIs. Giarraffa et al[22] reported that in spite of significant improvement in several pulmonary function and health outcome measures during a year of vest therapy conducted in patients diagnosed with familial dysautonomia, no significant

changes were noted in chest radiographs or laboratory data that would indicate a reduction in chronic infection. Medications during the year of treatment decreased slightly.

The AARC guidelines[5] has not advocated for prophylactic respiratory therapy treatment to maintain an otherwise clear pulmonary system, and state that these treatment techniques "may be based more on tradition and anecdotal report than on scientific evidence." The guidelines point out that cough and airway clearance are essential components of traditional therapy when the treatment is intended to mobilize secretions. In addition, these guidelines suggest that percussion be provided only if there is a productive cough and should be discontinued upon clear radiographic evidence and/or lack of sputum production as there are several potential hazards and complications of the treatment. These include hypoxia, increased intracranial pressure, hypotension, pain and injury to the muscles, spine and ribcage, vomiting and aspiration, bronchospasm, and/or dysrhythmias.[5] Moreover, the risk benefit factor of the long term prophylactic use of either manual CPT or HFCWO to limit future occurrences of respiratory infections has not been determined. The AARC guidelines[5] also suggest that percussion and vibration have been used excessively and in patients in whom it is not indicated. Demers[23] also pointed out that many providers often express the belief that "even if chest percussion does not add to the therapy, at least it does not detract" and "steadfast resistance is often encountered by those who attempt to limit the use of chest physiotherapy to only those patient groups in which it has been shown to be efficacious." He continued to suggest that in light of the trend toward evidence based practice, that "clinicians should not blithely assume that chest percussion might merely be neutral in its effects." This may also be the case for HFCWO as it also provides a vibratory force to the chest wall similar to the manual technique of vibration. Despite the conflicting

evidence, the medical provider felt that the potential benefits of providing an unproven prophylactic intervention outweighed the potential risks of treatment. The patient presented with a viable cough mechanism, and had no relative contraindications other than his inability to tolerate the positioning required with manual percussion and postural drainage. Perhaps the prophylactic intervention would better control respiratory infections, than simply providing treatment during periods of active treatment. Various outcome measures have been utilized to determine the effectiveness of CPT procedures .[24] The lack of consensus regarding the effectiveness and appropriate usage of the CPT interventions may in part be due to excess of or inconsistent outcome measures used. Sputum production has been measured by both weight and volume. [25] Arterial oxygenation, oxygen consumption, total lung/thorax compliance, airway resistance, expiratory reserve volume, and chest radiographic imaging are some of the measures that have been used to quantify whether chest physical therapy improves a patients health and well being.[20] These multiple methods of quantifying effectiveness may not necessarily determine the true effectiveness of manual CPT. McCool and Rosen [26] point out in their systematic review that studies evaluate effectiveness by reporting potential benefits ranging from functional total lung capacity and residual capacities to sputum production and radioactive tracer clearance. They further suggested that efficacy cannot be evaluated from current literature and that no study at that time "investigated health related quality of life measures, number of exacerbations, or hospital days per year."[26] For many patients, these quality of life outcome measures may be the true measure of effectiveness. Another outcome measure in addition to the quality of life measures that may be relevant to patients with neurological disorders is the frequency of seizures. Patients' caregivers often suggest that seizures may lead to aspiration episodes

which in turn could increase the incidence of URIs. Given the conflicting evidence, the question remains regarding the effectiveness of continued, long term chest physical therapy intervention (specifically HFCWO) and whether there are any detrimental repercussions to its long term prophylactic intervention. However, clinicians often continue to rely on an intuitive rationale rather than evidence based practice for implementing CPT and often continue treatment in spite of clear lung fields and lack of sputum production. The inconsistencies of usage protocols and lack of a gold standard to measure effectiveness of the treatment ultimately led to the question of the current study. Specifically, this study explored whether the provision of prophylactic HFCWO, regardless of radiographic evidence or other clinical signs of infection may have a positive impact on quality of life (as measured by a reduction in URIs and hospitalizations) for a patient diagnosed with developmental disability living in a long term care facility.

The purpose of this retrospective case report is to describe an individual's response to a prophylactic intervention of HFCWO that was performed in an effort to improve his respiratory health as measured by the severity of URIs (based upon days of sickness), hospitalizations and number of seizures. It was expected that the long term prophylactic use of this intervention would ultimately improve the patient's quality of life by decreasing hospital stays, reducing URIs requiring physician intervention which would ultimately correlate to diminished costs of care for the patient and long term care facility.

Case Description

Patient

At the time HFCWO was initiated, the patient was a 45-year-old non-ambulatory male diagnosed with profound mental retardation, hiatal hernia with gastroesphogeal reflux

(GERD), osteopenia, and a kyphoscoliosis. According to psychological evaluation, the patient was functioning at a mental age of 1 year and 5 months and had a behavioral age of 20 months. He resided in a long term care facility for developmentally delayed adults, and spent a majority of his awake time either sitting in a wheelchair or positioned on a mat table or bed with his head and trunk elevated approximately 30 degrees secondary to the diagnoses of GERD and a hiatal hernia. He also presented with a history of recurrent URIs and a productive cough mechanism. Medical and physical therapy staff felt that these neuro-musculoskeletal conditions made this patient highly susceptible to recurrent respiratory infections. Occasionally, the respiratory infections possibly combined with his limited mobility, and spinal deformities led to respiratory distress syndromes requiring hospitalization. The patient presented with a major motor primary generalized seizure disorder. The seizures would often result in status epilepticus, which also required hospitalization. Family members and caregivers subjectively felt that these violent seizures might lead to aspiration and subsequent URIs. The patient also presented with intermittent lower extremity edema related to his non-ambulatory, sedentary lifestyle. He had no cardiac related diagnoses. Prior to the prophylactic implementation of HFCWO, he was treated with standard accepted medical intervention that included drug therapy, suctioning, and manual chest percussion provided by physical therapy staff upon physician orders. A combination of Tegretol, phenobarbital, Ativan and Topamax were the medications used to control seizure activity throughout both the pre and intervention period. Specific dosages were occasionally adjusted but remained between 1600-1800 mg/day for Tegretol, 120-165 mg/day for phenobarbital, and 6 mg/day for Ativan. The Topamax remained at 250 mg/day until it was increased to 400 mg/day midway through the pre intervention period. It remained that way

throughout the remainder of the pre intervention and treatment period. Diastat was provided rectally whenever a seizure of greater than 3 minutes was noted. In spite of these procedures and interventions, the patient continued to develop recurrent bouts of respiratory infections that often led to hospitalization. This led the medical provider to make the decision to try CPT prophylactically with the goal of reducing the patient's respiratory infections and hospitalizations. Prior to prophylactic HFCWO treatment, manual CPT was performed 5 times per week under the supervision of a licensed physical therapist. However, the hiatal hernia and GERD prevented normal post percussion positioning in a reverse Trendelenburg that is required for adequate draining of the lower lobes. Behaviors and non-compliance also limited appropriate positioning during the manual treatments. The patient was playful in nature, and often refused to allow positioning to provide manual percussion and drainage techniques to the various lobes. These conditions led to the physician's clinical decision to use the HFCWO therapy. It was hoped that this intervention would ultimately reduce URIs and hospitalizations, thereby improving his overall quality of life.

Procedure

Implementation of the medical order to begin prophylactic HFCWO was initiated using the American Biosystems, Inc[*] vest system (Figure 1). This device is comprised of an air pulse generator attached to an inflatable, non-stretch vinyl vest that is snugly fitted to the chest and thorax of the patient. The vest is available in several sizes to accommodate a variety of patients. The vest is fastened in the front with 3 buckles with adjustable straps to secure the vest to the thorax. Two ports are located on the front of the vest, which use 2 large tubes to connect the vest to the air pulse generator. Upon activation, the vest fills with air and

[*] The Vest® Airway Clearance System. Hill-Rom Services Inc.1020 West County Road F St. Paul, MN 55126. Phone: 800-426-4224 or 651-490-1468 Fax: 877-368-5081

the pressure increases and decreases between 5 and 25 times per second, causing rapid oscillations to the patient's chest wall. The gentle, but rapid inflation and deflation of the vest causes the chest wall to be compressed and released, creating airflow within the lungs. This facilitates movements of the mucous toward the larger airways where it can be cleared by coughing. The treatment can be performed in any position, thus eliminating the need to position the patient in a reverse Trendelenburg position. Arbitrary pressure dial settings range from 1 to 10 and pulse frequencies range from 5 to 20 Hz. Settings are typically selected based upon patient comfort and more recently upon a tuning process which assesses airflow and volume of air displaced at the mouth.[27] This procedure had not been described at the time of treatment in this case.

Intervention

HFCWO therapy was typically provided while the patient was seated in his wheelchair or recliner regardless of his respiratory status. His trunk position varied from fully upright to a 20 degree reclined position. Treatment consisted of two 10-minute sessions at a pulse frequency of 12 Hz and a pulse dial setting of 9, which was performed by a physical therapy staff person 5 times per week, with nursing staff providing the service on holidays. A 5-minute rest period was provided between each session to allow for cough and airway clearance. Treatment was typically provided in the morning, while allowing at least one hour after the breakfast. The treatment was also halted periodically if a cough was noted during the session of oscillation. Prior to implementation of the prophylactic HFCWO, manual CPT consisting of compression was initially delivered per medical order upon diagnosis of respiratory infection. The HFCWO treatment was not provided during hospitalizations in the community hospital as that facility did not have access to the HFCWO vest machine.

Data Collection

The clinical data collected included the number of URIs (which included episodes of pneumonia, bronchitis, and congestion), hospitalizations due to URIs, days of hospitalization, and number of seizures. The clinical data was extracted from the patient's nursing and medical records for the three-year period prior to implementation of the prophylactic vest therapy and for the three-year period after implementation of the prophylactic vest therapy.

Diagnoses of URIs were based upon a combination of physician assessment, auscultation, presence/absence of fever, purulent pulmonary secretions, O_2 saturation index, and/or chest radiographs. Based upon the severity of the signs and symptoms, the patient's physician may have elected to order hospitalization in either the on site hospital or the local community hospital.

Respiratory diagnoses, seizure activity, hospital admissions and days of hospitalization were totaled and compared pre intervention and during intervention of HFCWO prophylactic therapy.

Outcomes

During the 15 calendar quarters prior to the initiation of prophylactic HFCWO, the individual was diagnosed with 11 URIs and was admitted to the hospital on 9 occasions. He spent a total of 64 days under hospital care. He also experienced 159 documented seizures during that time frame. Following the prophylactic vest therapy, the individual was diagnosed with 16 URIs and required 12 hospitalizations, which totaled to 116 days of hospital care. During the 15 calendar quarters following the prophylactic vest therapy, he experienced 80 documented seizures. For this patient, there were no reductions in health outcome measures including number of URIs diagnosed, hospitalization admissions, or days

of hospitalization when comparing the 3 year period prior to prophylactic HFCWO to the 3 year period during which prophylactic HFCWO was provided. Contrary to the intended results of the prophylactic HFCWO intervention, there was a 45% increase in the number of URIs, a 33% increase in hospital admissions, and an 81% increase in days of hospitalization. Interestingly, seizure activity was reduced by 50% during the same time frame (Figure 2).

Discussion

Respiratory compromise is thought to be a debilitating problem for individuals living in long-term care facilities. Due to the various neuromuscular and/or musculoskeletal problems in this population, HFCWO may often be the treatment of choice for many clinicians. This case report describes a patient's response to a 3 year trial of prophylactic HFCWO in an effort to limit bouts of recurrent respiratory infections, hospitalizations and days admitted to the hospital due to respiratory infection. In spite of routine prophylactic HFCWO, no reduction in the number of URIs, number of hospitalizations, or days of hospitalization due to respiratory infection was noted. Contrary to the intended results of the treatment, these outcome measures actually increased during the intervention phase of the prophylactic treatment indicating that long term prophylactic intervention may have a negative impact. Surprisingly, during that same time frame, the patient's number of seizures was reduced by 50%.

HFCWO is designed to mobilize lung secretions to a proximal airway so that an individual can more effectively expectorate the mucous. HFCWO is not a substitute for an effective cough. The treatment is meant to enhance the effectiveness of coughing. Patients with neuromuscular disease may develop progressive muscle weakness which can lead to impaired or diminished cough. This may contribute to higher risks of pulmonary infection

with progressive disease.[1] HFCWO may be less effective on patients with neuromuscular disease, and perhaps be detrimental for those with an active respiratory infection and a severe inability to clear their proximal airways by coughing. These patients are more likely to aspirate as they are unable to sufficiently clear their airways.[28,29] Therefore, the physician and physical therapist should have substantive evidence of a viable cough mechanism prior to implementing any HFCWO in patients with neuromuscular disease, whether used as a prophylactic or in response to acute respiratory infection. During this intervention, the patient continued to present with adequate muscle strength to produce a viable cough mechanism and was able to efficiently clear sputum during periods of active URIs.

Warwick and Hanson[10] suggest improvements in pulmonary function in patients receiving HFCWO and leveling off of expected declining lung function in patients with cystic fibrosis. However, they also point out that HFCWO did not prevent hospitalizations for acute pulmonary exacerbation in the patients studied. This is an outcome measure that is of paramount importance to the patient and/or caregivers for both quality of life and cost containment reasons. This case report seems to be consistent with their findings. The patient continued to require hospitalization for acute exacerbation at a rate greater than pre-treatment levels for the 3-year period after intervention of the prophylactic HFCWO (Figure 2).

One possible explanation for lack of improvement in respiratory infection control for this patient may be the impact of the aging process on his respiratory system. Sharma and Goodwin[30] point out that after about 25 years of age, there is a progressive decline in lung function. They further state that chest wall and spine deformities may lead to increased work of breathing, decreased respiratory muscle strength, and increased alveolar dead space. Furthermore, there is a general decrease in ventilatory response with age.[1] Given these

changes, one could expect minimal improvement in respiratory status regardless of the intervention in middle or older aged individuals diagnosed with multiple neuromuscular disorders, musculoskeletal deformities and/or the sedentary lifestyle often seen in long term care facilities. Further studies are warranted to determine if age and activity level limit the effectiveness of HFCWO.

Given the patient's increasing age, diminished neuromuscular health status, limited mobility, and physical deformities, it was also expected that in the absence of any intervention, seizure activity may have been a contributing factor to subsequent aspiration and could result in increased incidents of URIs over time. Seizure frequency can change with medication adjustment and/or time. Although there is the perception that seizures are more frequent in children and lessen with age, there is evidence in the current literature that indicates the incidence and prevalence of seizures actually increases with age.[31-33] However, in this patient, medications remained consistent and the patient aged a total of 6 years while seizure activity was reduced by about 50% during time period the HFCWO intervention was administered (Figure 2). It is interesting to note that Plioplys et al[34] reported that HFCWO, when provided to individuals experiencing seizures living in a long-term care facility, had reduced incidents of pneumonia as well as seizure activity. They proposed, "improved pulmonary toilet resulted in improved overall health and improved oxygenation," which lead to improved seizure control.[34] It is also possible, however, that a reduction in seizures could have led to diminished opportunities for aspiration and a subsequent reduction in URIs for those individuals. Unlike the findings from the study done by Plioplys et al[34] in this case, it was observed that there was a sharp reduction in seizures while URIs continued to escalate over the years of treatment. This could be due to the age differences between the subjects

used in both studies. The subjects in the study done by Plioplys et al [34] ranged in age from 7-28 years, with a median of 19 years, while the patient's age in the current report was 45 years when treatment was initiated. It is possible that, although seizure activity was diminished the other structural and physiological processes associated with aging resulted in higher number of URIs in this patient.

Janssens et al[35] point out that "physiologic aging is associated with dilation of alveoli, enlargement of airspaces and a decrease in exchange surface area" which results in "decreased static elastic recoil of the lung and increased residual volume and functional residual capacity." Additionally, they report that with age "compliance of the chest wall diminishes, thereby increasing the work of breathing." This decrease in lung compliance may in part be due to progressive calcification of the intercostal joints and rib vertebral articulations, narrowing of the disc spaces, and progressive kypho-scoliotic deformitiy.[1] The resulting rigidity could also lead to contractures of intercostal muscles, further compromising respiratory health by "shifting the breathing muscle-use pattern toward a smaller contribution from the thoracic muscles and a larger contribution from the diaphragm and abdomen."[1] It is also reported that respiratory muscle strength including that of diaphragm decreases with aging.[1,35] This weakness may result in an inability to adequately remove secretions, change breathing patterns, and significantly increase morbidity and mortality in patients, particularly in sedentary individuals such as those diagnosed with neurologic or neuromuscular disease or living in long term care settings.[1] Sharma and Goodwin[30] point out that "senile emphysema" may occur when the lung parenchyma loses its supporting structure. This phenomenon may lead to several physiological changes in addition to decreased elastic recoil. There may be a reduced capacity for oxygen and carbon monoxide diffusion; premature airway closure

resulting in an associated ventilation-perfusion mismatch and larger alveolar-arterial oxygen difference; small airway closure and air trapping; and reduced expiratory flow.[1] Any of these changes could pre dispose a patient to recurrent lung infections. Sharma and Goodwin[30] also point out that "older adults have decreased sensation of dyspnea and diminished ventilatory response to hypoxia and hypercapnia, making them more vulnerable to ventilatory failure during high demand states" such as heart failure or pneumonia.

As reported earlier seizures could predispose a person to respiratory infections by causing aspiration. Hence this outcome measure was used in this study. Interestingly with the HFCWO intervention, though the number of seizures decreased by 50% this did not translate to a reduction of URIs . This suggests that in the patient in the present study, seizure activity was poorly associated with aspiration episodes and subsequent respiratory infections. However, the structural and muscular changes that occur with aging, a sedentary lifestyle, and to a greater degree with progressive neuromuscular disease may have predisposed this patient to recurrent URIs, regardless of the interventions provided. Although there was no documentation in the patient's medical history regarding the degree of kyphosis, status of his chest, muscles of inspiration and accessory muscles prior to the intervention, the caregivers subjectively felt that his kyphosis had progressed slightly over the years. It is possible that with advancing kyphosis, the patient's chest cage could have become more rigid, impacting his respiratory function and resulting in an increased infection rate regardless of the intervention. Supporting this belief, Caro and DuBois[2] point out in patients with kyphosis, a decrease in total lung capacities is observed which can alter the pressure-volume relationship.

Based on the findings of this case report, it could be suggested that HFCWO may also have had an unexpected impact on the central nervous system (CNS). The HFCWO

treatment, which provides both vibratory and deep pressure stimulation may have had an impact on seizure reduction, independent of the potential effects on the pulmonary system. Grandin[36] as well as McClure and Holtz-Yotz[37] have suggested that deep pressure may provide a calming effect to the CNS. Various forms of proprioception and sensory stimulation that includes vibration and deep pressure have been used for years in the sensory integrative therapy approach to modulate arousal states.[38] Further research is needed to understand the potential effects of deep pressure and the usage of HFCWO as it relates to sensory stimulation, deep pressure and its dampening effect on the CNS, including its potential to inhibit seizure activity.

The interesting and unexpected finding of decreased seizure activity noted in this case report raises the question of whether HFCWO could be a useful adjunct to assist in seizure control. Many questions can be raised regarding the possible relationship between the HFCWO treatment and seizure control. Does the pressure of the vest or the vibration frequency component of the HFCWO have an impact, or is it the combination of both stimuli that may contribute to a reduction in seizure occurrence? Perhaps there is a link between deep pressure, vibration and the production of serotonin and/or dopamine. Prolonged vibration and/or deep pressure provided by the HFCWO could also serve to stimulate the vagus nerve, which can stimulate changes in heart rate, blood pressure and/or seizure activity. Vagus nerve stimulation has been used for years with varying degrees of success in controlling seizure activity,[39,40] yet there is a paucity of evidence of the neurological impact of HFCWO on the vagus nerve or the CNS as a whole. Further studies need to be conducted to determine if any relationship exists between the sensory stimulation provided by the HFCWO and the CNS's response to the vibration or compression provided by the HFCWO

treatment. Clinical trials should be done to determine if there is indeed a cause and effect relationship between HFCWO and a subsequent reduction in seizure activity.

Future research with a larger sample size needs to be conducted to test the prophylactic effectiveness of HFCWO in decreasing URIs in patients with developmental disabilities. Due to the impact of age and maturation on the respiratory system, it is critical that additional research focuses on use of HFCWO with various age groups and activity levels. Additional studies regarding the combination of other interventions combined with HFCWO used in a prophylactic manner are also needed. HFCWO may have been more effective as a prophylactic if used in conjunction with routine breathing treatments, or daily breathing exercises. Furthermore, additional studies should focus on various parameters such as frequency, pressure and duration of the HFCWO treatment and how those parameters might influence the efficacy of HFCWO in preventing URIs. Perhaps using the HFCWO tuning process outlined by Milla et al[27] or increasing the duration of the treatment would provide benefits not seen with the current treatment parameters.

In conclusion, in this case report, the patient continued to have respiratory infections and subsequent hospitalizations at a rate greater than pre prophylactic treatment rates indicating that prophylactic HFCWO intervention did not positively impact the patient's health as measured by the number of URIs, hospitalizations, or days of hospitalization. Interestingly, the number of documented seizures during the same time frame was reduced indicating that URIs may not have been a result of aspiration due to seizure activity. Age and diminished activity levels of the patient may explain the lack of improvement in the URIs with HFCWO in the present study.

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Figure 1. American Biosystems Inc. Vest System, Model 205

Figure 2. Seizure Activity Compared to Respiratory Heath Outcomes Pre and During Prophylactic HFCWO Intervention