Interdisciplinary Approach to the Rehabilitation of an 18-Year-Old Patient With Bronchopulmonary Dysplasia, Using Telerehabilitation Technology

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We describe the use of telehealth technology in the rehabilitation of a college student with bronchopulmonary dysplasia. The present telerehabilitation application was necessitated by the absence of a formal university-based pulmonary rehabilitation program at Texas State University–San Marcos. Patient referral, evaluation, and rehabilitation were accomplished via interdisciplinary efforts of 3 separate university entities. Initial referral was obtained from the student health center, with pulmonary evaluation provided by the respiratory care department. Commercially available telerehabilitation equipment was then utilized to resolve exercise supervision and physiologic data-acquisition concerns. Forty-five individualized exercise sessions were administered by physical therapists via telerehabilitation distance voice and vision technology. Results reveal no substantive changes in pulmonary function test results, but there was improvement in functional aerobic capacity. Given the reduced life expectancy associated with bronchopulmonary dysplasia, investigators were afforded a unique opportunity to study an adult patient with this condition. Further, it appears the combined application of telerehabilitation technology and interdisciplinary cooperation among university departments is efficacious in the identification, evaluation, and rehabilitation of students with selected pulmonary disorders. *Key words: bronchopulmonary dysplasia, BPD, peripheral oxygen extraction, pulmonary rehabilitation, telerehabilitation, interdisciplinary programs.* [Respir Care 2008;53(3):346–350. © 2008 Daedalus Enterprises]

Introduction

Because of advances in technology and care, many children with bronchopulmonary dysplasia (BPD) now survive into adulthood. Yet this encouraging observation must be balanced against the reality that BPD incidence is increasing.[1] Morbidity tables continue to classify BPD as the most frequent cause of chronic lung disease in neonates. Estimates in the United States suggest that 3,000–7,000 neonates are diagnosed with this condition annually, and about 4,000 survive infancy.[2] However, little is known about how associated functional disabilities might respond to pulmonary rehabilitation. In light of the limited data, we describe the case of an 18-year-old male college student

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with BPD and the subsequent exercise therapy he received while using a university-based telerehabilitation system. We also describe the use of telerehabilitation technology as a pulmonary rehabilitation adjunct for patients in underserved areas.

Telerehabilitation is defined as "the clinical application of consultative, preventive, diagnostic, and therapeutic therapy via 2-way interactive audiovisual linkage."[3] This technology is currently being applied in speech-language pathology, physical therapy, occupational therapy, and vocational rehabilitation settings. A search of the literature reveals only limited published data specific to "rehabilitation" when matched with the key terms "telemedicine" and "chronic obstructive pulmonary disease".[4–6] Further, no citations exist at all when these same topic headings are combined with "bronchopulmonary dysplasia."

Table 1. Comparison of Pulmonary Function Test Data Obtained Before and After Exercise Program

Variable	Best	Predicted	% Predicted
FVC before (L)	4.17	5.42	77
FVC after (L)	4.43	5.49	81
FEV_1 before (L)	2.31	4.68	49
FEV_1 after (L)	2.36	4.74	50
FEV_1/FVC before	0.55	0.85	65
FEV_1/FVC after	0.53	0.85	62
$FEF_{25-75\%}$ before (L/s)	1.26	5.17	24
$FEF_{25-75\%}$ after (L/s)	1.32	5.25	25

FVC = forced vital capacity
FEV_1 = forced expiratory volume in the first second
FEV_1/FVC = ratio of FEV_1 to forced vital capacity
FEF_{25-75} = forced expiratory flow during the middle half of the forced vital capacity maneuver

Case Summary

An 18-year-old white male and former 25-week premature infant (770 g) diagnosed with BPD was referred to us for evaluation and rehabilitation by a university student health center physician. The patient reported exertional dyspnea that manifested as a function of walking to class on a university campus that has substantial hills and grades. The patient's history included neonatal intensive care unit surveillance for 4 months after birth. While in the neonatal intensive care unit the patient was intubated and mechanically ventilated for a period of 3.5 months. Positively diagnosed with BPD, tracheomalacia, and subglottic stenosis, the infant patient was discharged to home with a tracheotomy. Decannulation of the tracheotomy did not occur until 5 years of age. During the first 5 years of life there were multiple bouts of gastroesophageal reflux, with aspiration pneumonia of the right lower lobe and asthma exacerbation. Aside from asthma, his health between ages 7 and 18 was unremarkable, but physical exercise was somewhat limited.

Upon assessment, the patient presented as a pleasant, conversant, somewhat cachectic male. His height and weight were 185.4 cm and 68.2 kg, respectively. Calculated body mass index was 20.8 kg/m^2. No shortness of breath was observed at rest. Initial vital signs revealed a resting heart rate of 76 beats/min, a respiratory rate of 24 breaths/min, a blood pressure of 136/80 mm Hg, and an oxygen saturation (as measured via pulse oximetry [S_{pO_2}]) of 98%. Chest assessment revealed a moderate pectus carinatum on the right chest, with scarring from previous infant surgeries. Normal thoracic movement was noted during quiet respiration, with no accessory muscle use. Percussion and palpation were within normal limits. All lung fields were clear upon auscultation.

Table 1 presents a summary of initial pulmonary function test (PFT) results. The data reveal moderate obstruction; forced expiratory volume in the first second (FEV_1), the ratio of FEV_1 to forced vital capacity (FEV_1/FVC), and the forced expiratory flow during the middle half of the FVC maneuver ($FEF_{25-75\%}$) were lower than predicted. Vital capacity was also below predicted, which possibly reveals a restrictive component. Present medications included daily formoterol fumarate (Foradil, 12 μg), one puff of budesonide (Pulmicort), albuterol sulfate inhaler for shortness-of-breath rescue, and 2 puffs of albuterol sulfate/ipratropium bromide (Combivent) before exercise. The patient's primary complaint was exertional dyspnea, which he experienced while negotiating hills on campus. Because of his familiarity with pulse oximetry, the patient was concerned about possible clinical desaturation related to the dyspnea he experienced while walking to class. The patient further indicated he was fearful of aerobic-type exercise and had not run since middle school. Pulmonary rehabilitation was subsequently ordered.

Although patient evaluation was easily accomplished via the student health center and the department of respiratory care, exercise therapy was another issue. First, the physical therapy clinic did not possess monitors for real-time patient electrocardiogram (ECG) surveillance. Second, the only ECG monitors available were located in the telehealth program facility located 2 floors above the clinic. Last, clinic space was limited, thus restricting placement of a unit in that area.

Faced with these barriers, an innovative solution to the problem was sought. What developed was as an interdisciplinary approach involving the student health center, the department of respiratory care, and the department of physical therapy telehealth program. ECG, pulse oximetry, and blood pressure monitoring were provided by a cardiopulmonary physical therapist who used remote voice and video technology located in the telehealth program office. Feed-

Fig. 1. Telerehabilitation monitoring station located in the department of physical therapy telehealth program.

Fig. 2. Patient monitoring apparatus in the department of physical therapy clinic.

back regarding these data were provided continuously to the treating therapist via headset link with the monitoring therapist. A transtelephonic system (Advantage, Scott Care, Cleveland, Ohio) was used to monitor the ECG and S_{pO_2}, and Scotty CareStation 156 Videophones (Scotty Group, Wilmington, North Carolina) were used to obtain video images. Both systems provided real-time transmission of all data. Exercise sessions were performed in the department of physical therapy clinic with a supervised physical therapy student directing all exercise sessions (Figs. 1 and 2). Ratings of both perceived exertion (on a 6-20 scale) and dyspnea (modified perceived exertion 0-10 dyspnea scale) were obtained at selected performance intervals. A registered respiratory therapist administered all PFT assessments in the standing position.

A total of 45 rehabilitation sessions (2–3 sessions/week) were completed over a 4-month period. Fifteen minutes prior to each exercise session the patient was instructed to pre-medicate with albuterol sulfate/ipratropium bromide. Initial exercise began conservatively, with interval treadmill walking at 53–67 m/min at a 0% grade for 8 min (approximately 2.5 metabolic equivalents). This routine was repeated once following an interposed one-minute rest. Both intensity and duration of exercise were progressively increased over time, based on patient progress (Table 2). Supplemental oxygen was immediately available but was never used. Absence of ischemic changes and maintenance of normal sinus rhythm led to discontinuation of ECG monitoring at session 37. By session 45 the patient was jogging continuously at 107–134 m/min at a 0% grade for 26 min (approximately 8.5 metabolic equivalents) without interposed rests. Pulse oximetry values never fell below 95% and all blood pressure values were within expected exercise limits. The ratings of perceived exertion values were consistent at 9 (very light) and dyspnea values averaged 3 (somewhat breathless). The patient completed all rehabilitation sessions without complaint. No exercise-induced bronchospasm was observed. Upon program termination, PFTs were once again administered; changes in pulmonary function were negligible (see Table 1).

Discussion

Our patient experienced improvements in exercise capacity. This finding is consistent with other published work on pulmonary rehabilitation.[7,8] However, the mechanisms of such improvement are not entirely clear regarding BPD. Though the literature provides little insight into this issue, data from patients with chronic obstructive pulmonary disease suggest that the changes are most likely due to a variety of factors. Beltman[9] theorized that improvement is a function of increased motivation, desensitization to the sensation of dyspnea, improved ventilatory muscle function, and improved technique performance. In addition, it cannot be overlooked that usual central (heart) and peripheral (extraction) mechanisms were probably functioning as well. Yet substantial changes in cardiac output could be questioned in the presence of BPD sequelae such as pulmonary hypertension and cor pulmonale.[10,11] Northway et al,[12] however, published data indicating that these complications are rare among adolescents and young adults with BPD. Also evident is the fact that our patient is not entirely analogous to an individual

Table 2. Representative Points in Exercise Program Progression

Session	Work Load* (m/min)	Duration (total min)	Heart Rate (breaths/min)	Blood Pressure (mm Hg)	S_{pO_2} (%)	Rating of Perceived Exertion	Metabolic Equivalents
1	53–67	14.0	110	188/65	98	ND	2.5–2.9
23	93–107	26.5	152	137/78	97	9	3.7–7.1
45	107–134	26.0	151	140/70	95	9	7.1–8.6

*All exercise performed on a motor-driven treadmill at 0% grade. All data represent peak exertion for the exercise session.
S_{pO_2} = blood oxygen saturation measured via pulse oximetry
ND = no data

with chronic obstructive pulmonary disease. BPD presents as a double threat, often manifesting both restrictive and obstructive disease characteristics, thus complicating the discussion of the actual mechanism(s).

The present case report would have benefited from acquisition of baseline and post-therapy maximum oxygen consumption ($\dot{V}_{O_2}$) data. Clearly a 21-mL/kg/min improvement over the span of the patient's therapy is suspect. We speculate the exercise starting point of 2.5–2.9 metabolic equivalents was, in effect, a substantial underestimation of the patient's initial performance capability. The low average rating of perceived exertion value (9) would support this assumption. Lacking maximum $\dot{V}_{O_2}$ data, the therapist may have opted for more conservative beginning work loads. Further, the patient's apprehension related to exertion may have influenced the therapist to adjust the work load downward. It is also possible that the patient became accustomed to his exertional dyspnea and subsequently became less fearful of the exercise regimen. Regardless of the initial starting point, it is noteworthy that the patient's final cardiopulmonary fitness level improved substantially, which permitted him to walk the grade and distance between university buildings without becoming short of breath.

The transtelephonic exercise monitoring system we describe is widely used in cardiac and pulmonary rehabilitation settings.[13,14] The single difference was addition of videophones, which permitted visualization of the patient and base station operator throughout therapy. Clear video signals were obtained via the Internet while audio and physiologic data were carried on a standard analog telephone line.

The implications of this preliminary study are far-reaching. First, telerehabilitation appears to be effective in addressing the issue of distance when therapy services are not readily available. Second, this technology can serve as a catalyst to unite various university and community medical programs in enhancing continuity of care. Third, we demonstrated that clinical instructors can successfully observe and have clear voice communication with students working at affiliation sites. Fourth, it appears that adult patients with BPD can be safely monitored via a telerehabilitation system such as the one we employed. Last, although Santuz et al,[15] Jacob et al,[16] Pianosi and Fisk,[17] and Mitchell and Teague[18] described exercise capacity in younger children with BPD, there is a lack of comparable data specific to adult survivors of BPD. We therefore suggest further prospective study of this topic, to include an expanded sample size with additional consideration given to both age and sex.

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