Effectiveness of Mechanical Insufflation-Exsufflation Device in Pediatric Patients with Cystic Fibrosis

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Introduction: Coughing is the body's defense mechanism to clean the airways from the foreign bodies and secretions. In patients with neuromuscular disorders or other diseases affecting the airways such as cystic fibrosis (CF), the effectiveness of this defense mechanism is often reduced due to the respiratory exhaustion. The aim of our study was to evaluate the effectiveness of mechanical insufflation-exsufflation device (MI-E) in pediatric patients with CF. **Materials and Methods:** In this study, we randomized 31 patients with CF admitted to the pediatric pulmonary ward of Masih Daneshvari hospital (Tehran – Iran) into two control and study groups which received the routine physiotherapy (including an active cycle of breathing technique, pursed-lips breathing, diaphragmatic/abdominal breathing, huffing, and coughing) and the routine physiotherapy plus 10sessions of MI-E, each for 20 minutes. MI-E pressure was set +5 to +30 cmH2O for inspiration and -8 to -33 for expiration, for 1-3 and 3-5 seconds, respectively. Two groups were then compared regarding the results of the 6-minute walking test (distance), spirometry, echocardiography, and arterial blood gases. **Results:** The mean age of the patients was 16.4± 4.6 years and 16 participants (23.6%) were male. Results of the analysis demonstrated that there were no significant differences between the two groups in outcome measures ($p > 0.05$), except in ejection fraction ($p = 0.005$). **Conclusion:** Our results demonstrated similar efficacy for conventional physiotherapy versus physiotherapy and MI-E regarding the improvement of pulmonary function and cleaning airway in CF patients.

Keywords: Mechanical Insufflator-Exsufflator; Respiratory Physiotherapy; Cystic Fibrosis

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Introduction

Cystic fibrosis (CF) is an inherited disease and chronic pulmonary infections which still comprises a major cause of mortality in affected patients. Coughing is the body's defense mechanism to clean the airways from foreign bodies, dust, and airway secretions (1, 2). This mechanism is particularly important in patients with pulmonary disease who experience muscle weakness due to increased respiratory workload or central nervous system disorders interfering with normal respiration (3). Moreover, effective coughing is a first-line defense against foreign pathogens. In its absence, the chance of lower respiratory tract infections significantly increases. The effectiveness of coughing is compromised in patients with genetic neuromuscular disorders, bronchiectasis, and CF. Aside from medications, a wide range of physiotherapeutic and rehabilitative techniques and devices are nowadays used to aid in the clearance of airway secretions. Cough is triggered by input from two distinct receptors: mechanical receptors commonly located in the

upper airways such as larynx, trachea, and carina, and chemical receptors found in bronchi and lower airways (4). In each cough reflex, the afferent impulse from stimulation of receptors is mainly relayed through the vagus nerve to the cough center in medulla and pons, which communicate with higher neural centers in the brain and cortex. This communication allows for voluntary initiation and control of the cough. In return, efferent fibers transfer the response to three organs: 1) motor neurons in the spinal cord, responsible for controlling expiratory muscles as well as pelvic sphincter to prevent the passage of urine during increased intra-abdominal pressure caused by coughing; 2) phrenic nerve, responsible for diaphragmatic contraction; and 3) vagus nerve, causing contraction of the larynx, trachea, and bronchi.

In addition, each cough cycle consists of three phases: 1) deep inspiration to provide enough air for initiation of cough; 2) increasing air pressure within the lungs by the closure of glottis and contraction of intercostal and abdominal muscles and diaphragm; and 3) rapid expiration of air by abrupt opening of the larynx (4). In patients with CF, the cystic fibrosis transmembrane conductance regulator (CFTR) is deficient and therefore causes losing CFTR mediated chloride conductance and secretion of HCO3 at the apical membrane of epithelial cells. As a result, the epithelial lining fluid of patients with CF would be acidified that this can be worsened during an infective exacerbation due to the enhanced inflammatory burden (4). Also, patients with CF often have a good peak cough flow, but in connection with a prolonged airway infection or when their health is deteriorated, the peak cough flow may be too weak to effectively evacuate airway mucus. Therefore, an ineffective cough can be considered as a major underlying cause of treatment failure and even death in pulmonary patients.In these situations, the mechanical insufflation-exsufflation (MI-E) device may be a good help.

The inability of respiratory muscles to sustain an effective cough cycle results in the retention of secretions and phlegm in the airways. These patients, therefore, require the use of MI-E devices to clean their airways. This device enhances the force of expiration to help cleaning the airways (4). By using a two-stage centrifugal suctioning mechanism, it produces positive airway pressure immediately followed by negative pressure in the airways provoking expiration. This negative pressure maintains and enhances the flow of air through exhalation and thins and mobilizes secretions towards the larynx. It can be connected to a facemask or a tracheostomy tube. The duration of each phase, as well as the corresponding pressure, can be adjusted automatically or manually depending on the patients' needs.

Application of the device usually involves 3-5 cycles during the expiration with or without intraabdominal pressure, followed by 30 seconds of rest (5). This cycle is repeated until secretions are successfully cleaned. Due to ineffective cough in cystic fibrosis patients, the aim of this study was using a cough assist device to improve the airway clearance and survey the outcome measure.

Material and Methods

In this quasi-experimental study, pediatric CF patients with age 2-18 years admitted to Masih Daneshvari pulmonary pediatric department (Tehran-Iran), who had resting oxygen saturation (SpO2) above 88% and were considered for respiratory physiotherapy by their pediatrician, were evaluated to enter the study. Informed consent was obtained from the patients or their legal guardians. Patients were randomized into two groups using a block randomization including a control group receiving conventional chest physiotherapy (percussion, vibration, chest mobilization), and a study group receiving conventional physiotherapy as well as MI-E using the Pegaso A-cough device (Dima Italia Srl, Bologna, Italy). Patients in the study group received MI-E at least two hours after their last meal and after receiving the mucolytic medications and enough hydration. Device settings were adjusted individually for each patient according to his or her pulmonary 6 function and treatment compliance. MI-E was used for10 sessions of 20 minutes for each patient. Device adjustments were made daily for each patient. A range of +20 to +30 cmH2O was utilized for the inspiration and -23 to -33 cm H2O for the expiration. Inspiratory time was set between 1 and 3 seconds, and expiratory time for 3 to 5 seconds. The inclusion criteria for the study were a definite diagnosis of CF by a physician, age between 2-18 years, and having a resting SpO2 above 88%. The exclusion criteria were defined as inability, noncompliance, or unwillingness to participate, and deterioration of symptoms. The two groups were compared regarding the following variables: spirometry findings, 6-minute walking test (6MWT) results, arterial blood gas (ABG) values, and echocardiography indices.

Data for each patient were collected in predefined forms covering demographic characteristics such as age, laboratory measurements, recordings of MI-E device, pulse oximetry indices, and ABG values. Statistical analysis was performed using SPSS 19 software (SPSS Inc., Chicago, USA). Normal

Table 1: Demographic characteristics of patients

	N	Mean	SD
Age(year)	31	16.4194	4.63878
Hight (cm)	31	147.8387	17.19127
Weight (kg)	31	36.0000	13.01345
BMI%	31	15.9467	3.43470

distribution of the data was assessed using the Kolmogorov-Smirnov test. Then, the independent t-test was applied to compare two groups. Descriptive statistics were presented as mean±standard deviation. *P*-value<0.05 was considered as the significant level.

Results

Overall, 31 patients with a mean age of 16.4 ±4.6 years were analyzed for the study. The study group comprised of 14 patients, who were compared to 17 patients in the control group. Demographic characteristics of subjects are shown in table 1. The results of a 6-minute walk test (distance), spirometry, echocardiography, and arterial blood gases are shown in table 2. Results of the statistic analysis demonstrated that the mean score for spirometry parameters was 37 (FEV1), 41 (FVC) and 85 (FEV1/FVC) in the study group in comparison with 40, 41 and 84 respectively in the control group after the treatment. As seen in table 2, all spirometry indices were not significant between two groups. The distance in 6MWT was 406 meters in the study group in comparison of 411m in the control group that there was no significant difference between two groups (*P*>0.05). Also, parameters of arterial blood gases (Pao2, Pco2, Hco3 and PH) were not significant between two groups (*P*>0.05). EF (ejection fraction) was 55 in the study group and 47 in control with a significant difference between them (*P*=0.005).

Table 2. Analytical statistics (* *P*<0.05)

Variables	Groups (study group: cough assist, control group: conventional physiotherapy)	Mean	P-value
FEV1%	cough assist	37.100	0.685
	conventional physiotherapy	40.063	
FVC%	cough assist	40.400	0.770
	conventional physiotherapy	41.188	
FEV1FVC %	cough assist	85.760	0.240
	conventional physiotherapy	84.267	
Distance (meter)	cough assist	406.1111	0.181
	conventional physiotherapy	411.8750	
PCO2 (mmHg)	cough assist	50.75000	0.310
	conventional physiotherapy	52.68824	
PaO2 (mmHg)	cough assist	36.97500	0.207
	conventional physiotherapy	45.75000	
HCO3(m Eq/L)	cough assist	33.60833	0.408
	conventional physiotherapy	29.49412	
PH	cough assist	7.41242	0.080
	conventional physiotherapy	8.71863	
EF%	cough assist	55.83333	0.005*
	conventional physiotherapy	47.08333	

Discussion

MI-E devices are used as a complementary assistance to conventional physiotherapy. An effective cough consists of three phases: deep inspiration, glottis closure, and sudden expiration (6). Difficulty at each of these phases may result in an ineffective cough mechanism, increasing the chance of pulmonary infections. This is the most common reason for patients' hospitalization with neuromuscular disorders (7). The main goal of respiratory physiotherapy, therefore, is to clean the airways especially in patients with CF and other conditions which increase respiratory secretions. Since the 1970s, different methods have been proposed for CF patients to facilitate the expulsion of sputum and mucus from the airways (7). These encompass a wide range of techniques including the active cycle of breathing technique, autogenic drainage technique, mucolytic techniques, local drainage, and thoracic massage and vibration, and devices including positive expiratory pressure FEV1: Forced expiratory volume in 1 second, FVC: Forced vital capacity, EF: Ejection fraction (PEP) device, vibration during PEP use, intra-airway percussion, and MI-E devices (8). In two shorts term reports by Thomas *et al.* and Van der Schans *et al.*, their use in patients with CF has been effective (9,10). However, there are no long-term studies evaluating the effectiveness of these physiotherapeutic techniques and devices. In a study by Chatwin *et al*, use of MI-E resulted in improvement of peak cough flow, as a measure of effective cough, (3), which is in disagreement with our findings. Moreover, a study by Boitano *et al.* Evaluating the effect of physiotherapy and rehabilitative programs in patients with neuromuscular disorders demonstrated improved quality of life and increased life expectancy in these patients (13). For CF patients, however, MI-E devices can be considered as a useful option for clearance of secretions, although their use is limited by their high costs and poor portability, rendering them only a suitable option for long-term treatment (14). These findings

are in accordance with our results. Another study confirmed the important role of cough assists in ICU patients, especially in those with muscle weakness (15).

Another similar study by Bach *et al.* showed the effectiveness of MI-E devices in conjunction with conventional physiotherapy techniques in patients with neuromuscular disorders and pulmonary infection (12). Finally, a study by Fauroux *et al.* on 17 clinically-stable children with Duchenne muscular dystrophy, spinal muscular atrophy, or congenital myopathy showed that the use of two inspiration three expiration cycles using 15, 30, and 40 cmH2O in each cycle had a significant effect on the physiology of respiration in these patients (17).

For the limitation of this study, the authors have to mention the poor accessibility of pulmonary treatment centers in Tehran.

Conclusion

The physiotherapy in conjunction with MI-E use for 10 sessions could enhance the pulmonary function parameters in CF patients. Although no significant difference was observed between the two groups patients in the study group experienced a significant increase for Ejection fraction in comparison with the control group. Due to the low number of CF patients, increasing the number of patients in subsequent research may play an effective role in the results.

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