Application of the Simeox airway clearance technology

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Simeox Clinical Notebook n°1

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Application of the Simeox airway clearance technology

in the treatment of cystic fibrosis pulmonary exacerbation

Case report

Abstract

Advancement of medicine, early diagnosis of cystic fibrosis in the course of newborn screening, improvement of care, introduction of new drugs as well as improvement of physiotherapy techniques translate into improved quality and longer life of patients. The paper presents a case of a 14-year-old girl treated for pulmonary exacerbation in the course of cystic fibrosis.

During the hospitalization, apart from antibiotic intravenous therapy, physiotherapy with the Simeox by PhysioAssist device was used. As a result of the applied treatment, clinical and lung function improvement were achieved.

The study emphasized the importance of the proper selection of physiotherapy techniques that are inherent in the management of bronchopulmonary disease in the course of cystic fibrosis.

Keywords : *cystic fibrosis, airway clearance, pulmonary function, chest physiotherapy, pulmonary exacerbation*

Introduction

Cystic fibrosis is a systemic, genetic disease, chronic, progressive, shortening life of patients. In its course, excessive amounts of dense mucus accumulate in the airways.
Impairment of mucociliary clearance promotes chronic inflammation and infection resulting in irreversible changes in the respiratory system and progressive loss of lung function [1,2]. Broncho-pulmonary disease is the most common cause of morbidity and mortality.

Therefore, chest physiotherapy aimed at facilitating the evacuation of secretions in the airways is one of the key components of treatment. It is used both to prevent or slow down the progression of the disease and to treat its exacerbations [3-5].

Case report

A 14.5-year-old girl with cystic fibrosis diagnosed in the neonatal period, under the care of the Cystic Fibrosis Center, was admitted to the hospital for treatment of bronchopulmonary exacerbation. One week prior to hospitalization, features of respiratory tract infections with intensified tiring cough and difficult expectoration of retained secretions were present. The girl did not get feverish. She had a decreased appetite. Despite the high-calorie diet, a reduction in body weight (-0.8kg) was observed during the last month. The patient did not report abdominal pain.

The child was born from the fourth pregnancy, the third delivery (one pregnancy was complicated by spontaneous abortion and one by intrauterine death due to malformation syndrome). The patient has a 21-year-old healthy sister. The course of pregnancy was uneventful. Childbirth was natural in 41 Hbd. Child was born in good general condition (Apgar score-10), birth weight -4300g, length- 57 cm. The patient was operated in the third day of life due to meconium ileus. Ileostomy was established by Bishop-Koop method. Cystic fibrosis was diagnosed in the neonatal period on the basis of clinical symptoms, sweat tests (pilocarpine iontophoresis: 100.7 mmol / l and 61.3 mmol / l, Vescor-117) and genetic tests in which mutations were identified in both **CFTR** (cystic fibrosis transmembrane conductance regulator) gene alleles: F508del / dele2,3 (21kb). At the age of 2 the patient underwent Bishop-Koop ileostomy closing surgery. Patients had DIOS (distal intestinal obstruction syndrome) episode at the age of 10 and 14.

The child has a chronic **methicillin-sensitive Staphylococcus aureus** (MSSA) respiratory infection. Due to the exocrine pancreatic insufficiency, pancreatic enzymes and fat-soluble vitamins supplementation is carried out.
In admission to the Department of Lung Diseases, the patient was in a moderate general condition, weakened, with a tiring, unproductive cough. Life parameters were normal: Sat O2 98%, HR 90/min, BP 84/63 mmHg. Slim body. Body weight

45.8 kg (10/25 inches), height 162 cm (<50 centile), BMI 17.4 (10c). In the physical examination postoperative scars on the abdominal skin, reddened throat, and crackles on auscultation over the lung fields were revealed. Normal heart activity.

Abdomen was soft, painless on palpation, without any pathological resistance. In laboratory tests, low indices of inflammation were found, kidney and liver indicators were normal. In functional tests of the respiratory system worsening of ventilation index was observed: FEV1 reduction to 2.48 (78% pred), FVC: 3.41 (96% pred), FEV1%FVC: 72.74 (81% pred) and LCI increase to 12.96 **(Fig 1.2).**

Chest x-ray examination showed bronchiectasis in both lungs, with the thickening of the bronchial walls and small fine-pleated densities, especially in the upper lung fields; quite significant peripheral distension of the lower pulmonary fields and moderate of the upper **(Fig 3).**

Due to clinical symptoms, deterioration of lung function, changes in chest radiograph pulmonary exacerbation was diagnosed (7 out of 12 symptoms according to Fuchs criteria). For treatment, intravenous antibiotic therapy (amikacin and ceftazidime) was introduced, chronic treatment and inhalation-drainage procedures were continued. Inhaled salbutamol, nebulization of dornase alfa and hypertonic saline solution (7%) were used.

After the physiotherapeutic consultation, the method of performing nebulization and drainage of the bronchial tree was discussed. The correct way to perform bronchial tree drainage using Aerobika was taught. The girl has been trained in the proper performance of the Active Cycle of Breathing Technique (ACBT).
During the hospitalization, the patient was trained to use the Simeox device by PhysioAssist, a new technology which helps mucociliary clearance by generating a vibratory pneumatic signal during passive expiration.

The device was used every day of the treatment, which lasted 10 days. The patient was adherent and worked very well during each session with the device. No adverse reactions to the technique used were observed. After each session dilution and evacuation of purulent secretion from the respiratory tract was obtained. The effectiveness and good tolerance of the method further motivated the girl to cooperate.

During the treatment, a gradual decrease in cough intensity, regression of additional auscultatory changes over the pulmonary fields and improvement of the patient's general condition were observed. Six symptoms of pulmonary exacerbation according to the Fuchs criteria have been resolved (reduction of cough and sputum, improvement in clinical status and appetite, resolution of auscultatory changes of the lungs, increase of FEV1 and FVC). In the control functional tests of the respiratory system, improvement of ventilation parameters was found: increase in FEV1: 3.20 (101% pred), FVC: 3.72 (104% pred), FEV1%FVC: 86,01 (96% pred) and a decrease in LCI to 11.78 **(Fig 1, 2).** After 2 weeks of treatment, the girl was in good general condition and therefore discharged with the recommendation of control and further specialist care in the Cystic Fibrosis Centre.

Discussion

According to the standards of cystic fibrosis treatment, the management of bronchopulmonary disease is based on the improvement of mucociliary clearance, treatment of inflammation and respiratory infections and nutritional management. It aims to facilitate the removal of mucus, improve lung function, reduce the number of pulmonary exacerbations and, consequently, improve the quality of life [3]. The treatment of infective exacerbations is based not only on antibiotic therapy but also on intense physiotherapy tailored to each patient [4,6,7].

Chest physiotherapy should be used systematically several times a day from the moment of diagnosis throughout the entire life of the patient. It is extremely important to adapt different methods of drainage to the age, clinical status and severity of the disease and the possibility of the patient's cooperation [8-11]. The occurrence of complications such as haemoptysis or pneumothorax and comorbidities is also taken into account. The patient's motivation and preferences regarding a given technique are important. In the pediatric group it is recommended to introduce active forms of physiotherapy based on active cooperation of the child at the time of drainage, striving for self-reliance, learning to autogenic drainage (AD).
According to the recommendations of the International Physiotherapy Group for Cystic Fibrosis (IPG/CF) many drainage techniques are used in children [12]. Through

modified postural drainage, forced exhalation technique, active cycle of breathing technique, autogenic/assisted drainage, positive expiratory pressure (PEP) to the technique of variable bronchial pressure (e.g. oscillatory elevated expiratory pressure-OPEP) [13, 14].

In the case discussed, a new technology of airway clearance without PEP was used with the Simeox device by PhysioAssist. By generating consecutive low-frequency vacuum vibrations during passive exhalation, thinning mucus and easier removal were achieved, while preventing the collapse of alveoli.
The purpose of physiotherapy was first of all to purify the airways from the retained secretions during the treatment of exacerbation. In addition, the aim was to obtain proper chest mobility, adequate strength and skeletal muscle strength, and maintain proper posture.

During physiotherapy, the cooperation with the patient was very good. She performed the physiotherapist's recommendations, which resulted in the optimal treatment effect and in improving airway clearance. The girl tolerated the drainage sessions well, no side effects were observed. The applied technique allowed liquefaction, facilitation of detachment from the bronchial walls, displacement and removal of residual mucus from the respiratory tract.

During the session, the patient expectorated the secretions. This led to improvement and optimal lung ventilation. Such actions prevented complications such as atelectasis, emphysema, or fixed changes such as bronchiectasis, cirrhosis and fibrosis.

The special role of physiotherapists experienced in the treatment of cystic fibrosis should be emphasized. Selection of an appropriate physiotherapy technique at every stage of treatment, knowledge of the indications and contraindications to their use, ability to work with the patient and motivate her to cooperate largely determines the success of the therapy.

Conclusions

Chest physiotherapy is an indispensable component of long-term maintenance therapy and treatment of exacerbations in cystic fibrosis.

The selection of appropriate techniques for the age and clinical condition of the patient is a challenge for the treatment team including the physician and physiotherapist who are experienced in the treatment of cystic fibrosis.

Their cooperation at every stage of the disease and the mobilization of the patient determine the success of treatment. Effective physiotherapy with comfortable technology such as the SIMEOX device improves the lung function and the clinical condition of the patient, thus extending and improving the quality of life.

Summary

The main goals of chest physiotherapy in patients with cystic fibrosis are the removal of residual mucus from the respiratory tract and the improvement of mucociliary clearance. It should be used in all patients from the moment of diagnosis throughout their life time. The techniques for cleaning the airways should be adjusted individually for each patient.

The presented Simeox airway clearance technology is an innovative method which facilitates the evacuation of airway secretion. Its advantages are high efficiency and good tolerance.
It could be one of the methods of chest physiotherapy in patients with cystic fibrosis with pulmonary exacerbation.

A multidisciplinary team including a physiotherapist specializing in cystic fibrosis should have comprehensive knowledge in the field of pathophysiology of the disease, physiotherapy techniques, indications and contraindications.

It gives the opportunity to modify the procedure at every stage of the disease to get the most effective treatment.

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Operator:		Diagnoza:	

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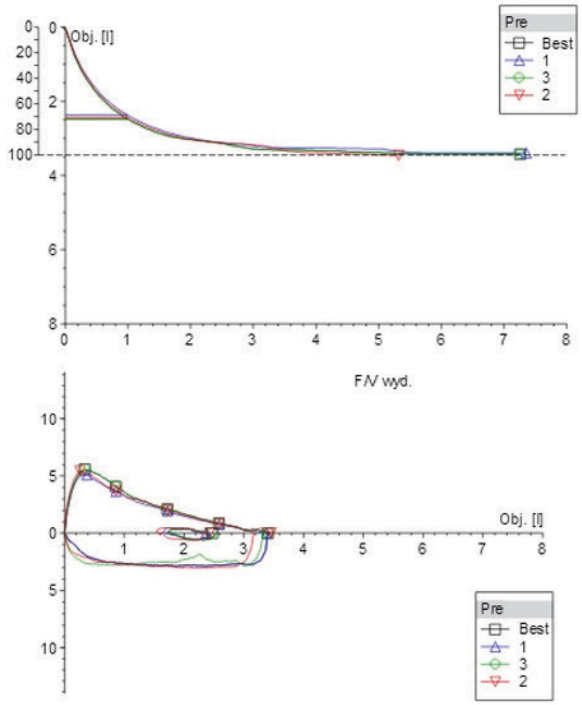

	Nal.	LLN	Best	% Nal.	Perc.	Z-S	P.1	P.2	P.3	Autor Pred.
FEV 1 % FVC %	89.59	78.47	72.74	81 %	1.42	-2.27	70.08	70.37	72.74	Quanjer GLI (2012)
FEV1 L	3.17	2.56	2.48	78 %	4.13	-1.85	2.37	2.43	2.48	Quanjer GLI (2012)
FVC L	3.56	2.87	3.41	96 %	34.95	-0.36	3.38	3.45	3.41	Quanjer GLI (2012)
FEV.5 L			1.77				1.67	1.73	1.77	
FEV.75 L			2.19				2.08	2.14	2.19	
PEF l/s	6.35	4.57	5.58	88 %	23.10	-0.86	5.06	5.41	5.58	Zapletal (1987)
MEF75 l/s	5.53	4.00	4.07	74 %	6.47	-1.91	3.64	3.70	4.07	Zapletal (1987)
MEF50 l/s	3.81	2.54	2.10	55 %	2.27	-2.26	1.91	1.99	2.10	Quanjer GLI (2012)
MEF25 l/s	2.00	1.12	0.87	43 %	2.72	-2.25	0.76	0.80	0.87	Quanjer GLI (2012)
MMEF l/s	3.81	2.54	1.82	48 %	1.24	-2.67	1.63	1.73	1.82	Quanjer GLI (2012)
PIF l/s			2.89				2.89	3.08	2.86	
FIV1 L			2.80				2.80	2.84	2.52	
FETPEF s			0.06				0.07	0.05	0.06	
FET s			6.05				6.37	5.23	6.05	
TBEex s			0.05				0.05	0.04	0.05	
VBEex L			0.06				0.05	0.05	0.06	
E-ERS			100				100	100	100	
EATS05			500				500	700	500	
Kod bł.			0				20	10	0	
Ciśnienie hPa			997							
Temperatura °C			25							
Wilgotność %			43							
Wysokość... m			100							

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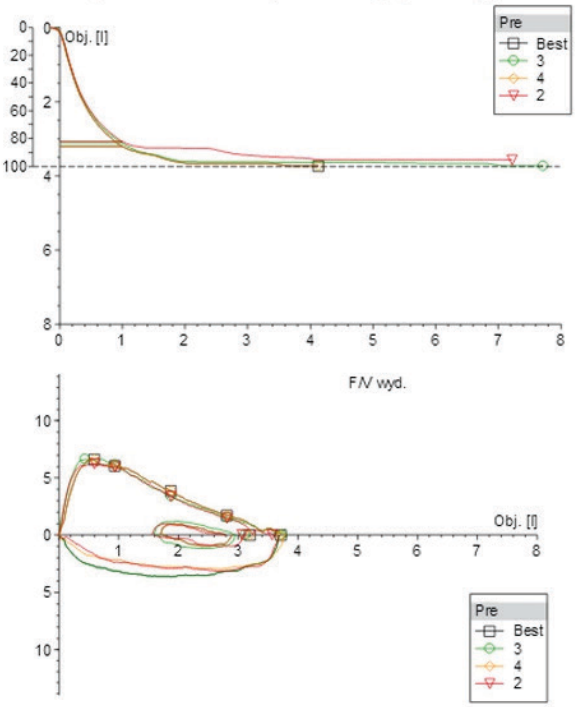

	Nal.	LLN	Best	% Nal.	Perc.	Z-S	P.2	P.3	P.4	Autor Pred.
FEV 1 % FVC %	89.59	78.47	86.01	96 %	28.88	-0.60	85.95	83.53	86.01	Quanjer GLI (2012)
FEV1 L	3.18	2.56	3.20	101 %	52.50	0.06	3.07	3.11	3.20	Quanjer GLI (2012)
FVC L	3.57	2.87	3.72	104 %	64.91	0.35	3.57	3.72	3.72	Quanjer GLI (2012)
FEV.5 L			2.37				2.27	2.30	2.37	
FEV.75 L			2.88				2.75	2.80	2.88	
PEF l/s	6.35	4.57	6.60	104 %	59.54	0.20	6.20	6.62	6.60	Zapletal (1987)
MEF75 l/s	5.53	4.00	6.04	109 %	71.54	0.48	5.93	6.14	6.04	Zapletal (1987)
MEF50 l/s	3.81	2.54	3.87	101 %	53.05	0.07	3.37	3.39	3.87	Quanjer GLI (2012)
MEF25 l/s	2.01	1.12	1.71	85 %	28.13	-0.49	1.44	1.52	1.71	Quanjer GLI (2012)
MMEF l/s	3.81	2.54	3.32	87 %	25.50	-0.61	2.95	3.04	3.32	Quanjer GLI (2012)
PIF l/s			3.67				3.17	3.67	3.02	
FIV1 L			3.38				2.88	3.38	2.81	
FETPEF s			0.09				0.10	0.07	0.09	
FET s			4.09				4.26	6.00	4.09	
TBEex s			0.17				0.13	0.09	0.17	
VBEex L			0.13				0.09	0.09	0.13	
E-ERS			100				0	0	100	
EATS05			4700				4	500	4700	
Kod bł.			10				0	20	10	
Ciśnienie hPa			1000							
Temperatura °C			22							
Wilgotność %			29							
Wysokość... m			100							

Figure 1. The results of spirometry of a 14-year-old girl with cystic fibrosis before and after treatment of pulmonary exacerbation.

Patient

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Weight:	[kg]	45,8	Baro. Pressure: [hPa]		1012
Gender:		Female	BTPS: (insp/exp)		1,119 / 1,063
BMI:		—	Pre/PostcapVd: [ml]		33,3 / 22
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			Cal. Status O2/CO2:		Ok

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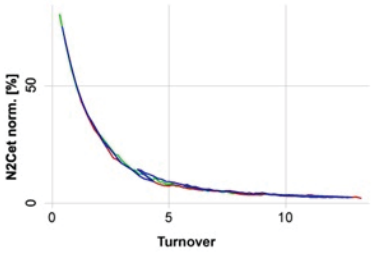
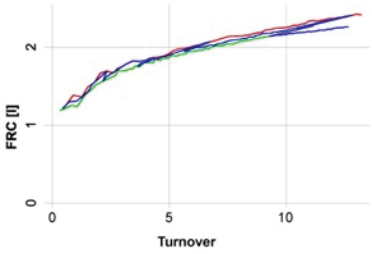
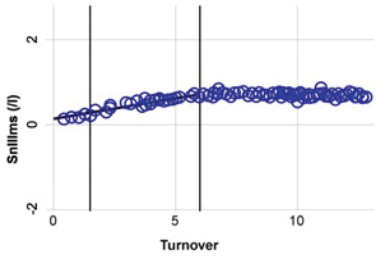




N2-Multiple Breath Washout * Houltz and Gustafsson 2012 (preliminary data)

Trial #	Pred.*	Results	z-score.	CV%	1	2
FRC [l]		2,34		3,3	2,418	2,263
LCI 2.5% norm.	6,57	12,96	12,5	2,1	13,23	12,68
LCI 5% norm.	4,87	7,52	12,1	4	7,82	7,22
M1/M0	1,45	2,71	12,2	1	2,73	2,68
M2/M0	4,14	16,66	11,7	3,9	17,3	16,01
Scond*VT	0,017	0,096	8,8	9,1	0,105	0,087
Sacin*VT	0,053	0,097	2,1	29,3	0,125	0,068
RQ	0,7-1,2	1,13		5	1,07	1,19
VT/FRC:		0,211		14,9	0,243	0,18
VTmean: [ml]		497		18,2	559	379
VdCO2: [ml]		89		8,8	97	81
CEV: [l]		34,52		2,6	35,42	33,61

Slope III Analyzes (all Trials)



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Comments:

Patient

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Weight:	[kg]	47,4	Baro. Pressure: [hPa]		1006
Gender:		Female	BTPS: (insp/exp)		1,116 / 1,063
BMI:		—	Pre/PostcapVd: [ml]		33,3 / 22
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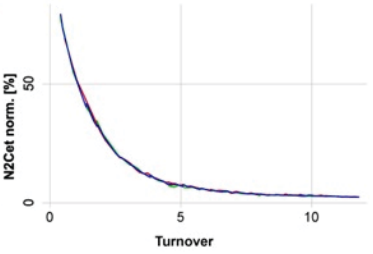
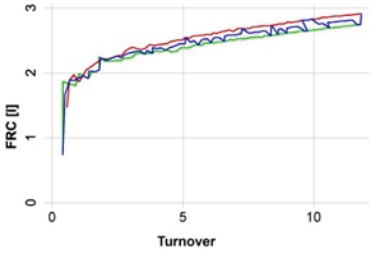
Remarks:

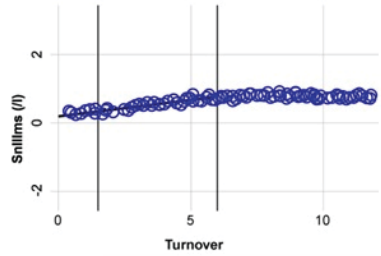




N2-Multiple Breath Washout * Houltz and Gustafsson 2012 (preliminary data)

Trial #	Pred.*	Results	z-score.	CV%	1	2
FRC [l]		2,83		3	2,914	2,745
LCI 2.5% norm.	6,57	11,78	11	0,1	11,8	11,77
LCI 5% norm.	4,87	6,69	8,3	3,6	6,93	6,45
M1/M0	1,45	2,41	10,3	1	2,43	2,39
M2/M0	4,14	13,13	10,1	1,4	13,31	12,94
Scond*VT	0,017	0,096	8,8	5,7	0,101	0,091
Sacin*VT	0,053	—	—	—	—	0,313
RQ	0,7-1,2	1,06		3,9	1,02	1,1
VT/FRC:		0,152		1,1	0,151	0,154
VTmean: [ml]		431		1,9	421	402
VdCO2: [ml]		94		1,4	95	92
CEV: [l]		38,52		2,8	39,59	37,45

Slope III Analyzes (all Trials)



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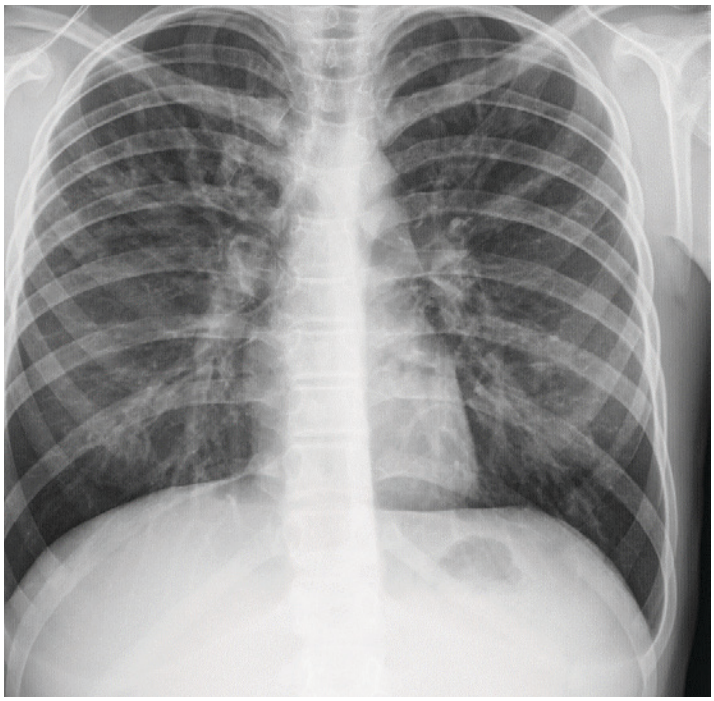


Figure 2. The results of the MBW test (multi-breath inert gas washout) of a 14-year-old girl with cystic fibrosis before and after treatment of pulmonary exacerbation.

Figure 3. Chest x-ray of a 14-year-old patient suffering from cystic fibrosis: bronchiectasis in the both lungs, with thickening of the bronchial walls and small fine-pleated densities, especially in the upper lung fields; quite significant peripheral distension of the lower pulmonary fields and moderate of the upper. From the collection of the Diagnostic Imaging Department in Dziekanów Leśny.

Katarzyna Walicka-Serzysko[1,2], Natalia Jeneralska [2], Dorota Sands[1,2]

Application of the Simeox airway clearance technology

in the treatment of cystic fibrosis (CF)

Case report

Context

Sylwia is a 17-year-old teenager suffering from cystic fibrosis (genotype F508del / F508del) living in Poland. The disease was diagnosed at the age of 3. At this time she was treated due to the first Pseudomonas aeruginosa respiratory tract infection (eradication). Now the patient has a chronic Staphylococcus aureus respiratory tract infection. She is suffering from CF-complications: chronic sinusitis, cystic fibrosis-related diabetes (CFRD), biliary cirrhosis with portal hypertension (esophageal varices, hypersplenism).
Sylwia is learning in high school. She is an intelligent, ambitious and wise girl seriously thinking about her future, planning to study abroad. He remains under care of other CF centre, but when she heard about the possibility of learning physiotherapy with Simeox device, she asked to be admitted to the Cystic Fibrosis Centre.

Objective

The patient was admitted to the Cystic Fibrosis Centre in order to modify physiotherapy practice and to train with Simeox device by PhysioAssist.

Initial assessment

In admission Sylvia was in a good general condition, without any complains. She was coughing after physiotherapy, expectorating secretions with difficulty. As a part of physical examination,on auscultation there were crackles over both pulmonary fields, enlarged spleen (+ 3 cm).
Chest X-ray revealed thickening of the bronchial walls on the right side **(Fig.1)**. Prior to hospitalization, Sylwia was performing drainage once a day using Flutter (oscillatory PEP).

Parameters monitored

Assessment of auscultatory changes over the pulmonary fields. Pulmonary function tests (spirometry, plethysmography, multiple-breath inert gas washout, oscillometry) were performed on admission and after 10 days of hospitalization.

Care provided

1. Maintenance therapy for chronic bronchopulmonary disease
2. Nebulization with dornase alpha and hypertonic saline solution

Bronchial mucus clearance

During her stay at our CF Centre, Sylwia learned to perform autogenic drainage with a thoracic strap and proper breathing with open glottis. Simeox by PhysioAssist has also been included in daily respiratory therapy. The patient performed drainage using Simeox twice a day for 10 days at the hospital. Drainage was preceded by hypertonic saline nebulization and followed by autogenic drainage with a thoracic strap for about 10 minutes.
The next stage was autogenic drainage with the simultaneous use of Simeox. Drainage using Simeox was performed in semi-recumbent position. Parameters: oscillation power 25% on consecutive days 50%, cycle 2 (8 breaths) repeated three times during one drainage therapy. Quiet exhalations with open glottis were performed between the cycles.

Results

The patient learned to work with Simeox very quickly. By correctly positioning the head, practicing passive exhalation, staying relaxed, the patient could avoid vibrations in the neck and cheeks. Thus, Sylvia was able to deliver vibrations to the chest directly. After the first day she noticed an increased amount of sputum. She claimed that despite drainage she still could feel a lot of secretion in her lungs. Drainage practiced with Simeox by PhysioAssist facilitated the relaxation and displacement of secretion in the airways, what made it much easier to expectorate.
After intensive thoracic physiotherapy, regression of auscultatory changes over the pulmonary fields and improved lung function assessed on the basis of functional test results were noticed (spirometry: FEV1-78% / 87%; FVC-79% / 85%; MEF25- 67% / 131%; FEV1% FVC% - 98% / 102%; MBW: LCI 2.5% norm 9,28 / 8,51; body plethysmography: R tot-130% / 145%, RV-103% / 84%, TLC-93 % / 93%, RV% TLC- 93% / 95%, FRC-80% / 71%) **(Fig. 2,3).**

Discussion

Sylvia's case is an example of how significant the role of physiotherapy is in the treatment of cystic fibrosis. The combination of various airway clearance techniques, tailored individually to a given patient allows improving the efficiency of the respiratory system, even without changing the chronic treatment or antibiotic therapy. Simeox technique by PhysioAssist was well tolerated by Sylvia. Despite the occurrence of many cystic fibrosis complications in this patient, side effects were not reported.

Conclusions

Drainage with the Simeox was not tiring for Sylwia, which indicates that she was performing it properly. The results she achieved using SIMEOX for a short time (10 days), visible in the functional tests of the respiratory system, made her believe in her own strength. She understood how important is a correctly performed drainage of the bronchial tree.
She also found out that a lot depends on her motivation. She would like to use Simeox by PhysioAssist at home.

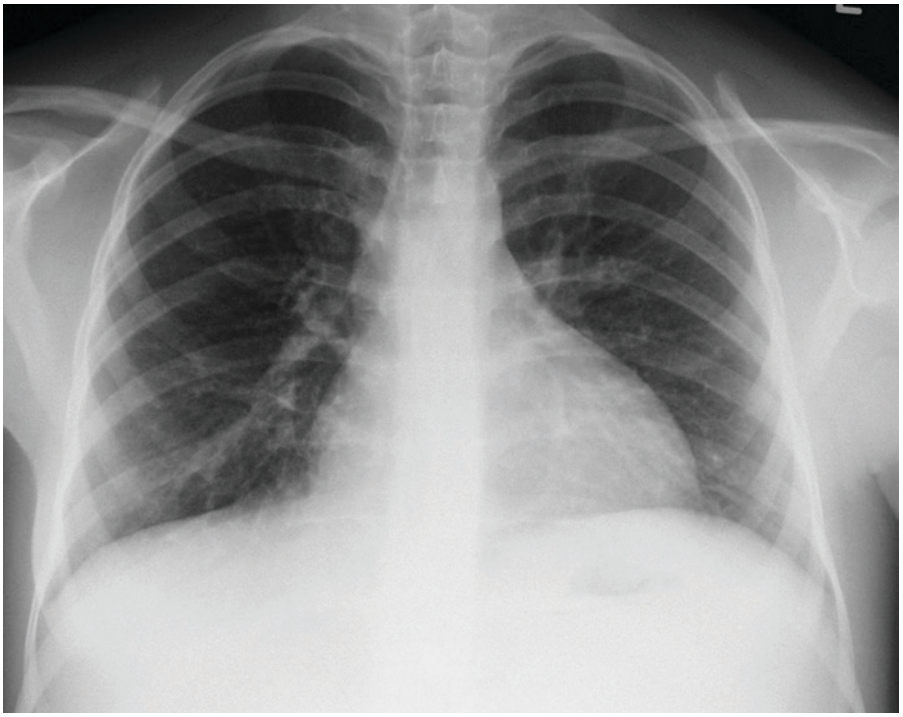
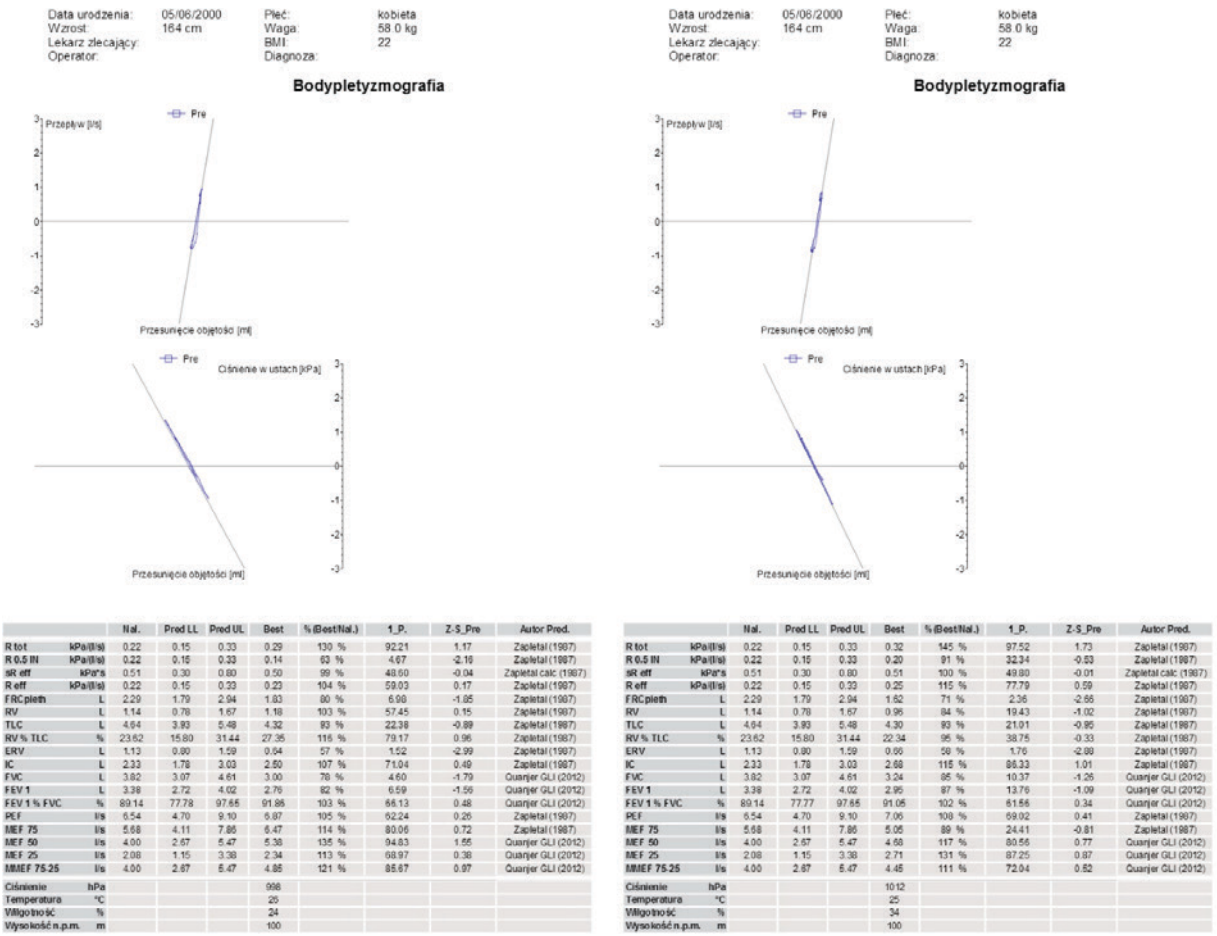


Figure 1. Chest x-ray o f a 17-year-old patient suffering from cystic fibrosis: thickening of the bronchial walls in the right side. From the collection of the Diagnostic Imaging Department in Dziekanów Leśny.



		Nal.	Pred LL	Pred UL	Best	% (Best/Nal.)	1_P.	Z-S_Pre	Autor Pred.
R tot	kPa/(l/s)	0.22	0.15	0.33	0.29	130 %	92.21	1.17	Zapletal (1987)
R 0.5 IN	kPa/(l/s)	0.22	0.15	0.33	0.14	63 %	4.67	-2.16	Zapletal (1987)
sR eff	kPa*s	0.51	0.30	0.80	0.50	99 %	48.60	-0.04	Zapletal calc (1987)
R eff	kPa/(l/s)	0.22	0.15	0.33	0.23	104 %	59.03	0.17	Zapletal (1987)
FRCpleth	L	2.29	1.79	2.94	1.83	80 %	6.98	-1.65	Zapletal (1987)
RV	L	1.14	0.78	1.67	1.18	103 %	57.45	0.15	Zapletal (1987)
TLC	L	4.64	3.93	5.48	4.32	93 %	22.38	-0.89	Zapletal (1987)
RV % TLC	%	23.62	15.80	31.44	27.35	116 %	79.17	0.96	Zapletal (1987)
ERV	L	1.13	0.80	1.59	0.64	57 %	1.52	-2.99	Zapletal (1987)
IC	L	2.33	1.78	3.03	2.50	107 %	71.04	0.49	Zapletal (1987)
FVC	L	3.82	3.07	4.61	3.00	78 %	4.60	-1.79	Quanjer GLI (2012)
FEV 1	L	3.38	2.72	4.02	2.76	82 %	6.59	-1.56	Quanjer GLI (2012)
FEV 1 % FVC	%	89.14	77.78	97.65	91.86	103 %	66.13	0.48	Quanjer GLI (2012)
PEF	l/s	6.54	4.70	9.10	6.87	105 %	62.24	0.26	Zapletal (1987)
MEF 75	l/s	5.68	4.11	7.86	6.47	114 %	80.06	0.72	Zapletal (1987)
MEF 50	l/s	4.00	2.67	5.47	5.38	135 %	94.83	1.55	Quanjer GLI (2012)
MEF 25	l/s	2.08	1.15	3.38	2.34	113 %	68.97	0.38	Quanjer GLI (2012)
MMEF 75-25	l/s	4.00	2.67	5.47	4.86	121 %	86.67	0.97	Quanjer GLI (2012)
Ciśnienie	hPa				998				
Temperatura	°C				25				
Wilgotność	%				24				
Wysokość n.p.m.	m				100				

		Nal.	Pred LL	Pred UL	Best	% (Best/Nal.)	1_P.	Z-S_Pre	Autor Pred.
R tot	kPa/(l/s)	0.22	0.15	0.33	0.32	145 %	97.52	1.73	Zapletal (1987)
R 0.5 IN	kPa/(l/s)	0.22	0.15	0.33	0.20	91 %	32.34	-0.53	Zapletal (1987)
sR eff	kPa*s	0.51	0.30	0.80	0.51	100 %	49.80	-0.01	Zapletal calc (1987)
R eff	kPa/(l/s)	0.22	0.15	0.33	0.25	115 %	77.79	0.59	Zapletal (1987)
FRCpleth	L	2.29	1.79	2.94	1.62	71 %	2.36	-2.66	Zapletal (1987)
RV	L	1.14	0.78	1.67	0.96	84 %	19.43	-1.02	Zapletal (1987)
TLC	L	4.64	3.93	5.48	4.30	93 %	21.01	-0.95	Zapletal (1987)
RV % TLC	%	23.62	15.80	31.44	22.34	95 %	38.75	-0.33	Zapletal (1987)
ERV	L	1.13	0.80	1.59	0.66	58 %	1.76	-2.89	Zapletal (1987)
IC	L	2.33	1.78	3.03	2.68	115 %	86.33	1.01	Zapletal (1987)
FVC	L	3.82	3.07	4.61	3.24	85 %	10.37	-1.26	Quanjer GLI (2012)
FEV 1	L	3.38	2.72	4.02	2.95	87 %	13.76	-1.09	Quanjer GLI (2012)
FEV 1 % FVC	%	89.14	77.77	97.65	91.05	102 %	61.56	0.34	Quanjer GLI (2012)
PEF	l/s	6.54	4.70	9.10	7.06	108 %	69.02	0.41	Zapletal (1987)
MEF 75	l/s	5.68	4.11	7.86	5.05	89 %	24.41	-0.81	Zapletal (1987)
MEF 50	l/s	4.00	2.67	5.47	4.68	117 %	80.56	0.77	Quanjer GLI (2012)
MEF 25	l/s	2.08	1.15	3.38	2.71	131 %	87.25	0.87	Quanjer GLI (2012)
MMEF 75-25	l/s	4.00	2.67	5.47	4.45	111 %	72.04	0.82	Quanjer GLI (2012)
Ciśnienie	hPa				1012				
Temperatura	°C				25				
Wilgotność	%				34				
Wysokość n.p.m.	m				100				

Figure 2. The results of body plethysmography of a 17-year-old patient with cystic fibrosis before and after hysiotherapy using the Simeox device.

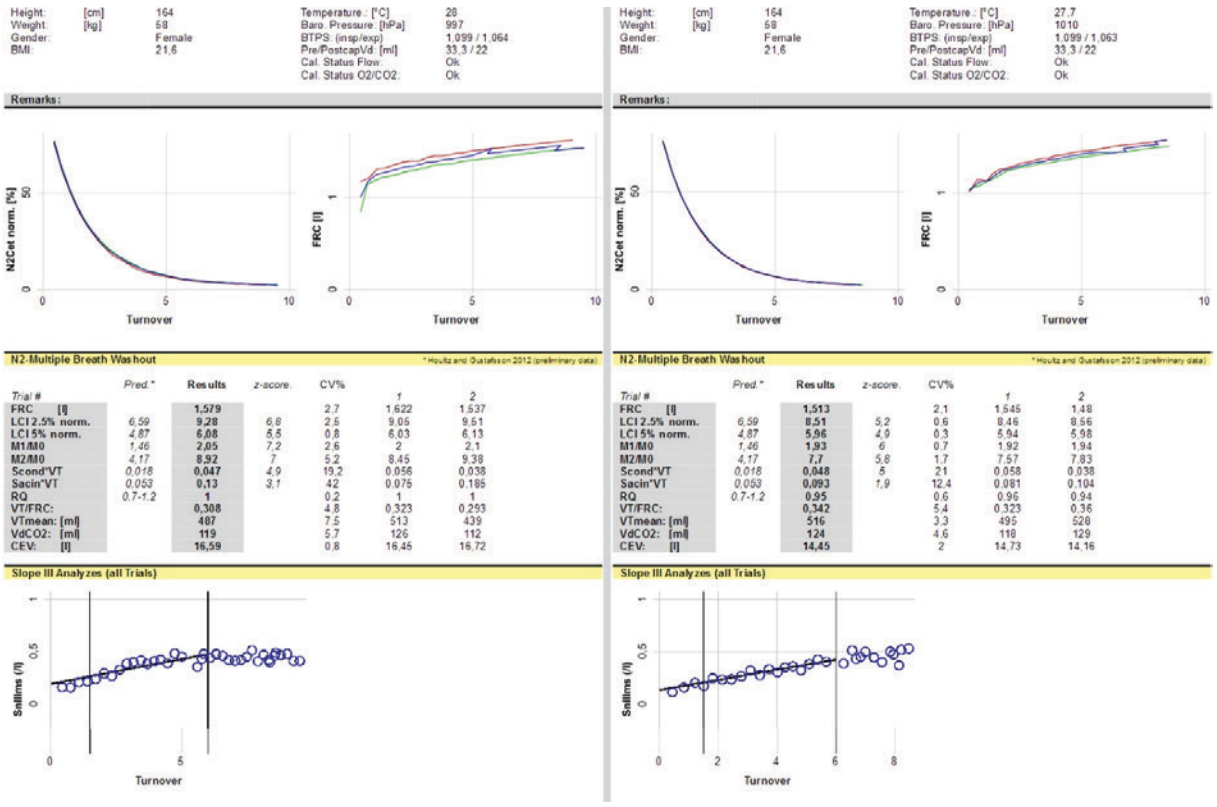


Figure 3. The results of the MBW test (multi-breath inert gas washout) of a 17-year-old patient with cystic fibrosis before and after physiotherapy using the Simeox device.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