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Original Article

Comparative Evaluation of Clinical, Spiro/ Oscillometric and Tomographic Parameters as a Global Assessment of Children with Cystic Fibrosis

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ABSTRACT

Aim: The aim of our study was to compare clinical severity scores and classic spirometry with impulse oscillometry (IOS) results and thoracic high resolution computed tomography (HRCT) scores in children with cystic fibrosis (CF) in order to determine the utility of the latter approach in patient follow-up.

Materials and Methods: CF patients over 6 years of age were included. Shwachman-Kulczycki score, underclassical spirometry and IOS were performed when not in acute exacerbation. Thoracic HRCT images obtained within the previous 6 months were evaluated using the Bhalla scoring system.

Results: The mean age of the children studied (n=30) was 12.1±4.2 years and 40% were female. *Pseudomonas aeruginosa (P. aeroginosa)* was isolated from sputum cultures of 40% of the patients. Patients with forced expiratory volume in one second (FEV1) below 80% exhibited significantly higher (resistance) R5, R10 values and significantly lower (reactance) X5 values on IOS (p=0.03, 0.027, 0.006, respectively). Patients with *P. aeruginosa* had significantly lower FEV1, forced vital capacity, and forced expiratory flow (25-75) values in classic spirometry when compared with patients without *P. aeruginosa* (p=0.002, p=0.002, and p=0.005, respectively). *P. aeruginosa*-positive patients showed significantly higher R5 and lower X5 values (p=0.047, 0.046, respectively). Bhalla scoring, bronchiectasis weight, peribronchial thickening, mucous plaques, saccularization, bronchial division, mosaic pattern parameters in groups with *P. aeroginosa* growth and/or FEV1 <80%; was found to be significantly more serious than the non-reproductive group (p<0.005, respectively). Again, in the group with *P. aeroginosa* growth, Shwachman-Kulczycki score was found to be significantly lower (p=0.001). No significant correlation was found between thoracic score data such as bronchiectasis weight and mosaic pattern presence and IOS values. In addition, in the group with high clinical score of Shwachman Kulczycki, resistance values such as R5 R10 R15 which are IOS parameters, and FEV1 were found above 80% (p=0.016, p=0.037, p=0.042, 0.004, respectively).

Conclusion: IOS and tomographic scoring can be used safely in early detection of impairment in lung function. Further studies are needed to evaluate the utility of IOS in the clinical monitoring of children with CF who are not compliant with spirometry maneuvers.

Keywords: Bhalla, cystic fibrosis, spirometry, impulse oscillometry, thoracic HRCT

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Introduction

Because pulmonary complications are responsible for the majority of mortality and morbidity in children with cystic fibrosis (CF), monitoring pulmonary function and detecting declines early are of critical importance (1,2). However, there is still no reliable method or combination of methods for assessing respiratory function. Disease severity scores are often related to the severity of airway disease (3). Pulmonary function testing, sputum culture, lung imaging methods, and scoring systems can be used to assess pulmonary involvement. In the stages when clinical findings can be detected in children, significant deterioration has occurred in pulmonary function tests (2,4). A major reason for this is that the spirometric methods routinely used to measure pulmonary functions require maneuvers that children cannot perform, especially at very young ages (5). Classic spirometry is used to demonstrate pulmonary functions in CF patients, and forced expiratory volume in one second (FEV1) has been associated with hospitalization and risk of death (5). However, due to problems with patient compliance, this method cannot be used in early childhood, when initial and substantial loss of lung function occurs. Reliable tests are needed to monitor pulmonary functions in young children who cannot undergo spirometry. The forced oscillation technique is a method of pulmonary function testing that is easy to use, does not require patient cooperation, and assesses airway resistance and reactance (6). Demonstration of its utility in CF will provide important data in the follow-up of lung involvement. In addition to pulmonary function tests, clinical scoring systems including data such as general activity, physical examination findings, infectious colonization, nutrition, and weight gain are used when following CF patients. A study using the Shwachman-Kulczycki score determined that decreasing score was significantly correlated with decline in respiratory function, lower body mass index (BMI), and infectious colonization (3). Similarly, higher scores were associated with better pulmonary function and quality of life in a study in which disease progression was assessed using spirometry, BMI, Fuchs criteria (exacerbation index), and the CF respiratory symptom diary-chronic respiratory infection symptom score (3). Radiological scoring systems are also used to assess pulmonary involvement in patients with CF. In many studies, patients with low spirometry FEV1 values showed deterioration of thoracic computed tomography (CT) scans showing pulmonary involvement, as well as lower radiological scores in patients with chronic infectious colitis (7,8).

The aim of this study is to show the effectiveness of impulse oscillometry (IOS) in respiratory functions by comparing pulmonary involvement, pulmonary function tests such as spirometry, IOS and Thorax high resolution computed tomography (HRCT) scores in patients followed up with the diagnosis of CF.

Materials and Methods

Study Population

The study included 30 consecutive patients over 6 years of age who were being followed in the Pediatric Allergy and Pulmonary Diseases Units of Manisa Celal Bayar University and Izmir Katip Celebi University with a diagnosis of CF and agreed to participate in study. CF diagnosis was based on clinical findings with two positive sweat tests and positive CF mutation analysis.

Study Design and Ethics Approval

This cross-sectional study was approved by the Manisa Celal Bayar University Clinical Research Ethics Committee (decision number: 20478486-202 dated 7 May, 2014).

Data Collection

Age, gender, weight and height percentiles, age at CF diagnosis, sweat test and CF mutation analysis results, and bacterial isolation from throat or sputum culture were recorded for all participants. More than one *P. aeroginosa* growth or chronic colonization in sputum culture was considered positive for the presence of *P. aeruginosa*. Thoracic HRCT images taken within the last 6 months were assessed using the Bhalla scoring system (9). IOS and spirometry values were recorded when patients were enrolled to the study. Pulmonary function tests were performed outside periods of acute exacerbations. Patients with congenital or secondary heart disease were excluded from the study.

Evaluation of Clinical Severity

For clinical evaluation of the patients we used the Shwachman-Kulczycki score, which includes general activity, physical examination, nutrition, and radiological findings (10). The criteria used in this scoring system for these four domains are: decrease in endurance, exercise symptoms, and presence of orthopnea for general activity; weight, muscle mass, abdominal distension, abnormal stool, and rectal prolapse for nutrition; digital clubbing, respiration rate, and hyperinflation for physical examination; and atelectasis, hyperinflation, and bronchiectasis as radiographic signs. According to the patient's findings, each domain is scored as 5, 10, 15, 20, or 25. The domain scores are summed to

obtain a total clinical condition score, which is categorized in one of 5 grades as excellent (86-100), good (71-85), average (56-70), poor (41-55), and severe (<40).

Assessment of Pulmonary Function

Classic Spirometry: Spirometry was performed with a Jager MS-IOS (care fusion/Germany) device. Forced vital capacity (FVC) and FEV1, [peak expiratory flow, forced expiratory flow (FEF) 25-75] were measured during respiratory maneuvers. After performing numerous measurements, the result of the trial in which the patient was most cooperative and achieved the best result was chosen for analysis.

Impulse Oscillometry Measurement: IOS was applied with the Jager MS-IOS (master screen IOS, care fusion/Germany) device. The measurements were taken with a device stored in appropriate humidity and temperature and calibrated daily. Prior to measurements, the children were informed about the procedure and trials were done to familiarize them. The patients were asked to sit in a comfortable position, hold their head erect, and breathe normally while wearing a mouth mask. In addition, a technician supported their cheeks and mouth in order to minimize vibrations of the upper airway. The frequencies of the pressure oscillations delivered ranged between 5 to 30 and 30 s measurements were obtained regularly. After performing the maneuver at least three times, the best measurement was recorded. Airway resistance (R, resistance), elastic capacity (X, reactance), and pulmonary impedance (Z) values were recorded at 5, 10, and 15 Hz. Results with values of 0.6 at 5 Hz and 0.8 at 10 Hz in the "validity" section were considered valid (11). Spirometry and IOS results were compared for the evaluation of respiratory functions.

Thoracic HRCT Scoring

CT scans were obtained using a Toshiba (Aquilion) 128 multi-slice CT instrument with parameters of 120 mKV and 180 mA and no contrast with the patient lying in supine position after being instructed to hold their breath for 5 seconds. On average, series of 1 mm thick cross-sectional images were obtained at 10 mm intervals from the lung apex to the base.

The patients' thoracic HRCT images were scored by a pediatric radiologist blinded to their clinical condition and pulmonary function test results. Ten features were identified on thoracic tomography: pulmonary bronchiectasis, peribronchial thickening, mucus plugs, abscess, bulla, emphysema, gas trapping or hyperinflation, mosaic perfusion or opacities, collapse or consolidation, and presence of intralobular or interlobular septal thickening. The modified Bhalla scoring system was used to evaluate these findings (9). Each criterion in the scoring system received 0 points for no pathology and 1 to 3 points if pathology was detected.

Statistical Analysis

Statistical analysis of the acquired data was done using statistical package for the social sciences (SPSS) 18.0 (SPSS Inc., Chicago, IL, USA) package software. Continuous variables were expressed as mean ± standard deviation (minimum-maximum) and categorical variables were expressed as number and percentage (%). Chi-square test was used for comparison of qualitative variables between groups, Student's t-test was used for comparison of data with normal distribution, and Mann-Whitney U tests were used for comparison of data with non-normal distribution. The correlation of the parameters was evaluated with the Pearson correlation test. P-values less than 0.05 were accepted as statistically significant.

Results

Demographic Characteristics

The mean age of the children studied (n=30) was 12.1±4.2 years and 40% were female. The age at CF diagnosis was 3.7±3.4 years. The most common CF mutation among the patients was delF508 (61%), and no mutation could be identified in 5 patients (23%) (Table I).

Clinical Findings

Clinical condition was excellent (86-100) in 40% of the patients, good (71-85) in 30%, average (56-70) in 13.3%, and poor (41-55) in 16.7%. No patients were in severe (<40) clinical condition. *P. aeruginosa* was detected in the sputum cultures of 40% of the patients (Table I). Shwachman scores were lower in the group of patients from whom *P. aeruginosa* was isolated (p=0.001). In the group with high Shwachman-Kulczycki scoring, the resistance value such as R5 R10 R15, which are IOS parameters, was found to be low and X5 reactance value was significantly higher (p=0.016, p=0.037, p=0.042, p=0.047, respectively). In addition, in the group with high Shwachman-Kulczycki score (excellent and good group), FEV1 was found above 80% (p=0.004) (chi-square test).

Pulmonary Function Test Findings

Classic Spirometry Results: FEV1, FVC, FEF25-75 values obtained in spirometry were significantly lower in

patients with *P. aeruginosa* than those without (p=0.002, p=0.002, and p=0.005, respectively) (Table II).

Impulse Oscillometry Results: The *P. aeruginosa*-positive patients showed significantly higher R5 (resistance) and lower X5 (reactance) values (p=0.047 and 0.046, respectively) (Table II).

Patients with FEV1 below 80% exhibited significantly higher R5 and R10 (resistance) values and significantly lower X5 reactance values (p=0.03, 0.027, and 0.006, respectively) (Table III) (Figures 1 and 2).

Radiologic Findings: Bronchiectasis was present in 20 patients (66.6%), peribronchial thickening in 20 (66.6%),

Table I. Demographic and clinical characteristics

	Patient group (n=30)
Age*	12.1±4.2
Gender** Male Female	 18 (60) 12 (40)
CF diagnosis*	3.7±3.4
Mutation** Del F508 (n/%) Other (n/%) Undetectable (n/%)	 18 (61) 5 (16) 7 (23)
*P. aeroginosa*** Positive	 12 (40)
Clinical scores** Excellent Good Mild Average Severe	 12 (40) 9 (30) 4 (13.3) 5 (16.7) 0 (0)

CF: Cystic fibrosis, ***P. aeroginos: Pseudomonas aeruginosa***
*Mean ± standard deviation, **Number (%)

Table II. Comparison of FEV1 and impuls ossilometry values with *Pseudomonas aseroginosa* positive/negative patients

	***P. aeroginosa* (-)**	***P. aeroginosa* (+)**	**p-value****
FEV1* (%)	**102 (32)**	**52.6 (50.68)**	**0.002**
FVC* (%)	**103.0 (35.5)**	**70.5 (51.0)**	**0.002**
PEF * (%)	74 (20)	60.4 (30.28)	0.192
FEF25/75* (%)	**90.5 (36.4)**	**26.5 (51.6)**	**0.005**
R5 %*	**96.1 (42.60)**	**149.5 (76.0)**	**0.047**
R5* [kPa(L/s)]	**0,54 (0.23)**	**0.79 (0.23)**	**0.037**
R10* %	101.0 (43.90)	118.35 (51.50)	0.150
R10* [kPa(L/s)]	0.53 (0.28)	0.51 (0.17)	0.456
R15 %*	93.50 (48.55)	113.70 (29.70)	0.275
R15* [kPa(L/s)]	0.48 (0.20)	0.42 (0.18)	0.347
X5 %*	**37.3 (138.85)**	**172.05 (183.53)**	**0.046**
X5* [kPa(L/s)]	**-0.089 (0.27)**	**-0.28 (0.42)**	**0.05**
X10 %*	134.4 (135.5)	308.30 (286.50)	0.194
X10* [kPa(L/s)]	-0.11 (0.17)	-0.20 (0.16)	0.152
X15 %*	50.6 (93.55)	103.0 (104.95)	0.458
X15* [kPa(L/s)]	-0.078 (0.15)	-0.16 (0.13)	0.164
Z5 %*	**105 (55.2)**	**132 (35.67)**	**0.047**

P. aeroginosa: Pseudomonas aeruginosa, FEV1: Forced expiratory volume in one second, FVC: Forced vital capacity, PEF: Peak expiratory flow
*Median (interquartile range), **Mann-Whitney U test

mucus plaques in 15 (50%), secularization in 6 (20%), bronchial deviation in 20 (66.6%), mosaic pattern in 19 (63%), and collapse in 8 patients (26.6%).

Similarly, patients with FEV1 below 80% showed significantly more severe bronchiectasis, peribronchial thickening, mucus plaques, mosaic perfusion and bronchial deviation compared to patients with FEV1 over 80% (p=0.006, 0.000, 0.012, 0.000, 0.003, respectively) (Table IV) (r=-0.52, -0.61, -0.66, -0.55, -0.30). No significant correlation was found between thoracic score data such as bronchiectasis weight and mosaic pattern presence and IOS values (p>0.05).

The *P. aeruginosa*-positive group also had significantly more severe bronchiectasis, peribronchial thickening, mucus plaques, secularization, bronchial division, and mosaic pattern when compared to patients who were negative for *P. aeruginosa* (p=0.006, 0.00, 0.012, 0.002, 0.003, 0.00, respectively (Table V).

Table III. Comparison of FEV1 values and impuls ossilometry values of patients

	FEV <80% (n=12)	**FEV >80% (n=18)**	**p-value****
R5%*	**160.0 (88.7)**	**98.3 (46.5)**	**0.03**
R5* [kPa(L/s)]	**0.75 (0.37)**	**0.56 (0.34)**	**0.045**
R10%*	**120.1 (53.0)**	**104.5 (34.7)**	**0.027**
R10* [kPa(L/s)]	0.488 (0.09)	0.57 (0.27)	0.388
R15%*	114.0 (49.05)	93.7 (47.43)	0.051
R15* [kPa(L/s)]	0.42 (0.06)	0.49 (0.25)	0.388
X5%*	**176.1 (181.6)**	**45.45 (119.57)**	**0.006**
X5* [kPa(L/s)]	**-0.35 (0.31)**	**0.06 (0.33)**	**0.000**
X10%*	376.6 (512.5)	147.3 (99.8)	0.208
X10* [kPa(L/s)]	-0.23 (0.21)	-0.12 (0.16)	0.09
X15%*	105.0 (125.0)	72.8 (108.1)	0.345
X15* [kPa(L/s)]	-0.189 (0.17)	-0.088 (0.13)	0.214
Z5%*	**140 (47.28)**	**102 (55.53)**	**0.004**

FEV: Forced expiratory volume
*Median (interquartile range), **Mann-Whitney U test

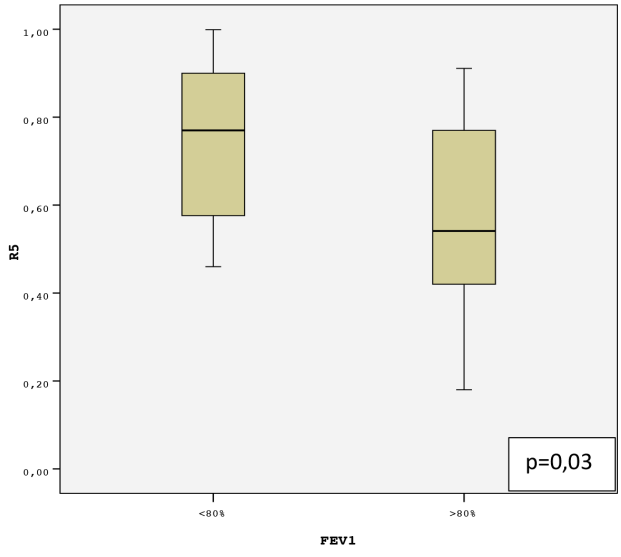

Figure 1. Comparison of FEV1 and R5 values
FEV1: Forced expiratory volume in one second

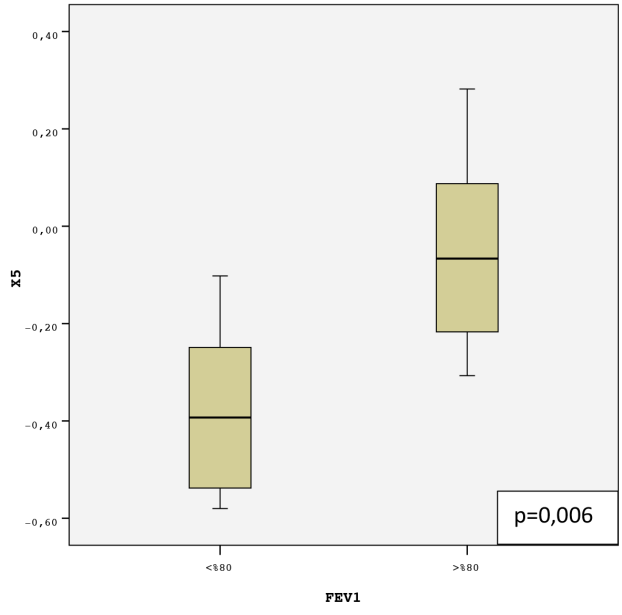

Figure 2. Comparison of FEV1 and X5 values
FEV1: Forced expiratory volume in one second

Table IV. FEV values and thorax HRCT findings in patients with cystic fibrosis

	FEV <80%* (n=12)	**FEV >80%* (n=18)**	**p-value****
Bronchiectasis	**1.90 (1.10)**	**0.75 (0.85)**	**0.006**
Peribronchial thickening	**1.90 (0.99)**	**0.75 (0.68)**	**0.002**
Mucus plaques	**2.0 (0.92)**	**0.5 (0.89)**	**0.000**
Mosaic perfusion	**2.2 (0.91)**	**0.87 (1.02)**	**0.003**
Bronchial deviation	2.4 (1.07)	1.5 (1.46)	0.106
Emphysema	0.40 (0.84)	0.00 (0.00)	0.067
Collapse-consolidation	0.40 (0.69)	0.25 (0.44)	0.509
Bhalla scor	**15.50 (6.5)**	**7.0 (5.55)**	**0.001**

FEV: Forced expiratory volume, HRCT: High resolution computed tomography
*Median (interquartile range) **Mann-Whitney U test

Table V. Thorax HRCT findings and presence of pseudomonas in patients with cystic fibrosis

	***P. aeroginosa* (-)* (n=18)**	***P. aeroginosa* (+)* (n=12)**	**p-value****
Bronchiectasis	**0.70 (0.98)**	**1.75 (0.86)**	**0.006**
Peribronchial thickening	**0.64 (0.70)**	**1.8 (0.83)**	**0.000**
Mucus plaques	**0.52 (1.06)**	**1.58 (0.99)**	**0.012**
Mosaic perfusion	**0.70 (0.98)**	**2.3 (0.49)**	**0.000**
Bronchial deviation	**1.23 (1.43)**	**2.6 (0.6)**	**0.003**
Emphysema	0.11 (0.48)	0.16 (0.57)	0.806
Collapse-consolidation	0.23 (0.43)	0.41 (0.66)	0.384
Bhalla scor	**2.5 (12.50)**	**13.50 (6.50)**	**0.003**

P. aeroginos: Pseudomonas aeruginosa
*Median (interquartile range) **Mann-Whitney U test

Discussion

In the present study, we evaluated the pulmonary functions of 30 CF patients over 6 years old using classic spirometry and IOS and compared them based on the detection of *P. aeruginosa* in sputum cultures and thoracic HRCT scores. Patients with FEV1 <80% in spirometry were found to have significantly higher R5 and R10 values and lower X5 reactance values in IOS. In addition, patients with chronic lung sequelae and *P. aeruginosa* colonization exhibited low FEV1 values and a proportionate increase in resistance and decrease in reactance. However, no significant correlation was found between the findings of chronic lung changes and IOS values.

CF is a chronic disease with progressive lung damage and decline in pulmonary function (1). Respiratory system involvement begins from infancy and lung injury occurs due to chronic inflammation and infection as the disease progresses. Chronic structural changes in the peripheral and central airways also occur in early CF, leading to decline in pulmonary function (11,12). Children who are not diagnosed at an early age, do not receive adequate treatment, and have progressive CF have lower respiratory function and worse quality of life due to early airway injury. Providing airway clearance therapy, practicing microbial surveillance and strategic antibiotic use in pulmonary infections, and properly monitoring pulmonary functions from the early stages are crucial for a better prognosis (13-15). Therefore, sensitive, minimally invasive tests are needed to demonstrate early pulmonary involvement and function in young children. Data regarding the follow-up of lung function in young children is limited due to the difficulty of performing pulmonary function tests in this age group. In some studies, pulmonary function in infant and preschool-aged CF patients was assessed with rapid expiratory flow and volumetric measurements using thoracoabdominal compression techniques. This method is difficult to apply, but has been used to show that airway resistance

increases between infancy and preschool age (16,17). Other studies have also evaluated pulmonary functions with gas techniques (multibreath washout), and although important data have been obtained regarding disease progression, they are difficult to apply and thus have been adopted in routine practice (15). After reaching school age, compliance with classic spirometry and regular FEV1 measurements enables monitoring of respiratory functions in these patients (18). However, the early onset of disease and patient non-compliance limit the use of this method. IOS is a pulmonary function test method that requires minimal patient cooperation, can be measured during normal breathing, is easy to apply, and evaluates airway resistance and elastic capacity. There are few studies regarding the use of IOS in patients with CF. In a study by Gangell et al. (19) including 56 CF patients, IOS resistance values were higher and reactance values were lower in CF patients compared to controls. In a study using spirometry and IOS to evaluate 49 CF patients during periods of acute exacerbation and remission, the patients showed higher R5,10,15 resistance values and lower X5,10,15 reactance values compared to the control group, and acute exacerbation was also associated with higher resistance values and lower reactance values within the patient group. The same study also determined that changes in IOS values were consistent with spirometry values (20). In another study comparing the spirometry and IOS values of CF patients, R5 resistance value was negatively correlated with FEV1 value, while no significant correlations with reactance value could be shown, and the authors stated that IOS could provide an alternative method to spirometry (21). Conversely, in another study evaluating IOS in the assessment of pulmonary function in CF patients, it was observed that although IOS parameters correlated with spirometry values, the results were not consistent with age-standardized parameters such as FEV1, and therefore the authors concluded that the technique was not reliable enough (22). A comparison of spirometry and IOS results in 34 CF patients during acute pulmonary exacerbation and remission demonstrated that despite a correlation between IOS and spirometry values, there were no significant differences in IOS measurements between acute exacerbation and remission periods (23).

In our study, a significant relationship was found between FEV1 value and R5 and X5 values, which show airway resistance and flexibility in small airways, and this relationship was observed to continue significantly in patients with FEV1 <80%. Although there are no safe values for age and gender in the grading of pulmonary insufficiency for IOS yet, it will be useful to follow these values in the long-term clinical follow-up of CF patients, especially those who are at an early age and cannot perform classical spirometry.

The thick secretions and inflammatory process of CF create a suitable environment for chronic infection, and thus play an important role in the mortality and morbidity of the disease. *P. aeroginosa, Staphylococcus aureus (S. aureus), Haemophilus influenza (H. influenza), and Stenotrophomonas maltophilia* are most commonly implicated in the pathogenesis of permanent parenchymal damage. In many studies, the use of broad-spectrum, and especially anti-pseudomonal antibiotics has been associated with improved respiratory function and increased life spans in CF patients (24). While infection and inflammatory processes cannot be clearly distinguished in these patients, reduced lung function and decreased FEV1 has been observed in those with pseudomonal infection or colonization (14). In a retrospective study of 770 CF patients, those with *P. aeruginosa* and methicillin-resistant *S. aureus* colonization showed reduced lung function and higher mortality and morbidity (25). In another study, the detection of proinflammatory pathogens (*P. aeruginosa*, *H. influenzae, Aspergillus* spp., *Streptococcus pneumoniae*) in bronchoalveolar lavage from young CF patients was clinically associated with deterioration of pulmonary function (26). In the present study, spirometry values (FEV1, FVC, FEF25-75) were lower in patients with *P. aeruginosa*-positive sputum cultures, while R5 resistance values were significantly higher and X5 reactance values were lower in IOS. Therefore, in CF patients with infectious colonization for whom FEV1 is being used to monitor pulmonary function, IOS can also be safely used to demonstrate pulmonary functions such as airway resistance and elastic capacity.

Several prospective studies have shown that pulmonary parenchymal changes, including bronchiectasis, may occur in CF during infancy and may be more common in patients with infection and inflammation during the first year of life, and that bronchiectasis was associated with increased morbidity and reduced pulmonary function (15,27). Because bronchiectasis and other accompanying chronic sequelae are sensitive indicators of disease progression, CT is used as a sensitive method for the early detection of pulmonary changes (27). In addition, many studies have reported that HRCT enabled more sensitive and earlier detection of pulmonary progression compared to spirometry. A positive correlation was also observed between bronchiectasis severity and infectious colonization (28,29). A study in which 31 CF patients were prospectively monitored by spirometry

and assessed by repeated HRCT scoring over a period of 4 years showed that HRCT progression preceded the deterioration of spirometry results (29). Similarly, another study evaluating 87 CF patients showed that thoracic HRCT findings were more sensitive than pulmonary function tests in detecting early and small changes in the lungs (30). In the CF patients in our study, we found a significant correlation between the degree of decline in thoracic HRCT scores and FEV1 values, and these patients also exhibited an increase in R5 and R10 resistance values and decrease in X5 reactance values. However, no significant correlation was found between the weight of chronic changes such as bronchiectasis weight or mosaic pattern presence and IOS parameters. For this situation, it is thought that more studies with more cases are needed.

Many scoring methods were used to evaluate the clinical severity of the disease. The Shwachman-Kulczycki score is a useful tool to monitor the severity of CF, which also adequately reflects chest radiography changes, especially in patients with marked lung dysfunction (31,32). Although it does not take into account the pulmonary function test, it is still the most commonly used score. In our study, higher spirometry values were found in patients with excellent-good score, and it was also found to be associated with lower resistance (R5, R10, R15) and higher reactance (X5) values.

Study Limitations

The small number and diversity of cases in our study is an important limitation. Despite this, the study demonstrated the use of IOS as a reliable tool for disease monitoring in children with CF.

Conclusion

In conclusion, deterioration of pulmonary function and worsening of thoracic HRCT scores can occur from infancy in CF patients; therefore, monitoring pulmonary function from an early age is crucial in these patients. The combined use of clinical, spirometric, and HRCT radiological methods as a global assessment of pulmonary function may yield more realistic results. In addition, IOS may be used in the follow-up of pulmonary disease in CF patients to detect decline in respiratory functions from early ages, and even before the appearance of significant clinical findings. However, there is a need for more prospective studies which involve the comparative evaluations described herein to standardize IOS thresholds for young children.

Ethics

Ethics Committee Approval: This cross-sectional study was approved by the Celal Bayar University Clinical Research Ethics Committee (decision number: 20478486- 202 and dated 7 May, 2014).

Informed Consent: Informed consent was taken from the participants.

Peer-review: Internally and externally peer-reviewed.

Authorship Contributions

Data Collection or Processing: A.K., E.E.Ö., Y.Ş., Analysis or Interpretation: E.T.K., Ö.Y., A.K., H.H.A., Writing: E.T.K., Ö.Y., H.Y.

Conflict of Interest: No conflict of interest is declared by the authors.

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