Early View

Research letter

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Research Letter

Comparison of Forced Oscillation Technique and Spirometry in Paediatric Asthma

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Conflict of Interest

The authors have no conflict of interest in relation to this work

Author contributions

EL performed the analysis and wrote the manuscript, GK and RI designed the study, participated in analysis and writing of the manuscript, ST performed the patient testing and participated in writing of the manuscript. All authors have accepted the final version of this manuscript.

Funding

EL acknowledges post-doctoral grants from Paediatric research foundation Finland and Tampere tuberculosis foundation.

Key words Respiratory function tests; feasibility study; correlation study

Take home message
Evaluation of airway obstruction with forced oscillations technique can be an adjunct to spirometry or used even as a primary method in those children unable to perform spirometry.
The Global Initiative For Asthma guidelines emphasize the use of spirometry in diagnosing and monitoring asthma in children from six years-of-age onwards. Spirometry requires good cooperation and younger children are sometimes unable to perform repeated forced expiratory blows. Alternative pulmonary function measurements, such as forced oscillations technique (FOT), are increasingly more available for children at preschool age. FOT measures lung function by imposing small soundwaves over tidal breathing through a mouthpiece, where pressure and flow changes in the airways are measured to derive respiratory system properties. The first study on bronchodilator responses by FOT in preschool-aged children was published already two decades ago. Guidelines endorse the use of respiratory oscillometry in diagnosing and following-up asthma in young children, and it has shown potential in predicting loss of asthma control in older children and adolescents. However, little is known how FOT indices correlate with flow-volume indices, when this technique is used in adjunct with conventional spirometry.

Children’s respiratory assessment laboratory in Evelina London Children’s Hospital has been using a commercial FOT application with fixed frequency at 8Hz oscillations input. We hypothesized that baseline and post-bronchodilator lung function measurements by FOT would have a mutual relationship with spirometry measurements obtained at the same visit, in children with moderate to severe asthma. In addition, we aimed to investigate agreement between the two methods regarding bronchodilator responsiveness (BDR).

Measurements were collected from a tertiary level asthma clinic between January and June in 2017. Data consist of 72 sequential clinic visits from an ethnically diverse regional population. First, baseline FOT (Resmon Pro, MGC diagnostics, US) measurement at 8Hz was performed with patient’s cheeks supported by a technician, according to current guidelines. Respiratory system resistance (Rrs8) was expressed as age-specific height-adjusted reference-values (Z-scores), using two different reference equations for 3-12-year-olds and for 13-17-year-olds. Then, baseline spirometry (EasyOne Pro Lab, NDD, Switzerland) was obtained, and forced vital capacity (FVC), forced
expiratory flow in one second (FEV₁), FEV₁/FVC-ratio and forced expiratory flow at 25-75% of forced vital capacity (FEF₂₅₋₇₅) were expressed as multi-ethnic reference values (Z-scores)¹¹. After 15 minutes from salbutamol (400μg) administration, the children were studied repeatedly with FOT and spirometry. Relative increases in FEV₁ ≥12% from baseline¹² or relative decreases in Rrs8 ≤ -32% from baseline defined abnormal BDR⁹. Clinical data on age, gender, ethnicity and use of asthma medication prior the testing were available. Statistical analyses were performed with SPSS (Statistical Package v. 26, IBM, USA). The results are expressed as means and standard deviations (SD) for continuous, and numbers and frequencies for categorized variables. Analysis of variance was used in the analysis of continuous, Fischer’s exact or Chi Square in the analysis of categorized variables, as appropriate. Bivariate correlations (R) were reported with Pearson coefficient for normally distributed, and with Spearman coefficient for non-normally distributed data.

All data were extracted retrospectively from de-identified clinical physiology reports. Ethical approval and data protection were provided by Evelina London Children’s Hospital local directorate review board (Guy’s and St Thomas’ NHS Foundation Trust, reg-nr 8901).

Seventy-two patients were measured during uninterrupted maintenance medication for asthma. Mean age was 10.9 years (SD 3.6) with range from 3.8 to 17.7 years. All 72 children were able to perform baseline FOT measurement. Six children (7.9, SD 5.0 years) were not able to produce repeatable spirometry, resulting in 66 (91.6%) measurements with both baseline tests. 18 children were unable to proceed to post-bronchodilator measurements due to clinical reasons (poor baseline performance, lack of time, non-co-operation). These children were on average younger (8.8, SD 3.7 years) compared to the 54 (75%) children who were able to perform both baseline and post-bronchodilator tests (11.6, SD 3.3 years, p=0.003). In these 54 cases (51.9% male), reported ethnicities were 41% Black, 46% Caucasian and 13% Asian, measured height 146 cm (SD 17.4) and weight 43 kg (SD 18.0). Thirteen (24.1%) reported use of bronchodilator within the last 12h before BDR testing.
In 54 children with both lung function tests available, baseline spirometric indices were abnormal (≤-1.65 Z-scores) in FEV1 in 21 (38.9%), FVC in 6 (11.1%), FEV1/FVC in 26 (48.1%) and FEF25-75 in 21 (38.9%) cases. After bronchodilation abnormal FEV1 was found in 9 (16.7%), FVC in 5 (5.3%), FEV1/FVC in 9 (16.7%) and FEF25-75 in 11 (20.4%) cases. Bronchodilator administration increased FEV1 on average from -1.19 (1.44 SD) to -0.40 (1.21) Z-scores, FVC from -0.33 (1.14) to -0.01 (1.07) Z-scores, FEV1/FVC from -1.64 (1.71) to -0.71 (1.24) Z-scores and FEF25-75 from -1.45 (1.48) to -0.47 (1.53) Z-scores. In FOT resistance at 8 Hz was abnormal (≥+1.65 Z-scores) at baseline in 20 (37.0%) cases and after bronchodilation in 5 (9.3%) cases. Rrs8 decreased on average from 1.21 (1.85 SD) to -0.73 (1.87) Z-scores respectively.

Statistically significant baseline FOT and spirometry bivariate correlations are presented in figure 1. Baseline respiratory system resistance at 8 Hz was significantly related with FEV1 (R=-0.56, p<0.001), FEV1/FVC (R=-0.61, p<0.001) and FEF25-75 (R=-0.63, p<0.001) but not with FVC. Post-bronchodilator Rrs8 was related with FEV1 (R=-0.38, p=0.005), FEV1/FVC (R=-0.35, p=0.01) and FEF25-75 (R=-0.36, p=0.008) but not with FVC. In BDR comparisons, decrease in Rrs8 was related with increase in FEV1 (r=-0.46, p<0.001) (Figure 1).

There were 11 (20.4%) children positive in BDR by FOT and 20 (37.0%) positive in BDR by spirometry. BDR tests were in concordance in 76% (41/54 vs. 13/54, p<0.001). Two cases (3.7%) were negative in spirometry but positive in FOT, and 11 (20.4%) positive in spirometry but negative in FOT. There were no significant differences in age, sex, ethnicity, height, weight, BMI or use of any bronchodilator before the BDR between cases with test agreement and disagreement (data not shown).

There were three main findings when evaluating the relationship between FOT and spirometry in asthmatic children. Firstly, baseline lung function tests showed moderate correlations between respiratory system resistance at 8 Hz and FEV1, FEV1/FVC and FEF25-75 but not with FVC. Second, there was a fair consistency between BDR defined by relative change in resistance at 8 Hz and change
in FEV₁ from baseline. Thirdly, all children were able to perform FOT whereas the younger were not able to perform spirometry.

Linear relationship between FOT and spirometry was strongest in baseline indices describing peripheral obstruction, i.e. FEV₁/FVC and FEF₂₅₋₇₅. This reflects our study population demonstrating significant reversible obstruction. Similar magnitudes of correlation (-0.51– -0.71) have been described between baseline FEV₁ and Rrs at 5 Hz using impulse oscillometry¹³,¹⁴, but literature comparing FOT and spirometry in children is scarce. In BDR, a negative correlation of -0.46 was in line with previously reported relationship between Rrs₈ and FEV₁¹⁵.

There was a moderate agreement with BDR comparisons between FOT and spirometry, with 13 outliers having either a pathological response in Rrs₈ or FEV₁, but not both. No clear demographic factor was found to be associated with test disagreement. BDR by spirometry seemed to pick up more cases, and discrepancies in BDR between two methods may be related to technical and physiological factors. Bronchodilation changes in oscillometric indices are mathematically more dependent from baseline than spirometric indices. For example, when airway obstruction is present, FOT baseline Rrs₈ is higher and the decrease due to bronchodilation is relatively smaller in percentage, whereas FEV₁ on the contrary shows more marked improvement in relation to baseline.

On the other hand, oscillometry is thought to be more sensitive to peripheral airways obstruction compared to spirometry, and previously baseline measurements rather than BDR with impulse oscillometry were more effective in distinguishing uncontrolled asthma status in children¹⁶. As a limitation to more specific FOT analysis, reactance data was not available in this study.

We aimed to look at clinical performance and consistency of FOT and spirometry findings in children followed-up at a tertiary level asthma clinic. Both baseline tests were available from 92% of children and 75% children had both tests accepted after bronchodilation. The time to obtain two consequent measurements was limited, and performance at baseline may have affected if testing was continued further. This data was not fully recorded and thus direct feasibility comparisons were not available.
In conclusion, FOT showed moderate correlations with spirometry indices, and was accessible to children with moderate to severe asthma. The findings support the use of FOT in adjunct with spirometry and even as a primary method in younger asthmatics unable to perform spirometry.

**Figure 1.** Bivariate correlations of baseline Rrs8 with FEV₁, FEV₁/FVC, FEF₂₅-₇₅ and relative change of Rrs8 (line: cut-off -32%) from baseline against relative change of FEV₁ (line: cut-off +12%) from baseline in 54 children with moderate to severe asthma at mean age of 11.6 years.

**REFERENCES**


