DEALING WITH SPIROMETRY IN CHILDREN UNDER SIX YEARS OF AGE: CHALLENGES AND OPPORTUNITIES IN ASTHMATICS

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ABSTRACT
Pulmonary function tests are essential in the diagnosis of asthma but these are seldom performed in preschool children. Although pulmonary function tests are critical to the diagnosis and follow up of asthmatics, there are challenges faced when dealing with the child under the age of six years and this leads to the under-utilisation of these tests. There is now a better understanding of the respiratory physiology in children and newer spirometry equipment is available with updated reference values for the paediatric age group. In this article the current literature, with regards to spirometry in the pre-schooler, is reviewed and its value in the young asthmatic child is stated.

INTRODUCTION

Spirometry measurements are essential in monitoring severity and recovery from an acute asthma attack and can serve as a guide for optimal management, especially in those with more severe disease. It is an inexpensive and reliable test that is commonly used in children over six years of age and teenagers. Studies have shown that children between three and five years of age are able to perform acceptable tests,[1] with animated incentive devices and skilled operators,[2] and without sedation. Spirometry parameters are influenced by weight, sex, height, ethnicity and environmental factors. A variety of other methods, other than spirometry, are being used to assess lung function in these children. These include gas washout techniques and tidal breathing techniques. However, these will not be discussed in this review.

TECHNICAL REQUIREMENTS

EQUIPMENT

Spirometers must be capable of measuring instantaneous flows with an accuracy of at least 5% and dead space should be minimised. Maximal forced expiration can be achieved in preschool children, by using incentive spirometry computer programmes with animation, in children as young as 2 years of age. When using interactive computerised incentives to encourage these manoeuvres, volume-driven incentive or flow may be used. These incentives provide motivation for the child to breathe maximally and to deliver maximal force from the beginning to the end of exhalation. They also aid the attention span of young children, which is short, and they may aid in improving the cooperation of the child.[3] Nose clips should be used, and this should be carefully explained to the child. The use or non-use of nose-clips, should be recorded. The technologist should observe the child closely to ensure that there is no leak. The position in which the test is done, i.e. standing or sitting, should also be recorded. The child should wear loose fitting clothing which will not restrict their breathing.

When performing spirometry it is critical that correct spirometric reference equations are utilised. The European Respiratory Society and American Thoracic Society have endorsed the implementation of global lung initiative (GLI), all age, reference equations, which include data for children as young as 3 years of age. The GLI reference equations have provided more standardised measurements which are adjusted according to sex, age group, ethnic groups, FEV_1 and FVC. These have streamlined the interpretation of spirometry results within, and between, populations worldwide.[12] In this large study, data was obtained from 33 countries from most continents except Africa. It is recommended that the spirometry reports in children should be expressed in centiles or Z-scores and currently the reference equations are recommended. There is an urgent need for African data to be obtained and to be included.

PERSONNEL

It is critical that the operators must have the ability to gain the trust of the child and obtain measurements without causing distress. The environment in which testing is done should also be child-friendly. Lung function technologists should have experience in performing testing in very young children, as this usually guarantees the best results.

CRITERIA FOR ADEQUATE SPIROMETRIC MEASUREMENTS

Body size is an indirect measure of lung size, the bigger the body size, the better the lung function measurement.

The weight and height of the child should be measured as accurately as possible and preferably with the same equipment each time. Standing height is preferable, but if not possible the arm span can be used. Young children are not sufficiently cooperative to cope with a great number of tests, which may lead to tiredness or boredom. A maximum of three attempts should be used for this age group.[4] To ensure the best results, the child should be familiarised with the equipment and technician.[5]

Figure 1. Familiarising children with spirometric equipment

It is recommended that the technician should be able to view flow-volume curves especially before the next expiration attempt,[5] and the following indices from each spirometry attempt should be available before the next attempt: forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), back-extrapolated volume (VBE) and peak expiratory flow (PEF).

A minimum of three manoeuvers should be recorded, if VBE is greater than 80ml, or 12.5% of FVC then the curve should be inspected but not necessarily excluded. The highest FEV_1 and FVC should be reported after examining data from all usable curves, even if they do not come from the same curve. The starting point for FEV_1 should be determined by back extrapolation. Ideally the subject should produce at least two acceptable curves, where the second highest FVC and FEV_1 are within 0.1 L or 10% of the highest value. If a single satisfactory manoeuver is recorded, then these results should not be excluded, simply because of poor repeatability. The number of technically satisfactory manoeuvers and repeatability results should always be reported.

Acceptability criteria for pre-schoolers differ from adults.[7] Firstly, young children have smaller absolute lung volumes and larger airway size, relative to lung volume. Secondly, forced expiration is completed in a shorter time, rather than the six seconds, recommended for adults. Young children often do not exhale for more than one second, therefore FEV_1 may not be an accurate index of bronchial obstruction. Recent studies have revealed the utility of $FEV_{0.5}$ and $FEV_{0.75}$ as an outcome measure in this group.[8] Thirdly, the start of a test in adults is assessed by measuring the VBE either as an absolute, or as percentage of FVC, but in children VBE is much lower and the ratio VBE/FVC is higher. The FEV_1/FVC ratio is considered as a reference parameter for detecting obstructive airway disease, but is not well suited for young children.[6]

SPIROMETRY IN ASTHMATIC CHILDREN

Asthma is a chronic reversible obstructive airway disease and is the most common childhood disease, a major public health concern, and increasing in prevalence in children.[9] The diagnosis of asthma in pre-school children is a challenge. Although clinicians can identify airflow obstruction clinically based on assessment of symptoms and physical findings, this does not assess reversibility of airway obstruction. Spirometry is the gold standard for the diagnosis and management of asthma, and its greatest value in the diagnosis of asthma, is the documentation of airway reversibility with short-acting bronchodilators. FEV_1 is the most sensitive measure of bronchodilator reversibility. The bronchodilator effect can clearly be demonstrated in children with moderate to severe asthma. Airway reversibility should be performed with the administration of a short-acting β2-agonist and should demonstrate an increase in FEV_1 of more than 12% to confirm the diagnosis of asthma.[10]

Table I highlights the various indications for spirometry in the asthmatic pre-schooler.

Table I. Indications for spirometry
To diagnose asthma by demonstrating airway reversibility
To measure the effect of disease on pulmonary function
To assess prognosis
To assess therapeutic intervention
Clinical research

Source: adapted from Miller RM *et al*.[5]

There is no absolute contra-indication to spirometry, but conditions such as haemoptysis of unknown origin, pneumothorax, aneurysm and recent abdominal surgery

are relative contra-indications.

In terms of interpretation of spirometry results, the identification of spirometry patterns must be assessed and these can be normal, obstructive, restrictive or mixed. Assessment of acceptability and repeatability is mandatory. There are two graphs that should be visualised, i.e. the flow-volume and volume-time curve. The flow volume curve is particularly used for evaluation of the initial part of the FVC manoeuvre and the volume-time curve for the latter part of the FVC manoeuvre. In pre-school children, the plateau is not well defined. Reporting may need to be tailor-made for this group, e.g. $FEV_{0.5}$ or $FEV_{0.75}$. FVC and PEF decrease with severity of symptoms, which indicate elevation of functional residual capacity as a strategy for breathing or elevation of residual volume (RV) due to air trapping. The grading of the severity of airway obstruction is possible in young children according to FEV_1 percentage predicted. FEV_1 less than 100% but greater than 80% indicates mild obstruction; FEV_1 between 30% and 50% indicates severe obstruction and FEV_1 less than 30% indicates very severe obstruction.

Other tests are available for use in this population group and include the interrupter technique, forced oscillometry, multiple breath inert gas washout, exhaled nitric oxide and plethysmography. Most of them are expensive and not feasible for young children and are certainly beyond the scope of this article.[13]

CONCLUSION

Spirometry is an ideal method for both clinical and research application in young children. It reflects the function of airways and is easy to perform with satisfactory repeatability. Despite all the challenges, the quality of spirometric measurements depends on the quality of equipment and testing procedure and is aided by the use of incentives to aid in the performance of spirometry. Most young children are able to perform acceptable spirometry and its use should be encouraged by all physicians treating children with asthma.

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