Diagnostic Spirometry in Pediatric Population

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ABSTRACT

Pediatric respiratory diseases are accountable for significant mortality and morbidity in smaller age groups. Out of the various pulmonary functions tests available, spirometry is considered to as an easier and useful tool in the diagnosis and monitoring of various pediatric respiratory diseases. This conceptual review on spirometry briefs the utility of spirometry in the pediatric population and the importance of addressing it's under-utility in the medical fraternity.

Keywords: Pulmonary function tests, Spirometry, Pediatrics.

1. INTRODUCTION :

Pulmonary function tests (PFTs) are a group of diagnostic tests, useful for the diagnosis and monitoring of patients with unexplained respiratory symptoms and known respiratory diseases. Respiratory diseases are considered to as the major cause of most pediatric hospital visits and hospitalizations around the globe, accounting to significant morbidity and mortality. Various professional bodies and organizations like National Asthma Education and Prevention Program, Global Initiative for Chronic Obstructive Lung Disease (GOLD), and American Thoracic Society (ATS), recommend the use of these tests [1-3]. According to its physiological application, PFTs are comprised of three focused components: diagnostic spirometry, lung volumes and diffusing capacity.

We intend to do a conceptual review of diagnostic spirometry in the pediatric population in relation to the principles, approach, and technical considerations.

The term 'spirometry' was originally combined from the Latin word 'spiro' means 'to breathe' and the Greek word 'metron' means 'measure'. Spirometry is one of the most commonly used tests for assessing lung function. This physiological test measures how an individual inhales or exhales volume as a function of time [4]. It is an important tool for assessing respiratory mechanics, both in terms of the airway as well as parenchymal involvement. Spirometry parameters are subjective to height, weight, age, gender, environmental factors, ethnicity, patient cooperation and effort, and technical factors [5, 6]. In all the age groups, spirometry is mainly performed to identify the involvement of obstructive or restrictive patterns in the respiratory system. Although it is observed that performing spirometry is a doable task in children in the primary care setting [7, 8] it is often underused in the pediatric population [9].

One of the major factor that decides the success of any PFT often depends on the child's age [10]. Assessment of pulmonary function in infants and younger children is more challenging as not included routinely in clinical examinations considering the need of sedation [11]. It is understood that, since the age of six, children usually would be able to undergo the same examinations as adults [12]. Although conventional PFTs can already be attempted in children aged two to five years, it is reflected that the performance may not be optimal and reliable interpretation may not be obtained [13].

Previously, spirometry was considered to as difficult to perform in preschoolers (2–6 years), due to the inability to perform voluntary breathing maneuvers as efficiently as older children and adults. However, in the present, it is observed that, with the availability of better equipment and modified criteria of

acceptability and repeatability, spirometry is a reliable and achievable test even in preschool children if done by trained personnel [14-17].

2. TYPES :

Technically, a wide range of spirometers from various manufacturers are currently available in the market; that ranges from the basic handheld spirometers to the one which can provide graphs and to the most hybrid spirometers connectable to computers and has built-in printers.

There are two types of spirometers based on their working principle: (1) those that record the amount of air exhaled or inhaled within a certain time i.e. volume based spirometry and (2) those that measure how fast the air flows in or out as the volume of air inhaled or exhaled increases i.e. flow based spirometry.

Volume spirometers record the forced expiratory maneuver as it is produced. When the subject breathes into a mouthpiece, the air moves a cylinder, a plastic bell, or a rubber or plastic diaphragm, which in turn moves a pen that traces a curve on a moving paper graph. The water seal, dry rolling seal, and bellows spirometers are the three most widely used types of volume spirometers. Flow spirometers measure how quickly air flows past a detector and then derive the volume by electronic means. They record the flow rate at very brief intervals and use the data obtained to reconstruct the flow rate at each point in time and volume. The most common types of flow spirometers are the pneumotachographs, ultrasonic based, turbine based and hot wire anemometers.

Diagnostically, there are static spirometry and dynamic spirometry. Static spirometry detects lung volumes like tidal volume, inspiratory reserve volume, expiratory reserve volume and inspiratory capacity, which are involved in the process of ventilation. Whereas dynamic spirometry explains the relationship between; volume and time, and the flow and volume. Dynamic spirometry is conducted by certain forced respiratory maneuvers and parameters like forced vital capacity (FVC), forced expiratory volume in 1st second, FEV1/FVC ratio (Tiffeneau-Pinelli index), peak expiratory flow (PEF), peak inspiratory flow (PIF), forced expiratory flow at 25% of FVC (FEF25), FEF50, FEF75 and maximum mid-expiratory flow between 25% and 50% of FVC (FEF25–75) [9-11] [18-20]. These parameters are normalized to BTPS conditions, i.e. the values are given at 37◦C, ambient pressure, saturated with water vapor [18].

3. INDICATIONS :

Some of the commonest indications of pediatric diagnostic spirometry include chronic cough, persistent wheezing [21], diagnosis and prognostication of asthma [22, 23] and cystic fibrosis [24, 25]. Similar to adults, it has been observed that spirometry plays an important role in assessing the control of asthma and disease activity of cystic fibrosis in children. Pre-operative spirometry is found to be helpful in assessing the post-operative lung status of the pediatric population [26].

Spirometry is also found to be useful in assessing the pediatric lung function, in transfusion-dependent thalassemia major [27]and sickle cell anemia [28], connective tissue disorders and chest wall deformities. Spirometry is considered as an effective tool for assessing the lung health of school going children [21].

4. CONTRAINDICATIONS :

Some of the relative contraindications of spirometry include; hemoptysis of unknown origin, pneumothorax, hemodynamic instability, pulmonary embolism, thoracic, abdominal or cerebral aneurysms, recent eye surgery, presence of an acute illness or symptoms that might interfere with test performance (e.g. influenza, nausea, vomiting); and recent thoracic or abdominal surgery [29].

5. TECHNIQUE :

The entire process and procedure must be informed to the child. The child is positively reinforced and demonstrate full commitment during the test, especially during the forced expiratory maneuver. The child is required to sit quietly and perform tidal breathing until a steady state/ stable end-expiratory level is achieved. At first, the slow vital capacity (SVC) maneuver is carried out: The child exhales slowly as much as possible to attain ERV, then maximally inhales to reach inspiratory vital capacity and, finally, exhales slowly and fully to expiratory vital capacity. Instruct the child to continue with normal tidal breathing. Then the maneuver for expiratory

FVC is carried out. After a complete exhalation and inhalation, the child is asked to exhale all the air as fast and as long as possible. The last phase renders FVC, FEV1, FEF25, FEF50, and FEF75. Three acceptable maneuvers usually performed for standardization [30]. In case of smaller children and infants, it is difficult to perform these maneuvers, in contrast to children of preschool and school age. Hence it is advised to perform spirometry during tidal breathing, as literature shows that a regular breathing pattern can best be achieved during natural sleep or in a state of sedation [31, 32].

6. ACCEPTABILITY :

American Thoracic Society (ATS) and European Respiratory Society (ERS) have put forward amendments in regard to the pulmonary function assessment of preschoolers [33]. It is been suggested that an extrapolated volume of <80mL or 12.5% of the FVC is acceptable as a good start in the preschool population.

In case of school going children, a minimum of three satisfactory spirograms are expected to achieve whereas, in preschool children, two acceptable spirograms are sufficient if the second highest FVC and FEV1 are within 100mL or 10% of the highest value, whichever is greater [18, 33]. Preschoolers are expected to have a short forced expiratory time, with a mean of 1.7 seconds [34]. Hence it has been suggested, to utilize FEV at 0.5^{th} second and FEV at 0.75^{th} second in preschool children [33].

7. INTERPRETATION :

The qualitative and quantitative results of spirometry allow the clinician to have a first impression on the patient's respiratory disorder. The first interpretation of spirometry is done with a qualitative analysis of the flow – volume and volume – time curves. The adequacy of these curves let the clinician to consider the quantitative results. In case of infants and small children, it was observed that tidal flow–volume loops are mainly examined, for their shape and the generation of simple measures, like the time to peak tidal expiratory flow to expiratory time ratio. This index has been used as a measure of lung function in healthy infants and in infants with asthma and severe chronic lung disease of prematurity [35]. Healthy children were differentiated from asthmatic children using this approach and the reversibility of airway obstruction was also identified [32].

The interpretation of spirometry is generally based on difference observed between the predicted values and measured values of parameters like FVC, FEV1, FEV1/FVC ratio, and FEF 25-75%. The difference observed based on these criteria suggest one of the four types of ventilation patterns: normal, obstructive, restrictive, or mixed pattern [36, 37]. The patient is said to have a normal lung mechanics, if the; FVC is >80% of predicted value or above the lower limit of normal value, FEV1 is >80% of predicted value or above the lower limit of normal value; and FEV1/FVC is >70%. The patient is said to have an obstructive airway pattern, if the; FEV1 is <80% of predicted value or below the lower limit of normal value; FEV1/FVC is <70%; Mid-expiratory flow (FEF 25-75% < 60%); and a normal or decreased FVC, according to severity of airway disease [38-42]. The patient is said to have a restrictive lung pattern, if the; FVC is <80% of predicted value or below the lower limit of normal value; FEV1 is normal or <80% of predicted value or below the lower limit of normal value; and a normal or increased FEV1/FVC ratio. The mixed pattern has a decreased value of all three parameters (i.e. FEV1, FVC, and FEV1/FVC). Post bronchodilator response may be used to confirm the reversibility of the obstructive pattern in spirometry. Before conducting a bronchodilator test it has to be ensured that the patient has not used any nebulized short/long β2-agonist in the past 6 hours and 12 hours. Bronchodilator response is assessed after 15 minutes of nebulized short acting bronchodilator. A spirometric response of >12% improvement in FEV1 or 15–25% improvement in FEF 25-75% is suggestive of reversibility of airway obstruction which is characteristic of asthma [38].

8. CONCLUSION :

Spirometry is a useful tool in assessing the lung function of a patient, be it obstructive or restrictive in origin and to differentiate the etiology of the patient's respiratory symptoms. Although it is beneficial in diagnosing and monitoring various pediatric respiratory diseases but is underused by treating physicians

and pediatricians. It is understood that with most of the current devices children can easily perform spirometry and that includes preschoolers too. Spirometry is a tool that can be implemented in pediatric practice after proper training for physicians and staffs who are responsible for it. This helps the physicians and staffs to have an understanding of the common pitfalls in the performance, reporting, and interpretation of results, and thereby correlate the results with the particular clinical scenario.

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