Review article

Lung function assessment in preschool children; a review of the utility of basic spirometry, interrupter technique and forced oscillation technique

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Objective lung function assessment in preschool children is a challenge; the mechanics of the lungs are changing rapidly with advancing age and maturation, the population is too old to ethically justify routine sedation prior to lung function assessment, as in infants, and also, they are too young to be able to focus sufficiently and perform elaborate respiratory manoeuvers required by commonly used lung function tests in older children and adults. But, clinically, a clear evidence based demarcation between isolated non-significant episodes of respiratory symptoms and pathognomonic symptoms is vital for the management. Even though many different lung function techniques are commonly used in the assessment of preschool children, the purpose of this review is to evaluate three commonly used pulmonary function tests, viz. basic spirometry, interrupter technique and forced oscillation technique in order to assess their usefulness in preschool children. We conclude that contrary to common misbelief, ample evidence exists that preschool children are capable of performing lung function tests. Basic spirometry, which stood the test of time, remains one of the most commonly used lung function tests. The interrupter technique and the forced oscillation techniques are quickly gathering reputation as reliable alternatives for lung function assessment in preschool children, especially due to the minimal co-operation required from the subject and the versatility of the test. These techniques will enable definitive diagnosis, assessment of severity and the therapeutic response of multiple, complex and often challenging clinical respiratory conditions to enable efficient management.

Keywords: spirometry, interrupter technique, forced oscillation technique, obstructive airway disease, asthma

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Introduction

Objective assessment of lung functions in preschool children is vital not only because significant development and maturation occurs in the lungs during this period1 but also because clinically a clear evidence based demarcation between isolated non-significant episodes of respiratory symptoms and pathognomonic symptoms is vital for the management. However, preschool children is a challenge. They are too old to ethically justify routine sedation prior to lung function assessment, as in infants, and also, they are too young to be able to focus sufficiently and perform elaborate respiratory manoeuvers required by commonly used lung function tests in older children and adults2. Evidence synthesis of different types of techniques is valuable in providing patient care as well as in planning further studies. The purpose of this review is to evaluate three commonly used pulmonary function tests, viz. basic spirometry, interrupter technique and forced oscillation

technique in order to assess their usefulness in preschool children.

Basic spirometry

Basic spirometry requires the subject to be able to take tidal volume breaths and then perform a maximal inspiration followed by maximal expiration to obtain forced vital capacity (FVC), forced expiration volume in first second (FEV1), flow rate measurements and also flow-volume and volume-time curves3–7, which are used for the assessment of lung function. Current evidence suggests that preschool children possess the ability to successfully perform technically acceptable spirometry4,8–14. The validity of spirometry data depend on strict quality control and following standard protocols15,16.The main handicap for using routine spirometry to assess lung functions in preschool children is the age-limited ability of the child to perform the required respiratory manoeuvers to obtain reproducible data to satisfy international standards set for adults or even older children2,17,18. For an example, the majority of preschool age children will have the capacity to perform spirometry to obtain technically acceptable forced expiratory volume values for 0.5 seconds but only significantly lesser number of children has the ability to sustain forced expiration for 1 second to obtain FEV1 data19, because the lung volume is comparatively smaller and the airway size is proportionately larger allowing younger children to exhale the vital capacity even within less than one second19,20. Therefore, it is advisable to substitute FEV1 with FEV0.5 or FEV0.75 in the case of preschool children19.

An official statement by the American thoracic society and European respiratory society recommends a period of training for the child3,12,19, interactive computerized flow driven incentives such as blowing the candles, availability of real time flow volume curves to the operator and the operator should actively engage with the child and monitor the process. Following changes are acceptable in the flow-volume curves produced by preschool children compared to adults, the descending portion is more convex in healthy preschool children20,21, forced expiration could last less than 1 second2, best forced vital capacity (FVC) and FEV should be reported but it is not mandatory that the values are obtained from one tracing. The adult repeatability criteria of three acceptable curves is adjusted to two acceptable curves with FVC and FEV within 10% range of the maximum value for preschool children3,19. Therefore, current evidence suggests obtaining repeatable, technically sound spirometry results that enable better diagnosis of respiratory diseases in preschool children is possible, but the technical specifications, methodology and data interpretation should be tailored to suit the age of the child22–25. The advantage of spirometry is the ability to detect airway obstruction and restriction. The restrictive pattern may be secondary to severe airway obstruction or a true restrictive pathology26, hence detection of restriction on spirometry warrants further assessment of lung volumes to confirm the diagnosis and differentiate between causes of restriction27–29

Interrupter technique

The interrupter technique30–33 is based on the physiological basis that following momentary occlusion of breathing at the level of the mouth, the pressure of the mouth will equal to the alveolar pressure. The pressure that is measured in the mouth following the occlusion of breathing is divided by the airflow just prior to the occlusion, to obtain the interrupter resistance (Rint)34. The occlusion is usually in response to peak expiratory flow and the closure lasts 100 ms to prevent initiation of voluntary breathing by the subject against the closure2,35. The subject only has to sit and quietly breathe through the mouthpiece, bacterial filter with the nose clip in situ. Cheek support should be provided by the operator to eliminate confounding of data by upper airway compliance2,36. Although a majority of tests were conducted during inspiration37 the significance of the difference in the interrupter resistance between inspiration and expiration measurements gradually declines with age in preschool aged children38. The popularity of the interrupter technique is mainly due to the minimal co-operation required from the subject and the versatility of test that enables it to be used in field settings2,34. It is also beneficial that reference values for interrupter resistance is available30,33,39,40. The interrupter technique is particularly important in instances, such as distinguishing asthmatic preschool children who present with vague symptoms of recurrent cough from isolated persistent cough41. Accuracy of the diagnosis is improved with combination of interrupter technique with bronchodilator responsiveness42.

Main disadvantages of the interrupter technique are that the best algorithm to calculate pressure in the mouth following occlusion is still to be proven and also this technique is incapable of assessing immediate post-exercise bronchial changes because it requires the subject to take quiet breaths during the assessment and, therefore, is unsuitable for diagnosing conditions such as exercise-induced variation of asthma2. But, overall, the interrupter technique provides an avenue of lung function testing with minimal subject co-operation and high reliability and high reproducibility.

Forced oscillation technique

Resistance and impedance of the respiratory system is non-invasively measured with the forced oscillation technique43–46 by superimposing normal tidal volume breathing with external pressure waves47. The subject is only required to sit, with a nasal clip on and have support to the cheek and the floor of the mouth, while taking tidal volume breaths through the mouthpiece and the bacterial filter. The forced oscillation technique is an easy to perform, repeatable and a reliable test that could be used to in epidemiological studies48, in pulmonary test laboratories and even in paralyzed, sedated or ventilated patients49, which makes it highly useful in an emergency or ICU setting50,51, where it could be even used to determine optimal ventilator settings52. An assessment of 150 acutely ill asthmatic patients admitted to the emergency department, demonstrated the superiority of forced oscillation technique compared to spirometry, especially in preschool children50 (relative risk of 10.5 with a 95% confidence interval ranging from 8.0 to 13.8) . Furthermore, the same study illustrated that respiratory impedance values correlated not only with disease severity but also with FEV1 measurements. Also in an acute setting, forced oscillation technique is useful for assessment of bronchodilator response and the response to treatment53,54. Another advantage of the forced oscillation technique is that it is ideal for the assessment of airways in young children2 who are incapable of performing complicated respiratory manoeuvers required by methods such as spirometry and plethysmography53.

Availability of reference values specifically for preschool children55,56 and their correlation with normal and abnormal spirometry results is highly beneficial57, even though a respiratory impedance cut off value for diagnosing airway obstruction remains to be determined53. Forced oscillation technique is ideal for assessment of airway obstruction, airway hyper-responsiveness and bronchodilator reversibility, particularly in young children with poor compliance to spirometry2. Even though it has limited use in the assessment of restrictive airway diseases, it is interesting that this technique could be used to diagnose and assess the severity of a variety of conditions such as asthma58, cystic fibrosis59, chronic bronchitis60, obstructive sleep apnoea syndrome61,62, additionally forced oscillation technique provides a rare diagnostic tool to confirm exercise-induced asthma63–65.

Conclusion

Contrary to common misbelief, ample evidence exists that preschool children are capable of performing lung function tests. Basic spirometry remains one of the most commonly used lung function tests. In preschool children the technical standards, analysis and interpretation of spirometry data should be tailored to the anatomical and physiological status of the child. Provided that adequate stimulation and supervision is done throughout the process, spirometry could yield high quality data for preschool children. The interrupter technique and the forced oscillation techniques are quickly gathering reputation as reliable tests of lung function in preschool children, especially due to the minimal co-operation required from the subject and the versatility of the test. In Sri Lanka, it is imperative that

further research is conducted on preschool children to establish local reference values and standards to enable clinical use of spirometry, interrupter technique and forced oscillation technique in the assessment of lung functions. These techniques will enable definitive diagnosis, assessment of the severity and the therapeutic response of multiple, complex and often challenging clinical respiratory conditions to enable efficient management.

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