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PRACTICAL PROCEDURES: PULMONARY FUNCTION TESTING

Measurement of maximal pressures and the sniff manoeuvre in children

Brigitte Fauroux* **and Guillaume Aubertin**

AP-HP, Hôpital Armand Trousseau, Pediatric Pulmonary Department, Université Pierre et Marie Curie-Paris 6, INSERM UMR-S 719, Paris, France

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Summary Maximal static inspiratory and expiratory pressures are simple, noninvasive tests that evaluate global inspiratory and expiratory muscle strength. But these tests may be difficult or impossible to perform in young children.

The sniff is a natural maneuver which many children find easier to perform than maximal pressures. The measurement of the nasal inspiratory pressure represents a valuable inspiratory muscle test which allows the extension of inspiratory muscle testing to a younger and larger paediatric population.

INTRODUCTION

Respiratory muscle testing is not routinely performed in children. However, it seems important that paediatricians have some knowledge of respiratory muscle testing because respiratory muscle weakness may be a cause of respiratory failure.[1] Pre-existing respiratory muscle weakness can precipitate respiratory distress during an infectious exacerbation or an anaesthetic procedure such as the use of nitrous oxide.[2,3] Moreover, respiratory muscle weakness or fatigue can be an important confounding factor in various other disease processes and situations such as malnutrition and steroid therapy.[4] A dysfunction of the respiratory muscles can be difficult to detect clinically, justifying the importance of objective measures.

For all these reasons, the clinician should be able to initiate and interpret the most simple respiratory muscle tests – the static maximal pressures and the sniff nasal pressure.

* Corresponding author. 26 avenue du Docteur Arnold Netter, 75571 Paris Cedex 12, France. Tel.: +33 1 44 73 66 18; Fax: +33 1 44 73 67 18.
E-mail address: brigitte.fauroux@trs.aphp.fr (B. Fauroux).

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MAXIMAL INSPIRATORY AND EXPIRATORY PRESSURES

Methodological considerations

The respiratory muscles have two functions: to develop force and to shorten. In the respiratory system, force is generally estimated as pressure and shortening as lung volume change or displacement of chest wall structures. Thus, quantitative characterisation of the respiratory muscles usually relies on measurements of volumes, displacements and pressures, and the rate of change of these variables with time.

Respiratory muscle testing can be classified as volitional or non-volitional manoeuvres and as non-invasive or invasive measurements. In clinical practice, volitional and non-invasive tests are the simplest to use. Within this context, pressure will be measured at the mouth (Pmo) or nose (Pna). Pmo is easy to measure and changes may give a reasonable approximation of change in alveolar pressure and thus oesophageal pressure, providing there is relatively little pressure loss down the airways or across the lungs. This may be realistic with normal lungs, particularly when changes in lung volume are small, but is unlikely to be the case in patients with severe lung or airway disease. When used in combination with voluntary static and dynamic manoeuvres at functional residual capacity (FRC), Pmo provides a global index of the action of synergistic respiratory muscles. Pna is also easy to measure but has the same caveats as Pmo.

Maximal static inspiratory (Pimax) and expiratory (Pemax) pressures are simple, volitional and non-invasive manoeuvres which measure the strength of the global inspiratory and expiratory muscles. During these tests, Pmo is measured at the side port of a mouthpiece. It should be possible to occlude the mouthpiece at the distal end and a small leak (approximately 2 mm internal diameter and 20–30 mm in length) should be incorporated to prevent glottic closure during the manoeuvre. The type of mouthpiece can significantly influence the results. A flanged mouthpiece is recommended. Some patients with neuromuscular disease involving the orofacial muscles may have difficulty in forming an airtight seal around either type of mouthpiece, which leads to an underestimation of static pressures.

Maximal pressures are measured with the child seated. A nose clip is not necessary. The inspiratory and expiratory pressures must be maintained ideally for at least 1.5 s, so that the maximum pressure sustained for 1 s can be calculated (Fig. 1). The minimal number of recommended measurements, according to the underlying disease, has not been validated in children. In routine practice, it is recommended to perform five or more measurements until two reproducible maximal values are obtained. Another option is to retain the maximum of three manoeuvres that vary by <20%. As maximal pressures are volitional maximal tests, the best values for Pimax and Pemax are retained.

Because of the force–length relationship and the varying contribution of the passive elastic recoil pressure of the respiratory system (Prs), Pimax and Pemax vary markedly with lung volume. Subjects find it easier to maximise their inspiratory efforts at low lung volume and expiratory pressures at high lung volume. Therefore, by convention and to standardise measurements, Pimax is measured at or close to residual volume and Pemax at or close to total lung capacity.[5] However, at residual volume, the measured Pimax is the sum of pressure developed by the inspiratory muscles and the outward recoil pressure of the respiratory system present at this lung volume (normally equal to 30 cm H_2O), whereas Pimax measured at FRC strictly represents the inspiratory muscles. Simultaneous measurement of lung volume at which maximal pressure is generated is thus recommended.

The test should be performed by an experienced operator, who should strongly urge the patient to make maximal manoeuvres. Because this is an unfamiliar manoeuvre, careful instruction and encouragement are essential. However, even low variability does not guarantee that maximal efforts have been made.

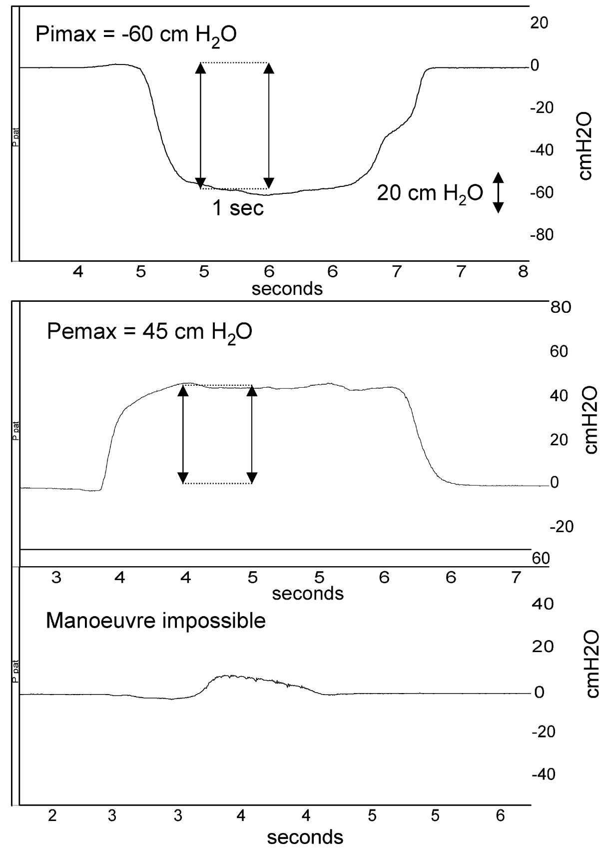

Figure 1 Example of a maximal inspiratory (Pimax, top) and maximal expiratory pressure (Pemax, middle) manoeuvre in a 14-year-old girl with a type III spinal muscular atrophy. The bottom tracing shows the impossibility of an 8-year-old boy with a congenital myopathy performing an adequate maximal expiratory manoeuvre.

Results, advantages and limitations

Maximal static pressures have the main advantages that they are non-invasive and normal values have been established in quite large series of children of different ethnicities (Table 1).[6–8] Maximal pressures exerted by infants and children are surprisingly high compared with adults. This seems to be related to the small radius of curvature of the rib cage, diaphragm and abdomen, which according to the Laplace relationship converts small tensions into relatively high pressures. In children, maximal pressures increase with

Table 1 Normal values of maximal inspiratory pressure (Pimax) and maximal expiratory pressure (Pemax) in children

Age (years)	Pimax (cm H_2O)		Pemax (cm H_2O)	
	Male	Female	Male	Female
8	77 ± 24	71 ± 29	99 ± 23	74 ± 25
10	105 ± 27	71 ± 29	123 ± 27	74 ± 25
11–13	114 ± 27	108 ± 29	161 ± 37	126 ± 32
13–17	126 ± 22	109 ± 21	166 ± 44	135 ± 29