Negative expiratory pressure test: a new, simple method to identify patients at risk for obstructive sleep apnea*, **

Teste de pressão negativa expiratória: um novo método simples para identificar pacientes com risco para apneia obstrutiva do sono

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Abstract

The objective of this article was to describe a new method for assessing expiratory flow limitation during spontaneous breathing, using the negative expiratory pressure test to identify patients at risk for obstructive sleep apnea. Upper airway collapsibility is evaluated by measuring decreases in flow and in expired volume in the first 0.2 seconds after negative expiratory pressure application at 10 cmH_2O. The negative expiratory pressure test is easily applied and could be adopted for the evaluation of expiratory flow limitation caused by upper airway obstruction in patients with obstructive sleep apnea.

Keywords: Sleep apnea, obstructive/diagnosis; Sleep apnea, obstructive/prevention and control; Airway resistance.

Resumo

O objetivo deste artigo foi descrever um novo método para avaliar a limitação ao fluxo expiratório durante a respiração espontânea, possibilitando a identificação do risco para apneia obstrutiva do sono através do teste de pressão negativa expiratória. A colapsabilidade da via aérea superior é avaliada pela medida da queda de fluxo e de volume expirado a 0,2 segundos imediatamente após a aplicação de pressão negativa expiratória de 10 cmH_2O. O teste de pressão negativa expiratória é de fácil aplicação e poderia ser utilizado na avaliação da limitação ao fluxo expiratório causada por obstrução da via aérea superior em sujeitos portadores de apneia obstrutiva do sono.

Descritores: Apneia do Sono Tipo Obstrutiva/diagnóstico; Apneia do Sono Tipo Obstrutiva/prevenção & controle; Resistência das Vias Respiratórias.

In recent years, there has been growing interest in the role that the upper airways play in breathing, especially during sleep. In large part, this interest has come from the increased recognition of the diagnosis of obstructive sleep apnea (OSA), which is characterized by pharyngeal collapse and occlusion during sleep, causing intermittent hypoxia, sudden reduction of intrathoracic pressure, and frequent awakenings with consequent sleep fragmentation.[1] It has been reported that OSA affects 2-5% of the middle-aged population,[2] and the syndrome is associated with significant morbidity and mortality. In a study of the epidemiology of sleep apnea, involving adults in the city of São Paulo, Brazil, the reported prevalence of OSA was even higher (24.8% and 9.6% in males and females, respectively).[3] In addition, OSA has significant social implications related to accidents,[4] cardiovascular risk,[5] neuropsychological impairment,[6] impaired quality of life,[7] and increased health care utilization.[8] Therefore, the underdiagnosis of OSA can have relevant consequences. Approximately 50% of individuals with OSA are also hypertensive.[9] In patients with OSA, the relative odds of having a stroke are increased by 58% and those of developing coronary artery

* Study carried out under the auspices of the Graduate Program in Rehabilitation Sciences, Nove de Julho University, São Paulo, Brazil.

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Financial support: This study received financial support from the *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq, Brazilian National Council for Scientific and Technological Development; Research Productivity Grant no. 307618/2010-2).
Submitted: 12 April 2011. Accepted, after review: 4 August 2011.

** A versão completa em português deste artigo está disponível em www.jornaldepneumologia.com.br

disease are increased by 27%.[10] The mechanism responsible for pharyngeal collapse during sleep remains uncertain. Investigators have implicated anatomic factors[11] and neuromuscular control factors,[12] as well as fluid accumulations and fat deposits,[13] as factors that can increase pharyngeal collapsibility during sleep in OSA patients.

Despite the abundance of scientific evidence, OSA is still underdiagnosed in the general population. This is due to multiple causes, such as lack of knowledge on the part of physicians and the limited access that patients have to diagnosis and treatment of OSA.[14] In addition, the diagnostic procedures are expensive, and predictive criteria are still unsatisfactory. Obesity parameters are important predictors, although not all OSA patients are obese and not all obese subjects have OSA. The identification of new markers of OSA would be useful. Because increased upper airway collapsibility is one of the main determinants of OSA,[15] the response to the application of negative expiratory pressure (NEP) could be a predictor of this disorder.

The NEP test involves applying negative pressure at the mouth during expiration. It is performed during waking and requires minimal subject cooperation. It is based on the principle that, in the absence of expiratory flow limitation (EFL), the increase in the pressure gradient between the alveoli and the airway opening caused by NEP should result in increased expiratory flow. Subjects in whom NEP application does not elicit an increase in flow during the terminal portion of the tidal expiration compared with the previous flow-volume loop are classified as flow-limited. More recently, NEP has also been used in studies of upper airway characteristics in obese subjects and subjects with OSA. It has been suggested that, in the absence of intrathoracic airway obstruction, the response to NEP application reflects the degree of upper airway collapsibility.[16-20]

In obese subjects and subjects with OSA, EFL has to date been quantified by the proportion of tidal expiration over which NEP does not induce any appreciable increase in flow with respect to the control expired tidal volume. However, this method does not always make it possible to discern between EFL of extrathoracic origin and EFL of intrathoracic origin.[19] Alternative assessments of the capacity of NEP application to detect upper airway obstruction could be useful. The application of NEP elicits a flow spike, mainly because of dynamic airway compression downstream from the compliant oral and neck structures, and, to a small extent, because of the common-mode rejection ratio of the differential pressure transducer used to measure flow,[17] followed by a decrease in flow of variable degrees among subjects. The sudden decrease in flow is caused by an increase in resistance of the oropharyngeal structures,[16] which reflects upper airway collapsibility (extrathoracic EFL).

During the test, NEP is generated by a circular Venturi device (AeroMech Devices; Almonte, ON, Canada) attached to a tank of compressed air. The Venturi device includes a solenoid valve. The solenoid valve has an opening time of 50 ms; it is automatically activated in early expiration and remains open for 2 s by software control (DirecWin version 2.18a; Raytech Instruments Inc., Vancouver, BC, Canada). A pneumotachograph (model 3830; Hans Rudolph, Kansas City, MO, USA) is connected to the mouthpiece. As shown in Figure 1, flow and mouth pressure are also measured (DirecNEP model 200A; Raytech Instruments Inc.). An NEP value of 10 cmH_2O was assessed by occluding the mouthpiece with a stopper and adjusting the compressed air flow.

The application of NEP during early expiration produces an immediate peak flow, followed by a sudden decrease of a variable degree. Upper airway collapsibility is evaluated by measuring flow limitation as Δflow, expressed as a percentage of the peak flow immediately after NEP application. The minimum flow is identified in the first 200 ms of NEP application to avoid reflex and voluntary reactions to the NEP stimulus.[16] Values of Δflow% are calculated considering the highest of seven measurements. Upper airway collapsibility is also evaluated by measuring expired volume in the first 0.2 s ($V_{0.2}$) after NEP application (Figure 2). These values are expressed as a percentage of the mean inspiratory volume of the three breaths preceding NEP application. Measured volumes are accepted only when differences between inspiration and expiration for each of the three previous breaths were less than 10%. Values of $V_{0.2}$ are calculated as the mean of seven measurements.

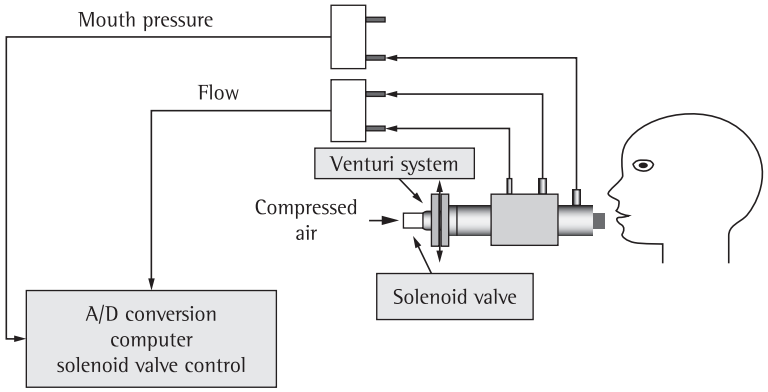

Figure 1 - Experimental setup used in the negative expiratory pressure (NEP) test. The mouth pressure and flow were simultaneously registered during spontaneous breathing and during NEP application. A/D: analog/digital.

In the present study, care was taken to keep the neck in a neutral position during the test. The subjects performed the test while awake, during quiet breathing with a nose clip, in the sitting and supine positions. At least four regular breaths were allowed between NEP applications. The flow and mouth pressure signals were filtered through a low-pass filter and sampled at 200 Hz. Both digital signals were displayed in real time on the computer screen and stored on the computer for subsequent analysis. Data analysis was performed using software developed by the Italian National Research Council, Institute of Biomedicine and Molecular Immunology A. Monroy, Palermo, Italy, written in MATLAB 6.5 (The MathWorks, Natick, MA, USA).

This method was initially used to assess intrathoracic EFL in patients with COPD.[17] In another study, the authors have proposed to evaluate upper airway obstruction by flow interruption technique, i.e., extrathoracic EFL measured as Δflow expressed as a percentage of the peak flow immediately after NEP application.[16]

In a validation study,[20] 37 subjects underwent the NEP test in a sitting position at 10 cmH_2O. The analysis performed with Δflow% showed a strong correlation with the apnea-hypopnea index. We also assessed EFL induced by NEP as flow, in the flow-volume loop, during NEP application, which was equal to or lower than the corresponding flow in any part of the control flow-volume loop (EFL), expressed as a percentage of control tidal volume (%V_T) and Δflow%, based on the mean of four measurements.[16] A controlled study involving 48 subjects tested this new measure as described above (with Δflow% and $V_{0.2}$ measurements),

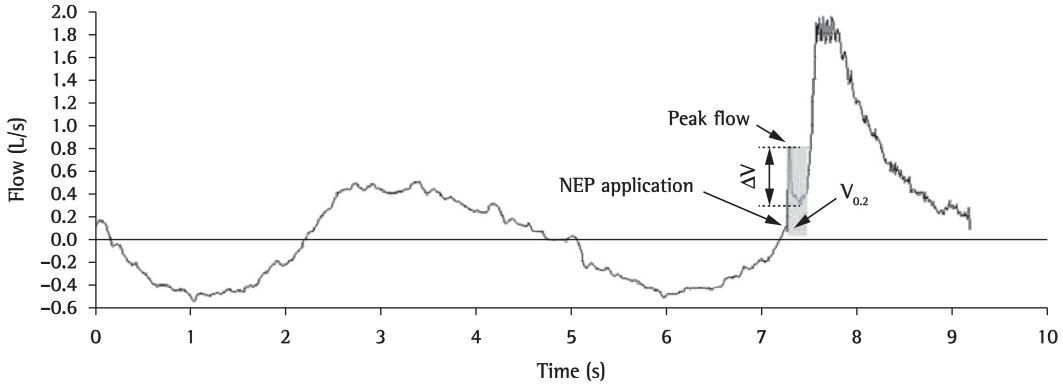

Figure 2 - Measurement techniques of upper airway collapsibility: expiratory volume within 0.2 s ($V_{0.2}$), expressed as a percentage of the mean inspiratory volume of the three breaths preceding negative expiratory pressure (NEP) application, and the decrease in flow (ΔV), expressed as a percentage of the peak flow.

in order to investigate the usefulness of this technique as a screening test for severe OSA (apnea-hypopnea index > 30 events/h). In both analyses, significant differences were found between normal subjects and those with apnea, indicating that this might be a useful parameter for identifying subjects with severe OSA.[20]

In conclusion, the NEP test is easily applied and could facilitate the evaluation of EFL caused by upper airway obstruction in individuals with OSA.

References

1. Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research. The Report of an American Academy of Sleep Medicine Task Force. Sleep. 1999;22(5):667-89.
2. Young T, Palta M, Dempsey J, Skatrud J, Weber S, Badr S. The occurrence of sleep-disordered breathing among middle-aged adults. N Engl J Med. 1993;328(17):1230-5.
3. Tufik S, Santos-Silva R, Taddei JA, Bittencourt LR. Obstructive sleep apnea syndrome in the Sao Paulo Epidemiologic Sleep Study. Sleep Med. 2010;11(5):441-6.
4. Sassani A, Findley LJ, Kryger M, Goldlust E, George C, Davidson TM. Reducing motor-vehicle collisions, costs, and fatalities by treating obstructive sleep apnea syndrome. Sleep. 2004;27(3):453-8.
5. Nieto FJ, Young TB, Lind BK, Shahar E, Samet JM, Redline S, et al. Association of sleep-disordered breathing, sleep apnea, and hypertension in a large community-based study. Sleep Heart Health Study. JAMA. 2000;283(14):1829-36.
6. Kim HC, Young T, Matthews CG, Weber SM, Woodward AR, Palta M. Sleep-disordered breathing and neuropsychological deficits. A population-based study. Am J Respir Crit Care Med. 1997;156(6):1813-9.
7. Flemons WW, Tsai W. Quality of life consequences of sleep-disordered breathing. J Allergy Clin Immunol. 1997;99(2):S750-6.
8. Otake K, Delaive K, Walld R, Manfreda J, Kryger MH. Cardiovascular medication use in patients with undiagnosed obstructive sleep apnoea. Thorax. 2002;57(5):417-22.
9. Peppard PE, Young T, Palta M, Skatrud J. Prospective study of the association between sleep-disordered breathing and hypertension. N Engl J Med. 2000;342(19):1378-84.
10. Shahar E, Whitney CW, Redline S, Lee ET, Newman AB, Javier Nieto F, et al. Sleep-disordered breathing and cardiovascular disease: cross-sectional results of the Sleep Heart Health Study. Am J Respir Crit Care Med. 2001;163(1):19-25.
11. Schwab RJ, Gefter WB, Hoffman EA, Gupta KB, Pack AI. Dynamic upper airway imaging during awake respiration in normal subjects and patients with sleep disordered breathing. Am Rev Respir Dis. 1993;148(5):1385-400.
12. Jeffries B, Brouillette RT, Hunt CE. Electromyographic study of some accessory muscles of respiration in children with obstructive sleep apnea. Am Rev Respir Dis. 1984;129(5):696-702.
13. Brennick MJ, Pack AI, Ko K, Kim E, Pickup S, Maislin G, et al. Altered upper airway and soft tissue structures in the New Zealand Obese mouse. Am J Respir Crit Care Med. 2009;179(2):158-69.
14. Logan AG, Perlikowski SM, Mente A, Tisler A, Tkacova R, Niroumand M, et al. High prevalence of unrecognized sleep apnoea in drug-resistant hypertension. J Hypertens. 2001;19(12):2271-7.
15. Fogel RB, Malhotra A, White DP. Sleep. 2: pathophysiology of obstructive sleep apnoea/hypopnoea syndrome. Thorax. 2004;59(2):159-63.
16. Insalaco G, Romano S, Marrone O, Salvaggio A, Bonsignore G. A new method of negative expiratory pressure test analysis detecting upper airway flow limitation to reveal obstructive sleep apnea. Chest. 2005;128(4):2159-65.
17. Koulouris NG, Valta P, Lavoie A, Corbeil C, Chassé M, Braidy J, et al. A simple method to detect expiratory flow limitation during spontaneous breathing. Eur Respir J. 1995;8(2):306-13.
18. Tantucci C, Duguet A, Ferretti A, Mehiri S, Arnulf I, Zelter M, et al. Effect of negative expiratory pressure on respiratory system flow resistance in awake snorers and nonsnorers. J Appl Physiol. 1999;87(3):969-76.
19. Van Meerhaeghe A, Delpire P, Stenuit P, Kerkhofs M. Operating characteristics of the negative expiratory pressure technique in predicting obstructive sleep apnoea syndrome in snoring patients. Thorax. 2004;59(10):883-8.
20. Romano S, Salvaggio A, Hirata RP, Lo Bue A, Picciolo S, Oliveira LV, et al. Upper airway collapsibility evaluated by a negative expiratory pressure test in severe obstructive sleep apnea. Clinics (Sao Paulo). 2011;66(4):567-72.

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