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Original article

Air leakage during nocturnal mechanical ventilation in patients with neuromuscular disease

Fuites d'air durant la ventilation assistée nocturne chez des patients ayant une maladie neuromusculaire

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Abstract

Objective. – Air leakage is a major problem in long-term assisted ventilation both invasive and non-invasive that becomes even more important during sleep. The objective of this work was to provide a method for continuous estimation of tidal volume changes in patients under ventilatory support during sleep.

Materials and methods. – Recordings were from 14 patients with neuromuscular disorders admitted to hospital for a routine evaluation of assisted ventilation during sleep. Air leakage was continuously evaluated from: 1) the difference between the insufflated and expired volume using a flow meter; 2) the changes in lung volume using inductance plethysmography.

Results. – Both methods showed presence of air leaks in all patients and also variations in their amount throughout the night. However, inductance plethysmography provided more rigorous measurement of air leaks than flow meters as it measures the amount of air actually entering the lungs. The magnitude of leakage does not appear to be related to the method of assisted ventilation (invasive or non-invasive) or to the characteristic of the assistance mode (volume control or volume assist control).

Conclusion. – The proposed method offers a reliable, non-invasive, continuous, bedside evaluation of air leak changes in ventilated patients. On-line analysis can be performed to find optimal ventilator settings in order to compensate for leakage while providing patient comfort.

Résumé

Objectif. – Les fuites d'air au cours de la ventilation assistée constituent un problème majeur d'autant plus que leur quantité est accrue au cours du sommeil. Ces fuites existent quelle que soit la méthode d'assistance ventilatoire employée, invasive ou non invasive. L'objectif de ce travail a été de mettre au point une méthode d'estimation en continu du volume courant au cours du sommeil chez le patient ventilé.

Matériel et méthodes. – Chez 14 patients ayant une maladie neuromusculaire, hospitalisés pour une évaluation de leur assistance ventilatoire au cours du sommeil, l'estimation des fuites a été faite d'une part, en faisant la différence entre l'air insufflé et l'air expiré, et, d'autre part, en mesurant les variations de volume pulmonaire par pléthysmographie par inductance.

Résultats. – Les deux méthodes montrent l'existence de fuites chez tous les patients ainsi que des variations de l'importance de ces fuites au cours de la nuit. Cependant, la pléthysmographie par inductance permet une évaluation plus précise des fuites car elle mesure la quantité d'air atteignant effectivement les poumons. L'importance des fuites ne semble pas dépendre de la méthode d'assistance ventilatoire (invasive ou non invasive) ni du mode d'assistance (volume contrôlé ou volume assisté contrôlé).

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Conclusions. – La méthode proposée offre une possibilité d'évaluation des fuites qui est continue, précise et non invasive. Elle peut ainsi être utilisée au lit du patient et une analyse en temps réel des données permettrait de trouver les réglages optimaux des ventilateurs : associer la diminution de la quantité de fuites et le meilleur confort du patient.

Keywords: Respiratory inductance plethysmography; Respiratory failure; Long-term assisted ventilation

Mots clés : Pléthysmographie respiratoire par inductance ; Insuffisance respiratoire ; Ventilation assistée à long terme

1. Introduction

Mechanical ventilation efficacy depends upon adaptation of assisted ventilation to the patient's need. This is particularly crucial in patients with chronic respiratory failure because they not only require long-term ventilatory support but they are also conscious. One major problem in long-term assisted ventilation is the existence of air leakage from around the mask and through the mouth in patients receiving non-invasive ventilation and from around the cuffless tracheostomy tube in invasively ventilated patients.

The most frequent mechanism responsible for the increasing leaks during sleeping is air which escapes out of the mouth. Such leaking may not only create uncomfortable side effects for the patient, it can also lead to an incomplete response to therapy. Leakage of air out of the mouth has been shown to adversely affect sleep quality [1,2] and contribute to failure to fully correct nocturnal gas exchange [3], all of which may affect the patient's tolerance and long-term response to therapy.

The detrimental effect of leaks is not solely the reduction in alveolar ventilation [3]. During continuous positive airway pressure leakage has been shown to increase nasal resistance [4]. Large leaks may interfere with ventilator cycling and compromise minute ventilation [5]. However, the greater problem associated with air leakage is that it increases during sleep [6,7,1] leading to impairment of sleep quality despite no marked decrease in oxygenation. Sleep disorders associated with leaks have been observed in patients with COPD [8] as well as in patients with neuromuscular disease [1,2]. Reducing the amount of air leakage has been considered to be the principal means of improving efficacy of assisted ventilation [9]. This has been demonstrated in neuromuscular patients during wakefulness [3].

Leak measurement may be considered as a prerequisite to leak compensation. However, few studies have been devoted to leak measurement. Using a lung model Mehta et al. [5] tested leak-compensating capacity of various positive pressure ventilators. They found that the tidal volume differed between ventilators even in the absence of leakage. Their study also demonstrated that the ability to compensate for leakage varies considerably among ventilators. Respiratory inductance plethysmography (RIP) have been used by Meyer et al. [2] to measure air leaks in patients with symptoms of chronic hypoventilation. However, values of leaks were obtained by subtracting the volume obtained by calibrated RIP from the volume of air delivered through the nose.

The aim of the present study was to develop a non-invasive method of estimating tidal volume changes in patients on mechanical ventilation not only during wakefulness but also during sleep. Ventilator settings are generally adjusted only when awake while major detrimental effect of leakage is observed mainly during sleep leading to poor sleep quality. The method was developed using data obtained from patients with neuromuscular disease invasively or non-invasively ventilated during sleep. Non-calibrated RIP was used to evaluate breath-by-breath changes in tidal volume in proportion of their values during sleep latency time; decreases in tidal volume indicate increases in air leaks.

2. Methods and materials

2.1. Patients

The data analyzed in this study were obtained from 14 patients (Table 1) with neuromuscular disorders admitted to the Raymond-Poincaré Hospital in Garches (France) for a routine evaluation of assisted ventilation during sleep. Institutional review board approval was not necessary as no additional device or recording time to the routine protocol was used. Informed consent has been obtained from patients for anonymous analysis of their recording aimed at technical research as authorized by national ethical committee.

Seven patients were ventilated through a cufless tracheostomy and seven patients received non-invasive ventilation through a nasal mask.

Twelve patients were ventilated with an EOLE 3 ventilator (EOLE 3, ResMed, Saint-Priest, France) and the other two patients with an AIROX HOME 2 ventilator (Tyco, Elancourt, France). The ventilation mode was either volume control (five patients) or volume-assisted control (nine patients). The volume and frequency setting for each patient and the blood gas analysis during mechanical ventilation while awake are given in Table 2.

2.2. Measurements

In addition to the polysomnographic recording, thorax and abdomen section surface area changes were recorded using a computer-assisted respiratory inductance plethysmograph the Visuresp® (RBI, Meylan, France) system. A flow signal, measured by a pneumotachograph (PNT) inserted between the ventilator and the patient's interface device (tracheal tube or nasal mask), was also recorded, using the Visuresp® system.

2.3. Signal processing and analysis

The Visuresp® system includes specific signal processing software that provides cycle delimitation on a flow signal