Bol Med Hosp Infant Mex. 2017;xxx(xx):xxx–xxx

Boletín Médico del
Hospital Infantil de México

www.elsevier.es/bmhim

REVIEW ARTICLE

Respiratory monitoring of pediatric patients in the Intensive Care Unit☆

Alejandro Donoso*, **Daniela Arriagada**, **Dina Contreras**, **Daniela Ulloa**, **Megan Neumann**

Hospital Clínico Metropolitano La Florida, Santiago, Chile

Received 26 October 2015; accepted 2 February 2016

KEYWORDS
Respiratory monitoring;
Mechanical ventilation;
Lung physiology;
Ventilation mechanics

Abstract Respiratory monitoring is important in the care of children with acute respiratory failure. Therefore, its proper use and correct interpretation (recognizing which signals and variables should be prioritized) should help to a better understanding of the pathophysiology of the disease and the effects of therapeutic interventions. Also, ventilated patient monitoring, among other determinations, allows evaluating various parameters of respiratory mechanics, knowing the status of the different components of the respiratory system and guiding the adjustments of ventilation therapy.

In this review, the utility of several techniques of respiratory monitoring including conventional respiratory monitoring and more recent methods are described. Moreover, basic concepts of mechanical ventilation, their interpretation and how the appropriate analysis of the information obtained can cause an impact on the clinical management of the patient are defined.

PALABRAS CLAVE
Monitorización respiratoria;
Ventilación mecánica;
Fisiología pulmonar;
Mecánica ventilatoria

Monitorización respiratoria del paciente pediátrico en la Unidad de Cuidados Intensivos

Resumen La monitorización respiratoria representa un importante rol en el cuidado del niño con falla respiratoria aguda. Por tanto, su apropiado uso y correcta interpretación (reconociendo qué señales y variables deben ser priorizadas) deberían ayudar a un mejor entendimiento de la fisiopatología de la enfermedad y de los efectos de las intervenciones terapéuticas. Asimismo, la monitorización del paciente ventilado permite, entre otras determinaciones, evaluar diversos parámetros de la mecánica respiratoria, conocer el estado de los diferentes componentes del sistema respiratorio y guiar los ajustes de la terapia ventilatoria.

☆ Please cite this article as: Donoso A, Arriagada D, Contreras D, Ulloa D, Neumann M. Monitorización respiratoria del paciente pediátrico en la Unidad de Cuidados Intensivos. Bol. Med. Hosp. Infant. Mex. 2017. http://dx.doi.org/10.1016/j.rx.2017.06.007

* Corresponding author.
E-mail address: adonosofuentes@gmail.com (A. Donoso).

https://doi.org/10.1016/j.bmhime.2017.09.001

En esta actualización se describe la utilidad de diversas técnicas de monitorización respiratoria incluyendo métodos convencionales y otros más recientes, se definen conceptos básicos de mecánica ventilatoria, su interpretación y cómo el adecuado análisis de la información puede ocasionar un impacto en el manejo clínico del paciente.

1. Introduction

The objectives of mechanical ventilation (MV) have changed over the course of the last few decades[1–5] (Table 1). Since they are beyond the exclusive adequacy of gas exchange, the treating physician should achieve the monitoring of a set of physiological parameters, in addition to the possible alterations that cause lung damage or distant organic dysfunction.

The ideal clinical monitoring should describe anatomical and physiological changes at the regional level, should be noninvasive, fast processing and available at the patient bedside.

Currently, multiple parameters deliver objective data, which allow to evaluate specific therapeutic interventions, establish diagnoses, goals and avoid complications caused by dynamic changes in the patient.

In the critical patient, the monitoring of respiratory mechanics is emphasized to adjust the strategy and personalize the prescription of the MV. However, this is just one of the aspects to be evaluated.

The objective of the present study was to review the evaluation of gas exchange, the main available monitoring techniques, maneuvers and respiratory mechanics calculations and studies in the pediatric patient. Multimodal monitoring to consider in the ventilated patient is summarized in Table 2. Finally, future modalities of monitoring, particularly biomarkers, are discussed.

2. Clinical monitoring

As in any medical act, the adequate inspection of the patient in MV is significant. Once the endotracheal intubation is performed and the patient is connected to the ventilator, chest expansion, pulmonary auscultation, and peripheral tissue perfusion must be evaluated. The physician can assess whether the ventilation support is suitable for the demand of the patient through the verification of indirect signs, such as sweating, tachycardia, and hypertension (adrenergic response).

It is important to note that auscultation should be understood as a complement to more accurate diagnostic methods. Two centuries have passed since René Théophile Hyacinthe Laënnec (1781-1826) invented the stethoscope,[6] which became an element of immediate availability and diagnostic support. Nevertheless, it presents some drawbacks since the interpretation of the information obtained is subjective and of scarce consistency.[7] Therefore, it is considered as a more descriptive than a quantitative instrument in pulmonary assessment.

2.1. Basic respiratory monitoring

Considering that acute respiratory failure is one of the main causes of admission in the pediatric intensive care units (PICU), the continuous monitoring, reliability, and accuracy of different respiratory parameters both in the admission and the posterior follow-up of the patient allow the early detection of an acute respiratory failure. Also, the evaluation of the need of ventilator support, the response to treatment, the decrease in the associated complications with MV, the optimization of the patient/ventilator interaction, and the determination of the moment when the patient is in condition to weaning. However, the monitoring by itself does not imply a specific management for the patient nor leads to a determined therapeutic result. Everything will depend on the knowledge and the ability of the person who interprets the information.

In general terms, indicators of gas exchange, such as oxygenation, ventilation, dead space and those relating to pulmonary mechanics should always be assessed.

3. Fundamentals of mechanical ventilation monitoring

3.1. Mechanical properties of the respiratory system

Three basic concepts will be defined to understand the behavior of the respiratory system: the unit of volume displaced per unit of time, referred to as *flow*; the opposition to the flow of air caused by the friction forces, as *resistance*; and the force that a gas exerts on a surface, as *pressure*. Considering that the displacement of a gas always occurs in response to pressure gradients—whether caused by the contraction of the respiratory muscles, or by the action of a mechanical ventilator, the transrespiratory pressure gradient between the upper airway (P_{ao}, *airway opening pressure*) and the existing at the alveolar level (P_{alv}) determine the magnitude of both inspiratory ($P_{ao} > P_{alv}$) and expiratory flows ($P_{alv} > P_{ao}$) (Fig. 1A).

As is well known, the Hagen-Poiseuille law designates that a relative decrease in the radius (r) produces a noticeable increase in the resistance of the respiratory system (R_{sr}) (Fig. 2). The constant of proportionality is a