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Review

Weaning From Mechanical Ventilation in Paediatrics. State of the Art☆

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ABSTRACT

Weaning from mechanical ventilation is one of the greatest volume and strength issues in evidence-based medicine in critically ill adults. In these patients, weaning protocols and daily interruption of sedation have been implemented, reducing the duration of mechanical ventilation and associated morbidity. In pediatrics, the information reported is less consistent, so that as yet there are no reliable criteria for weaning and extubation in this patient group. Several indices have been developed to predict the outcome of weaning. However, these have failed to replace clinical judgment, although some additional measurements could facilitate this decision.

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Retirada de la ventilación mecánica en pediatría. Estado de la situación

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RESUMEN

La retirada de la ventilación mecánica es una de las temáticas con mayor volumen y solidez en medicina basada en la evidencia en adultos gravemente enfermos. La protocolización del destete y la interrupción diaria de la sedación han sido instauradas, reduciendo la duración de la ventilación mecánica y la morbilidad asociada en esta población. En pediatría la información reportada es menos consistente, propiciando que el destete y la extubación no cuenten aún con criterios de inicio objetivos y reproducibles. Diversos índices han sido desarrollados para predecir el resultado del destete; sin embargo, estos no han logrado reemplazar el juicio clínico, aunque algunas mediciones complementarias pudieran facilitar esta decisión.

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Introduction

Mechanical ventilation (MV) is a life-support therapy aimed at maintaining adequate alveolar ventilation and effective gas exchange in critically ill patients. The percentage of pediatric patients requiring MV and hospitalized in intensive care units (ICU) varies between 30% and 64%.[1] While MV improves survival in these patients, it can lead to complications such as lung damage,[2] MV-associated pneumonia,[3] and dysfunction of the right ventricle.[4] Therefore, weaning should be carried out as soon as the patient is able to maintain spontaneous breathing.

Ventilator disconnection, in a broad sense, includes two completely different but related situations: the progressive decline in ventilation (weaning) and the removal of the endotracheal tube (extubation).

Weaning can be defined as the gradual reduction in respiratory support, assigning a spontaneous breathing time to let the patient take responsibility for an acceptable gas exchange.[5] This process can take between 40% and 50% of the total period receiving MV. However, some patients fail, prolonging the time with the ventilator. Various pathophysiological conditions have been linked to this failure, such as ventilatory overload, hemodynamic dysfunction, neuromuscular incompetence (central and/or peripheral), diaphragmatic muscle weakness, nutritional disorders, and

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metabolic disorders, among others.[6] However, identifying the predominant mechanism remains a challenge for the treating team, as this is usually complex and multifactorial.

Extubation is the removal of the endotracheal tube. Generally, this point coincides with the determination that the patient is able to maintain an effective gas exchange without ventilator support or with minimal additional support. However, extubation has specific predictors of success and/or failure, which are usually associated with the ability to protect the airway, the management of secretions and patency of the upper respiratory tract.[7]

The term *extubation failure* (EF) represents a set of conditions that determine the need for reintubation and MV restoration within the first 24–72 h after the removal of the endotracheal tube.[5–8] About 55 studies in adults (approximately 33 000 patients) have reported an average EF rate of 12.5% (range 2%–25%). In pediatrics, the EF rate is equally heterogeneous, and varies between 4.9% and 29%.[9] There is a controversy on the optimal EF rate, since very low values may reflect an unnecessary prolongation of MV, which would lead to an increased risk of MV-associated pneumonia, extended hospital stay and increased mortality. In this regard, Kurachek et al.[7] reported that 62.5% of 136 unplanned extubations did not require reintubation, and so many of these children could have been extubated earlier than planned. In contrast, very high values would indicate early extubation, which is associated with potential catastrophic morbidities, primarily of a hemodynamic and respiratory nature.[10] However, both situations may increase the duration of mechanical ventilation, ICU and hospital stays and, therefore, health care costs.[11–13] Thus, the decision to initiate the weaning process and perform extubation should be based on objective and reproducible criteria, which in pediatrics still has a limited level of evidence.

The objective of this review was to analyze the available information on weaning and extubation in children, comparing it with the most important studies on the subject in the adult population. Based on current information, we suggest ways to address this decision in seriously ill children.

Weaning Protocols

The decision to start weaning depends on the fulfillment of certain clinical criteria, such as control of what caused the connection to MV, the effective gas exchange, an appropriate neuromuscular condition, an appropriate level of consciousness allowing the protection of airways, and a stable hemodynamic status.[14] This decision usually lies with the intensive care physician, who begins the process when a possible successful weaning is suspected.[6] However, application of weaning protocols guided both by nurses and respiratory therapists suggests that early identification of patients able to conduct a spontaneous breathing trial (SBT) through the evaluation of specific clinical criteria, reduces weaning time, duration of mechanical ventilation and ICU stay in adult patients.[15–21] One of the first reports on the subject, by Ely et al.,[21] showed that a daily assessment of certain criteria ($PaO_2/FiO_2 \geq 200$, positive end-expiratory pressure (PEEP) $\leq 5\ cmH_2O$, presence of cough reflex, respiratory rate/tidal volume ratio (RR/V_T) ≤ 105, without vasopressors and sedatives) while applying SBT reduced the duration and complications associated with MV, lowering health care costs.

In pediatrics, the efficacy of weaning protocols is still controversial.[22–24] Schultz et al.[22] reported that the use of a protocol reduced the time devoted to weaning, compared to an intervention guided by the intensive care physician. However, both duration of MV and extubation time did not differ between groups. A multicenter prospective study carried out by the PALISI research group showed that the use of a weaning protocol in pediatric patients receiving MV who had experienced a prior weaning failure did not significantly reduce weaning time or EF rate compared with the standard procedure. In addition, the authors cautioned that overtreatment with sedatives delayed weaning time. This study suggests that assessment of specific clinical criteria, combined with daily interruption of sedation, could be effective in reducing the duration of mechanical ventilation in pediatric patients.[24]

Table 1
Clinical Criteria to Start Weaning in Pediatric Patients Undergoing Mechanical Ventilation.

1.	Resolution or improvement of the cause of respiratory failure
2.	Hemodynamic stability: absence or progressive decrease of vasoactive drugs
3.	Adequate level of consciousness (COMFORT $\geq$ 18)
4.	Spontaneous respiratory effort
5.	Discontinue sedatives
6.	Discontinue muscle relaxants at least 24 h
7.	No clinical signs of sepsis
8.	Cough reflex present
9.	Correction of significant metabolic and electrolyte imbalances
10.	Adequate gas exchange with PEEP $\leq 8\ cmH_2O$ and $FiO_2 \leq 0.5$

In this regard, excessive sedation during MV is a major problem, extending ventilator stay. In adults, Kress et al.[25] observed that daily interruption of sedation reduced the duration of mechanical ventilation and ICU stay and, additionally, the rate of adverse events did not increase, and better neurological evaluation was possible. In pediatrics, Jin et al.[26] reported that implementation of a sedation protocol including the COMFORT scale reduced duration of MV, ICU stay, total dose of sedatives, and incidence of withdrawal symptoms. Recently, Foronda et al.[27] implemented a daily assessment strategy coupled with SBT in 294 children receiving MV for more than 24 h. They managed to reduce the duration of mechanical ventilation without increasing EF rate. According to the authors, the differences with the results obtained by Randolph et al.[24] were associated with patient selection, since only patients who had experienced a previous weaning failure were included in the latter study. Moreover, it should be noted that, although the breathing parameters set before SBT application were relatively high in the study by Foronda et al.,[27] this did not represent a risk factor for EF, so the authors speculated that the differences between the two research groups could be attributed to daily assessment with conservative criteria and reluctance to perform SBT in patients with high ventilation assistance, as occurred in the control group.

In this regard, we believe that daily assessment with integrated clinical and functional parameters might shorten the identification of patients eligible for SBT.[28] Despite the disparity in the criteria used by different authors, in our unit we use the criteria described in Table 1.

Weaning Techniques

The weaning method most commonly used in pediatrics is the gradual reduction of ventilator settings during synchronized intermittent mandatory ventilation (SIMV).[1] With this practice, MV removal is carried out when low respiratory rates are achieved. In addition, this mode is typically programmed with pressure support, which guarantees a specific tidal volume according to patient needs, and would potentially have the advantage of reducing the additional respiratory effort imposed by the endotracheal tube and the mechanical circuit of the ventilator.[5,29] However, this method in adults has been shown to extend MV, compared to the use of daily SBT and pressure support.[30,31] Esteban et al.[30] reported that weaning time depends on the technique used,

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