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Original article

Implementation of a weaning algorithm in postoperative cardiac ICU: simple enough to be implemented in a ventilator software☆

Test d'un algorithme simple de sevrage ventilatoire en chirurgie cardiaque en vue de son intégration dans un respirateur

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Abstract

Objective. – The aim of this study was to test the efficacy of a respiratory weaning algorithm (WA) in postoperative cardiac surgery patients. This algorithm was made simple enough to be implemented in medium-end ventilator software.

Patients. – Twenty consecutive postoperative patients who underwent scheduled cardiac surgery with normal postoperative haemodynamic and respiratory status.

Methods. – A 3 step WA (Controlled Mode Ventilation, Pressure Support (PS) at +20 cmH_2O and at +10 cmH_2O) was applied every 15 minute by the same investigator. A 15 minute period of respiratory stability at one step led to commute to a step ahead until patient was judged "ready for extubation" (RFE, i.e. stable during 15 min under PS +10 cmH_2O). Once reaching this time, the patient was left under PS +10 until nurse and doctors in charge decided extubation according to our routine clinical criteria.

Results. – the patients were routinely extubated, in average 187 ± 169 min later than when judged RFE by the algorithm. Heart rate ($P < 0.05$) and mean arterial pressure rose when they reached the time of effective extubation, by comparison to the RFE time point.

Conclusion. – A WA has clinical advantage in cardiac surgery as it reduces respiratory weaning duration. It helps to avoiding haemodynamic stress related to delayed extubation. Such an algorithm is simple enough to be implemented in medium-end ventilators.

Résumé

Objectif. – Tester l'efficacité d'un algorithme de sevrage ventilatoire (AS) en période postopératoire immédiate de chirurgie cardiaque. Cet algorithme a été conçu pour être suffisamment simple afin de pouvoir être implémenté dans un respirateur de moyen de gamme.

Type d'étude. – Prospective, en réanimation.

Patients. – Vingt patients consécutifs opérés de chirurgie cardiaque réglée et ayant des suites postopératoires immédiates simples, sans anomalie hémodynamique ou respiratoire.

Méthodes. – Un AS en trois étapes (ventilation contrôlée, aide inspiratoire (PS) à +20 cmH_2O et à +10 cmH_2O) était appliqué toutes les 15 minutes par le même investigateur. Après 15 minutes de stabilité respiratoire sur un mode, le patient était passé au mode suivant jusqu'à ce qu'il soit jugé « prêt pour l'extubation », c'est-à-dire stable durant 15 minutes à PS +10. Le patient était maintenu dans ce mode jusqu'à l'extubation effective, appréciée par l'infirmière et confirmée par le médecin, selon des critères cliniques usuels.

Résultats. – Les patients étaient extubés en moyenne 187 ± 169 minutes après le moment où ils étaient jugés extubables par l'algorithme. La fréquence cardiaque ($p < 0,05$) et la pression VO_2 augmentaient au moment où le patient était jugé extubables par l'infirmière par comparaison à moment où l'algorithme les avait au préalable jugés extubables.

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Conclusion. – Cet algorithme présente l'avantage de permettre de reconnaître le moment où le patient serait extubable, de façon plus précoce qu'en situation de routine clinique. Une gestion du sevrage par un algorithme est susceptible de réduire la durée de ventilation et ainsi, la contrainte hémodynamique préextubation. Cet algorithme simple est susceptible d'être inclus dans le logiciel d'un respirateur de moyen de gamme.

Keywords: Ventilator weaning; Technologies; Algorithms; Postoperative period

Mots clés : Sevrage de la ventilation ; Algorithme ; Postopératoire

1. Introduction

Weaning from mechanical ventilation (MV) can be difficult in some ICU patients due to respiratory muscle weakness, impaired gas exchange or altered respiratory mechanics [1,2]. In such ICU patients, protocol weaning algorithms driven by nurse or therapist have provided significant clinical advantage such as reduced MV duration [3,4]. One step beyond, a computer-based expert algorithms included in the ventilator could drive weaning and save medical time [5,6]. Such devices are already commercially available in high-end ventilators (Evita4®, Dräger, Lübeck, Germany) dedicated to difficult weaning in COPD patients. Those brand-new "intelligent" ventilators demand heavy software capabilities and require many sophisticated inputs e.g. expired CO_2 measurement.

Contrary to medical ICU patients like COPDs who often require long term MV, postoperative cardiosurgical patients are prone to follow a fast-track course in the ICU [7]. Indeed, most of them do not suffer from chronic pulmonary disease and short postoperative MV is the rule. Indeed, a rapid decrease in respiratory support allows timely extubation as soon as haemodynamic stability, full awakening and rewarming are achieved. However, even in this favourable context, extubation is sometimes delayed due to inadequate recognition of early respiratory autonomy. Such delay creates a time lag between the « ready for extubation » time point and that when actual extubation occurs, inflicting a potentially deleterious haemodynamic load. Therefore, weaning algorithm in postoperative cardiosurgical patient may prove beneficial through accurate recognition of early extubation time. In cardiosurgical patients, such an algorithm would not demand heavy software requirements and could easily be implemented in medium-end ventilators. We prospectively tested the hypothesis that a simple, spirometric-based weaning algorithm could speed up extubation time and reduce haemodynamic burden in postoperative cardiac patients.

2. Methods

2.1. Patients and surgery

After approval by our local institutional review board and patient informed consent, twenty consecutive postoperative cardiosurgical patients were included in the study.

Total intravenous anaesthesia consisted in TCI administration of propofol and sufentanil. Paralysis was achieved with pancuronium bromide. Surgery was performed under normothermic (37 °C) cardiopulmonary bypass (roller pumps and heparin coated tubing). At the end of surgery, anesthetized patients were admitted in surgical ICU under Controlled Mode Ventilation (CMV). Initial postoperative analgesia was provided with intermittent paracetamol injections (1g every 6 hours) and continuous morphine infusion (1 to 2 mg/h). After extubation, analgesia was commuted to a morphine patient-controlled analgesia. Immediate postoperative inclusion required the confirmation of normothermia (> 36 °C), stable haemodynamic status, normoxia ($PaO_2/FiO_2 > 300$), no bleeding (< 150 ml/3 h) and the absence of myocardial ischemia (assessed by a ST segment elevation). As a result, only patients with uneventful weaning were included.

2.2. Weaning algorithm

Once admitted in ICU, patients were placed in a semi-recumbent position (+30°) and mechanically ventilated in CMV to achieve $PaO_2 > 100$ mmHg (with inspired oxygen fraction < 50%) and a $PaCO_2$ close to 35 mmHg. Haemodynamic support and fluid loading were provided as prescribed by the attending clinician.

Weaning algorithm was driven by the same investigator (AB) in all patients as follows: according to spirometric data recorded by the ventilator (Evita Dura®, Dräger™, Lübeck, Germany), CMV was stepwise switched to pressure support (PS) mode with decreasing pressure levels (+20 and then +10 cmH_2O). At any moment, pressure support could be increased or switched back to CVM if spirometric data indicated hypoventilation. In case of dynamic hyperinflation, pressure support level was lowered. Patients were considered « ready for extubation » when they disclosed stable spirometric data without hypoventilation under +10 cmH_2O PS. The following steps and their respective duration were recorded: total time spent under +20 cmH_2O, and number of switch to +20 cmH_2O PS, same for +10 cmH_2O PS, the time at which patient was judged « ready for extubation » and the actual extubation time point (Fig. 1). Extubation delay, defined as duration between the « ready for extubation » time point and that of actual extubation was recorded for every patient. A nurse, blinded to protocol, checked extubation criteria and performed actual extubation after referral to the attending clinician. Local consensual extubation criteria in our ICU are 1) adequate respiratory parameters excluding hypoventilation at +10 cmH_2O PS; 2) absence of haemodynamic instabili; 3) absence of active bleeding; 4) patient fulfilling one of the following condition: a) positive response to the question « Are