British Journal of Anaesthesia **105** (3): 326–33 (2010)
Advance Access publication 22 July 2010 · doi:10.1093/bja/aeq184

BJA

Do simple ventilation and gas exchange measurements predict early successful weaning from respiratory support in unselected general intensive care patients?

F. Monaco[1], G. B. Drummond[2], P. Ramsay[2], G. Servillo[3] and T. S. Walsh[2]*

[1] Department of Cardiothoracic Anaesthesia and Intensive Care, Istituto Scientifico S. Raffaele, Via Olgettina 60, Milan 20132, Italy
[2] Department of Anaesthesia, Critical Care, and Pain Medicine, Edinburgh Royal Infirmary, Little France Crescent, Edinburgh EH16 4SA, UK
[3] Medical Intensive Care Unit, Department of Surgical and Anaesthesiological Sciences, Federico II of Naples, Via Pansini 5, Naples 80100, Italy

* Corresponding author. E-mail: twalsh@staffmail.ed.ac.uk

Key points

- Standard physiological variables (tidal volume, respiratory rate, minute volume, and rapid shallow breathing index) did not predict successful weaning from pressure support ventilation in general ICU patients.
- [I–E] CaO_2 and $P_{E'CO_2}$ before a weaning trial were weak predictors of weaning.
- Age, APACHE II, and SOFA scores and baseline arterial [H^+] were higher in patients who did not wean successfully.
- Previously investigated physiological variables should not be used for routine prediction of weaning in unselected patients.

Background. The value of respiratory variables as weaning predictors in the intensive care unit (ICU) is controversial. We evaluated the ability of tidal volume (Vt_{exp}), respiratory rate (f), minute volume (MV_{exp}), rapid shallow breathing index (f/Vt), inspired–expired oxygen concentration difference [$(I-E)O_2$], and end-tidal carbon dioxide concentration ($P_{E'CO_2}$) at the end of a weaning trial to predict early weaning outcomes.

Methods. Seventy-three patients who required >24 h of mechanical ventilation were studied. A controlled pressure support weaning trial was undertaken until 5 cm H_2O continuous positive airway pressure or predefined criteria were reached. The ability of data from the last 5 min of the trial to predict whether a predefined endpoint indicating discontinuation of ventilator support within the next 24 h was evaluated.

Results. Pre-test probability for achieving the outcome was 44% in the cohort (n=32). Non-achievers were older, had higher APACHE II and organ failure scores before the trial, and higher baseline arterial H^+ concentrations. The Vt, MV, f, and f/Vt had no predictive power using a range of cut-off values or from receiver operating characteristic (ROC) analysis. The $[I-E]O_2$ and $P_{E'CO_2}$ had weak discriminatory power [area under the ROC curve: $[I-E]O_2$ 0.64 (P=0.03); $P_{E'CO_2}$ 0.63 (P=0.05)]. Using best cut-off values for $[I-E]O_2$ of 5.6% and $P_{E'CO_2}$ of 5.1 kPa, positive and negative likelihood ratios were 2 and 0.5, respectively, which only changed the pre- to post-test probability by about 20%.

Conclusions. In unselected ICU patients, respiratory variables predict early weaning from mechanical ventilation poorly.

Keywords: blood gas analysis; capnography; continuous positive airway pressure; mechanical ventilation, positive pressure ventilation, PEEP; pulmonary gas exchange; ventilator weaning

Accepted for publication: 19 May 2010

A test that accurately predicted readiness to wean from mechanical ventilation would be useful in intensive care units (ICUs), but is not currently available. Weaning patients from the ventilator involves several stages: first, recognizing patients who are ready to start weaning; secondly, progressively decreasing the support provided by the ventilator; and thirdly, the process of extubation and disconnection from the ventilator.[1]

Despite an extensive published literature, the role of respiratory variables as weaning predictors remains controversial, in part because of the low methodological quality of many previous studies.[2–5] Reliable predictors could improve the success of nurse- or respiratory therapist-led weaning, which can reduce ventilation times.[6 7] Systematic reviews of factors associated with weaning success or failure highlight the need to define carefully the question asked of a physiological test.[8 9] Specifically, is the test intended to predict a successful reduction in respiratory support, passing a spontaneous breathing trial (SBT), successful extubation, or a composite of these factors? Most published studies failed to conceal test data from clinicians and were open to selection bias.[8 10 11] Research using broad non-selected groups of critically ill patients, concealing the test data where possible, is lacking.

We undertook a pragmatic controlled study to answer the question: can respiratory variables predict early weaning

outcomes after reduction in ventilator support in unselected general intensive care patients? We wished to examine variables that have been used before, with contradictory results, such as tidal volume (Vt) and minute volume (MV), respiratory rate (f), and rapid shallow breathing index (f/Vt). We also evaluated inspired–expired oxygen concentration difference ($[I-E]O_2$) and end-tidal carbon dioxide concentration ($P_{E'_{CO_2}}$), which have not been extensively studied but are available with modern monitoring.

Methods

Setting and patients

The study took place in the general ICU of the Royal Infirmary of Edinburgh, Scotland, an 18-bedded ICU that admits adult medical and surgical patients, excluding cardiac surgery. Inclusion criteria were: (i) the patient had received >24 h of mechanical ventilation since ICU admission and (ii) met a simple pragmatic checklist of readiness to start reduction of respiratory support (Table 1). We took these criteria from our previous study, which showed that this checklist could predict eventual successful weaning.[1] We excluded patients aged <16 yr, those re-admitted or re-ventilated, those with a primary neurological diagnosis, those planned for terminal care or treatment limitation, and those with a significant leak around the tracheal tube cuff during ventilation (invalidating metabolic and spirometry measurements). We also excluded patients in whom maximum inspiratory support via pressure support ventilation (PSV) was already <15 cm H_2O (irrespective of PEEP level), as a semi-arbitrary cut-off value for a low level of mechanical support at baseline. Because we screened all patients from ICU admission, we expected this cut-off to mainly exclude patients with short periods of mechanical support and had confirmed this in earlier work. The study was approved by the local Ethics Committee and consent was obtained from the patient's nearest relative.

Study protocol

All admissions were assessed for eligibility. Relatives of eligible patients were approached for consent. If consent was obtained, the patient was assessed each day until the weaning checklist was fulfilled. The patient then had a standardized weaning trial as soon as possible after fulfilling the checklist (usually within a few hours).

Standardized weaning trial

In order to evaluate the value of the ventilation and gas exchange variables as a predictive test, we aimed to subject all patients to the same weaning trial at study entry. We anticipated that some patients would be unable to tolerate reduction of all mechanical support in this standardized manner, so we agreed *a priori* by consensus some 'abandonment criteria' to minimize patient distress and ensure patient safety. Before baseline measurements, the level of sedation was adjusted if necessary, so that the patient was awake, co-operative, and not agitated. Sedation then remained unchanged during the trial unless changes were clinically indicated. Tracheal suction was avoided for at least 60 min before starting the study to minimize instability in the physiological measurements. All patients were monitored with continuous ECG, invasive arterial pressure, pulse oximetry, end-tidal carbon dioxide partial pressure ($P_{E'_{CO_2}}$), expired Vt (Vt_{exp}), expired MV (MV_{exp}), respiratory rate (f), and $[I-E]O_2$. The rapid shallow breathing index was subsequently calculated as the respiratory rate/tidal volume ratio (f/Vt). Respiratory measurements were made using a commercially available spirometry device, the M-COVX module (GE Healthcare, Helsinki, Finland). Data were downloaded to a laptop using a customized software from the monitoring systems.

Table 1 Criteria used to define patients considered ready to commence weaning from the ventilator

Variable	Cut-off value
Pa_{O_2} to $F_{I_{O_2}}$ ratio	>25 kPa
PEEP	<10 cm H_2O
Haemoglobin	>7 g dl^{-1}
Axillary temperature	Between 36°C and 38.5°C
Plasma K^+ concentration	Between 3 and 5.0 mmol $litre^{-1}$
Plasma Na^+ concentration	Between 128 and 150 mmol $litre^{-1}$
Inotrope dose	Reduced or unchanged over previous 24 h
Spontaneous respiratory rate	>6 bpm on current level of support

If PSV was not already being used, patients were switched to this mode. A baseline blood gas analysis was performed at the level of PSV subsequently set. The weaning trial was carried out by research staff and was blinded from the responsible clinicians. The trial comprised a progressive reduction in PSV of 5 cm H_2O every 10 min until the trial was either stopped by the investigator because an abandonment criterion was reached or the patient successfully achieved 5 cm H_2O continuous positive airways pressure (CPAP) ventilation for 10 min continuously. The predefined 'abandonment criteria' were: (i) Sa_{O_2} <92% for more than 1 min (on any $F_{I_{O_2}}$ value), (ii) heart rate more than 150 beats min^{-1} for more than 1 min, (iii) evidence of myocardial ischaemia on the ECG, (iv) new cardiac arrhythmia (new atrial fibrillation, any ventricular arrhythmia other than ventricular ectopics, heart rate <45 beats min^{-1}), and (v) appearing stressed or agitated to an extent deemed unsafe by an investigator, the nurse with the patient, or both.

A blood gas sample was obtained at the end of the trial or at the time of abandonment. The ventilator settings were returned to the pre-trial levels, irrespective of the patient's performance during the trial, without informing the clinicians responsible for the patient of the study outcome. Decisions about weaning the patient were subsequently made by the clinical team, from whom the trial data were concealed. A log was kept to confirm that all patients received a daily