Weaning from mechanical ventilation: a national survey of Australian paediatric intensive care units

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The objective was to describe the management of weaning from mechanical ventilation, together with unit activity, patient admission and staff profile characteristics, of paediatric intensive care units (PICUs) in Australia. The study employed a non-experimental design using a mailed survey to clinical nurse leaders of Australian PICUs. Clinical nurse leaders of all seven (100%) units responded.

Annual admissions to Australian PICUs totalled 5421, of which 2587 (48%) required ventilation. All units reported having ventilation guidelines but no unit had weaning guidelines in practice. Medical staff prescribed and made ventilatory changes in the majority of units but, in some units, this was done in consultation with nursing staff. A total of 426 nurses were employed in Australian PICUs, with specialist PICU qualifications held by 140 (33%) nurses.

The results of this survey provided some insight into the management of weaning children from mechanical ventilation in Australian PICUs; as well a brief overview of unit characteristics and staffing. The results demonstrated an inconsistency in management of the weaning process in Australian PICUs and identified a significant patient population. Conflicting evidence about which optimal ventilatory weaning mode persists, however, there is evidence from studies in the adult population to support the use of standardised guidelines for weaning children from mechanical ventilation. It is recommended the Australian PICU clinicians collaborate to generate these and that appropriate education and support be provided to support their implementation.

Children can require respiratory support for a variety of pulmonary and non-pulmonary problems. It is estimated that up to 7,500 children are admitted annually to Australian and New Zealand paediatric intensive care units (PICUs)\(^1\). Approximately half of this population (3,750) would require ventilation. The child remains ventilated until the underlying cause of the respiratory failure is improved or resolved.

The focus of management and care is therefore facilitating the resumption of spontaneous ventilation, which is commonly referred to as weaning. Weaning is a relatively neglected area of intensive care, as much of the initial focus of management is resuscitation and stabilisation. Weaning from mechanical ventilation is a complex process made all the more challenging when incorporating the unique needs of children.

The aim of this study was to survey all seven dedicated PICUs in Australia to ascertain the current status of the management of weaning, together with patient admission and staff profile characteristics of PICUs in Australia.

Significance and background

Weaning from mechanical ventilation is the process of assisting the patient to breathe spontaneously\(^1\). Up to 40% of a patient's ventilatory time may be taken up by attempts to wean; this may prove problematic for 25% of ventilated patients\(^3\).

A wide variety of methods and approaches are prescribed for patients, and traditionally doctors and nurses use weaning techniques and approaches based on their experience, preference or consultative advice\(^4\). This

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variation in practice may lead to inconsistent decision making about weaning, which has implications for the patient’s physical and mental health as well as cost.

The reported benefits of reduced ventilation times include:
- reduced risk of secondary pneumonia,
- reduced ICU admission time and resultant costs,
- reduction of patient and family stress levels, and
- earlier return to normal daily activities and sleep patterns.

Too rapid or inappropriate weaning may reduce the success of spontaneous patient ventilation and lead to a post-extubation failure. Reintubation rates have correlated with poor outcomes, including increased mortality.

In an effort to acquire a better understanding of the physiology of weaning and determine a best-practice approach, clinicians have conducted research including a variety of different outcome measures. Of the numerous articles reviewed on ventilation and weaning, only 10 were concerned directly with the paediatric population. There were, however, a number of papers concerning strategies for weaning and extubation in adult populations. However, their recommendations for practice may be inappropriate for the care of infants or children as major physiological and psychological differences exist. Children are smaller anatomically and, with immature respiratory and cardiorespiratory systems, they have fewer compensatory reserves.

The majority of paediatric studies have focused on testing the effectiveness of a variety of indices to predict a patient’s readiness to wean and/or extubate and the subsequent success or failure. Indices trialled include maximum inspiratory pressure ratio (Plmax), tidal volume (Vt) indexed to body weight, fraction of inspired oxygen (Fio2) requirement and index, mean airway pressure (MAP), peak inspiratory pressure (PIP), percentage of ventilator work, rapid shallow breathing index (f/Vt ratio), and compliance of respiratory system.

Evaluation of the Plmax and f/Vt ratios had proven successful in adult studies. The other respiratory indices measured as part of normal clinical ICU monitoring reflect the level of ventilatory support the patient requires. The studies used non-randomised sampling, with sample sizes ranging from 33 to 208 using prospective study designs.

Khan and colleagues concluded bedside measurements of respiratory function could predict extubation success and failure in children but integrated indices (useful in adults) did not reliably predict extubation success or failure. Indeed, El Khatib and colleagues’ study revealed the Plmax ratio was not statistically significantly different between extubation successes and failures, and so not predictive of extubation outcome in children.

The f/Vt ratio was associated with risk of reintubation (OR 1.23, CI 1.11–1.36) but had proven to be a poor predictor of weaning success or failure in children. However, when Baumstein and colleagues used a modified f/Vt ratio of <11bpm/mlkg in the paediatric population, sensitivity and specificity related to successful extubation were stronger (0.79 and 0.78 respectively).

Only two studies have examined weaning modes in the paediatric population. The first examined spontaneous breathing trials in 84 infants and children. Eighty-nine percent of the sample tolerated the spontaneous breathing trial and 84% of these patients remained extubated. The high successful extubation rate following trials of spontaneous breathing led the authors to conclude that a spontaneous breathing trial of up to two hours should be attempted in every clinically stable patient deemed ready to wean. However, T-piece trials are difficult in paediatric population because of the increased work of breathing through a narrow lumen endotracheal tube (ETT) and subsequent risk of alveolar collapse even with continuous positive airway pressure (CPAP).

The second study demonstrated that O2 consumption and metabolic work of the respiratory muscles was significantly lower when SIMV was employed and CPAP was used. The researchers concluded SIMV was a more efficacious weaning mode in children and that time spent on CPAP should be minimised.

In 1998, Curley and Fackler sought to identify weaning patterns in young children recovering from acute hypoxaemic respiratory failure. Three distinct patterns of weaning were identified — sprint, consistent and inconsistent. Logistic regression analysis allowed the authors to determine the probability of membership in a particular subset. This enabled clinicians to identify which subset a patient would be in and let them plot and modulate the patient’s weaning trajectory.

The limited research in the paediatric population, small samples and lack of consistency in research methodologies used make it difficult for the clinician to draw any firm conclusions from which to base their decision making regarding weaning from mechanical ventilation. Similarly, conflicting evidence about weaning modes and predictive indices remains in the adult population, in spite of the larger number of studies and sample sizes in this population. However, standardised approaches facilitated through weaning protocols or guidelines in the adult population have proven successful.
Prior to the commencement of this study, there had only been one pilot study evaluating the impact of weaning protocols on children post cardiac surgery. During the writing of this paper, Randolph and colleagues have published the results of their randomised controlled study examining the effect of a ventilator weaning protocol on respiratory outcomes in infants and children.

Eligible patients were randomised to one of three groups; manual pressure support protocol (PSV, n=62); automated pressure support protocol (VSV, n=60); and no protocol (n=60). Results demonstrated that there was a slight reduction in mean weaning duration, PSV (38.4 hours) as compared with VSV (43.2 hours) and no protocol (48 hours). The reduction in hours did not, however, reach statistical significance. Moreover, it is interesting to note the mean weaning duration was differed by 10 hours and this could be clinically significant as it equates to the length of a shift.

A second study examining weaning guidelines in the PICU did not demonstrate an absolute difference between the variables of the protocol and control groups using a time series design; the researchers demonstrated a relative reduction in weaning duration by 12.5 hours.

The past decade, within the larger health care community, has been marked by a growing interest in tools guiding clinical practice. The interest has been prompted by the desire to establish best practice patterns, streamline processes and reduce health care costs. Clinical practice tools may include guidelines, protocols, standards of care, or critical pathways. The development and use of clinical practice tools can facilitate the utilisation of research and interdisciplinary collaboration. The tools can reflect joint decision making and the responsibility of the health care team involved with a particular patient population. A clinical condition in which collaboration is necessary is weaning a patient from mechanical ventilation.

**Aim of study**

The aim of this study was to survey all seven dedicated PICUs in Australia to ascertain the current status of the management of weaning. To achieve this aim, the specific research question asked was "Is there a standardised approach to weaning from mechanical ventilation in Australian PICUs?" A secondary aim was to describe unit activity, patient admission and staff profile characteristics of PICUs in Australia.

**Research design**

This study employed a non-experimental design using a mailout survey, with the primary purpose of auditing current weaning practice in the various national units.

Patient admission (activity, bed numbers, diagnosis) and staff profile characteristics (staffing levels, qualifications) was also collected to describe the setting.

**Ethical approval**

The survey was the first phase of a multi-phase doctoral study researching weaning from mechanical ventilation in the paediatric population. Ethical approval for the overall study was sought and granted by both university and hospital ethics committees. The survey did not involve patients or their families directly. A cover letter explaining the rationale and purpose of the study, as well as an assurance regarding confidentiality and anonymity, was sent to each potential participant. Only aggregate data would be published. Participation was entirely voluntary and participants were free to withdraw at any time. Consent was assumed by return of the completed survey. A copy of the results was sent to the participants.

**Sample**

The population consisted of the seven dedicated PICUs in Australia identified through records held by the Australian and New Zealand Paediatric Intensive Care Society (ANZPICS). All seven units were surveyed to avoid any sampling bias or error and to obtain a national perspective.

**Development of questionnaire**

The investigator developed the data collection tool based on variables identified in the literature on weaning in the adult and paediatric populations (modes, presence of guidelines, patient population and diagnoses, staffing ratios and qualifications). Dillman developed the 'total design method' for mail and telephone surveys, and elements of the method were used to guide the presentation and distribution of the survey in this study. Dillman's method draws on the social exchange theory, which asserts that a cost-reward balance is inherent in people. In this study the investigator aimed to keep the time and effort (or cost) on the participant's part to a minimum by developing clear and concise questions on the topic. A note of appreciation and the promise of feedback of the results were potential rewards for the participant.

The national survey developed by the investigator consisted of 18 items and was three pages in length. The questions were arranged with the most pertinent questions about patient population and ventilation and weaning first. The last item on the survey consisted of an open-ended question, which invited participants to provide further comments about the management of weaning from mechanical ventilation on their unit and a final note of thanks and appreciation of the participant's time and effort.

The initial version of the survey was piloted on clinical nurse leaders in three adult ICUs to test content and face
validity. Overall feedback was positive and only minor revisions were required before the final draft of the survey was forwarded.

Data collection
A written survey method was used for this descriptive study. Surveys are considered an appropriate tool for collecting detailed descriptions of the characteristics of a work area. The data generated can be used to justify and assess current practice and inform prospective changes in health care/service delivery. A courtesy telephone call to all the clinical nurse leaders of each PICU was undertaken in order to provide preliminary information about the study. An information letter, together with the survey, was then forwarded to the same nurse leaders. Each participant also received an addressed and reply paid envelope to facilitate the return of the survey.

Analysis and results
A 100% response rate was achieved, with all seven PICUs in Australia returning the survey. Data were coded and entered into a database file. Due to small numbers, no statistical analysis was undertaken. Unit activity and practice were not compared. Only aggregate data are reported.

Unit characteristics and activity
Over a 12 month period preceding the survey, there were 5421 admissions to Australian PICUs, of which 2587 (48%) required ventilation. Annual admission rates for the individual units ranged from 515 to 1347, with admissions for ventilation ranging from 177 to 852. There were a total of 89 PICU beds across the seven PICUs in Australia. Unit size measured by bed numbers ranged from 8-24 potentially and 4-15 actually funded.

The participants were asked to rank the three main reasons for admission to the unit for mechanical ventilation. Respiratory disorders were the main reason for admission to five of the seven units. Cardiac causes were the main reason for two units and also cited as the secondary reasons for patient admissions for other units. Neurological causes were reported as a secondary reason for admission to three units and the third reason for two other units. Other reasons for admission included trauma and surgery. These data are illustrated in Figure 1.

Staffing characteristics
In 2000, there were a total of 426 nurses employed in Australian PICUs. This number equalled 341.2 full time equivalents (FTE) and calculated to a ratio of five FTEs per

PICU bed. Of the 221 (52%) Australian PICU nurses holding postgraduate qualifications, 140 (33%) nurses held a postgraduate PICU certificate. Other postgraduate qualifications included paediatric qualifications (n=30 or 7%); adult ICU qualifications (n=17 or 4%); paediatric and ICU qualifications (n=10 or 4%); and NICU qualifications (n=17 or 4%). Two hundred and five nurses (48%) held no postgraduate qualification.

Management of ventilation and weaning
The majority of units (five) used Servo ventilators (both 300 & 900 versions). The Bearcub was the next most commonly used ventilator, followed by a range of machines that included Drager Evita 4, Babylog, Sechrist. Biphasic positive airway pressure (BiPAP) and high frequency oscillatory ventilation (HFOV) were reported to be in use in two units. Five units reported having criteria for extubation.

All units reported having ventilation guidelines primarily aimed at nursing staff. However, no unit had weaning guidelines in practice. One unit had developed guidelines for weaning, but these were awaiting validation. In the absence of guidelines, the survey asked respondents to describe the usual weaning process. Respondents reported readiness to wean was determined by the stability of patient's condition. Weaning was largely facilitated by a gradual reduction in the ventilator rate using synchronised intermittent mandatory ventilation (SIMV) with positive end expiratory pressure (PEEP), plus or minus pressure control (PC) or pressure support (PS). Accompanying this reduction in ventilator support was hopefully an increase in

Figure 1. Reasons for admission to Australian PICUs in 2000.
the patient’s spontaneous respiratory effort. CPAP was used for difficult to wean patients or assessing neonates with a history of apnoea. These results are pictured in Figure 2.

The participants were asked to report on who was responsible for determining changes and actually making adjustments to ventilator parameters during the weaning process. In five units, doctors alone determined ventilator changes while the remaining two units indicated doctors, in collaboration with nurses, determined appropriate changes to ventilatory support. The actual changes to ventilation were made by both doctors and nurses in five units, while two units indicated doctors alone made changes.

Discussion

The results of this study demonstrate that, while the management of ventilated patients receives a high profile, the management of weaning does not. All units reported having ventilation guidelines, but no unit reported having implemented weaning guidelines. The different approaches employed demonstrate the diversity in practice and also the conflict and disparity with research in this area.

Unit characteristics and activity

The reported range of activity in each PICU was probably reflective of the difference in the metropolitan cities that each unit serves. The majority of units indicated that children with respiratory disorders were the primary reason for admission for ventilatory support to their unit. However, a number of research protocols often exclude this population because of the dynamic nature of each patient’s response to illness.

Figure 2. Range of weaning modes used by Australian PICUs.

The two published studies and weaning guidelines for children to date were applied to quite different populations and it would therefore be difficult to transpose the findings to the Australian setting 30, 31.

Staff characteristics

A total of 52% of Australian PICU nurses held a post graduate qualification, with 33% holding a PICU qualification. ANZICS 36 recommend that the majority (i.e. >50%) of ICU nurses hold specific ICU qualifications. It would not be unreasonable to transpose this recommendation to paediatric intensive care. If weaning a patient from ventilation is considered an extension of the nurses’ role, then a specific qualification would be able to address the knowledge and skills required for this.

An improvement in the availability and/or accessibility of PICU courses within Australia may help redress the shortfall of specifically PICU qualified nurses within Australian units. Complementary support from the clinical areas (i.e. financial support, study-leave) would also be required.

Management of ventilation and weaning

SIMV with PEEP+PC/PS was cited as the most used weaning mode in the paediatric units. This contrasts with weaning in the adult population, where PS with PEEP and CPAP are the preferred weaning modes due to reduced weaning time and decreased risk of patient-ventilator dysynchrony 37, 38. Manczar et al’s 39 study does not support this weaning strategy in the paediatric population. Their study demonstrated there was a decrease in work of breathing and oxygen consumption in children supported by SIMV as opposed to CPAP 39. Other literature recommended that CPAP be used for only short periods (i.e. 10 minutes), as there was increased WOB and alveolar collapse due to breathing through a small lumen endotracheal tube 31, 39, 41.

However, some units cited using CPAP as part of a weaning strategy for difficult to wean or long-term ventilated patients. Another study claimed that spontaneous breathing trials were a successful weaning mode for children 42. These inconsistencies within both practice and research highlight the need for more research into comparing weaning modes in the paediatric population.

A number of studies have developed and evaluated the effect of various weaning tools in the adult population 45, 46, 47, 48. All these studies demonstrated a positive impact on patient outcomes measured that included total ventilation time, length of stay (in ICU), patient comfort and financial costs.
Some of the weaning tools were aimed at all members of the health care team, acknowledging the multidisciplinary approach to weaning in intensive care. It would therefore seem prudent, for clinical and economic reasons, that collaborative guidelines for weaning children from mechanical ventilation be developed and implemented into Australian PICUs.

Conclusion and recommendations

This study has identified an inconsistency in the management of the weaning process in Australian PICUs. Disagreement continues about which mode is optimal for children. SIMV was the most frequently used weaning mode; however, PS and CPAP were also used for some patients. More research comparing weaning modes in paediatric population is required.

However, there is evidence in the literature to support the development and implementation of a standardised approach to weaning. This evidence also positively evaluates increasing the nurses’ role in the management of weaning process. It is therefore recommended that national guidelines for weaning paediatric patients from mechanical ventilation be developed and disseminated. Nursing staff would then require educational support (internal or external) to feel confident and competent to contribute to the weaning process. The increased cost of providing this support needs to be weighed against the (potential) improvement in outcomes and quality of care provided in Australian PICUs.

If appropriately prepared, implemented and reviewed, guidelines can encourage health care professionals to share and define practice to meet common goals. They are an ideal mechanism to facilitate the use of research in practice.

References


