International Perspectives on the Influence of Structure and Process of Weaning From Mechanical Ventilation

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Background Recently, clinical and research attention has been focused on refining weaning processes to improve outcomes for critically ill patients who require mechanical ventilation. One such process, use of a weaning protocol, has yielded conflicting results, arguably because of the influence of existing context and processes.
Objective To compare international data to assess differences in context and processes in intensive care units that could influence weaning.
Methods Review of existing national data on provision of care for critically ill patients, including structure, staffing, skill mix, education, roles, and responsibilities for weaning in intensive care units of selected countries.
Results Australia, New Zealand, Denmark, Norway, Sweden, and the United Kingdom showed similarities in critical care provision, structure, skill mix, and staffing ratios in intensive care units. Weaning in these countries is generally a collaborative process between nurses and physicians. Notable differences in intensive care units in the United States were the frequent use of an open structure and inclusion of respiratory therapists on the intensive care unit's health care team. Nurses may be excluded from direct management of ventilator weaning in some institutions, as this role is primarily assumed by respiratory therapists guided by medical directives. Availability of critical care beds was highest in the United States and lowest in the United Kingdom.
Conclusion Context and processes of care that could influence ventilator weaning outcomes varied considerably across countries. Further quantification of these contextual influences should be considered when translating research findings into local clinical practice and when designing randomized controlled trials. (*American Journal of Critical Care.* 2011;20:e10-e18)

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In an effort to reduce morbidity and mortality associated with mechanical ventilation, in the past 15 years, clinical and research attention has been focused on reducing the duration of mechanical ventilation by improving the processes of ventilator weaning. To date, well-conducted clinical trials[1,2] have shown that the ventilatory mode used in weaning is not as important as the clinical processes that facilitate timely recognition of a patient's readiness to be weaned from ventilation.[3] Consequently, the focus of weaning in recent years has moved from an informal approach, based on the clinician's education and experience, to a formal approach that uses guidelines or protocols.

Weaning protocols generally include 2 components: (1) a daily assessment of weaning readiness by using a list of objective criteria and (2) a spontaneous breathing trial during which the patient is evaluated for extubation readiness and/or an algorithm that details stepwise reductions in ventilatory support before assessment for extubation. This standardized approach may reduce variation in practice, thereby improving weaning outcomes, yet studies of weaning protocols have produced conflicting results. A recent Cochrane review on the efficacy of weaning protocols reported some evidence that protocols can reduce the duration of mechanical ventilation but the effect is not consistent across studies.[4]

The Complexity of Weaning

Weaning is a complex clinical intervention that comprises a range of interrelated and interdependent components including (1) context and setting (critical care provision, organization of the intensive care unit [ICU], resources and staffing, unit culture), (2) characteristics of health care professionals (skill mix, education and training, interprofessional relationships), and (3) clinical processes (guidelines, protocols, algorithms, frequency of assessment and monitoring, interdisciplinary decision making). Each component may affect weaning outcomes. When the influence of these components is not clearly defined or understood, it is difficult to determine the utility of weaning protocols within individual settings.[5]

The concept of complex clinical interventions is not new to clinical practice. In a seminal paper, Donabedian[6] used the domains of structure, process, and outcome to describe how the environment or context (structure) and processes of care are predictive of patients' outcomes. Similarly, Pawson and Tilley[7] proposed realistic evaluation of context, mechanism, and outcomes to explain why interventions work in some circumstances and not in others, thereby highlighting the role of context and mechanisms for introduction and delivery of interventions. The lack of effect of weaning protocols on the duration of mechanical ventilation in some studies has been attributed to the existing organizational structure of the ICU and to local clinical processes that promote optimal weaning practices.[8-11] Yet little work explores the structure and processes that influence the weaning process.

> Weaning protocols may reduce mechanical ventilation duration but data is not consistent across studies.

Aim

We sought to describe the context and process of weaning from an international perspective in terms of patterns of organization, staffing, skill mix, and role responsibility that could influence practices related to weaning from mechanical ventilation. Of specific interest was the role of critical care nurses.

Methods

Selection of Countries for Comparison

Because of practical considerations in terms of data availability, we chose 7 countries: Australia,

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Table 1
Critical care services[a]

Country	No. of ICUs	Population, million	ICU bed capacity, per 100 000 population
Australia	151	22	6.3
New Zealand	26	4	5.3
Denmark	50	5.5	7.0
Sweden	85	9	7.8
Norway	70	4.4	NA
United Kingdom	233	61	3.3
United States	93 990	303	20.0

Abbreviations: ICU, intensive care unit; NA, not available.

[a]Based on data from Martin et al,[17] Sundhedsstyrelsen [Danish Department of Health],[18] Norwegian Intensive Registry,[19] Swedish Intensive Registry,[20] and on United Kingdom population statistics (National Statistics 2009),[21-23] and Halpern and Pastores.[24]

New Zealand, Denmark, Norway, Sweden, the United Kingdom, and the United States. These countries were selected for evaluation because study collaborators have previously described aspects of weaning processes through formal evaluation of protocols or automated weaning systems,[8,9] exploration of nurse roles and decision making,[12,13] description of nurses' education and training practices for mechanical ventilation,[14] and the study of an outcomes-managed approach to weaning.[15,16] We anticipate that the findings will provide relevant information for further work on weaning in these geographical areas.

Data Collection

We sought the following information about each country: (1) population data, (2) total number of ICUs, (3) ICU bed capacity, (4) descriptors of care provided by ICUs, (5) staffing models (clinician to patient ratios, skill mix), (6) critical care nursing education, and (7) nursing roles and responsibilities in relation to ventilator weaning. To obtain this information, we used 3 search methods. First, we obtained publicly accessible data from reports located on Web sites of critical care societies or organizations of individual countries (American Association of Critical Care Nurses, Society of Critical Care Medicine, Australian College of Critical Care Nurses, Australia and New Zealand Intensive Care Society, Intensive Care Society of the United Kingdom, British Association of Critical Care Nurses, European Federation of Critical Care Nursing Associations, European Society of Intensive Care Medicine) as well as respective government Department of Health Web sites. Second, for data that could not be obtained by using this method, we searched peer-reviewed publications on the following electronic databases: MEDLINE (1950 to September 2009), Embase (1988 to September 2009), Cumulative Index to Nursing and Allied Health Literature (1981 to September 2009), and ISI Web of Science (to September 2009). We used the following key words: *critical care* or *intensive care* combined with *organizations, critical care* combined with *education, nurse role* combined with *weaning* and with *mechanical ventilation.* Third, in the event that data could not be located by using the first 2 methods, information was sought from other sources through personal contact and e-mail communication with relevant government agencies or national critical care medical /nursing associations. We sought the most recently available data. Contributing authors located data; data sources and accuracy were confirmed by a second author (L.R.).

There is wide variation in the provision of critical care across countries.

Data Analysis

Numerical data obtained from relevant sources were assembled and presented in summary tables. Data on the roles and responsibilities of nurses for mechanical ventilation and weaning were summarized as narrative description.

Results

Unit Structure and Staffing Models

The provision of critical care varies widely across countries (Table 1). Overall bed capacity was similar in the Scandinavian countries (Denmark, Sweden, Norway), Australia, and New Zealand. The United Kingdom has the lowest availability of beds in adult ICUs (3.4 beds/100 000 population) and the United States has the highest (20.0/100 000).[25] ICU bed classification does not follow a standard format from country to country. In Australia and New Zealand, ICUs are categorized according to 3 levels of care: complex multisystem life support (level 3), general intensive care (level 2), and immediate resuscitation and short-term cardiorespiratory support (level 1).[26,27] Scandinavian countries use a similar categorization scheme, whereas for ICUs in the United States, the descriptors of the care levels are reversed.[28,29]

In the United Kingdom, a 4-level patient (as opposed to ICU) classification system exists. Level 3 patients require advanced respiratory support or other multiorgan support, whereas level 2 patients need continuous monitoring and support of 1 failing organ system.[30] Level 3 patients receive care in an ICU, whereas level 2 patients receive care mainly in high-dependency units. Level 1 patients are managed in general care areas (wards) of acute hospitals with guidance from the critical care team (critical care

Table 2
Unit structure and staffing models[a]

Country	ICU type	Nurse to patient ratio	Medical staffing	Respiratory therapists
Australia	Closed	1:1	1:2.7 ventilated beds	No
New Zealand	Closed	1:1	1:2 ventilated beds	No
Denmark	Closed	1:1 (1:2 night)	1:2-3 patients	No
Sweden	Closed	1:1 (1:2 night)	1:2-3 patients	No
Norway	Closed	1:1 (1:2 night)	1:2-3 patients	No
United Kingdom	Closed	1:1 (1:2, 1:3[c])	1:2 (+1 on-call) ventilated beds	No
United States	Open (most) Closed (some)	1:2 (1:1/1:3[c])	Varies according to ICU type	Yes[d]

Abbreviations: ICU, intensive care unit.

[a]Based on data from Martin et al,[17] Joint Faculty of Intensive Care Medicine,[18] Espersen et al,[32] Audit Commission,[33] Angus et al,[34] and Chapman et al.[35]
[b]Open ICUs: patients are admitted, often without triage, and the attending physician regardless of specialty, has overall responsibility. Some open ICUs function with intensivist co-management. Closed ICUs: patients' admission and care are directed by the intensivist with consultation from other specialties as mandated by the patient's condition.
[c]Depending on acuity.
[d]Respiratory therapist to patient ratio depends on hospital and time of day.

outreach). Level 0 patients require only treatment in a general care area (ward).

Patients' outcomes and quality of care are influenced by how care is organized within the ICU and the intensity of staff delivering care.[31] Table 2 presents data on unit structure and staffing models. Intensive care units are organized as open or closed units.[36] ICUs in Australia and New Zealand, Scandinavia, and the United Kingdom all function as closed units. In the United States, the structure, staffing, and skill mix of ICUs are more heterogeneous than in other countries. Most ICUs function as open units without intensivist coverage.[34] The Leapfrog Group (an American initiative aimed at improving patient safety and quality) ICU Physician Staffing Standards recommend that intensivists provide exclusive on-site ICU coverage during daytime hours with after-hour coverage from nonintensivist physicians or physician extenders available within 5 minutes.[37] However, few US ICUs currently meet these standards.[34]

Other factors related to the process of intensive care delivery are the number and type of professionals who deliver care.[38] Australia and New Zealand are the only countries where a 1:1 nurse to patient ratio for mechanical ventilator patients is mandated by the College of Intensive Care Medicine[26] and fully supported by the Australian College of Critical Care Nurses.[27] A 1:2 nurse to patient ratio may be used in lower acuity patients who do not require mechanical ventilation. In Scandinavia, nurse to patient ratios are 1:1 for day shift and 1:2 during the night.[32] Nurse to patient ratios in the United Kingdom for level 3 patients is generally 1:1 (Table 2). In the United States, the nurse to patient ratio is determined by severity of illness, specific care needs, and the amount of advanced technology (eg, renal replacement therapy and intra-aortic balloon pumping) required by the patient.[35] Mechanical ventilation alone does not mandate a 1:1 nurse to patient ratio. Although nurse staffing ratios are not federally mandated in the United States, individual states have adopted regulations to ensure adequate staffing. Examples include reportable nurse staffing plans, mandated unit-based nurse to patient ratios (California established a 1:2 ratio in 1999),[39] and disclosure of nurse staffing to the public and/or regulatory bodies.[40]

> Intensive care unit bed classification does not follow a standard format among countries.

Medical staffing of ICUs is difficult to quantify because of the heterogeneity of institutional as well as ICU models of care, particularly in the United States. In Australia and New Zealand, the ratio of medical specialists (intensivist or other) is consistent at 1:3 ventilator beds in Australia and 1:2 in New Zealand.[17] Level 3 ICUs in Denmark have a physician to patient ratio of 1:2 or 1:3.[32] A typical 6-bed unit in the United Kingdom has approximately 3 consultants committed full-time to ICU and 3 available on-call.[33]

One group of professionals included in the ICU staffing profile of the United States, but not other countries, is respiratory therapists. Respiratory therapists are ancillary personnel responsible for respiratory therapeutic treatments, including mechanical ventilation and weaning, and some diagnostic testing while practicing under the supervision of a physician.[41] Inclusion of respiratory therapists in the ICU staffing profile must be considered when comparing clinician to patient ratios for ventilator patients across countries.

Table 3
Critical care nursing education[a]

Country	Educational program type			National accreditation	Critical care course, %
	Diploma	Graduate certificate/diploma	Masters		
Australia		✓	✓	✓	53
New Zealand		✓	✓		44
Denmark	✓[a]			✓	60
Sweden		✓		✓	100
Norway		✓		✓	100
United Kingdom	✓	✓	✓		25-50
United States		✓	✓	✓	Unknown

[a]Based on data from Martin et al,[17] Aitken et al,[42] Baktoft et al,[43] McCormick and Blackwood,[44] and the American Association of Critical Care Nurses.[45]
[b]2-year nonacademic course.

Critical Care Nursing Education

Available specialty education for critical care nurses is outlined in Table 3. In Australia and New Zealand, a range of tertiary programs specific to critical care are available at the graduate certificate, diploma, and master's level.[42] Graduate critical care programs include didactic content and clinical experiential learning focused on physiology and pathophysiology, as well as technical skills including management of invasive and noninvasive ventilation and weaning. In Australia, a portfolio-based credentialing process is offered by the Australian College of Critical Care Nurses. However, few nurses complete this nonmandatory credentialing process. In the United States, as in Australia and New Zealand, a range of tertiary programs specific to critical care are available that enable nurses to assume advanced practice roles including critical care clinical nurse specialist and acute care nurse practitioner.

In Denmark, specialization in critical care nursing is available (but not required) as a 2-year (nonacademic) course.[43] Both Sweden and Norway have a required specialization course available at universities and community colleges at the baccalaureate level.

Specialty education at the postregistration level in the United Kingdom varies according to the length of study (6 months to 2 years), course content, and education entry level (undergraduate or postgraduate). In some institutions, these courses are "nested" in a diploma, degree, or masters program that requires additional modules for achievement of the relevant academic award.

Nursing Roles and Responsibilities for Mechanical Ventilation and Weaning

In general, medical staff have overall responsibility for the management of ventilation and weaning. Nurses, though involved in ongoing assessment and monitoring of weaning, previously were not acknowledged to have the autonomy to initiate or direct change.[46-48] Most ICUs in Australia and New Zealand foster interdisciplinary collaboration between nurses and physicians,[49,50] which extends to the management of mechanical ventilation and weaning.[51] Although variation exists across ICUs in Australia and New Zealand, in many units, nurses are responsible for manipulation of ventilator settings adjusted in response to physiological parameters and are actively engaged in the management of weaning, generally in the absence of protocols.[13,51] These activities are considered within the scope of nursing practice and do not require written orders from medical colleagues.

Scandinavian nurses usually make certain ventilator changes and are responsible for adjustment of the dosages of sedative drugs.[52] About one-third of ICUs use weaning protocols.[53,54] Weaning in Danish ICUs is usually dependent on dynamic interprofessional collaborative decision making as opposed to weaning protocols.[12] In the United Kingdom as in Australia and New Zealand, mechanical ventilation is generally the domain of nurses and physicians in collaboration, with additional support from physiotherapists and medical physics technicians. Members of the interdisciplinary team work collaboratively to set and achieve goals for patients, with nurses conducting and monitoring the practical application of mechanical ventilation and its weaning. The extent of individual nurses' decision making related to weaning is dependent on their clinical experience. The past 2 decades has seen implementation of nurse-led weaning by protocol in the United Kingdom[55-58] based on the results of US studies that showed substantial reductions in the duration of mechanical ventilation with use of a weaning protocol. However, the extent of the uptake of such protocols and compliance with their use are unknown.

The role of nurses relative to ventilator adjustments and weaning in the United States varies by institution according to availability of respiratory therapists and the presence of policies and protocols that empower nurses to manage different aspects of ventilator management. Weaning protocols are widely used to guide the weaning process, although for the most part as the domain of respiratory therapists.[14] According to the 2010 hospital standards, all respiratory care services must be ordered by a physician but may be delegated to an eligible nonphysician practitioner if the responsible physician co-signs all orders.[59] In many institutions, respiratory therapists operating under medical directives insist that ventilator parameter changes (including weaning) are solely within their practice domain (often excluding physicians from making ventilator adjustments). In many institutions, management of mechanical ventilation and weaning is not seen as part of nurses' scope of practice,[60] resulting in a separation of care wherein care of the patient and adjunct therapies such as sedation and analgesia are handled by the nurse and management of the ventilator is handled by the respiratory therapist.

Discussion

Our findings suggest that the context of US ICUs differs from the context of ICUs in other selected countries because of the frequent use of an open ICU structure and the inclusion of respiratory therapists in the work force. Nurses may be excluded from direct management of ventilator weaning in some institutions, as this role is primarily assumed by respiratory therapists guided by medical directives. International comparisons of critical care structures and processes are necessary to develop a better understanding of the utility of ICUs in various populations of patients, to identify factors that improve patients' outcomes, and to determine the transferability of study findings.[61] The implications of differences and similarities must be carefully considered because the structure and context of ICUs affects the process of care. Differences in availability of critical care services influences the ICU patient profile,[62] access to ICU beds, overall case mix ,and clinician workload.[61] Bed availability may influence adoption of clinical practices that may reduce ICU length of stay, such as weaning protocols and daily spontaneous breathing trials, enabling provision of services to more patients.

Weaning protocols are an excellent example of a complex clinical intervention, the outcomes of which are directly affected by contextual elements. Substantial reductions in the duration of ventilation reported in early studies of weaning protocols conducted in the United States led to widespread interest and adoption of such protocols. Yet subsequent studies that did not report similar reductions suggest that ICU context strongly influences the effectiveness of weaning protocols.[8,9,11] Protocols may be redundant in units with existing high physician and nursing staffing levels and structured processes that promote early recognition of weaning readiness and, if appropriate, rapid transition to extubation.[8,9] Krishnan and colleagues[11] postulated that failure to demonstrate a reduction in the duration of ventilation in their US-based evaluation of a weaning protocol was the result of high physician staffing levels compared with the staffing levels reported in previous US studies of weaning protocols.[63-65]

> Australia and New Zealand have a 1:1 nurse to patient ratio for mechanically ventilated patients.

Recent recommendations for weaning state that weaning protocols are most valuable when physicians do not otherwise adhere to standardized guidelines.[3] Absence of intensivists may adversely affect the timeliness and duration of weaning as nonintensivist physicians may be unaware of best practices or unavailable for decision making. No identified study directly examined the effect of physician staffing levels on the duration of ventilation and weaning. A meta-analysis[30] of studies done to evaluate physician staffing models and patients' outcomes indicated that high physician staffing, defined as a closed ICU model or mandatory intensivist consultation, was associated with decreased hospital and ICU mortality and hospital and ICU length of stay. Increased availability of intensivists is likely to facilitate timely decision making for the weaning process. In units with low-intensity physician and nurse staffing, weaning protocols may delineate decision-making trajectories that reduce unnecessary delays.

> US intensive care units' context differs from other countries due to use of open intensive care units and respiratory therapists.

Less convincing evidence exists for the positive effect of high nurse staffing in the ICU despite 1:1 nurse to patient ratios mandated in Australia and New Zealand. A recent systematic review[66] of nursing resources and ICU outcomes identified 15 studies that were done to evaluate the impact of staffing ratios and skill mix on mortality and on adverse events. Few studies cited in this review showed an association between nursing resources and mortality;

the link to a reduction in adverse events and nursing resources was more evident. Increased availability of critical care nurses may facilitate more frequent assessment of weaning readiness and monitoring of patients' progression through the weaning continuum toward successful extubation. Variation across countries and individual institutions results in quality differences in critical care nursing education. Nurses with little education specific to management of ventilator weaning may benefit from availability of an institutional protocol to guide decision making about weaning. In a study specific to the process of weaning, Thorens and colleagues[67] reported a reduction in the duration of weaning for patients with exacerbation of chronic obstructive pulmonary disease when nursing resources were optimized. Similarly no studies have provided empirical evidence of the effect of nurse specialty education on outcomes for critically ill patients.

Increased availability of intensivists may facilitate weaning decision making.

Differences in role responsibility and scope of practice also may influence weaning management. Exclusion of staff other than respiratory therapists from the responsibility of manipulating mechanical ventilation and managing weaning, as occurs in some US settings, may result in treatment and decision-making delays, thus increasing the duration of mechanical ventilation.[60,68] Respiratory therapists, though skilled and specialized in the management of ventilation, are not constantly available at the ICU bedside as is the case with ICU nurses. Despite the benefit of personnel focused specifically on the provision of mechanical ventilation and weaning of patients from such ventilation, the addition of respiratory therapists to the disciplines involved in the weaning process may add steps to the decision-making process, causing delay. In some institutions, staffing models require respiratory therapists to be responsible for the respiratory care of patients across many hospital departments, resulting in the potential for considerable delays due to priorities of care for other patients. If other members of the interdisciplinary team are not skilled in ventilator management or permitted to make appropriate ventilator changes, including the timely initiation of weaning, threats to patient safety may occur with inappropriate and potentially injurious ventilation occurring. Interdisciplinary collaborative decision making with appropriate education and skill development of all team members is a model that may facilitate appropriate and timely weaning.

Inability to replicate research findings in different settings is arguably due to differences in context and process.

Translation of research findings to useful application in clinical practice is a major challenge.[69] Replication of research should result in a body of evidence that converges toward estimates that are stable and do not change with additional data.[70] However, more often, we see variation in results that leads to reduced confidence in study findings and translational failure. Inability to replicate research findings in different settings is arguably due to differences in context and process. Studies of weaning interventions such as protocols frequently require comparison to the usual care existent in study units. Because of the potential for substantial variation, detailed description of "usual care" is required to enable assessment of transferability of study findings to various clinical contexts, both nationally and internationally.

Conclusion

Context and processes of care that could affect outcomes of ventilator weaning varied considerably across the countries we considered. Further quantification of these contextual influences should be considered when translating research findings into local clinical practice and when designing future randomized controlled trials.

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