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A systematic review of nurse-led weaning protocol for mechanically ventilated adult patients

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ABSTRACT

Objectives: The aim of this systematic review is to synthesize the current best evidence for the effectiveness of weaning protocols led by nurses compared with usual physician-led care.

Background: Protocol-directed weaning has been shown to reduce the duration of mechanical ventilation. Studies have reported that a weaning protocol administered by nurses leads to a reduction in the duration of mechanical ventilation and has a major effect on weaning outcomes. This can have especially positive consequences for critically ill patients.

Study design: Systematic review with meta-analysis.

Search strategy: The databases CINAHL, PubMed, Scopus, and the Cochrane Central Register of Controlled Trials were searched from as far back as the database allowed until January 2016.

Inclusion and exclusion criteria: Searches were performed to identify the best available evidence including quantitative studies of nurse-led weaning protocols for mechanically ventilated adult patients. We excluded all studies of weaning protocols implemented by non-nurses and non-invasive mechanical ventilation and studies that addressed patient populations younger than 18 years of age.

Results: The database searches resulted in retrieving 369 articles. Three eligible studies with a total of 532 patients were included in the final review. Pooled data showed a statistically significant difference in favour of the nurse-led weaning protocol for reducing the duration of mechanical ventilation (mean differences = −1.69 days, 95% confidence interval = −3.23 to 0.16), intensive care unit length of stay (mean differences = −2.04 days, 95% confidence interval = −2.57 to −1.52, $I^2 = 18\%$, and $p = 0.00001$); and hospital length of stay (mean differences = −2.9 days, 95% confidence interval = −4.24 to −1.56, $I^2 = 0\%$, and $p = 0.00001$).

Conclusion: There is evidence that the use of nurse-led weaning protocols for mechanically ventilated adult patients has a positive impact on weaning outcomes and patient safety.

Relevance to clinical practice: This review provides evidence supporting intensive care unit nurses' crucial role and abilities to lead weaning from mechanical ventilation.

Key words: Adult intensive care ● Critical care nursing ● Systematic review ● Ventilator weaning ● Weaning protocol

INTRODUCTION

Weaning is the process of discontinuing mechanical ventilation (MV). Intensive care unit (ICU) patients spend half of their total ventilator time being weaned (Cederwall *et al.*, 2014). Prolonged MV is associated with higher morbidity, longer hospital stays, and adverse effects for critically ill patients (Blackwood *et al.*, 2011; McConville and Kress (2012). Various studies suggest that the use of ventilator-weaning protocols provides a standardized approach to help patients reduce their stay in the ICU by reducing the duration of MV and improving patient outcomes (Blackwood *et al.*, 2009; McConville and Kress, 2012). Weaning protocols are generally based on three components: readiness to wean criteria, guidelines for reducing ventilator support, and extubation criteria, although the criteria and the content of the guidelines may vary. Furthermore, not all protocols include extubation criteria (Blackwood *et al.*, 2009, 2011). Protocols are based on the principle that the collective knowledge of a group (Blackwood *et al.*, 2009) and the common goal of all ICU team members involved in caring for mechanically ventilated patients is successful weaning from ventilatory support (Fulbrook *et al.*, 2004); thus, there is an increased interest in developing weaning protocols that provide structured guidelines and deliver more consistent practice

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in ICUs (Blackwood *et al.*, 2009). Weaning protocols are guidelines that decrease variability and standardize care in ICUs, which is particularly useful when limited staffing for treatment is available (Plani *et al.*, 2013). Moreover, evidence from previous studies reveals that protocol-directed weaning reduces ventilator-associated complications, the duration of MV, and reintubation rates (Ely *et al.*, 1996; Kollef *et al.*, 1997; Marelich *et al.*, 2000; Grap *et al.*, 2003; McLean *et al.*, 2006). Therefore, the use of protocols allows the staff to identify the earliest opportunity for the extubation of any patient capable of breathing spontaneously, optimize extubation timing, avoid both reintubation and overlong intubation, and reduce weaning time (Fulbrook *et al.*, 2004). There is also evidence that the involvement of nurses and therapists in this process is beneficial. Traditionally, weaning patients from the mechanical ventilator and extubation were the responsibility of physicians; thus, they were the major decision-makers during weaning. An evidence-based appraisal of the literature suggests that nurses and the related health staff might adhere to the protocols more closely than physicians. These findings are supported by a systematic review of randomized controlled trials (RCTs) by Blackwood *et al.* (2011), which concluded that weaning protocols implemented by the non-physician health care staff had a major effect on weaning outcomes and reduced the duration of MV. Nursing involvement in the weaning process has increased over the past two decades with the introduction of weaning protocols (Rose *et al.*, 2011). Critical care nurses play a central role in developing weaning plans with patients (Crocker and Scholes, 2009). The decision to wean is based on patient readiness according to compliance with a list of physiological criteria and on the holistic assessment of patients' readiness to wean, to which nurses provide an important contribution (Blackwood, 2000). Weaning is just one example of the complexity of managing ICU patients (White *et al.*, 2011). Research shows that nurses in Australia and New Zealand are frequently independently responsible for the manipulation of ventilator settings titrated to physiologic parameters (Rose *et al.*, 2011).

Justification for review

There is a lack of research synthesis exploring the effectiveness and influence of nurse-led weaning protocols on MV outcomes for critically ill adult patients to guide nursing practices. Previous reviews on this subject compared non-physician-driven weaning protocols used by respiratory therapists (RTs) or a combination of nurses and RTs with physician-driven weaning protocols. In this review, we investigated the implementation of weaning protocols led by ICU nurses alone to guide weaning patients from MV. We believe that the current systematic review study is the first synthesis and meta-analysis of nurse-led weaning protocols compared with usual physician-led care.

Objective of review

The aim of this systematic review is to synthesize the current best evidence for the effectiveness of nurse-led weaning protocols by answering the following question: Do nurse-led weaning protocols reduce the duration of MV, weaning time, ICU and hospital length of stay (LOS), hospital mortality, ventilator-associated pneumonia (VAP) rate, and reintubation rate in critically ill adult patients (≥18 years) who have undergone invasive MV compared with usual physician-led care?

METHODS

Inclusion and exclusion criteria

Study design: We included quantitative studies with a diversity of research methodologies: (a) RCTs, (b) non-RCTs, (c) quasi-experimental studies, and (d) prospective and retrospective cohort studies of nurse-led weaning protocols for mechanically ventilated patients.

The exclusion criteria were (a) study designs such as case studies, observational studies, qualitative studies, literature reviews, practice development reports, conference reports, practice guidelines, and surveys and editorials; (b) weaning protocols implemented by non-nurses; (c) all studies of home ventilation and chronic ventilation settings and non-invasive MV; and (d) studies that exclusively addressed patient populations younger than 18 years of age.

Patients and settings

Studies of adult patients (aged ≥18 years) who were mechanically ventilated and had an endotracheal tube in the ICU were included.

Intervention

The use of weaning protocols led by critical care nurses to wean patients from MV compared with the weaning patients from MV without the use of a protocol, that is, physician-led weaning (usual care).

Outcome measures

Outcomes were the duration of MV in days (defined as the period from the day of endotracheal intubation until the day of MV discontinuation); weaning time (time from the identification of weaning readiness criteria to the discontinuation of MV); ICU LOS in days (the period from the day of hospitalization in the ICU until discharge); hospital LOS; hospital mortality; the rate of VAP; and the rate of reintubation.

Search strategy

We searched PubMed, Scopus, CINAHL, and the Cochrane Central Register of Controlled Trials databases because they are the largest sources of nursing and allied health journals. The databases were searched from as far in the past as they allowed until January 2016. Studies were retrieved with focused searches using combinations of the following terms: MV weaning, MV-weaning protocol, and MV-weaning protocol and critical care nursing. The reference lists of identified articles were examined for potentially relevant citations. No language restrictions were applied. Table S1, Supporting information, presents the records identified through the database search.

Data extraction

Titles and abstracts of studies were retrieved using the search strategy, screened independently by the first author, and confirmed by the second author to identify studies that potentially met the inclusion criteria outlined above. The full text of potentially eligible studies was retrieved and independently assessed for eligibility by the same two authors. Disagreements between the two authors over the eligibility of particular studies were resolved through discussion with a third reviewer. The two reviewers conducted data extraction and assessed the methodological quality of the studies. The authors predeveloped and piloted a specific data extraction tool that was used to increase the rigour of data extraction according the variables of the study. The extracted information included

study identification, study setting, study methodology, participant characteristics, and details of the intervention, outcomes, and results (Table 1).

Quality assessment

The methodological appraisal was conducted in accordance with the Cochrane Collaboration's tool for assessing risk of bias (ROB) (Higgins and Green, 2011). The tool ensured the collection of data related to the following six domains: adequate sequence generation, concealment of allocation, blinding, addressing of incomplete outcome data, and elimination of selective reporting and other biases (Table S2).

The Cochrane (ROB) tool suggests that the process in assessing risk of bias is a step in the right direction. Extensions of the tool for non-parallel group randomized trials and non-randomized studies were identified as a priority (Savović *et al.*, 2014).

Data analysis

A narrative synthesis of the findings from the included studies was structured around the type of intervention, target population characteristics, type of outcome and intervention content.

Statistical analysis

We performed the meta-analysis using Review Manager 5.3 (The Cochrane Collaboration, 2011). Continuous variables, including MV duration, ICU LOS, and hospital LOS, were reported as mean differences (MD), medians, and interquartile ranges (IQRs) with 95% confidence intervals (CIs) through the application of the inverse variance method. A p value <0.05 was considered statistically significant. We assessed the heterogeneity of the studies using the I-squared statistic (I^2) test, which measures the impact of heterogeneity ($I^2 > 50\%$, significant heterogeneity). If the I^2 index was ≤50%, the fixed-effects model was selected to calculate the pooled effects; otherwise, a random-effects model was used (Higgins and Green, 2011). In only one of the three studies, the outcome data were available as means and standard deviations (Tonnelier *et al.*, 2005), while in the other two studies (Roh *et al.*, 2012Danckers *et al.*, 2013), outcomes were reported as medians and IQRs, probably because of the non-normal distribution. For these two studies, we approximated the mean and calculated approximate standard deviation estimates. According to Hozo *et al.* (2004), the estimates of the mean and standard deviation can be fairly accurate and useful when there is no indication of the underlying distribution of the data.

RESULTS

The search resulted in 369 articles. After the initial screening, 39 articles required further investigation to assess whether they were to be included or excluded from the systematic review. Of the 39 articles retrieved, 30 were excluded. The most common reason for the exclusion of articles was the research design. After the abstract and article review process, we identified nine articles to retrieve in full text for review. Figure S1 illustrates the review selection process with a PRISMA flow diagram (Moher *et al.*, 2009).

Of the nine articles retrieved, six were excluded. The most common cause of exclusion of the articles was weaning protocols implemented by non-nurses (Ely *et al.*, 1996; Kollef *et al.*, 1997; Krishnan *et al.*, 2004; Plani *et al.*, 2013). The study by Rose *et al.* (2007) was excluded because it was a cohort prospective study (descriptive design), while in the Blackwood and Wilson-Barnett (2007) study, the focus was on nurses' perception, knowledge, and attitudes and not on the patients. Table 1 provides an overview of the three selected studies, which are described in more detail in the subsequent section.

Quality assessment

All the studies had some ROB across the Cochrane Collaboration domains (Table S2).

The allocation sequence was adequately generated and concealed in only one study (Roh *et al.*, 2012) because it was a prospective RCT. Neither of the other two studies had adequately generated and concealed allocation sequences: one was a prospective non-randomized study (Danckers *et al.*, 2013), and the other was a prospective cohort study (Tonnelier *et al.*, 2005).

Because of the nature of the intervention, the blinding of participants and staff to the intervention was not possible in the three included studies. Thus, in the Roh *et al.* (2012) study, nurses who were motivated to wean patients were assigned to the nurse-led protocol group; both physicians and nurses were attentive to managing their patients, and they were aware they were being observed. While neither of the two studies (Tonnelier *et al.*, 2005; Danckers *et al.*, 2013) specified whether outcome assessors were blinded to the intervention (they compared prospective intervention groups led by nurses with retrospective data for physician-driven ventilator weaning–i.e., historical controls), the details of outcome assessor blinding were not provided or mentioned in any of the three studies. All the studies reported complete outcome data: the three included studies reported recruitment, attrition, and exclusion adequately for assessment purposes, and all three studies published the weaning protocol and reported all prespecified outcomes. The three studies' chosen and specified outcomes based on objectives with statistically significant results were reported. The three studies were free of 'other sources of bias', as defined in the Cochrane Collaboration's domain-based evaluation, although sample size calculations were not mentioned in any of the three studies.

Methodological quality

The three studies clearly described four patient characteristics (gender, age, primary diagnosis, and Acute Physiology and Chronic Health Evaluation II [APACHE II] score). No significant differences were revealed in the baseline characteristics between the intervention and control groups in the three studies, and they were free of selective reporting of results (outcomes). The tools used to measure intervention adherence and outcomes in each of the three studies varied. The weaning methods used in each of three studies also varied (Table S3). Two of the studies (Roh *et al.*, 2012; Danckers *et al.*, 2013) secured ethical approval, while Tonnelier *et al.* (2005) did not indicate whether ethical approval was obtained.

Three studies were identified that compared a nurse-led ventilation-weaning protocol with physician-led weaning by usual care. In these studies, protocols were designed to facilitate weaning and extubation through the use of both screening to assess weaning readiness and a spontaneous breathing trial. Danckers *et al.* (2013) conducted a prospective, non-randomized study that used a nurse-led protocol-directed approach and compared

Table 1 Characteristics of included studies

Study (Author, year, country)	Study design	Sample size (*n*)	Participants	Interventions	Outcome measures	Results
1-(Danckers *et al.*, 2013) USA, New York, medical-surgical ICU	Comparative study with historical controls—A prospective, non-randomized study	202 patients	Mechanically ventilated adult patients for more than 24 h (short-term period)	Control (C): $n = 100$ Physician-driven ventilator weaning (historical control) Intervention (I): $n = 102$ Nurse-driven ventilator-weaning protocol	Duration of MV in days, ICU LOS, hospital LOS, rate of VAP, hospital mortality, and attitudes of physicians towards the nurse driven, protocol-directed ventilator weaning.	Median duration of MV(d): C: 4 days(2–13), I: 2 days (2–11), ($p = .001$). Median length of ICU stay (d): C: 7 days, I: 5 days, ($p = .01$). Time of extubation:2 h and 13 min earlier in the intervention group (nurse-led protocol). But there was no significant difference in hospital LOS (d): C: 18 (6–41.5), I: 15 (7–32), ($p = .32$), hospital mortality (%):C:17.0, I:15.7, ($p = 0.85$). Rate of VAP (%) ($p = .37$), and reintubation rate (%) ($p = 1.0$) between the two groups
2-(Roh *et al.*, 2012) Korea, medical ICU of the Asian Medical Centre (AMC)	Randomized controlled trial (RCT)	122 patients	Patients on mechanical ventilation for more than 12 h or less than 14 days (short-and long-term period)	Control (C): $n = 61$ Physician delivered Protocol Intervention (I): $n = 61$ Critical care nurse driven ventilator-weaning protocol	Weaning time, overall duration of mechanical ventilation, ICU LOS, hospital LOS, and frequency of complications (tracheostomy, failure of discontinuation, death).	Weaning time (h): C:47 h (interquartile range, 24–168 h), I: 25 h (interquartile range, 5.75–134 h, ($p = 0.010$). Median (IQR) duration of MV(d): C:6.2 days, I:5.7 days. ($p = 0.016$) Median (IQR) (length of ICU stay (d): C: 14 days, I: 12 days, ($p = 0.069$). Hospital LOS (d): C:41 (27.25–81.5), I: 39 (22–64), $p = 0.576$). Hospital mortality)%): C:11(18.0), I: 9 (14.8), ($p = 0.625$). The results also showed the number of patients who successfully discontinued mechanical ventilation was similar in the two groups (PBW, 46 patients, 75.4%; UC, 47 patients, 77.0%; $p = .832$).
3-(Tonnelier *et al.*, 2005) France, A university hospital ICU Centre (HospitalierUniversitaire de la Cavale Blanche)	Comparative study with historical controls—A prospective cohort study	208 patients	Patients were mechanically ventilated through an endotracheal tube and required MV for longer than 48 h.	Control (C): $n = 104$ conventional physician-directed weaning (historical control) Intervention (I): $n = 104$ Nurse-driven ventilator-weaning protocol	The overall duration of MV and the ICU LOS, the overall incidence of ventilator-associated pneumonia, unsuccessful extubation rates and ICU mortality.	Mean duration of MV(d) C: 22.5 ± 2 I:16.6 ± 1, ($p = 0.02$) Mean ICU LOS (d) C: 27.6 ± 21.7 I:21.6 ± 14.3, ($p = 0.02$). Ventilator associated pneumonia, ventilator discontinuation failure rates and ICU mortality did not change, and were similar between the two groups.

AMC, Asian Medical Centre; ICU, intensive care unit; IQR, interquartile range; LOS, length of stay; MV, mechanical ventilation; PBW, protocol-based weaning; RCT, randomized controlled trial; VAP, ventilator-associated pneumonia.

it with retrospective data for physician-led ventilator weaning (historical controls) to collect outcome data. This was achieved by reviewing the hospital records of all patients with MV admitted to the same medical-surgical ICU during the same period 1 year earlier (January 2007 to June 2007) to minimize the impact of seasonal variations on indications for MV between the two groups. The aim of the study was to evaluate whether ventilator-weaning protocols could improve clinical outcomes. The study was undertaken to examine the relationships of ICU structure, staffing, and acceptability by ICU physicians. The participants were enrolled in the study over a 5-month period. The authors concluded that the results favoured the protocol driven by ICU nurses, which was found to lead to a reduction in MV duration and ICU LOS without adverse effects. A prospective RCT by Roh *et al.* (2012) compared protocol-based weaning (PBW) with usual care. The aim of this clinical trial of patients on MV was to determine whether a weaning protocol implemented solely by nurses could reduce the weaning time relative to usual care. A total of 122 patients who received invasive ventilation were enrolled in the study for 2 years. The study relied on dedicated MV weaning, which was performed by nurses, for protocol adherence data, and computerized records designed for patients were randomized to the PBW group. The charge nurses screened the mechanically ventilated patients in the medical ICU every morning, and eligible patients were randomly assigned to the PBW or usual care group. Spontaneous breathing trials (SBTs) and extubations were only allowed from 07:00 to 17:00. The researchers concluded that the weaning protocol administered by the nurses was safe and reduced the weaning time from MV in patients who were recovering from respiratory failure. Tonnelier *et al.*'s (2005) study relied upon a dedicated research nurse to prospectively collect protocol adherence and outcome data for a prospective cohort study using a nurse-led, protocol-directed procedure (cases) and compared them with a 1:1 matched historical control group who underwent conventional physician-directed weaning. Participants were enrolled in the study for approximately 1 year (from January 2002 to February 2003). The aim of the study was to determine whether the use of a protocol-directed weaning procedure by nurses was associated with a reduction in the duration of MV and ICULOS. Thus, eligible patients were identified for the weaning procedure through daily screening by nurses. Eligible patients required more than 48 h of MV and had satisfied the eligibility criteria for an SBT for 90 min using a T-piece; screening began immediately after ICU admission. The researchers found that nurse-led, protocol-directed weaning was safe and promoted significant outcome benefits.

The three included studies reported on the duration of MV and the length of ICU stay. Two studies reported on hospital LOS and mortality (Roh *et al.*, 2012; Danckers *et al.*, 2013). In contrast, only one study reported on weaning time (Roh *et al.*, 2012), whereas two studies reported on VAP rates (Tonnelier *et al.*, 2005; Danckers *et al.*, 2013). Details of the three studies can be reviewed in Table 1 above.

Outcomes

All three studies found a significant decrease in the duration of MV (Tonnelier *et al.*, 2005; Roh *et al.*, 2012; Danckers *et al.*, 2013). While two studies found a significant decrease in the median durations of ICU LOS (Tonnelier *et al.*, 2005; Danckers *et al.*, 2013), one study found a significant decrease in weaning time (Roh *et al.*, 2012), although there was no significant decrease in the ICU LOS. Two of the studies reported no significant decrease in hospital LOS or hospital mortality (Roh *et al.*, 2012; Danckers *et al.*, 2013). Two studies reported no significant decrease in VAP rates (Tonnelier *et al.*, 2005; Danckers *et al.*, 2013).

Duration of MV (days)

Data from three included studies illustrate a statistically significant difference in favour of nurse-led weaning protocols for reducing the duration of MV. The analysis showed a significant difference as the weighted mean results did not go below zero, with the test of overall effect resulting in a p value = 0.03. For data included in the meta-analysis, the chi-squared test for heterogeneity was also significant ($p = 0.003$), and the I^2 test was 83%. The mean number of days by which MV was reduced was 1.69 (range from 2 to 6 days) (Figure 1).

Weaning time (hours)

One study reported weaning time as an outcome (Roh *et al.*, 2012). In that study, weaning time was defined as the time from enrolment (initiation of weaning) to successful discontinuation of MV. The result was 47 h (IQR, 24–168 h) in the physician-led group and 25 h (IQR, 5.75–134 h) in the nurse-led weaning protocol group ($p = 0.010$). The results represent a significant decrease in the weaning time for patients whose MV was managed using a nurse-led protocol.

ICU LOS (days)

Data from the three studies illustrate a statistically significant difference in favour of nurse-led weaning protocols for reducing the ICU LOS: the weighted mean results were not below zero, and the test of the overall effect resulted in a p value = 0.00001. For the data included in the meta-analysis, the chi-squared test for heterogeneity was not significant ($p = 0.30$), and the I^2 test result was 18%. The mean ICU LOS was reduced by 2.04 days (Figure S2).

Hospital LOS (days)

Two of the three included studies demonstrated that the nurse-led weaning protocol reduced the length of hospital stay (Roh *et al.*, 2012; Danckers *et al.*, 2013). Figure S3 shows a significant reduction in hospital LOS for the nurse-led weaning protocol group, with $p = 0.001$. For the data included in the meta-analysis, the chi-squared test for heterogeneity was not significant ($p = 0.67$), and the I^2 test result was 0%. The mean hospital LOS was reduced by 2.9 days (Figure S4).

Substantial heterogeneity of $I^2 = 83\%$ was found for the MV duration. For the ICU LOS, low heterogeneity of $I^2 = 18\%$ was found, and no significant heterogeneity was found for hospital LOS.

DISCUSSION

In this systematic review, we assessed evidence from three studies on the effect of nurse-led weaning protocols on the duration of MV weaning time and ICU and hospital LOS in critically ill adults. The results of this review evidenced that the nurse-led weaning protocols reduce the duration of MV, weaning time, and ICU LOS and affect other outcomes for critically ill adult patients compared with usual physician-led care. Meta-analysis showed a significant difference in reducing the duration of MV and ICU and hospital LOS

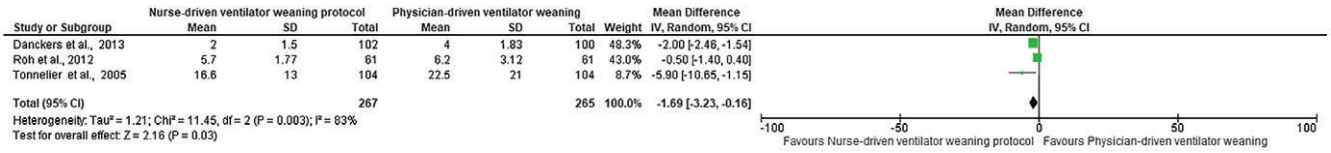

Figure 1 Comparison of nurse-led weaning protocol versus physician-led care. Outcome: Mechanical ventilation duration.

in favour of nurse-led weaning protocols. Only one study (Roh *et al.*, 2012) reported on weaning time and found that it was significantly decreased. Although the data from the pooled summaries alone appear to support nurse-led weaning protocols, they should be viewed with caution because of the significant heterogeneity among studies, particularly in terms of the MV duration ($I^2 = 83\%$.).

The reduction in the MV duration in our findings is in accordance with earlier RCTs (Ely *et al.*, 1996; Kollef *et al.*, 1997; Marelich *et al.*, 2000) and is also supported by non-RCTs (Dries *et al.*, 2004; Plani *et al.*, 2013) and Price's (2001) systematic review of nurse-led weaning from MV. That review found a reduction in ventilation time without additional complications, and the protocol-directed weaning was managed by nurses and RTs. Accordingly, Danckers *et al.* (2013) and Tonnelier *et al.* (2005) found that the protocol driven by ICU nurses led to a reduction in the MV duration and ICU LOS without adverse effects. This is similar to the findings of a study by Smyrnios *et al.* (2002) but contrary to findings of studies (Ely *et al.*, 1996; Kollef *et al.*, 1997; Grap *et al.*, 2003; Roh *et al.*, 2012) that reported no significant decrease in ICU LOS despite a decrease in the duration of MV without explicitly stating the reasons for their results. Another study (Krishnan *et al.*, 2004) did not find a shorter MV duration and ICU LOS; thus, they suggested that their results may be because of the high levels of physician staffing in their closed ICU or to the use of a template on rounds to promote daily discussion of mechanically ventilated patients. Additionally, some physicians, nurses, or RTs changed their practice of usual care for ventilator management because they were aware of the study in progress (Hawthorne effect). Nevertheless, Roh *et al.* (2012) reported that the nurse-administered weaning protocol established a significant reduction in MV weaning time. This is in accordance with Ely *et al.* (1996), who found a significant reduction in the weaning duration. Our review found a significant reduction in hospital LOS, contrary to earlier studies (Ely *et al.*, 1996; Kollef *et al.*, 1997). Furthermore, we found that the use of nurse-led protocols to guide weaning had no effect on adverse events, including hospital mortality, reintubation, and VAP rate. These findings are in accordance with the findings of Ely *et al.* (1996), Kollef *et al.* (1997), and Krishnan *et al.* (2004). Other studies (Dries, 2004; Marelich *et al.*, 2000; Plani *et al.*, 2013) found that ventilator-weaning protocols were associated with a decrease in the incidence of VAP.

The weaning protocols that were used in these studies varied. Danckers *et al.* (2013) and Roh *et al.* (2012) described PBW that included spontaneous breathing trials with CPAP; for patients who satisfied the eligibility criteria for weaning, the duration of SBTs ranged from 30 to 120 min through a ventilator circuit. This is in accordance with six other studies (Ely *et al.*, 1996, Kollef *et al.*, 1997; Marelich *et al.*, 2000; Namen *et al.*, 2001; Krishnan *et al.*, 2004; Piotto *et al.*, 2011). However, in Roh *et al.* (2012), SBT *via* T-piece was used for 30 min for patients who were ventilated for longer than 72 h. In contrast, Marelich *et al.* (2000) used weaning protocols consisting of stepwise reductions in synchronized intermittent mechanical ventilation (IMV) and pressure support before the SBT for patients with the same MV duration (>72 h). In contrast, Tonnelier *et al.* (2005) used a 90-min SBT with a T-piece to screen patients who had required more than 48 h of MV and satisfied the eligibility criteria for readiness for a weaning trial. Indeed, further investigation is warranted to determine whether specific protocols are more beneficial than others for specific populations of patients. The evidence supporting the use of weaning protocols in clinical practice is not consistent across all populations, and the results may indicate that the protocols vary in more than composition alone (Blackwood *et al.*, 2009). Furthermore, this review shows that a nurse-administered weaning protocol is safe and promotes significant outcome benefits for patients on MV. This is in accordance with a study by Rotello *et al.* (1992) that found that nurses adhere to directed protocols. Additionally, nurses are more readily available than physicians and can successfully wean patients from MV and contribute to better management (Roh *et al.*, 2012). Timely and safe discontinuation of MV is an desirable outcome for patients (Blackwood *et al.*, 2009). Weaning protocols increase nurses' direct involvement in decisions related to patient care and provide an additional avenue for communication with the health care team (Rose *et al.*, 2011). Roh *et al.* (2012) reported that the administration of a weaning protocol by nurses is an effective use of the limited resources in the ICU. The responsibility for identifying patients ready to wean from MV and assisting in the weaning trial can be successfully assumed by ICU nurses (Tonnelier *et al.*, 2005Roh *et al.*, 2012; Danckers *et al.*, 2013).

Strengths and limitations of the review

We believe that our review is the first synthesis and meta-analysis of nurse-led weaning protocols compared with usual physician-led care and that it provides further assurance that ICU nurses alone can guide weaning from MV. In this systematic review and meta-analysis of nurse-led weaning protocols, all studies provided a comprehensive description of methods.

Our challenges were that only three studies of nurse-led weaning protocols were included in this review, and only one study was an RCT. Thus, the results should be interpreted with caution.

A methodological limitation was the inability to blind the health staff to the weaning method because of the interventions required for PBW; consequently, it is

possible that the decisions and actions of the health staff could have been influenced, resulting in biased estimates of treatment outcomes. Furthermore, the protocols used in the three studies were different.

Implications for clinical practice

- Nurse-led weaning protocols for mechanically ventilated critically ill adult patients have a positive impact on weaning outcomes.
- Nurse-led weaning protocols for mechanically ventilated critically ill adult patients are safe and viable to implement.
- Health staff should be involved in developing, evaluating, and revising weaning protocols as new evidence emerges.

CONCLUSION

The findings show that nurse-driven weaning protocols can be implemented safely and effectively and have a major impact on patients' outcomes. Remarkably, the results emphasize that the weaning protocols led by critical care nurses resulted in reductions in the duration of MV, ICU LOS, and hospital LOS and that they are easy to implement, safe, and accepted by the ICU health staff.

Uniform weaning protocols based on the best available evidence minimize variations in clinical weaning practices. Indeed, the protocol is a vital part of the weaning process. Constant re-evaluation and modification of the protocol based on evidence are essential to successful weaning and improving patient outcomes. Critically ill patients need constant care and evidence-based systems of practice. Implications for future research include a need for extensive randomized controlled studies to gain more evidence in support of nurse-led weaning protocols and effective durations of MV, ICU LOS, and hospital LOS.

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SUPPORTING INFORMATION

The following Supporting information is available for this article:

Figure S1. Review selection process.
Figure S2. Comparison Nurse-led weaning protocol versus Physician-led care. Outcome: ICU Length of Stay.
Figure S3. Comparison Nurse-led weaning protocol versus Physician-led care. Outcome: Hospital Length of Stay.
Table S1. Records identified through database search
Table S2. Summary of risk of bias assessment: Cochrane Collaboration Tool for assessing risk of bias
Table S3. Characteristics of weaning methods for critically ill adults on mechanical ventilation

Additional supporting information may be found online in the Supporting Information section at the end of the article.

WHAT IS KNOWN ABOUT THIS TOPIC

- Prolonged MV can be associated with adverse outcomes and higher morbidity in patients
- Ventilator-weaning protocols have been reported to reduce the duration of MV, reduce ventilator-associated complications, and have beneficial outcomes for patients.

WHAT THIS ARTICLE ADDS

- The current study provides additional evidence that nurse-led weaning protocols have a major impact on weaning outcomes compared with usual care.
- Systematic weaning protocols based on evidence can reduce variations in clinical weaning practices and offer an internationally standardized process.
- Standardized weaning protocols led by nurses were effective in reducing MV time and ICU and hospital LOS.

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