Miia Jansson

THE EFFECTIVENESS OF EDUCATION ON CRITICAL CARE NURSES’ KNOWLEDGE AND SKILLS IN ADHERING TO GUIDELINES TO PREVENT VENTILATOR-ASSOCIATED PNEUMONIA
MIIA JANSSON

THE EFFECTIVENESS OF EDUCATION ON CRITICAL CARE NURSES’ KNOWLEDGE AND SKILLS IN ADHERING TO GUIDELINES TO PREVENT VENTILATOR-ASSOCIATED PNEUMONIA

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University of Oulu Graduate School; University of Oulu, Faculty of Medicine, Institute of Health Sciences, Nursing Science; Medical Research Center; Oulu University Hospital, Department of Anaesthesia, Division of Intensive Care Medicine

Abstract

Professional practice in critical care settings is characterized by the application of relevant theories, research and evidence-based guidelines to clinical practice. However, critical care nurses’ knowledge and skills in adhering to evidence-based protocols and guidelines for avoiding ventilator-associated pneumonia are inadequate.

The aim of the study was to evaluate critical care nurses’ knowledge and skills in adhering to best-practice endotracheal suctioning recommendations and ventilator bundles, to develop and validate instruments to evaluate the care of mechanically ventilated patients, and to evaluate the effectiveness of continuing education on critical care nurses’ knowledge and skills, with a focus on ventilator bundles.

In the first study, a descriptive and cross-sectional correlation study was conducted to evaluate critical care nurses’ (n = 40) endotracheal suctioning practices in relation to current best-practice recommendations. In the second study, a descriptive design with a literature review was conducted to assess the effectiveness of educational programmes in preventing ventilator-associated pneumonia. In the third study, an instruments validation study was conducted to develop and test the psychometric properties of the Ventilator Bundle Questionnaire (VBQ) and Observation Schedule (VBOS). In the fourth study, the effectiveness of human patient simulation education was evaluated among thirty (n = 30) critical care nurses who were randomly allocated to intervention and control groups (n = 15 each).

Critical care nurses’ knowledge and skills in adhering to best-practice endotracheal suctioning recommendations and ventilator bundles continues to be inadequate. However, educational programmes were linked to significant improvements in learning and clinical outcomes. The VBQ and VBOS were developed and shown to have acceptable psychometric properties (CVI 0.99–1.0, ICC 0.93–1.0). After human patient simulation education, the mean skill scores of the intervention group increased significantly (p_{tg} = 0.02).

Educational programmes may have a significant impact on clinical outcomes and thus, patients’ safety and quality of care, through improvements in nurses’ knowledge and skills in adhering to evidence-based guidelines in critical care settings. The VBQ and VBOS can provide an objective method measuring whether evidence-based guidelines are being used in clinical practice. In addition, there was a significant transfer of learned skills to clinical practice following human patient simulation education.

Keywords: critical care nursing, instrument, nursing education, patient simulation, ventilator bundle, ventilator-associated pneumonia
Jansson, Miia, Kouluksen vaikuttavuus tehohoitajien tietoihin ja taitoihin noudattaa hoitosuosituksia ventilaattori pneumonian ehkäisyksi.
Oulun yliopiston tutkijakoulu; Oulun yliopisto, Lääketieteellinen tiedekunta, Terveystieteen laitos, Hoitotiede; Medical Research Center; Oulun yliopistollinen sairaala, Anestesiaklinikka, Tehooidon toimialue
Oulun yliopisto, PL 8000, 90014 Oulun yliopisto

Tiivistelmä

Teho-osastoilla ammatillinen erityisosaaminen edellyttää tutkitun tiedon, teorioiden sekä näytöön perustuvan hoitosuositusten soveltamista kliniseen käytäntöön. Kuitenkin tehohoitajien tiedot ja taidot noudattaa näyttöön perustuvia hoitokäytäntöjä ja suosituksia hengityslaitehoitoon liittyvän keuhkokuumeen ehkäisyksi ovat olleet puutteellisia.

Tutkimuksen tarkoituksena oli arvioida tehohoitajien tietoa ja taitoa noudattaa hyväksi havaittuja hengitysteiden imukäytäntöjä sekä hengityslaitehoitoon liittyviä hoitosarjakäytäntöjä, kehitettä ja validoida mittareita hengityslaitehoitoa saavien potilaiden hoidon laadun arviointimenetelmiä sekä arvioida täydennyskoulutuksen vaikuttavuutta tehohoitajien tietoihin ja taitoihin noudattaa hengityslaitehoitoon liittyviä hoitosarjakäytäntöjä.

Ensimmäisessä osatyössä arviotiin kuvanlevan ja korrelatiivisen tutkimusasetelman avulla tehohoitajien (n = 40) alahengitysteiden imukäytäntöjä suhteessa havaittuihin toimintakäytäntöihin. Toisessa osatyössä arviotiin kuvanlevan kirjallisuuskatsauksen avulla koulutusinterventiojen vaikuttavuutta hengityslaitehoitoon. Kuitenkin osatyössä arvioitiin koulutusinterventiojen vaikuttavuutta hengityslaitehoitoon. Kuitenkin osatyössä arvioitiin koulutusinterventiojen vaikuttavuutta hengityslaitehoitoon.

Tehohoitajien tiedot ja taitot noudattaa hyväksi havaittuja hengitysteiden imukäytäntöjä sekä hengityslaitehoitoon liittyviä hoitosarjakäytäntöjä olivat edelleen puutteellisia. Kuitenkin koulutusinterventiojen vaikuttavuus kliinisissä hoitotuloksissa sekä oppimistuloksissa oli merkittävä. VBQ- ja VBOS-mittareiden psykometriset ominaisuudet osoittautuivat hyväksyttäviksi (CVI 0,99–1,0, ICC 0,93–1,0). Simulaatiokoulutuksen jälkeen interventioryhmän taidot noudattaa hoitosuosituksia lisääntyivät merkittävästi (p < 0,02).

Koulutusinterventiojen kliininen vaikuttavuus potilasturvallisuuden ja hoidon laadun kehitämissessä voi olla merkittävää, kun hoitajien tietoja ja taitoja noudattaa käytäntöön perustuvia hoitosuosituksia lisäädään kliinisissä tehohoitotyössä. VBQ- ja VBOS-mittarit voivat tarjota objektiivisen tavan arvioida tutkitun tiedon siirtymistä kliiniseen käytäntöön. Simulaatiokoulutuksen jälkeen opittujen taitojen siirtovaikutus kliiniselle käytäntölle oli merkittävä.

Asiakirjat: hengityslaitehoitoon liittyvä hoitosarja käytäntö, hengityslaitehoitoon liittyvä keuhkokuume, hoitotyön koulutus, mittari, potilassimulaatio, tehohoitotyö
To Jussi, Iida and Daniel for their love and continuous support
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I also want to remember my parents, now passed away, who I know would have been proud of my work and whose influence on my life has been of great importance. In addition, my hearty and loving gratitude goes to my little sister Ninni. Other relatives are respectfully acknowledged.
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Oulu, February 2014

Miia Jansson
## Abbreviations

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<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>AACN</td>
<td>American Association of Critical-Care Nurses</td>
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<tr>
<td>CACCN</td>
<td>Canadian Association of Critical Care Nurses</td>
</tr>
<tr>
<td>Cohen’s $\kappa$</td>
<td>Cohen’s Kappa Coefficient</td>
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<tr>
<td>CVI</td>
<td>Content Validity Index</td>
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<tr>
<td>EBG</td>
<td>Evidence-Based Guideline</td>
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<td>EfCCNa</td>
<td>European federation of Critical Care Nursing associations</td>
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<tr>
<td>ETS</td>
<td>Endotracheal Suctioning</td>
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<tr>
<td>HOB</td>
<td>Head of the bed</td>
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<td>HPS</td>
<td>Human Patient Simulation</td>
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<tr>
<td>ICC</td>
<td>Intraclass Correlation Coefficient</td>
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<td>ICU</td>
<td>Intensive Care Unit</td>
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<tr>
<td>RCT</td>
<td>Randomized Controlled Trial</td>
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<td>VAP</td>
<td>Ventilator-Associated Pneumonia</td>
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<tr>
<td>VB</td>
<td>Ventilator Bundle</td>
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<tr>
<td>VBOS</td>
<td>Ventilator Bundle Observation Schedule</td>
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<tr>
<td>VBQ</td>
<td>Ventilator Bundle Questionnaire</td>
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<tr>
<td>WFCCN</td>
<td>World Federation of Critical Care Nurses</td>
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List of original publications

This thesis is based on the following original publications, which are referred to in the text with Roman numerals I–IV.


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1 Introduction


The need for critical care services has grown substantially over the last few decades (Ewart et al. 2004) and demands for such services will increase over the decades ahead (Needham et al. 2005, Adhikari et al. 2010). Changes in patient profiles and in health care environments, varying socioeconomic conditions, and advances in science and information technology pose many challenges for the nursing profession and particularly nursing education (EfCCNa 2004, Adhikari et al. 2010, Vandijck et al. 2010) and research (Blackwood et al. 2011a). Research priorities reflect worldwide healthcare concerns and objectives related to patients’ safety and infection control (Blackwood et al. 2011a, Adhikari et al. 2010), whereas nosocomial infections (Baktoft 2008, Simerka 2009), medication errors and equipment failures are the main types of adverse events that affect critically ill patients (Baktoft 2008).

Ventilator-associated pneumonia (VAP) is a sub-type of hospital-acquired pneumonia, occurring in patients who are mechanically ventilated via an artificial airway, causing substantial morbidity, a two-fold increase in mortality rates (Klompas et al. 2012), extra costs (Chen et al. 2009), all coupled with the prolonged use of ventilators (Stone et al. 2011, Klompas et al. 2012) and extended stays in intensive care units (ICU) and hospitals (Karhu et al. 2011, Stone et al. 2011, Klompas et al. 2012). According to previous international surveys, the theoretical and applied knowledge of critical care nurses has been limited (Fulbrook et al. 2012). In addition, critical care nurses’ knowledge of (Blot et al. 2007, Labeau et al. 2008a, El-Khatib et al. 2010, Jansson et al. 2013a), adherence to (Gurses et al. 2008), and attitudes toward (Kaynar et al. 2007, Pogorzelska & Larson 2008) evidence-based guidelines (EBGs) to prevent VAP have been inadequate.

Although ventilator bundles (Baktoft 2008), nursing education (Baktoft 2008, Simerka 2009, Blackwood et al. 2011a, Mellin-Olsen et al. 2010) and simulation
education (Baktoft 2008, Rall et al. 2011) are the key elements that should be taken into consideration in order to improve patient safety and quality of care, the effectiveness of simulation education in the continuing education of critical care nurses is still largely unknown (Jansson et al. 2013c, Jansson et al. 2014). In addition, there is a lack of reliable and valid instruments to evaluate simulation-based learning outcomes (e.g. knowledge, skills) in nursing education (Kardong-Edgren et al. 2010).

Therefore, the aim of this study was to evaluate critical care nurses’ knowledge and skills in adhering to best-practice endotracheal suctioning (ETS) recommendations and ventilator bundles (VBs), to develop and validate instruments to evaluate the care of mechanically ventilated patients, and to evaluate the effectiveness of continuing education on the knowledge and skills of critical care nurses, with a focus on VBs. The results could be applied in nursing practice, nursing education and nursing research.
2 Review of the literature

This literature review consists of four parts. First, the advantages of VBs on clinical and economic outcomes are described. In the second part, the literature review continues by describing critical care nurses’ knowledge and skills in adhering to VBs. In the third part, the use of human patient simulation education in critical care settings is described. Finally, the main gaps in the previous literature are summarized.

2.1 Ventilator bundles

The Institute for Healthcare Improvement (IHI) developed the concept of “bundles” to help health-care providers more reliably deliver the best possible care for patients undergoing particular treatments with inherent risks. VBs are considered as a “package” of EBGs, designed to help reduce VAP and promote adherence to evidence-based protocols and guidelines in order to improve clinical outcomes (Berwick et al. 2006, Rello et al. 2010). These include combinations of sedation vacation and use of weaning protocols (Rello et al. 2010, IHI 2011), elevation of the head of the bed (HOB) between 30° and 45° (Tablan et al. 2004, IHI 2011), daily oral care with chlorhexidine (Tablan et al. 2004, Rello et al. 2010, IHI 2011), adequate hand hygiene (Tablan et al. 2004, Rello et al. 2010), and ulcer and deep vein thrombosis prophylaxis (IHI 2011).


These studies have demonstrated the significant advantages of VBs in improving patient safety through the reduction of adverse clinical outcomes such as reduced incidences of VAP (Blamoun et al. 2009, Hawe et al. 2009, Zaydfudim et al. 2009, Al-Tawfig & Abed 2010, Bird et al. 2010, Bouadma et al. 2010, Morris et al. 2011, Stone et al. 2011, Crimlisk et al. 2012), reduced numbers of ventilator-days (Blamoun et al. 2009, Bloos et al. 2009, Al-Tawfig & Abed 2010,
Bouadma et al. 2010, DePalo et al. 2012), reduced lengths of stay (Al-Tawfig & Abed al. 2010, Crimlisk et al. 2012), lower costs (Al-Tawfig & Abed 2010, Bird et al. 2010, Crimlisk et al. 2012), and reduced monthly use of sedatives (Bloos et al. 2009) and antibiotics (Morris et al. 2011). In addition, there have been trends towards lower mortality rates (Hawe et al. 2009, Morris et al. 2011). However, VBs are frequently inconsistently adopted, implemented and evaluated (Pogorzelska et al. 2011, Jansson et al. 2013b).

2.2 Critical care nurses’ knowledge and skills in adhering to ventilator bundles

Professional practice in high risk critical care setting requires specialized knowledge and advanced skills to assess, monitor and effectively respond to the needs of critically ill patients (EfCCNa 2004, AACN 2008, CACCN 2009). In addition, it is characterized by the application of relevant theories, research and EBGs to clinical practice (EfCCNa 2004, AACN 2008, Fulbrook et al. 2012).

2.2.1 Critical care nurses’ knowledge

According to a previous international survey, conducted with 1142 critical care nurses in Europe, the theoretical and applied knowledge of those nurses was limited. The relatively low mean scores (56–63%) have been related to respiration, mechanical ventilation and infection control. (Fulbrook et al. 2012.) In other surveys, the relatively low mean scores have been related to EBGs for the prevention of VAP (41.2–78.1%) as well as catheter-related bloodstream (45.1%) and surgical site (29.0%) infections (Blot et al. 2007, Labeau et al. 2008a, Labeau et al. 2008b, Labeau et al. 2009, El-Khatib et al. 2010, Jansson et al. 2013a). The level of ICU experience (>5 yrs), age (≥40), and gender (male) have been independently associated with better knowledge scores (Blot et al. 2007, Labeau et al. 2008a, Fulbrook et al. 2012, Jansson et al. 2013a).

2.2.2 Critical care nurses’ skills

According to a cross-sectional survey, conducted in 415 ICUs in 250 US hospitals, approximately 68% of ICUs have a written policy for VBs (Pogorzelska et al. 2011). In addition, 66% of those ICUs monitored their implementation and of those, only 39% have reported full bundle compliance defined as occurring
95% of the time or greater (Pogorzelska et al. 2011). In other international studies, the relatively low mean scores have been related to critical care nurses’ obtained (20–78%), documented (39%) and self-reported (84%) skills in adhering to VBs (Zaydfudim et al. 2009, Al-Tawfig & Abed 2010, Bird et al. 2010, DePalo et al. 2010, Morris et al. 2011, Pogorzelska et al. 2011, Jansson et al. 2013a).

Optimally managed and monitored sedation has been associated with patients needing shorter periods of mechanical ventilation, a reduced length of stay in ICU (Jackson et al. 2010, Barr et al. 2013), reduced costs, lower incidence of nosocomial infections and lower mortality rates (Jackson et al. 2010). In the United States, 80% of ICUs had a written policy for sedation vacation (Pogorzelska et al. 2011). In addition, 74% of those ICUs monitored their implementation; of those, only 48% reported full bundle compliance (Pogorzelska et al. 2011). In other observational intervention studies, critical care nurses’ skills in adhering to sedation vacation policy have ranged from 70% to 99% (Hawe et al. 2009, Bird et al. 2010, Morris et al. 2011).

Optimally managed mechanical ventilation aims at preventing complications associated with mechanical ventilation by emphasizing the importance of lung protective ventilation and the prevention of unnecessary delays to the weaning process (Boles et al. 2007, Blackwood et al. 2011b, EFCCN 2012). Despite this, the weaning process continues to be delayed (Burns et al. 2009, Bird et al. 2010, DePalo et al. 2010). Approximately 56–69% of ICUs had a written policy for protocol-led weaning while 55% of ICUs had used automated weaning modes (Rose et al. 2011). In other observational intervention studies, 52–96% of patients receiving mechanical ventilation were assessed daily for weaning (Hawe et al. 2009, Zaydfudim et al. 2009, Bird et al. 2010, DePalo et al. 2010). According to Morris et al. (2011), 90% of critical care nurses failed to document or make decisions about “wake and wean” while the analysis of weaning and extubation experiences revealed a large percentage of self-extubations (Weireter et al. 2009). In addition, obtained tidal volumes have been higher than recommended (Bloos et al. 2009, Linko et al. 2009).

Elevation of the HOB between 30° and 45° has generally been preferred to prevent aspiration in critically ill patients who are receiving mechanical ventilation and enteral feeding (Masterton et al. 2008, AACN 2011, Metheny & Franz 2013). According to Pogorzelska et al. (2011), 90% of American ICUs had a written policy about HOB elevation. In addition, 78% of those ICUs have monitored their implementation but, of those, only 48% reported full bundle compliance (Pogorzelska et al. 2011). In other observational studies, the correct
position has ranged from a low of 22% to a high of 100% (Bloos et al. 2009, Hawe et al. 2009, Bingham et al. 2010, Bird et al. 2010, Rose et al. 2010, Morris et al. 2011, Gatell et al. 2012) whereas the median of the mean was 22–24° (Hanneman & Gusick 2005, Bloos et al. 2009).

Airway management practices and suctioning techniques emphasize the importance of the prevention of aspiration of oropharyngeal secretions into the lower airways (AARC 2010, Albertos et al. 2011). Although evidence-based oral care protocols exist (Browne et al. 2011, AACN 2010), only 37–72% of ICUs have a written policy for them (Sole et al. 2003, Cutler & Davis 2005, Feider et al. 2010) and of those, compliance has ranged from a low of 6% to a high of 95% (DeKeyser et al. 2009, Hawe et al. 2009, Zaydfudim et al. 2009, Bingham et al. 2010, Feider et al. 2010, Garcia et al. 2010, Morris et al. 2011, Gatell et al. 2012). In addition, previous studies conducted in Oceania (McKillop 2004), Asia (Chau et al. 2007), Europe (Kelleher & Andrews 2008, Day et al. 2009) and the Middle-East (Özden & Görgülü 2012) have reported significant differences between the quality of critical care nurses’ ETS practices (Table 1).

Hand hygiene is the most effective measure for preventing nosocomial infections (Siegel et al. 2007, Masterton et al. 2008, WHO 2009). However, only 44.2% of hospitals had a written policy for them (Larson et al. 2007). In addition, critical care nurses’ obtained skills in adhering to hand hygiene guidelines have been ranged from a low of 6% to a high of 65% (Larson et al. 2007, Bingham et al. 2010, DeWandel et al. 2010, Marra et al. 2010, Sahay et al. 2010, Gatell et al. 2012, Morgan et al. 2012).
<table>
<thead>
<tr>
<th>Author</th>
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<th>Design</th>
<th>Data collection and measurements</th>
<th>Results</th>
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<tr>
<td>McKillop 2004</td>
<td>ICU nurses (n = 105); multicenter-study in New Zealand and Australia</td>
<td>Intervention study with repeated measurements</td>
<td>Structured, non-participatory method of observation with structured best-practice information sheet; knowledge and ETS² practices</td>
<td>The degree of uptake of the evidence was variable across the sites and recommendations. Improved practices were seen between the pre and post tests.</td>
</tr>
<tr>
<td>Chau et al. 2007</td>
<td>Registered nurses (n = 51); ICUs of two major acute hospitals in Hong Kong</td>
<td>Intervention study with repeated measurements</td>
<td>Structured, non-participatory method of observation with structured audit tool; ETS² practices</td>
<td>In the baseline, 65% of participants scored above the 70% level. Compliance to guidelines significantly increased from 73% to 89% after project implementation.</td>
</tr>
<tr>
<td>Kelleher &amp; Andrews 2008</td>
<td>Critical care nurses (n = 45); two adult ICUs in Ireland</td>
<td>Observation study</td>
<td>Structured, non-participatory method of observation with a 20-item observation schedule; ETS² practices</td>
<td>The mean skill score was 64.6% of total score.</td>
</tr>
<tr>
<td>Day et al. 2009</td>
<td>Nurses and physiotherapists (n = 95); two acute hospitals in the UK³</td>
<td>Experimental design with repeated measurements in simulation environment and clinical practice</td>
<td>Self-administered 20-item questionnaire and structured non-participatory method of observation with a 20-item observation schedule; knowledge and ETS² practices</td>
<td>Intervention group performed significantly better in terms of knowledge (p = 0.014) and practice (p = 0.037) at final follow-up.</td>
</tr>
<tr>
<td>Özden &amp; Görgülü 2012</td>
<td>ICU nurses (n = 48); single academic center in Turkey</td>
<td>Intervention study with repeated measurements</td>
<td>Self-administered 50-item questionnaire and structured non-participatory method of observation with observation form; knowledge and ETS² practices</td>
<td>The mean knowledge score increased significantly from 61.9% to 92.1% after training; however compliance to guidelines remained satisfactory.</td>
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¹ Intensive care unit, ² Endotracheal suctioning, ³ United Kingdom
2.3 Human patient simulation education in critical care settings

The dynamic nature of critical care settings requires new and more effective evidence-based educational interventions to ensure patient safety and a high quality of care (Cronenwett et al. 2007, Simerka 2009). Over the past few decades, there has been a rapid increase by nurse anesthetists of awareness and adoption of simulation education applied to acute, perioperative, and emergency care settings to improve the quality of care (Lupien 2007).

Simulation is interactive (Gaba 2004) and a unique method of experimental learning (Decker et al. 2008) and/or evaluation (Gaba 2004, Lupien 2007, Decker et al. 2008). It uses human patient simulators, which are computerized full-body mannequins programmed to provide realistic physiological responses to practitioners’ actions (Decker et al. 2008). These high-fidelity, full-scale simulations require realistic environments and the use of actual medical equipment and supplies (Fig 1).

Generally, in nursing education, simulation education has been incorporated into basic and graduate nursing programs, hospital-based orientation programs, and continuing education and certification programs (Nagle et al. 2009) to evaluate and develop participants’ cognitive, behavioral and psychomotor skills as well as clinical competencies. In previous experimental studies conducted in the United States (Dine et al. 2008, Ford et al. 2010, Pascual et al. 2011), the effectiveness of human patient simulation (HPS) education on critical care nurses’ competencies (Dine et al. 2008, Ford et al. 2010, Pascual et al. 2011) and clinical outcomes (Ford et al. 2010) were evaluated in simulation environments (Dine et al. 2008, Pascual et al. 2011) and clinical practice (Ford et al. 2010).

However, the effectiveness of HPS education in critical care nurses’ continuing education is still largely unknown due to a lack of published studies and robust evidence (Jansson et al. 2013c). Also, the effectiveness of simulation education in improving infection control practices is unknown (Jansson et al. 2014). There is also a lack of reliable and valid instruments to evaluate simulation-based learning outcomes (e.g. knowledge, skills) in nursing education (Kardong-Edgren et al. 2010).
Fig. 1. Human patient simulator mannequin (HAL®, Gaumard) receiving mechanical ventilation, continuous sedation and enteral nutrition in a critical care setting. Equipment for nursing includes oral care, endotracheal suctioning (e.g. open and closed suction), and personal protective equipment (e.g. gloves, hand disinfectant, masks and aprons), as well as charts for sedation and pain evaluation, cuff pressure meter, stethoscope and patient monitor.

2.4 Summary of the literature

VBs may have significant advantages for the improvement of patient safety through the reduction of adverse clinical outcomes. However, they are frequently inconsistently adopted, implemented and evaluated (Pogorzelska et al. 2011, Jansson et al. 2013b). In addition, critical care nurses’ knowledge and skills in adhering to evidence-based protocols and guidelines for avoiding complications associated with intubation and mechanical ventilation are currently limited (Pogorzelska et al. 2011, Fulbrook et al. 2012). Moreover, the effectiveness of simulation education in critical care nurses’ continuing education is still largely unknown (Jansson et al. 2013c). Also, there is a lack of reliable and valid instruments to evaluate simulation-based learning outcomes in nursing education (Kardong-Edgren et al. 2010). The main gaps in the extant literature from the perspective of this current study are:

1. Critical care nurses’ knowledge and skills in adhering to current ETS best-practice recommendations and VBs are incomplete, especially in Scandinavia, where the topic has not been widely discussed.
2. There is a lack of knowledge related to the effectiveness of educational programmes for preventing VAP.
3. There is a lack of reliable and valid instruments that can be used to evaluate the care of mechanically ventilated patients. In addition, there is a lack of language-validated (Finnish) instruments to evaluate critical care nurse’s knowledge and skills in adhering to VBs.

4. There is a lack of randomized controlled follow-up studies that evaluate the effectiveness of HPS education in improving infection control practices in nursing continuing education and identify the transfer of learned skills to clinical practice.
3 Aims and hypotheses of the study

The aim of this study was to evaluate critical care nurses’ knowledge and skills in adhering to best-practice endotracheal suctioning recommendations and ventilator bundles, to develop and validate instruments to evaluate the care of mechanically ventilated patients, and to evaluate the effectiveness of continuing education on critical care nurses’ knowledge and skills, with a focus on ventilator bundles. This study consists of four sub-studies (I–IV) and addressed the following research questions and hypotheses:

1. What are critical care nurses’ practices prior to, during and post endotracheal suctioning events, and how do practices differ from current best-practice recommendations (I)?
   a) It was hypothesized that critical care nurses’ performance in relation to current best-practice recommendations in their daily practice prior to, during and post endotracheal suctioning event is inadequate.

2. What is the effectiveness of educational programmes on learning and clinical outcomes (II)?

3. What are the psychometric properties of the Ventilator Bundle Questionnaire and Observation Schedule (III)?

4. How do knowledge and skills related to the management of mechanically ventilated patients differ between randomly allocated intervention and control groups before and after human patient simulation education in both the simulation environment and clinical practice (IV)?
   a) It was hypothesized that intervention groups’ knowledge and skill in adhering to ventilator bundles might increase compared to the control group after the human patient simulation education.
4 Material and methods

This chapter describes the study samples, data collection, analysis and ethical questions of this four-phase study (I–IV). Different designs, samples, settings, methods of data collection and analysis were used throughout the study (Table 2).

Table 2. The detailed approaches of the study.

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample and setting</th>
<th>Design</th>
<th>Data collection and measurements</th>
<th>Analysis</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Critical care nurses (n = 40); a 22-bed adult, mixed medical-surgical ICU¹ in a single academic center in Finland</td>
<td>Prospective, descriptive and cross-sectional correlation study</td>
<td>Structured, non-participatory method of observation with a 25-item structured best-practice information sheet</td>
<td>Descriptive and inferential statistics</td>
<td>Performance</td>
</tr>
<tr>
<td>II</td>
<td>Studies published between 2003 and 2012; seven multi-disciplinary databases</td>
<td>Descriptive study design</td>
<td>Systematic review</td>
<td>Quality assessment, narrative synthesis</td>
<td>Learning and clinical outcomes</td>
</tr>
<tr>
<td>III</td>
<td>Methodological (n = 6) and content expert panelists (n = 10); critical care nurses (n = 23–65); a single academic center in Finland</td>
<td>Instruments validation study</td>
<td>Literature review, expert analysis, test-retest and inter-rater procedures</td>
<td>Content validity, test-retest stability and inter-rater equivalence reliabilities</td>
<td>Validated questionnaire (VBQ) and observation schedule (VBOS)</td>
</tr>
<tr>
<td>IV</td>
<td>Critical care nurses (n = 30); a 22 bed adult mixed medical-surgical ICU¹ in a single academic center in Finland</td>
<td>Parallel randomized controlled trial with repeated measurements</td>
<td>Self-administered 49-item multiple-choice questionnaire and structured non-participatory method of observation with 86-item observation schedule</td>
<td>Descriptive and inferential statistics</td>
<td>Knowledge and skills</td>
</tr>
</tbody>
</table>

¹ Intensive Care Unit
4.1 Evaluation of critical care nurses’ endotracheal suctioning practices (I)

A prospective, descriptive and cross-sectional correlation study was conducted to evaluate critical care nurses’ performance in relation to current best-practice recommendations in their daily practice prior to, during and post ETS events (Table 2). A convenience sample of critical care nurses \( (n = 40) \) was observed in the participants’ daily working environments during morning (07:00–15:00) and evening (14:30–21:30) shifts in nursing care and extubation contexts. Inclusion criteria were as follows: 1) informed consent was obtained after a potential participant was fully informed about the study’s aim and procedure; 2) participants were direct care providers. Event sampling was assumed as the most appropriate method of observation because of the erratic nature of the ETS procedure (Polit & Beck 2013).

The structured, non-participatory method of observation provided a systematic and purposeful data collection method, particularly for recording participants’ behavior in real-life situations (Burns & Grove 2009, Moule & Goodman 2009, Polit & Beck 2013). In this non-participatory design, the observer was unobtrusive, did not interfere with the participants’ daily duties and did not intervene or provide information (Parahoo 2006). The method was guided by a highly structured 25-item best-practice information sheet, which was adapted from existing tools (McKillop 2004, Kelleher & Andrews 2008) in order to facilitate comparison with published studies (Polit & Beck 2011).

The best-practice information sheet was divided into four sections: practices prior to ETS event, infection control practices, and practices during and post ETS events. The quality of ETS practices was assessed using a readily quantified rating scale to reduce observers’ subjectivity and enhance objectivity and reliability (Burns & Grove 2009, Moule & Goodman 2009). If participants adhered to an item in the recommended procedure, they were assigned one point, yielding a quality score range of 0–25. Higher scores indicated higher levels of skills.

4.2 Review of the effectiveness of educational programmes in preventing ventilator-associated pneumonia (II)

The systematic review was conducted using seven multi-disciplinary databases to assess the current body of literature regarding the effectiveness of educational
programmes covering the prevention of VAP (Table 2). A preliminary search strategy was developed using Medic, Ovid MEDLINE®, and the Cumulative Index to Nursing and Allied Health Literature to identify optimal search terms.

The final review focused on peer-reviewed empirical studies written in English, Swedish or Finnish and published over the last ten years (2003–2012). A comprehensive literature search strategy was formulated in association with an information specialist, based on comparison of outputs of advanced and basic searches with appropriate permutations of terms (CDR 2009). The search terms were as follows (Table 3):

<table>
<thead>
<tr>
<th>Database</th>
<th>Search term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Search</td>
<td>“ventilator-associated pneumonia” OR “pneumonia ventilator associated” OR “VAP” AND educat* OR teach*</td>
</tr>
<tr>
<td>Premier</td>
<td></td>
</tr>
<tr>
<td>CINAHL</td>
<td>“pneumonia ventilator associated” AND educat* OR teach* AND Age groups: Adult: 19-44 years, Aged: 45-64 years, Aged: 65+ years, Aged: 80 and over</td>
</tr>
<tr>
<td>Cochrane Library</td>
<td>“ventilator-associated pneumonia” OR “pneumonia ventilator associated” OR “VAP” AND educat* OR teach*</td>
</tr>
<tr>
<td>Medic</td>
<td>“ventilator-associated pneumonia” OR “pneumonia ventilator associated” OR “VAP” AND educat* OR teach*</td>
</tr>
<tr>
<td>Ovid Medline®</td>
<td>Pneumonia, Ventilator-Associated AND Educat* AND Education, Nursing, Continuing AND Education, Nursing, Graduate AND Nursing Education Research AND “all adult (19 plus years)”</td>
</tr>
<tr>
<td>Scopus</td>
<td>“ventilator-associated pneumonia” OR “pneumonia ventilator associated” OR “VAP” AND educat* OR teach* AND adult* or aged AND prevent* OR Control*</td>
</tr>
<tr>
<td>Web of Science</td>
<td>“ventilator-associated pneumonia” OR “pneumonia ventilator associated” OR “VAP” AND educat* OR teach* AND adult* or aged</td>
</tr>
</tbody>
</table>

The study selection process was conducted in two stages by the review team, which consisted of methodological and content experts who were selected based on their methodological and/or clinical ICU expertise (Higgins & Green 2008, JBI 2008, CDR 2009, Polit & Beck 2013). Studies were included if they met inclusion criteria, which were tailored to the extremely specific research question, target population (e.g. registered critical or intensive care nurses), interventions (e.g. educational intervention used with or without other educational strategies), type of outcomes (e.g. learning or clinical outcome), and study design (e.g. intervention studies) to guide decision-making (CDR 2009). However, grey literature was excluded from the review.
4.3 Psychometric instruments validation study (III)

An instruments validation study (Table 2) was conducted to develop and test the psychometric properties of the Ventilator Bundle Questionnaire (VBQ) and Observation Schedule (VBOS). The study was divided into two phases: 1) domain identification, item generation and instruments formation and 2) psychometric testing (Table 4).

Domain identification, item generation and the formation of instruments based on existing instruments, along with a list of pharmacological and non-pharmacological nurse-led interventions, were described in the literature (e.g. Ovid MEDLINE®, the Cumulative Index to Nursing and Allied Health Literature, the Cochrane Library) and supported with varying degrees of evidence (Table 4). After domain identification, the contents of the instruments were divided into three main categories. The first category covered factual data about demographics (e.g. clinical characteristics) and the phenomenon of interest (e.g. etiology, epidemiology, and pathogenesis of VAP). The second (“intubation and mechanical ventilation”) and third (“prevention of airway colonization”) categories covered interventions aimed at reducing the duration of mechanical ventilation and microbiological colonization of the lower airways (Figure 2).
Finally, the instruments were formatted using previously published scoring formats (Table 4). A structured, self-administered, multiple-choice questionnaire with response alternatives was assumed to be an appropriate method of objectively measuring participants’ knowledge of VBs (Burns & Grove 2009, Gerrish & Lacey 2010, Polit & Beck 2011). In addition, a highly structured checklist with a rating scale was assumed to be an appropriate method of observation in order to enhance reliability (Burns & Grove 2009, Moule & Goodman 2009). Moreover, the highly structured formats ensured the comparability of the findings. Also, the use of precoded instruments allowed for quick analysis (Polit & Beck 2013).

After domain identification, item generation and instruments formation, the previously published instruments (Labeau et al. 2007, Kelleher & Andrews 2008) were translated from English into Finnish (Table 4). The principle of a double-blind, forward-back-forward translation process was adopted to avoid a biased translation process (Endacott et al. 2010, Sousa & Rojjanasrirat 2010). This
approach was carried out by three independent bilingual experts to generate two translated versions that covered both the medical and the ordinary spoken language with its cultural nuances (Sousa & Rojjanasrirat 2010).

After the double-blind translation process, the face and content validities of the developed instruments were tested by an expert panel using a structured procedure (Table 4). The panel consisted of methodological and content experts, who were selected based on their methodological and/or clinical ICU expertise (Lynn 1986, Polit & Beck 2013).

After content validation, the strength of relationships between repeated measurements (stability reliability) were tested twice in the simulation environment with a total of 65 critical care nurses using a test-retest procedure (Table 4). Finally, the agreement between two observer’s ratings (equivalence reliability) was tested in clinical practice ($n = 23$) using an inter-rater procedure.
Table 4. The main phases and steps taken in the instrument validation study (III).

<table>
<thead>
<tr>
<th>Phases and steps</th>
<th>Purpose</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1: Domain identification, item generation, and instrument formation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step I</td>
<td>To identify existing instruments to evaluate critical care nurses’ knowledge and skills in adhering to ventilator bundles</td>
<td>Literature review during April and June 2011</td>
</tr>
<tr>
<td>Step II</td>
<td>To identify the content of instruments in order to determine the items, concepts and elements to be included in the newly developed instruments</td>
<td>Literature review during August and September 2011</td>
</tr>
<tr>
<td>Step III</td>
<td>To develop instruments based on the previously published formats to facilitate cross-cultural comparisons</td>
<td>VBO¹ was formulated as a structured, self-administered, multiple-choice questionnaire with response alternatives. VBOS² was formulated as a highly structured checklist with a rating scale</td>
</tr>
<tr>
<td>Step IV</td>
<td>To translate previously published instruments into Finnish to facilitate cross-cultural comparisons</td>
<td>Double-blind, forward-back-forward translation process during October 2011</td>
</tr>
<tr>
<td>Phase 2: Psychometric testing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step I</td>
<td>To establish instrument face and content validity and test instrument format and instructions</td>
<td>Content validity index calculation during November 2011; methodological (n = 6) and content (n = 10) experts</td>
</tr>
<tr>
<td>Step II</td>
<td>To establish the observation schedule’s stability reliability</td>
<td>Test-retest procedure in the simulation environment: researcher conducted the measurement of a sample twice and then compared the scores</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1&lt;sup&gt;st&lt;/sup&gt; measurement: January 2012; critical care nurses (n = 40)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; measurement: May 2012; critical care nurses (n = 25)</td>
</tr>
<tr>
<td>Step III</td>
<td>To establish observation schedule’s equivalence reliability</td>
<td>Inter-rater procedure in clinical practice during August and October 2012: researcher and a second observer observed critical care nurses (n = 23) independently recording the data according to prescribed instructions and then compared the scores</td>
</tr>
</tbody>
</table>

¹Ventilator Bundle Questionnaire, ²Ventilator Bundle Observation Schedule
4.4 Randomized controlled trial (RCT) of the effectiveness of human patient simulation education (IV)

A single-center, prospective, parallel RCT with repeated measurements was carried out to evaluate the effectiveness of HPS education in the nursing management of mechanically ventilated patients (Table 2). Randomly selected critical care nurses were invited, via letter and electronic mail, to participate. Inclusion criteria were: holding a degree qualification as a registered nurse and being a direct care provider. The sample size \((n = 40)\) was determined through power analysis by a biostatistician (Polit & Beck 2013). The participants were randomly allocated to intervention \((n = 20)\) and control \((n = 20)\) groups using a computer-generated randomization list. They were separated into two age-based strata in order to enhance the sample’s representativeness (Polit & Beck 2013).

HPS education began with a brief bedside introduction from the simulation educators, giving a hands-on explanation of the simulation process and use of the HPS mannequin (HAL®, Gaumard). During the 10 minute scenario, participants were observed while managing an adult ICU patient with an artificial airway who was receiving continuous sedation, mechanical ventilation and enteral nutrition. During the simulations, the software of the HPS mannequin was programmed to cough and change vital signs. Participants had access to all necessary equipment used in the ICU environment and could ask the facilitator questions. Only the intervention group received verbal feedback and participated in a 60 minute structured debriefing (O’Donnell et al. 2009, Zigmont et al. 2011) that dealt with the definitions, epidemiology, etiology and pathogenesis of VAP as well as the effectiveness of VBs on clinical outcomes.

The scenario was designed and evaluated by the purposive sample of simulation educators \((n = 4)\) and physicians \((n = 2)\), who were selected based on their methodological and clinical ICU expertise (Polit & Beck 2013). In addition, the instruments used and the specific simulation process were pilot tested among a single cohort of 10 randomly selected critical care nurses.

Identical measurements were taken for the intervention and control groups by the same trained and experienced observer (Fig 3). The first post-intervention measurements (3 months after the intervention) were conducted in the simulation environment (follow-up I), with the final post-intervention measurements (6 months after the intervention) being carried out during the morning shift (07:00–15:00) in clinical practice (follow-up II).
Participants’ skills were evaluated using a direct, structured, non-participatory method of observation (Burns & Grove 2009, Moule & Goodman 2009, Polit & Beck 2013). The method was guided by the predetermined, 86-item highly structured checklist with a rating scale (VBO S). If participants adhered to an item in the recommended procedure, they were assigned one point, yielding a quality score range of 0–60.

The level of participants’ knowledge was evaluated at the end of the observational sessions using a 49-item multiple-choice questionnaire (VBQ). If participants answered correctly, they scored one point, yielding a quality score range of 0–37. Higher scores indicated a higher level of knowledge and skills. The validated questionnaires were distributed to participants by the same trained and blinded research assistant, who arranged an appropriate time and venue to gather the responses.
Eligible participants (N = 149)

Randomize

Obtain consent

Intervention group (n = 20)

Baseline measurements (n = 15)

Intervention (n = 15):
- 20-minute briefing
- 10-minute scenario
- 60-minute structured debriefing

I Follow-up measurements (n = 13)

II Follow-up measurements (n = 13)

Control group (n = 20)

Baseline measurements (n = 15)

I Follow-up measurements (n = 12)

II Follow-up measurements (n = 10)

Comparison

Fig. 3. The study participants’ group allocation (IV).
4.5 Data analysis

This section on data analysis consists of three parts. First, qualitative data analyses are described (e.g. quality assessment, narrative synthesis). Second, quantitative data analyses are described (e.g. descriptive and inferential statistics). Finally, testing of psychometric properties (e.g. validity, reliability) of the instruments developed is described. In addition, there is a graphical description of the data including flow charts, tables, histograms, boxplots and multiple line graphs.

Qualitative data analyses (II)

The standardized Critical Appraisal Checklist for Cohort/Case Control Appraisal was used to assess the methodological quality of relevant studies prior to inclusion in the final review (JBI 2008). The quality of relevant studies was assessed by the review team independently (Higgins & Green 2008, CDC 2009, Polit & Beck 2011) using a scoring system whereby 1 point was allocated for each relevant criterion included or 0 points if not, yielding a quality score range of 0–9, with higher scores indicating a higher level of quality (studies with ≥ 5 points were included in the final review).

The principles of narrative synthesis were used to describe, evaluate and summarize the findings of the included studies. After data extraction, a preliminary synthesis of the findings of the included studies was developed. The relationship between the studies was also explored. Finally, the robustness of synthesis (e.g. methodological quality of the studies included and the credibility of the synthesis) was evaluated (Popay et al. 2006, CRD 2009).

Quantitative data analyses (I, III–IV)

SPSS 18.0 for Windows (SPSS Inc., Chicago, IL, USA) and SAS for Windows (version 9.2, SAS Institute Inc., Cary, NC, USA) were used for quantitative data analyses. The quantitative data were analyzed in collaboration with blinded biostatisticians. In all studies, a two-tailed $P$ value less than 0.05 was considered statistically significant (Brown & Prescott 2006, Burns & Grove 2009).

Univariate descriptive statistics were used to describe, organize and summarize the data. These included frequency (e.g. frequencies, percentages) and variability (e.g. ranges, std. deviations) distributions as well as measures of
central tendency (e.g. means, medians). Bivariate descriptive statistics (e.g. Spearman correlation coefficient) were used to summarize the magnitude and direction of a nonlinear relationship between two variables (Table 5).

Table 5. The strength of correlation according to Fain (2009).

<table>
<thead>
<tr>
<th>Spearman correlation coefficient</th>
<th>Strength of correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00–0.25</td>
<td>Little, if any</td>
</tr>
<tr>
<td>0.26–0.49</td>
<td>Low</td>
</tr>
<tr>
<td>0.50–0.69</td>
<td>Moderate</td>
</tr>
<tr>
<td>0.70–0.89</td>
<td>High</td>
</tr>
<tr>
<td>0.90–1.0</td>
<td>Very high</td>
</tr>
</tbody>
</table>

Inferential statistics were used for hypothesis testing in order to generalize findings to the population and to examine causalities (e.g. linear mixed model) and significance of differences between categorical (e.g. Fisher’s exact test) and continuous variables (e.g. one-sample and independent-sample t-tests). In addition, a linear mixed model with a covariance pattern model was used to analyze changes in behavior over time (Brown & Prescott 2006, Shek & Ma 2011).

\[ P \]-values reported for repeatedly measured data were as follows: \( p \)-time \((p_t)\), the overall change over time; \( p \)-group \((p_g)\), the average between-group difference; and \( p \)-time*group \((p_{tg})\), the interaction between time and group. All the participants were included in the analysis within the initially allocated groups (ITT – intention-to-treat analysis), which ignores noncompliance, protocol deviations, withdrawal and anything that happens after randomization (Hollis & Campbell 1999).

Testing of psychometric properties (III)

Content and face validity testing were undertaken to determine the clarity and relevance of content. According to Lynn (1986), the content validity index (I-CVI) of each item, question and answer was rated using a four-point rating scale of relevance (Table 6). Any I-CVI above 0.80 was considered good (Polit & Beck 2011). In addition, the content validity indexes for entire instruments were calculated (S-CVI/Ave). S-CVIs above 0.90 were considered excellent (Polit & Beck 2011). In addition, an instrument’s face validity was established based on
non-statistical evaluation by the expert panel (Lynn 1986). Items met the clarity criterion if 70% of experts rated the item as clear (Burns & Grove 2009).

Table 6. Relevance categories according to Lynn (1986).

<table>
<thead>
<tr>
<th>Relevance categories</th>
<th>Rating scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not relevant</td>
<td>1</td>
</tr>
<tr>
<td>Somewhat relevant</td>
<td>2</td>
</tr>
<tr>
<td>Quite relevant</td>
<td>3</td>
</tr>
<tr>
<td>Very relevant</td>
<td>4</td>
</tr>
</tbody>
</table>

Stability and equivalence reliability testing were undertaken to determine the strength of relationship between repeated measurements (test-retest procedure) and agreement between two observer’s ratings (inter-rater procedure). The intraclass correlation coefficient (ICC), including confidence intervals (95% CI) and Cohen’s kappa coefficient (κ) of each item along with the mean scale score were calculated. An ICC above 0.80 was considered acceptable (Burns & Grove 2009, Polit & Beck 2013), whereas Cohen’s κ above 0.75 was considered good (Cohen 1960, Polit & Beck 2011), demonstrating substantial or almost perfect agreement (Table 7).

Table 7. The strength of relationship according to Landis and Koch (1997).

<table>
<thead>
<tr>
<th>Cohen’s κ</th>
<th>Strength of agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.21–0.40</td>
<td>Fair agreement</td>
</tr>
<tr>
<td>0.41–0.60</td>
<td>Moderate agreement</td>
</tr>
<tr>
<td>0.61–0.80</td>
<td>Substantial agreement</td>
</tr>
<tr>
<td>0.81–1.0</td>
<td>Almost perfect agreement</td>
</tr>
</tbody>
</table>

4.6 Ethical considerations of the study protocol

This section on ethical considerations consists of five parts. First, the ethics of the study design are described. Second, the approvals obtained are described. Third, informed consents are described. Then, the protection of human rights and the beneficence of the study are described.

The ethics of the study design

In this study, national legislations (Medical Research Act 488/1999, Personal Data Act 523/1999) and international ethical principles (WMA 2013) regarding
medical research involving human subjects have been carefully followed throughout the study process. The study aims, research questions and hypotheses were justifiable because they were based on the main gaps in the existing literature (Polit & Beck 2013). Power analysis was used to estimate the sample size needed (Study IV). The permission to translate, modify and use existing instruments was obtained from the respective authors (McKillop 2004, Labeau et al. 2007, Kelleher & Andrews 2008). The reporting of the study complied with the STROBE (STROBE 2007), CONSORT (Boutron et al. 2008) and PRISMA (Moher et al. 2009) standards.

Research ethics approvals

The research plans were accepted by the Research Council of the University of Oulu in 2010 and 2011. In addition, the approval of the Northern Ostrobothnia Hospital District was obtained from the chief nursing officer from the Division of Intensive Care Medicine, Oulu University Hospital in 2010 (Study I: 12th August 2010; drno 910) and 2011 (Studies III–IV: 28th September 2011 and 20th October 2011; drno 92). According to the Medical Research Act (488/1999 and amendments 295/2004), approval by the local ethics committee was not required for studies focusing on healthcare practitioners.

Obtaining informed consent

In accordance with the Medical Research Act (488/1999), written informed consent was obtained from each participant after they were fully informed about the study’s aim, procedure and requirements. Participants were assured of the confidential, voluntary nature of their participation and the anonymity of the data. In addition, participants were informed that they could withdraw from the study at any time without giving any justification (Medical Research Act 488/1999). Moreover, each member of the expert panels received written information about the study and the purposes of that expert panel (Study III). The act of responding to the questionnaire was considered to be informed consent (Finnish Advisory Board on Research Integrity 2009).
Protection of human rights

Privacy, anonymity and confidentiality were maintained by coding the participants, based on their free and informed consent (Medical Research Act 488/1999). The personal data were processed and anonymized lawfully in compliance with good processing practice (Personal Data Act 523/1999). The data (e.g. paper and electronics) are stored in safe storage and will be destroyed according to regulations and ethical guidelines (Personal Data Act 523/1999, Finnish Advisory Board on Research Integrity 2009).

Balancing benefits and risks in participating in the study

The research was conducted with respect for, and awareness of, ethical dilemmas between research ethics (e.g. researcher’s and clinician’s role), research design (e.g. RCT, blindness, recruitment, withdrawal) and the nature of nursing. Participation in high-fidelity simulations has been reported to cause temporary emotional and physical discomfort to the participants (Müller et al. 2009). However, the predicted outcomes of the study as well as actual and potential benefits for the individual subjects, society and future research were assessed to outweigh the potential risks to the individual subjects (Burns & Grove 2009).
5 Results

The detailed descriptions of the results are explained in the original publications I–IV. In this section, the main results are presented in five parts. First, critical care skills in adhering to current best-practice recommendations in their daily practices prior to, during and post ETS events are described. Second, the effectiveness of educational programs on learning and clinical outcomes is described. Third, the psychometric properties of the developed instruments are described. Fourth, the effectiveness of HPS education in the nursing management of mechanically ventilated patients is described. Finally, the main results are summarized.

5.1 Critical care nurses’ endotracheal suctioning practices (I, IV)

In study I, a total of 40 individual ETS events were observed, with each nurse being involved with only one event. The majority of participants were registered nurses (97.5%) with more than five years working experience (57.5%).

The addressed hypothesis was supported by the data: the mean scale score was 13.73 out of 25 points (range 8–19, SD 2.66). Significant discrepancies were observed in infection control practices prior to (e.g. protection of practitioners and patients from secretions and maintaining the sterility of the suction catheter until its insertion into the airway) and post (e.g. adequate disposal of the used catheter and gloves, hand disinfection) ETS events (Table 8). Other discrepancies were observed in practices prior to (e.g. ETS assessment techniques), during (e.g. adequate suction pressure) and post (e.g. confirmation of proper ET tube placement and maintenance of optimal cuff pressure) ETS events.

In study IV, a total of 30 individual ETS events were observed in the simulation environment (Table 8). All the participants ($n = 30$) were registered nurses often with a bachelor’s degree (96.7%), permanent employment (66.7%) and less than five years working experience (53.3%).

In addition, the addressed hypothesis was supported by the data: the mean scale score was 15.80 out of 26 points (range 11–21, SD 2.20). Significant discrepancies were observed in infection control practices prior to (e.g. protection of practitioners and patients from secretions and maintaining the sterility of suction catheter until its insertion into the airway and post (e.g. adequate disposal of the used catheter and gloves, hand disinfection) ETS events (Table 8). Other discrepancies were observed in practices prior (e.g. ETS assessment techniques), during (e.g. adequate suction pressure) and post (e.g. confirmation of proper ET tube placement and maintenance of optimal cuff pressure) ETS events.
In addition, critical care nurses’ knowledge of current ETS best-practice recommendations was evaluated (Study IV). The mean scale score in the knowledge test was 6.07 out of 14 points (range 1–10, SD 1.93). The most well-known recommendations were related to accurate cuff pressure (100.0%) and accurate duration of suction applied to airway (86.7%). The least well-known recommendations were related to accurate gloving (0.0%), sodium chloride instillation (3.3%), suction pressure (20.0%), pre and post suctioning hyperoxygenation (30.0%) and catheter size (43.3%). In addition, only 46.7% knew that suctioning should only be carried out when clinically indicated.
Table 8. Critical care nurses’ endotracheal suctioning (ETS) practices prior to, during and post ETS events. Data are expressed as frequencies.

<table>
<thead>
<tr>
<th>Practices prior to, during and post ETS event</th>
<th>Study I; n (%)</th>
<th>Study IV; n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Patient assessment prior to ETS event</td>
<td>2 (5.3)</td>
<td>11 (36.7)</td>
</tr>
<tr>
<td>2. Patient preparation</td>
<td>24 (61.5)</td>
<td>27 (90.0)</td>
</tr>
<tr>
<td>3. Elevation of the head of the bed between 30° and 45°</td>
<td>-</td>
<td>19 (63.3)</td>
</tr>
<tr>
<td>4. Pre suctioning hyperoxygenation</td>
<td>23 (57.5)</td>
<td>27 (90.0)</td>
</tr>
<tr>
<td>5. Cuff pressure checked¹</td>
<td>21 (56.8)</td>
<td>22 (73.3)</td>
</tr>
<tr>
<td>6. Protection of eyes from secretions¹</td>
<td>10 (25.0)</td>
<td>7 (23.3)</td>
</tr>
<tr>
<td>7. Protection of central venous catheter from secretions¹</td>
<td>26 (65.0)</td>
<td>12 (40.0)</td>
</tr>
<tr>
<td>8. Protection of environment from secretions¹</td>
<td>-</td>
<td>0 (0)</td>
</tr>
<tr>
<td>9. Analgesic administered¹</td>
<td>8 (21.1)</td>
<td>26 (43.3)</td>
</tr>
<tr>
<td>10. Hand disinfection prior to suctioning</td>
<td>26 (72.2)</td>
<td>20 (66.7)</td>
</tr>
<tr>
<td>11. Gloves worn</td>
<td>40 (100.0)</td>
<td>30 (100.0)</td>
</tr>
<tr>
<td>12. Apron worn</td>
<td>13 (32.5)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>13. Face mask worn</td>
<td>39 (97.5)</td>
<td>30 (100.0)</td>
</tr>
<tr>
<td>14. Sodium chloride instillation</td>
<td>10 (25.0)</td>
<td>8 (26.7)</td>
</tr>
<tr>
<td>15. Sterility of suction catheter maintained until inserted into airway</td>
<td>25 (67.6)</td>
<td>6 (20.0)</td>
</tr>
<tr>
<td>16. Shallow suctioning¹</td>
<td>-</td>
<td>20 (66.7)</td>
</tr>
<tr>
<td>17. Correct withdrawal¹</td>
<td>-</td>
<td>30 (100.0)</td>
</tr>
<tr>
<td>18. Continuous pressure¹</td>
<td>-</td>
<td>30 (100.0)</td>
</tr>
<tr>
<td>19. Correct number of suction passes</td>
<td>30 (75.0)</td>
<td>29 (96.7)</td>
</tr>
<tr>
<td>20. Accurate duration of suction applied to airway</td>
<td>29 (72.5)</td>
<td>30 (100.0)</td>
</tr>
<tr>
<td>21. Accurate suction pressure</td>
<td>6 (15.0)</td>
<td>21 (70.0)</td>
</tr>
<tr>
<td>22. Two nurses working as team to create suction¹</td>
<td>34 (85.0)</td>
<td>30 (100.0)</td>
</tr>
<tr>
<td>23. Reconnection of oxygen within 10 seconds post suctioning</td>
<td>33 (89.2)</td>
<td>30 (100.0)</td>
</tr>
<tr>
<td>24. Post-suctioning hyper oxygenation</td>
<td>25 (62.5)</td>
<td>25 (83.3)</td>
</tr>
<tr>
<td>25. Patient assessment post ETS event</td>
<td>0 (0.0)</td>
<td>6 (20.0)</td>
</tr>
<tr>
<td>26. Patient reassured</td>
<td>21 (55.3)</td>
<td>-</td>
</tr>
<tr>
<td>27. Hand disinfection post suctioning</td>
<td>21 (52.5)</td>
<td>5 (16.7)</td>
</tr>
<tr>
<td>28. Used catheter and gloves disposed of in a manner that prevents contamination from secretions</td>
<td>24 (61.5)</td>
<td>8 (26.7)</td>
</tr>
<tr>
<td>29. Cuff pressure checked¹</td>
<td>6 (23.1)</td>
<td>10 (33.3)</td>
</tr>
<tr>
<td>30. Subglottic suctioning¹</td>
<td>-</td>
<td>27 (90.0)</td>
</tr>
<tr>
<td>31. Confirmation of proper endotracheal tube placement¹</td>
<td>-</td>
<td>1 (3.3)</td>
</tr>
</tbody>
</table>

¹ Supplemented in Kelleher and Andrews’ (2008) original instrument, ² Measurement in the clinical practice, ³ Baseline measurement in the simulation environment
5.2 Effectiveness of educational programmes on learning and clinical outcomes (II)

In the first stage (N = 310) of the review, duplicate publications (n = 130) within the seven different databases were excluded. In the second stage, potentially relevant studies were assessed by comparing the titles (n = 180) and abstracts (n = 40). In the third stage, the full texts (n = 11) of studies that appeared to meet the inclusion criteria were obtained for detailed assessment against the predetermined inclusion criteria. Finally, eight out of the eleven original studies were included in the final review (72.7%).

The quality of each included study (n = 8) was assessed as high (range: 5–8; mean: 6.8 out of 9 points). These demonstrated significant advantages of educational programmes on patient safety through improvements in the learning (e.g. knowledge and skills in adhering to EBGs) and clinical outcomes (e.g. decreased incidence of VAP, reduced length of ICU and hospital stays, lower mortality and reduced monthly antibiotic and hospitalization costs) in critical care settings.

5.3 Psychometric properties of developed instruments (III)

Validity of the VBQ and VBOS

The face and content validities of the instruments developed were established by a purposive sample of methodological (n = 6) and content (n = 10) experts. The majority of participants were female (81.3%), often with a master’s degree (50%) and over 10 years working experience (87.5%).

The final VBQ contained 49 questions divided into three main categories: demographics (11 questions), intubation and mechanical ventilation (8 questions), and prevention of airway colonization (30 questions). The item level CVIs ranged from 0.91 to 1.0 and the scale level CVI, using the averaging approach, was 0.998. All the questions met the clarity criterion.

The final VBOS contained 86 items divided into three main categories: demographics (12 items), intubation and mechanical ventilation (4 items), and prevention of airway colonization (70 items). The item level CVIs ranged from 0.70 to 1.0 and the scale level CVI, using the averaging approach, was 0.99. The lowest value was related to the spontaneous breathing test (I-CVI 0.70); however, all the items met the clarity criterion.
Reliability of the VBOS

After content validation, stability and equivalence reliabilities were established for randomly selected critical care nurses. The majority of participants were female (75.0%), often with a bachelor’s degree (97.5%), permanent employment (72.5%) and more than five years working experience (50.0%).

The strength of relationship between repeated measurements (test-retest stability) ranged from 0.93 to 1.0, while 95% of CIs for the ICCs ranged from 0.88 to 1.0. The majority of Cohen’s κ values demonstrated almost perfect (75.0–88.9%) agreement while a minority of values demonstrated substantial (9.3–16.7%), moderate (8.3%) or fair (1.8%) agreement. The lowest Cohen’s κ values were associated with the duration of handrub (κ = 0.24–1.0) and hand hygiene technique (κ = 0.48–1.0).

The agreement between two observer’s ratings (inter-rater equivalence) ranged from 0.99 to 1.0, while 95% of CIs for the ICCs ranged from 0.98 to 1.0. The majority of Cohen’s κ values demonstrated almost perfect (93.9%) agreement while a minority of values demonstrated substantial (4.1%) or fair (2.0%) agreement. The lowest Cohen’s κ value was associated with the length of time suction should be applied to the airway (κ = 0.25).

5.4 Effectiveness of human patient simulation education in the nursing management of mechanically ventilated patients (IV)

The majority of participants (n = 30) were female (70.0%), often with a bachelor’s degree (96.7%), permanent employment (66.7%) and less than five years working experience (53.3%). The withdrawal rate between the groups ranged from 13.3% (intervention group) to 33.3% (control group). The main reason for withdrawal was a sudden illness.

In the baseline measurement, the mean knowledge score was 20.13 out of 37 points (range 12–25, SD 3.20). However, the addressed hypothesis was not supported by the data: after HPS education, the change in mean knowledge scores within either group was not statistically significant (Fig 4). However, the intervention group had higher scores (p_{g} = 0.05) over the whole study period.
In the baseline measurement, the mean skill score was 28.70 out of 60 points (range 20–37, SD 3.87). The addressed hypothesis was supported by the data: after the HPS education, intervention groups’ skill used for adhering to VBs increased significantly ($p_{t*g} = 0.02$) compared to the control group, increasing from 46.8 to 60.0% of the total score in the final post-intervention observation (Fig 5). The significant changes over time were related to intubation and mechanical ventilation ($p_t < 0.001$) and the prevention of airway colonization ($p_t = 0.02$). The significant time group interactions were related to the prevention of airway colonization ($p_{t*g} = 0.02$).
5.5 Summary of the main results

The main results of the study are:

1. The quality of observed practices prior to, during and post ETS events was significantly lower than the recommended care.
2. Educational programmes were linked to significant improvements in learning (e.g. knowledge and skills) and clinical outcomes (decreased incidence of VAP, reduced length of ICU and hospital stays, lower mortality, and reduced monthly antibiotic and hospitalization costs).
3. The VBQ and VBOS were developed and shown to have acceptable psychometric properties.
4. HPS education significantly improved skills among critical care nurses in managing mechanically ventilated patients, an improvement that was still
evident after 6 months of follow-up. In addition, a significant transfer of learned skills to clinical practice was identified.
6 Discussion

In this discussion section, the main results will be discussed in light of current healthcare concerns and objectives. Then, the validity and reliability of the study will be discussed in light of methodological literature. Finally, suggestions for future research and practical implications are presented.

6.1 Discussion of results

According to intensive care nursing research priorities in Europe (Blackwood et al. 2011a), the results of this study reflect worldwide healthcare concerns and objectives related to patient safety (e.g., prevention of adverse events, interventions to prevent and decrease VAP), the impact of evidence-based practice on outcomes (e.g., the impact of development and use of evidence-based protocols on patient outcomes, factors influencing implementation strategies of evidence-based practice, nurse-led weaning protocols and patient outcomes) and the impact of workforce on outcomes (e.g., effectiveness of continuing education of the critical care nurses’ competencies, with a focus on knowledge and skills).

Critical care nurses’ knowledge and skills in adhering to interventions to prevent and decrease VAP (I, IV)

In this study, critical care nurses’ knowledge of evidence-based protocols and guidelines for avoiding complications associated with intubation and mechanical ventilation was shown to be limited: the mean knowledge score in the baseline measurement was 54.4% of total score (Study IV), which is in line with previous literature (Blot et al. 2007, Labeau et al. 2008a, Jansson et al. 2013a). Thirty percent of the critical care nurses failed to achieve a mean score of 50%. These results are in line with previous international cross-sectional surveys, which established that there was a lack of knowledge and a need for continuing education (Blot et al. 2007, Labeau et al. 2008a, Fulbrook et al. 2012, Jansson et al. 2013a).

In addition, this study confirms that critical care nurses’ skills in adhering to evidence-based protocols and guidelines for avoiding complications associated with intubation and mechanical ventilation are currently limited: the mean skills score in the baseline measurement was 47.8% of total score (Study IV). Seventy three per-cent of the critical care nurses failed to achieve a mean score of 50%. In
addition, the quality of observed practices prior to, during and post ETS events were significantly lower than the recommended care: the mean skills score ranged from 54.9% (Study I) to 60.8% (Study IV), which is in line with several previous studies (Table 1).

**Development and use of evidence-based protocols on clinical outcomes (II)**

According to the Health Care Act (1326/2010, and amendments 601/2013), the provision of health care should be based on evidence and recognized treatment and operational practices. In addition, the health-care provided should be of high quality, safe, and appropriately organized. However, VBs are frequently inconsistently adopted, implemented and evaluated, especially in Scandinavia, where the topic has not been widely discussed. In this study, critical care nurses’ daily activities were based more on intuition and tradition than on evidence-based protocols and guidelines, which is line with previous studies (Labeau et al. 2007, Day et al. 2009, DeKeyser et al. 2009).

In the current environment where ICU resources are limited and ventilated patients already use a significant proportion of acute care resources, the adaptation, implementation and regular evaluation of evidence-based protocols and guidelines have all been highlighted (Adhikari et al. 2010, Baktoft 2008, Blackwood et al. 2011a, Cherry et al. 2012). This study highlights the importance of nursing education and active implementation strategies (Sinuff et al. 2008, Schweizer et al. 2013), which may have a significant impact on clinical outcomes, and thus patients’ safety and quality of care, through improvements in nurses’ knowledge and skills in adhering to evidence-based protocols and guidelines.

However, other co-workers have highlighted that the overall adherence to VBs should be ≥95% to realize a bundle’s full potential (Hawe et al. 2009, Zaydfudim et al. 2009, Pogorzelska et al. 2011). In addition, the internal and external validity of previous outcome research has been variable due to the lack of a universal method of outcome measurements (e.g. variations in research design and samples, lack of standardization of instruments, measurements and follow-up times, along with diagnostic difficulties etc.).
Effectiveness of continuing education on critical care nurses’ knowledge and skills (III–IV)

This study is the first longitudinal randomized controlled trial to evaluate the effectiveness of HPS education in infection control on nurses’ continuing education and has identified a significant transfer of learned skills to clinical nursing practice. Generally in nursing education, there has been a significant gap between the theory taught in the classroom and the realities of clinical practice (Baktoft 2008). In this study, the intervention group’s skills for managing mechanically ventilated patients differed significantly from the control group in both the simulation environment and clinical practice after HPS education. In addition, these improvements were still evident after 6 months of follow-up.

In the baseline measurement, 20% of the intervention achieved a mean score of 50%. (Study IV). However, in the final post-intervention observation, 92.3% of them achieved a mean score of 50%. These results suggest a real-world impact on clinical outcomes by reducing preventable errors that could potentially result in harm (Baktoft 2008, Rall et al. 2011). However, the explanation of the statistically significant difference in the average knowledge scores within the groups over the whole study period remains debatable: there were no significant differences between the mean age and test scores, which is known to influence the level of knowledge (Blot et al. 2007, Labeau et al. 2008, Fulbrook et al. 2012) and attitudes toward clinical practice guidelines (Pogorzelska & Larson 2008, Feider et al. 2010).

The variability of findings among the published studies might result from the lack of robust evidence and a universal method for outcome measurements (e.g. standardized scenarios and instruments, variations in the samples, research designs and use of simulation education, lack of standardized measurements and follow-up times). In addition, the potential use of simulation for evaluation (e.g. formative and summative evaluation) and/or competency testing cannot be achieved until nurse educators and researchers develop realistic simulation scenarios and outcome validation in the patient care areas, as well as design and validate standardized and reliable testing methods (Decker et al. 2008).

In this study, we developed language-validated instruments to evaluate the care of mechanically ventilated patients. In addition, the contents of existing instruments were updated and expanded to cover interventions related to adequate hand hygiene (e.g. alcohol-based handrub, hand hygiene technique, duration of handrub), appropriate enteral nutrition (e.g. body positioning, maintenance of
optimal cuff pressure), daily oral care (e.g. oral decontamination with chlorhexidine, brushing of teeth, moisturizing, subglottic suctioning) and updated best-practice ETS recommendations, all of which are essential treatment-related risk factors in the pathogenesis of VAP. These newly developed instruments have been shown to have acceptable psychometric properties and might be applicable in clinical practice and nursing education research.

Direct observation of health-care practitioners during patient care activity by trained and validated observers is recognized as the gold standard for hand hygiene monitoring (WHO 2009). In this study, the results of the Cohen’s $\kappa$ analysis interpreted moderate agreement with the duration of handrub and hand hygiene technique ($\kappa = 0.48–1.0$). These results are in line with previous literature (Braun et al. 2009, Sax et al. 2007, Sax et al. 2009, Boyce 2011, Morgan et al. 2012), where the methodological limitations in the method of hand hygiene observation are highlighted (e.g. different aspects of hand hygiene, lack of standardized methodology). To some extent, the “My five moments for hand hygiene” approach (Sax et al. 2007) or emerging technologies, such as wireless locating systems and electronic sensors (Boyce 2011, Morgan et al. 2012), could have been used to reduce observer’s effect.

6.2 Validity and reliability of the study

Comprehensive, ongoing quality control was assured throughout the study in order to ensure the accuracy of the data. In this section, the validity (e.g. internal and external validities) and reliability of the research designs, samplings, measurements, and analysis will be discussed for studies I–IV.

Study I

A prospective, descriptive and cross-sectional study design was used to identify problems with current practices in a single academic center. Event-sampling was assumed as the most appropriate method of observation because of the erratic nature of ETS procedures. However, the sample size was not assessed for statistical significance and the participants were selected using a non-probability method of sampling, which may have increased the risk of sampling bias (Fain 2009, Polit & Beck 2013).

The prospectively collected data were collected by a trained and experienced observer a previously validated and pre-tested observational rating scale designed
by Kelleher and Andrews (2008). To some extent, the videotaping or inter-rater procedure could have been used to reduce observer’s effect (Parahoo 2006). However, a number of practical and methodological difficulties, as well as ethical and legal issues, limited their use (Parahoo 2006).

The data were analyzed in collaboration with a biostatistician. However, a single-center study with methodological weaknesses (e.g. unpresentative sample, instruments with limited reliability and validity) limit any generalization. On the other hand, the sample was of sufficient size to reveal differences between critical care nurses’ performance in relation to current best-practice recommendations. In addition, the results were in line with the previous literature.

**Study II**

A systematic review was assumed as the most reliable and valid approach to summarize previous research findings. However, the search strategy focused only on peer-reviewed empirical studies written in English, Swedish or Finnish and published over the last 10 years (2003–2012), which may have led to publication or language bias (CRD 2009). The expansion of the search strategy to other databases or trial registers could have reduced the risk of publication bias (CRD 2009, Polit & Beck 2013). However, there is no consensus on whether systematic reviews should include grey literature (Polit & Beck 2013).

The study selection process was carried out by one content and one methodological expert, independent of each other (Higgins & Green 2008, JBI 2008, CDR 2009, Polit & Beck 2013). The standardized Critical Appraisal Checklist for Cohort/Case Control Appraisal was used to assess methodological quality of relevant studies in order to avoid incorrect or misleading conclusions (JBI 2008, CRD 2009, Polit & Beck 2011). The indexes of inter-rater reliability were not calculated (Polit & Beck 2013). However, there was complete agreement between the reviewers’ final selections.

During the process, the search strategy and study selections were documented carefully to ensure their reproducibility (CRD 2009, Polit & Beck 2011). The quality of relevant studies was assessed as being high by two reviewers independently (Higgins & Green 2008, CDC 2009, Polit & Beck 2011). To some extent, the use of standardized data extraction forms could have been used to reduce bias and improve validity and reliability (CRD 2009). However, the data extraction form used had been tailored to the specific review question and objectives (JBI 2008, CRD 2009).
Further synthesis (e.g. meta-analysis) was limited because of the lack of robust evidence. However, narrative synthesis is viewed as a 'second best' approach for the synthesis of findings from multiple studies (Popay et al. 2006). Systematic reviews represent a crucial aid to external validity precisely because they focus on replications across time, space, people and settings to explore consistencies (Polit & Beck 2013).

**Study III**

A psychometric instrument validation study was conducted due to the lack of reliable and validated instruments that could be used to evaluate critical care nurses’ knowledge and skills in adhering to VBs. The content of the instruments developed was based on a comprehensive list of international guidelines for the management of patients undergoing mechanical ventilation. In addition, acceptable psychometric properties were established. However, criterion-related and construct validities of the instruments could not be established due to the lack of existing instruments (Moule & Goodman 2009) or external criteria (Polit & Beck 2013).

In addition, the stability reliability of the VBQ was not established because the level of knowledge was assumed to change over time, regardless of the instrument’s stability (Burns & Grove 2009, Polit & Beck 2013). As the estimates of validity and reliability are specific to the sample being tested (Burns & Grove 2009, Endacott et al. 2010), further testing with diverse samples is needed to strengthen the generalizability of the VBQ and VBOS.

**Study IV**

An RCT with repeated measurements was assumed to be an appropriate design for establishing causality (Polit & Beck 2013). In addition, random sampling, random assignment and the use of the control group were assumed as the most effective approaches for controlling confounding variables to reduce bias and thus enhance the internal validity of the study (Polit & Beck 2013). However, the group assignment of participants was not blinded, which may have increased the risks of expectation or awareness bias, undermining the construct validity (Polit & Beck 2013).

The instruments and simulation process used were piloted among randomly selected critical care nurses, who were similar in characteristics to the intended
participants, to identify errors in the question design, problems with the instructions and typographical mistakes (Parahoo 2006, Moule & Goodman 2009). Structured methods were assumed as the most appropriate data collection methods, particularly for recording participants’ behavior and knowledge (Burns & Grove 2009, Moule & Goodman 2009, Polit & Beck 2013).

The prospectively collected data were cross-checked against multiple sources and analyzed in collaboration with a biostatistician, who was unaware of the group allocation in order to enhance objectivity (Polit & Beck 2013). ITT analysis was the most robust analytical method for analyzing the results of an RCT with repeated measurements (Hollis & Campbell 1999). Fifty-three percent of the sample had five or less years of ICU experience which may have skewed the results.

According to Polit and Beck (2013), the lack of significant enhancement of participant knowledge may have been attributable to the limited sample size (statistical conclusion validity) or unreliable instrument (construct validity). In addition, the VBQ may have been insufficiently sensitive. However, the study population was statistically sufficiently powered to provide skill scores.

The attrition bias is a serious challenge in longitudinal studies, limiting the generalizability of the findings (Polit & Beck 2013). The withdrawal rate between the groups ranged from 13.3% to 33.3%. Random sampling, random assignment and use of the control group (standard care) were used to enhance the external validity of the study (e.g. representativeness, generalizability). In addition, the use of two age-based strata enhanced the sample’s representativeness (Polit & Beck 2013). However, a single-center study with limited sample size limits generalizability. The results may not be applicable to different populations, settings or situations.
6.3 Suggestions for future research

Using the results of the study, the following suggestions for further research are presented below:

1. Further research is needed to evaluate the adaptation and implementation of best-practice ETS recommendations and VBs, especially in Scandinavia, where the topic has not been widely discussed.

2. Further multi-centre, parallel or cluster randomised controlled, follow-up trials are needed to evaluate the effectiveness of active implementation strategies (e.g. education) on critical care nurses’ adherence to VBs, with a focus on clinical outcomes.

3. Further testing with diverse samples is needed to strengthen the generalizability of the VBQ and VBOS. In addition, web-based and language-validated (English) versions are needed to facilitate both national and international research collaboration with a large number of participants.

4. Further research is needed to design and validate standardized instruments and scenarios to evaluate the effectiveness of HPS education in critical care nurses’ competencies (e.g. clinical, professional and managerial domains) and clinical outcomes.
6.4 Practical implications of the study

Using the results of the study, the following practical implications for nursing practice, administration, organization, educators and society are presented below:

In the current environment, where ICU resources are limited and ventilated patients already use a significant proportion of acute care resources, evidence-based strategies that improve both the efficiency and efficacy of critical care services should be carefully adapted, implemented and regularly evaluated to standardize patient care. Every ICU should have a written policy of evidence-based protocols and guidelines (e.g. sedation and pain management and assessment, weaning protocols, comprehensive oral care and hand hygiene programmes) to ensure consistency and a high quality of standardized care. In addition, updated ETS recommendations, innovative educational interventions (e.g. clinical and virtual learning environments, self-study and multifaceted programmes) and active implementation strategies (e.g. electronic VAP dashboards, reminders) should be adapted, implemented and regularly evaluated in order to improve current practices as well as clinical outcomes.

The VBQ and VBOS can provide objective methods to measure whether EBGs are being used in clinical practice. Regular auditing and prompt feedback would be beneficial. In addition, nurse educators’ knowledge and skills in adhering to evidence-based protocols and guidelines should be refined and evaluated regularly to ensure appropriate education.

The multifaceted educational programmes should concentrate on respiration, mechanical ventilation and infection control, with a focus on the basic principles and practices for preventing transmission of infectious agents, including information about local epidemiology, patient-related and treatment-related risk factors as well as clinical outcomes. In addition, infection control capabilities should be strengthened within health care settings.
7 Conclusions

This study contributed the following new information to the existing knowledge:

1. Critical care nurses’ endotracheal suctioning practices differed significantly from current best-practice recommendations. Significant discrepancies were observed in infection control practices prior to and post endotracheal suctioning events.

2. According to the systematic review, educational programmes may have a significant impact on clinical outcomes, and thus patients’ safety and quality of care, through improvements to nurses’ knowledge and skills in adhering to evidence-based guidelines in critical care settings.

3. The Ventilator Bundle Questionnaire and Observation Schedule can provide an objective method to measure whether evidence-based guidelines are being used in clinical practice.

4. After human patient simulation education, the intervention group’s skills for managing mechanically ventilated patients differed significantly from the control group in both the simulation environment and clinical practice. However, the mean knowledge scores within either group did not change statistically significantly after human patient simulation education.
References


Original publications


The original publications have been reprinted with permission from Sciedu Press (I) and Elsevier Publishing (II–IV).

Original publications are not included in the electronic version of the dissertation.
<table>
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<td>Alcohol affects the outcome after head trauma</td>
<td>Vaaramo, Kalle</td>
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<td>1231.</td>
<td>Heterotopic ossification in skin: special focus on multiple miliary osteoma cuts and the role of bone morphogenetic proteins</td>
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<td>1232.</td>
<td>Kohti suhdekeskeisyyttä lääkärin ja potilaan kohtaamisessa: laadullinen tutkimus potilas-lääkärisuhteen hahmotumisesta yleislääkäreiden koulutuksessa</td>
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<td>1234.</td>
<td>Ultrastructural and functional characterization of myofibroblasts in lung diseases</td>
<td>Karvonen, Henna</td>
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Miia Jansson

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