TITLE PAGE: Longitudinal effects of single-dose simulation education with structured debriefing and verbal feedback on endotracheal suctioning knowledge and skills – a randomized controlled trial

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Conflict of interest

The authors declare that they have no conflict of interests.

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Author contributions

M.M.J., H.P.S., P.P.O., M.H.M., H.A.K., and T.I.A.-K. contributed to the study design. M.M.J. contributed to data collection. M.M.J. and P.P.O. performed the data analysis. M.M.J., H.P.S., P.P.O., M.H.M., H.A.K., and T.I.A.-K. contributed to data interpretation and manuscript preparation.

ABSTRACT

Background. To evaluate the longitudinal effects of single-dose simulation education with structured debriefing and verbal feedback on critical care nurses' endotracheal suctioning knowledge and skills.

Material and methods: A prospective, parallel, randomized controlled trial with repeated measurements was conducted in a 22-bed adult mixed medical-surgical intensive care unit in Finland from February 2012 to March 2014. Thirty critical care nurses enrolled in the baseline measurements, of whom seventeen completed all the study procedures. The longitudinal effects of simulation education was evaluated through the validated Ventilator Bundle Questionnaire and Observation Schedule at the baseline and 24-months after simulation education. Data were analysed using a linear mixed model and intention-to-treat analyses.

Results: After simulation education, no significant time (p_t = 0.68) and group (p_g = 0.15) differences or time-group interactions (p_{t*g} = 0.27) were identified in endotracheal suctioning skills between the study groups. In addition, no significant changes over time (p_t = 0.50) or time-group interactions (p_{t*g} > 0.9) were identified in endotracheal suctioning knowledge scores. However, the intervention group had higher knowledge scores over the whole study period (p_g = 0.010).

Conclusion: Single-dose simulation education with structured debriefing and verbal feedback was insufficient to change critical care nurses' endotracheal suctioning knowledge and skills.

Keywords: evidence-based practice, nursing, simulation, tracheal suctioning, randomized controlled trial

BACKGROUND

Endotracheal suctioning (ETS) is one of the most common invasive procedures performed in patients with an artificial airway.[1] Because of the risk of adverse effects, such as respiratory (e.g., hypoxemia, decrease in dynamic lung compliance and functional residual capacity) and hemodynamic (e.g., hypo- or hypertension, cardiac dysrhythmias, increased intracranial pressure) alterations, infections (e.g., increased microbial colonisation of lower airways, pneumonia), barotraumas (e.g., tissue trauma to the tracheal and/or bronchial mucosa), bronchospasms, and atelectasis, healthcare workers need to take all necessary precautions to ensure patient safety and the quality of nursing care. [1 – 3]

Previous studies have demonstrated widespread discrepancies in current practices prior to (e.g., ETS assessment technique, protection of patient and environment from secretions, hyperoxygenation, analgesia), during (e.g., adequate suction pressure and suction depth), and post (e.g., confirmation of proper ET tube placement and maintenance of optimal cuff pressure) ETS events, which may increase the risk of adverse effects among invasively ventilated patients. [4 – 9] The need for continuing education, updated policies and adequate support is evident.

Traditional teaching methods (e.g., conventional lectures, practical bedside demonstrations, individualized performance feedbacks) have demonstrated significant improvements in ETS knowledge and practices immediately after education. [10 – 11] Generally in nursing education, high-fidelity simulation using a computerised full-body mannequin has been an effective teaching method when best practice guidelines are adhered to. [12 – 13] In addition, simulation education may have some advantages over other teaching methods, depending on the context, topic and method. [14 – 16] However, most of the effects have remained small to moderate and often short-term.

The longitudinal effects of traditional and advanced (high-fidelity) teaching methods are still uncertain due to the lack of published studies and robust evidence. [17 – 18] In addition, there is a lack of studies evaluating critical care nurses' knowledge of current ETS guidelines, especially in Scandinavia, where the topic has not been widely discussed. Furthermore, nursing documentation practices are unknown.

MATERIAL AND METHODS

Study design

A randomized controlled trial (RCT) with repeated measurements (Figure 1).

Aims

The primary aim of the study was to evaluate the longitudinal effects of single-dose simulation education with structured debriefing and verbal feedback on critical care nurses' endotracheal suctioning knowledge and skills. A secondary aim was to explore nursing documentation practices in order to improve the quality of current practices.

Sample and ethical considerations

The study was conducted in a single academic centre among critical care nurses in a 22-bed adult, mixed, medical-surgical intensive care unit (ICU) in Finland from February 2012 to March 2014. Randomly selected critical care nurses were invited via letter and electronic mail between December 2011 and January 2012. Inclusion criteria were a holding degree qualification as a registered nurse and being a direct care provider.

According to the Medical Research Act (488/1999 and amendments 295/2004), the approval of the local ethics committee is not required for studies focusing on healthcare staff. However, the study protocol was approved by the relevant academic centre in the autumn of 2011 and 2013. In addition, written informed consent from participants was obtained prior to inclusion in the study (Declaration of Helsinki 2013).

Sample size determination

The sample size was determined through power analysis, which revealed that a sample size of 32 participants was required to detect a 20% difference between means (mean difference = 2.74, SD = 2.66 points [alpha=0.05 and power=0.90]). The estimation of the effect size was based on a previously reported study of critical care nurses' ETS practices. [9] Further, we anticipated a 20% drop-out rate, which led to a sample size of 20 patients per group (40 participants in total).

Randomization and blinding

Participants were randomly allocated to intervention (n = 20) and control (n = 20) groups by the biostatistician using a computer-generated randomization list (allocation ratio of 1:1). Randomization was stratified into two age-based strata according to the median age of the study population (≤35 and >35 years). Due to the nature of intervention, unfortunately,

blinding was not possible. However, the biostatistician and research assistant who analysed and collected the data were blinded to group assignment.

Intervention and study protocol

The high-fidelity, human patient simulation education and its evaluation process began with a brief (20 min.) introduction to the simulation center (SimLab, Oulu University of Applied Science) and mannequin (HAL, Gaumard, Miami, FL) capabilities followed by an actual simulated scenario (10 min.). Post-scenario, only the intervention group participated in a structured and standardized debriefing session (60 min.) and received verbal feedback. Debriefing was carried out by two independent educators who specialised in simulation pedagogy and key areas (e.g., recommended practices prior to, during, and post ETS event).

Identical repeated measurements were taken for intervention and control groups by the same trained and experienced observers; the procedural flowchart for the data collection is shown in Figure 1, in compliance with CONSORT guidelines. The baseline (initially before the intervention) and initial post-intervention (3 months after the intervention) measurements (e.g., knowledge and skills) were conducted in the high-fidelity simulation setting (post-test I). In addition, the final follow-up measurements (6 and 24 months after the intervention) were conducted during the morning shift (07:00–15:00) in clinical practice (post-tests II and III).

Outcomes

Critical care nurses' skills in adhering to current ETS guidelines were evaluated using a direct, structured, non-participatory method of observation. The method was guided by a 26-item highly structured Ventilator Bundle Observation Schedule (VBOS). If participants adhered to a recommended practice, they were assigned one point, yielding a skill score range from 0 to 26. [19]

The level of critical care nurses' knowledge was evaluated at the end of each observational session using a validated 14-item Ventilator Bundle Questionnaire (VBQ), which was developed in a similar format to the VBOS, enabling comparisons to be drawn between knowledge and skills. [19] The VBQs were distributed to participants by the blinded research assistant, who arranged an appropriate time and place to gather the responses. If a participant answered correctly, they scored one point, yielding a knowledge score range from 0 to 14. [19]

Documentation of online nursing practices was recorded from the medical database (Centricity Critical Care Clinisoft, GE Healthcare) only in real-life clinical practice. If ETS practice and observations related to volume, colour, and consistency of secretions were documented correctly [1], they were assigned one point, yielding a skill score range

from 0 to 4. Higher scores indicated higher levels of ETS knowledge and skills as well as improved nursing documentation practices.

Validity and reliability

Simulation education and its evaluation process were pilot tested among a single cohort of 10 randomly selected critical care nurses in January 2012. The face and content validities of the VBOS and VBQ were evaluated using an expert panel. The item-level content validity indexes (CVIs) ranged from 0.91 to 1.0 while the average scale-level CVIs ranged from 0.99 to 1. In addition, all the items, questions and response alternatives met the chosen clarity criteria. [19]

The intraclass correlation coefficient (ICC), including a 95% confidence interval (CI), and the Cohen kappa coefficient (κ) of each item and the average scale score (VBOS) were tested using a second observer during the data collection. The ICC of the average scale score was 0.98 (95% CI 09.46–0.99). In addition, the Cohen κ coefficient of each item varied from 0.69 to 1.0, demonstrating an acceptable level of inter-rater reliability. [20] Discrepancies between the observers were resolved through consensus.

Data analysis

The statistical analysis was performed using SPSS 18.0 for Windows (SPSS INC., Chicago, IL). The repeatedly measured data was analysed using a linear mixed model with a covariance pattern model (continuous variables) or by generalised linear mixed model (categorical/dichotomous variables). *P* values reported for repeatedly measured data are 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_{t*g}), the interaction between time and group. All participants were included in the groups to which they were originally assigned (intention-to-treat analysis). An independent samples t-test was used to compare the median delta scores (baseline score minus final post-intervention score) between the study groups. A two-tailed *P* value less than 0.05 was considered statistically significant.

RESULTS

Thirty (n = 30) out of forty (n = 40) initially randomized critical care nurses enrolled in the baseline measurements (15 participants per group), of whom seventeen (n = 17) completed all the study procedures (Figure 1). Most of the participants were female (70.0%), often with a bachelor's degree (96.7%) and permanent employment (66.7%). Fifty-three per cent of the participants had a less than five years of working experience. The withdrawal rate between the study groups varied from 26.7% (intervention group) to 60.0% (control group). After baseline measurement, the reasons for withdrawal from the intervention group were sudden illness (n = 1), job transfer (n = 1), declining to participate (n = 1) and not known (n = 1). The main reasons for withdrawal from the control group were declining to participate (n = 3), sudden illness (n = 2), other reason (n = 2), and job transfer (n = 2).

Endotracheal suctioning knowledge

In the baseline measurement (Table 1), the average knowledge score was 6.6 out of 14 points (SD 1.5) in the intervention group (47.1% of the total score), and 5.5 out of 14 points (SD 2.2) in the control group (39.3% of the total score). Twenty-four months after simulation education, there was no significant change over time (p_t = 0.50), nor any time-group interactions ($p_{t*g} > 0.9$) between the study groups in the average ETS knowledge scores. However, the intervention group had higher knowledge scores over the whole study period (p_g = 0.010).

In the baseline measurement, 26.7% (intervention group) compared to 13.3% (control group) of participants achieved a mean score of 50%. However, in the final post-intervention measurement, a low of 16.7% (control group) to a high of 60.0% (intervention group) of participants achieved it. The median delta knowledge scores were 1 (25^{th}–75^{th} pct. -1–1) in the intervention group compared to -0.5 (25^{th}–75^{th} pct. -1–1) in the control group (p = 0.78).

Endotracheal suctioning skills

In the baseline measurement (Table 2), the average skill score was 15.2 out of 26 points (SD 2.2) in the intervention group (58.5% of the total score), and 16.4 out of 26 points (SD 2.1) in the control group (63.1% of the total score). Twenty-four months after simulation education, no significant time (p_t = 0.68) and group (p_g = 0.15) differences or time-group interactions (p_{t*g} = 0.27) were identified between the study groups in the average ETS skill scores.

In the baseline measurement, 73.3% (intervention group) compared to 93.3% (control group) of participants achieved a mean score of 50%. However, in the final post-intervention measurement, a low of 83.3% (control group) to

a high of 100.0% (intervention group) of participants achieved it. The median delta skills scores were 2 (25^{th}–75^{th} pct. 0.0–2.0) in the intervention group compared to 1.5 (25^{th}–75^{th} pct. -1.0–3.0) in the control group ($p = 0.38$).

Inconsistent and non-recommended practices were seen in relation to standard infection control precautions and pre-medication and oxygenation practices (Table 3). Hand disinfection activity increased from 60.0% to 72.7% prior to and 20.0% to 70.0% post ETS events in the final post-intervention measurement. However, a majority of values remained below the recommended limit. In addition, against the current guidelines, sedatives (45.5%) were administered more frequently than opioids (26.7%). However, the average dose of opioid administered increased from 0.3 (0–2, SD 0.6) to 1.7 (0.6–3.0, SD 0.95) µg in the final post-intervention measurement. Moreover, against the current guidelines, the average time for pre suctioning oxygenation increased from 86.1 (29–210, SD 50.8) to 109.9 (15–240, SD 78.2) seconds and the average level of suction pressure increased from 20.3 (15–25, SD 4.4) to 33.0 (25–40, SD 7.6) kPa in the final post-intervention measurement.

Nursing documentation practices

Six months after simulation education (Table 4), the average nursing documentation scores was 3.6 out of 4 points (SD 0.8) in both the intervention and the control groups (90.3% of the total score). Twenty-four months after simulation education, the nursing documentation score increased to 3.7 points (SD 0.9) in the intervention group (93.3% of total score). Contrary to the intervention group, the average nursing documentation score in the control group decreased from 3.6 points (SD 0.8) to 3.3 (SD 1.0) points in the final post-intervention measurement (83.3% of the total score). However, the median delta scores between the study groups did not differ in the final post-intervention measurement ($p = 0.19$).

DISCUSSION

The primary aim of the study was to evaluate the longitudinal effects of single-dose simulation education with structured debriefing and verbal feedback on critical care nurses' endotracheal suctioning knowledge and skills. It was hypothesised that the nurses who participated in structured debriefing and received verbal feedback would demonstrate a higher level of ETS knowledge and skills than those who did not participate in debriefing and receive feedback. However, the results of this experimental study did not support this hypothesis.

In line with previous literature, critical care nurses' knowledge and skills in adhering to current ETS guidelines were generally poor. [4 – 5, 7, 9, 21] In our study, insufficient knowledge and non-recommended ETS practices were observed prior to and post ETS events both in a simulation and clinical settings. For example, the majority of observed ETS events were carried out without any clinical reason, which may suggest a tendency for suctioning to occur routinely, rather than when clinically indicated. [1 – 2] In harmony with previous literature, a great number of participants failed in pain management, even though the painful stimuli may cause physiological, hemodynamic, and respiratory alterations. [1, 22 – 23] Moreover, the majority of critical care nurses were unaware of the recommended ETS pressure and ETS depth whereas the use of shallow suctioning is recommended to prevent barotraumas (e.g., mucosal damage to the trachea, carina and other surrounding tissues) and vagal responses. [1] Additionally, the majority of participants failed in standard infection control precautions (e.g., protection of eyes and central venous catheters from secretions, use of personal protective equipment) intended to prevent transmission of infectious agents in healthcare settings [24] even though invasive ventilation and ETS impede the effect of normal defence systems and it is highly recommended to maintain a strictly aseptic [2, 25 – 26] or sterile [1] technique. In addition, the majority of participants failed in hand hygiene (e.g., hand disinfection with alcohol-based handrub prior to and post ETS event, hand disinfection after removing and disposing of personal protective equipment, disposing of used catheters) even it's a major component of standard precautions. [24]

According to our findings, single-dose simulation education with structured debriefing and verbal feedback was insufficient to change critical care nurses' ETS and infection control practices. This non-significant result was inconsistent with the findings reported by other researchers; the discrepancy between the studies may be due to the previous studies' use of audio-visual or individualized performance feedback with repeated bedside demonstrations. [10 – 11, 14 – 16, 27] In addition, it was shown in a recent randomized controlled study that the frequency of simulation training is associated with higher cardiopulmonary resuscitation skills. [27] In our study, we used single-dose simulation education with verbal feedback, but without audio-visual or individualized feedback, practical demonstrations, or repetition possibilities, which may be insufficient in promoting behavioural change. On the other hand, the effectiveness of educational interventions

on learning outcomes compared to other educational interventions is difficult to assess due to the lack of a universal method of outcome reference measurement.

The secondary aim was to explore nursing documentation practices, because accurate, comprehensive, and consistent nursing documentation practices are essential in ensuring the quality of care, maintaining continuity of care, providing legal evidence, and reflecting professional accountability. [6] According to our findings, the majority of participants documented the hour when the ETS procedure was carried out. In addition, the volume of secretions was adequately documented. However, other essential information, such as the colour and consistency of secretions, was inadequately documented, which may, for example, jeopardise continuity of care by interfering with the diagnostics of ventilator-associated respiratory infections. Twenty-four months after simulation education, however, the level of the nursing documentation score was at an international level. [6, 21] In the previous literature, the monitoring of the characteristics of the secretions increased from 72.7% to 100% in the final post-intervention measurement. In addition, the documentation of the effectiveness of ETS procedure increased from 43.1% to 100%. [6]

The lack of significant enhancement may have been attributable to the limited sample size; the number of drop-outs was substantial. In addition, the study was conducted in a single centre. Nevertheless, the consistency of the insufficient knowledge and non-recommended ETS practices provides confidence that these findings may be representative of this area. Due to the lack of significant enhancement, certain aspects of suctioning, such as assessment techniques, pain management, shallow suctioning, and documentation practices (e.g., colour and consistency of secretions, adverse reactions during ETS procedure), as well as infection control practices, require more reinforcement than others. The need for regularly repeated educational sessions with audio-visual or individualized performance feedback and repeated bedside demonstrations is evident. In addition, all healthcare practitioners' (e.g., nurses and physicians) ETS practices (including level of knowledge) in operating and recovery rooms, extended care facilities, homes, out-patient clinics, and transport vehicles should be explored. In addition, further research is needed to evaluate the adaptation and implementation of clinical practice guidelines to the incidence of adverse events.

CONCLUSION

Both groups had repeatedly low scores for current ETS guidelines as related to the knowledge and skill scores. In addition, single-dose simulation education with structured debriefing and verbal feedback was insufficient to change critical care nurses' knowledge and skills in adhering to current ETS guidelines.

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Table 1. Participants' endotracheal suctioning knowledge before and after simulation education

Recommendations related to	Baseline[1]		Post-test I[1]		Post-test II[2]		Post-test III[2]		p_t [3]	p_g [4]	p_{t*g} [5]
	Intervention group (n = 15)	Control group (n = 15)	Intervention group (n = 13)	Control group (n = 12)	Intervention group (n = 13)	Control group (n = 10)	Intervention group (n = 11)	Control group (n = 6)			
Total score (range, 0–14)	6.6 (SD 1.5)	5.5 (SD 2.2)	6.9 (SD 1.7)	6.1 (SD 1.2)	6.9 (SD 2.3)	6.2 (SD 1.1)	7.6 (1.35)	6.2 (2.14)	0.50	0.010	> 0.9
1. Suction technique	9 (60.0)	8 (53.3)	4 (30.8)	8 (66.7)	3 (23.1)	7 (70.0)	3 (30.0)	2 (33.3)			
2. Daily changes of in-line suction catheters	3 (20.0)	0 (0.0)	1 (7.7)	1 (8.3)	0 (0.0)	0 (0.0)	1 (10.0)	1 (16.7)			
3. Subglottic suctioning	8 (53.3)	6 (40.0)	7 (53.8)	5 (41.7)	8 (61.5)	4 (40.0)	5 (50.0)	4 (66.7)			
4. Suctioning when clinically indicated	7 (46.7)	7 (46.7)	7 (53.8)	6 (50.0)	8 (61.5)	4 (40.0)	6 (60.0)	0 (0.0)			
5. Suctioning without disconnecting the patient from the ventilator	13 (86.7)	15 (100.0)	12 (92.3)	11 (91.7)	13 (100.0)	9 (90.0)	9 (90.0)	6 (100.0)			
6. Pre- and post-suctioning hyperoxygenation	6 (40.0)	1 (6.7)	8 (61.5)	0 (0.0)	5 (38.5)	1 (10.0)	8 (80.0)	2 (33.3)			
7. Sterile gloving	0 (0.0)	0 (0.0)	3 (23.1)	1 (8.3)	5 (38.5)	0 (0.0)	0 (0.0)	1 (16.7)			
8. Diameter of catheter size	8 (53.3)	5 (33.3)	8 (61.5)	3 (25.0)	9 (69.2)	4 (40.0)	4 (40.0)	0 (0.0)			
9. Saline instillation	0 (0.0)	1 (6.7)	0 (0.0)	1 (8.3)	1 (7.7)	2 (20.0)	3 (30.0)	4 (66.7)			
10. Use of shallow suctioning	0 (0.0)	0 (0.0)	2 (15.4)	1 (8.3)	4 (30.8)	3 (30.0)	3 (30.0)	2 (33.3)			
11. Level of suction pressure	3 (20.0)	3 (20.0)	3 (23.1)	1 (8.3)	2 (15.4)	2 (20.0)	6 (60.0)	4 (66.7)			
12. Duration of suction applied to airway	13 (86.7)	10 (66.7)	11 (84.6)	7 (58.3)	8 (61.5)	7 (70.0)	10 (100.0)	4 (66.7)			
13. Two nurses working as a team to create suction	15 (100.0)	14 (93.3)	13 (100.0)	10 (83.3)	13 (100.0)	10 (100.0)	10 (100.0)	6 (100.0)			
14. Patient reconnected to oxygen within 10 seconds post suctioning	13 (86.7)	10 (66.7)	11 (84.6)	9 (75.0)	10 (76.9)	9 (90.0)	8 (80.0)	4 (66.7)			

[1] Baseline and initial post-intervention measurements (3 months after the intervention) were conducted in the simulation environment (post-test I). [2] The final post-intervention measurements were made 6 months (post-test II) and 24 months (post-test III) after the intervention in the morning shift (7 AM–3 PM) in clinical practice. NOTE: Values for total scores are given as means (SD). Values (valid percentage) for skills are presented as n (%). P values reported for repeatedly measured data are as follows: [3] the overall change over time (p_t), [4] the average group difference (p_g), and [5] the interaction between time and group (p_{t*g}). A $P < 0.05$ is considered significant.

Table 2. Participants' endotracheal suctioning practices before and after simulation education

Recommended practices	Baseline[1]		Post-test I[1]*		Post-test II[2]*		Post-test III[2]*		p_t [3]	p_g [4]	p_{t*g} [5]
	Intervention group (n = 15)	Control group (n = 15)	Intervention group (n = 13)	Control group (n = 12)	Intervention group (n = 13)	Control group (n = 10)	Intervention group (n = 11)	Control group (n = 6)			
Total score (range, 0–26)	15.2 (SD 2.2)	16.4 (SD 2.1)	17.6 (SD 3.2)	16.5 (SD 2.1)	16.0 (SD 2.4)	15.7 (SD 1.6)	16.9 (SD 1.6)	16.3 (SD 1.9)	0.68	0.15	0.27
Practices prior to ETS event											
1. Patient assessment prior to ETS event	5 (33.3)	6 (40.0)	5 (38.5)	7 (58.3)	5 (38.5)	1 (10.0)	6 (54.5)	5 (83.3)			
2. Explaining to patient about the procedure	13 (86.7)	14 (93.3)	12 (92.3)	10 (83.3)	11 (84.6)	7 (70.0)	10 (90.9)	5 (83.3)			
3. Elevation of the head of the bed (30 – 45°)	9 (60.0)	10 (66.7)	13 (100.0)	10 (83.3)	13 (100.0)	10 (100.0)	10 (90.9)	5 (83.3)			
4. Pre-suctioning hyperoxygenation	13 (92.9)	14 (93.3)	12 (92.3)	12 (100.0)	6 (46.2)	9 (90.0)	11 (100.0)	5 (83.3)			
5. Cuff pressure checked	10 (66.7)	12 (80.0)	5 (38.5)	9 (75.0)	6 (46.2)	6 (60.0)	8 (72.7)	5 (83.3)			
6. Analgesic (opioid) administered	4 (26.7)	6 (40.0)	10 (76.9)	7 (58.3)	7 (53.8)	2 (20.0)	5 (45.5)	2 (33.3)			
7. Level of suction pressure 10.6–20kPa	9 (60.0)	12 (80.0)	13 (100.0)	7 (58.3)	3 (25.0)	9 (90.0)	3 (37.5)	2 (33.3)			
8. Protection of eyes from secretions	2 (13.3)	5 (33.3)	3 (23.1)	2 (16.7)	1 (8.3)	1 (10.0)	0 (0.0)	0 (0.0)			
9. Protection of central venous catheter from secretions	7 (46.7)	5 (33.3)	6 (46.2)	3 (25.0)	4 (33.3)	3 (30.0)	1 (9.1)	0 (0.0)			
10. Apron worn	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	10 (76.9)	4 (40.0)	8 (72.7)	2 (33.3)			
11. Face mask worn	15 (100.0)	15 (100.0)	13 (100.0)	12 (100.0)	10 (76.9)	10 (100.0)	11 (100.0)	6 (100.0)			
12. Hand disinfection prior to suctioning	9 (60.0)	11 (73.3)	6 (66.7)	12 (100.0)	10 (76.9)	9 (90.0)	8 (72.7)	5 (83.3)			
13. Sterile technique	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)			
Practices during ETS event											
14. Shallow suctioning	7 (46.7)	13 (86.7)	7 (53.8)	5 (41.7)	6 (46.2)	3 (30.0)	1 (9.1)	3 (50.0)			
15. Number of suction passes ≤3	15 (100.0)	14 (93.3)	12 (92.3)	12 (100.0)	11 (84.6)	9 (90.0)	9 (81.8)	5 (83.3)			
16. Duration of suction applied to airway <15 seconds	15 (100.0)	15 (100.0)	12 (92.3)	12 (100.0)	10 (76.9)	8 (80.0)	10 (90.9)	6 (100.0)			
17. Correct withdrawal	15 (100.0)	15 (100.0)	13 (100.0)	12 (100.0)	13 (100.0)	10 (100.0)	11 (100.0)	6 (100.0)			
18. Saline instillation	4 (26.7)	4 (26.7)	2 (15.4)	7 (58.3)	5 (38.5)	3 (30.0)	4 (36.4)	0 (0.0)			
19. Two nurses working as a team to create suction	15 (100.0)	15 (100.0)	13 (100.0)	12 (100.0)	13 (100.0)	10 (100.0)	11 (100.0)	6 (100.0)			
Practices post ETS event											
20. Patient reconnected to oxygen within 10 seconds post suctioning	15 (100.0)	15 (100.0)	13 (100.0)	12 (100.0)	13 (100.0)	10 (100.0)	11 (100.0)	6 (100.0)			
21. Post-suctioning hyperoxygenation	12 (80.0)	13 (86.7)	12 (92.3)	10 (90.9)	6 (46.2)	9 (90.0)	10 (90.9)	3 (60.0)			
22. Subglottic suctioning	13 (86.7)	14 (93.3)	13 (100.0)	10 (100.0)	13 (100.0)	9 (90.0)	11 (100.0)	6 (100.0)			
23. Confirmation of proper endotracheal tube placement	0 (0.0)	1 (6.7)	3 (23.1)	1 (8.3)	11 (84.6)	10 (100.0)	8 (72.7)	5 (83.3)			
24. Patient assessment post ETS event	4 (26.7)	2 (13.3)	4 (30.8)	2 (16.7)	2 (15.4)	0 (0.0)	3 (27.3)	1 (16.7)			
25. Used catheter and gloves disposed of in a manner that prevents contamination from secretions	5 (33.0)	3 (80.0)	5 (38.5)	2 (83.3)	11 (84.6)	7 (70.0)	4 (40.0)	3 (60.0)			
26. Hand disinfection post suctioning	3 (20.0)	2 (16.7)	7 (53.8)	4 (44.4)	10 (76.9)	4 (40.0)	7 (70.0)	3 (60.0)			

[1] The baseline and initial post-intervention measurements (3 months after the intervention) were conducted in the simulation environment (post-test I). [2] The final post-intervention measurements were made 6 months (post-test II) and 24 months (post-test III) after the intervention in the morning shift (7 AM–3 PM) in clinical practice. NOTE: Values for total scores are given as means (SD). Values (valid percentage) for skills are presented as n (%). P values reported for repeatedly measured data are as follows: [3] the overall change over time (p_t), [4] the average group difference (p_g), and [5] the interaction between time and group (p_{t*g}). A $P < 0.05$ is considered significant.

Table 3. Participants' pre-medication and oxygenation practices before and after simulation education

Practices	Baseline[1]		Post-test I[1]		Post-test II[2]		Post-test III[2]	
	Intervention group (n = 15)	Control group (n = 15)	Intervention group (n = 13)	Control group (n = 12)	Intervention Group (n = 13)	Control group (n = 10)	Intervention Group (n = 11)	Control group (n = 6)
Pre-suctioning oxygenation: mean seconds (SD)	86.1 (50.8)	78.5 (47.9)	120.9 (106.5)	108.4 (44.9)	84.0 (119.7)	107.0 (53.3)	109.9 (78.2)	151.8 (125.0)
Cuff pressure: mean cmH_2O (SD)	25.1 (3.2)	28.8 (3.4)	25.6 (2.0)	28.3 (2.9)	28.6 (1.3)	29.8 (0.5)	30.2 (3.1)	33.7 (5.1)
Opioid dose: mean µg (SD)	0.3 (0.6)	0.5 (0.7)	1.2 (0.8)	0.8 (0.9)	0.9 (1.0)	0.4 (0.8)	1.7 (1.0)	3.5 (2.1)
Sedative dose: mean mg (SD)	7.3 (11.6)	6.7 (7.2)	9.2 (10.4)	11.7 (19.0)	4.7 (12.0)	8.0 (25.3)	7.3 (4.7)	6.7 (5.2)
Delivery time: mean seconds (SD)	117.7 (53.8)	88.8 (70.2)	170.8 (124.2)	158.0 (76.0)	306.0 (159.1)	NA[3]	417.0 (250.1)	NA[3]
Number of suction passes (SD)	2.3 (0.5)	2.3 (0.6)	2.0 (0.6)	2.1 (0.3)	2.3 (1.2)	2.3 (1.0)	2.5 (0.9)	2.0 (1.3)
Duration of suction passes: mean seconds (SD)	9.9 (2.4)	10.5 (2.4)	8.7 (4.1)	8.3 (2.7)	14.8 (5.8)	13.5 (2.8)	11.1 (5.8)	10.2 (3.3)
Suction pressure: mean seconds (SD)	20.3 (4.4)	20.3 (2.5)	19.5 (1.2)	20.2 (6.7)	32.6 (9.2)	34.5 (9.3)	33.0 (7.6)	34.5 (15.5)

[1] The baseline and initial post-intervention measurements (3 months after the intervention) were conducted in the simulation environment (post-test I). [2] The final post-intervention measurements were made 6 months (post-test II) and 24 months (post-test III) after the intervention in the morning shift (7 AM–3 PM) in clinical practice. [3] Not available.

Table 4. Documentation of online nursing practices in real-life clinical practice at 6 and 24 months after simulation education

Practices	**Post-test II[1]***		**Post-test III[1]***	
	Intervention group (*n* = 13)	Control group (*n* = 10)	Intervention group (*n* = 11)	Control group (*n* = 6)
Documented ETS event	13 (100.0)	10 (100.0)	11 (100.0)	6 (100.0)
Documented volume of secretions	13 (100.0)	10 (100.0)	10 (90.9)	6 (100.0)
Documented colour of secretions	11 (84.6)	8 (80.0)	10 (90.9)	4 (66.7)
Documented consistency of secretions	10 (76.9)	8 (80.0)	10 (90.9)	4 (66.7)
Total score (range, 0–4)	3.6 (0.8)	3.6 (0.8)	3.7 (0.9)	3.3 (SD 1.0)

The final post-intervention measurements were made at 6 month (post-test II) and 24 months (post-test III) after the intervention in morning shift (7 AM–3 PM) in clinical practice. NOTE. Values for practices are presented as *n* (%).