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EMPIRICAL RESEARCH QUANTITATIVE

Design and content validation of a checklist about infection-prevention performance of intensive care nurses in simulation-based scenarios

Marta Raurell-Torredà RN, MSN, PhD[1,2,3] | Oscar Arrogante RN, Psy, MSc, PhD[2,4] | Anna María Aliberch-Raurell RN, MSN[2,5] | Francisco Javier Sánchez-Chillón RN, MSN[2,6] | Martín Torralba-Melero RN, MSN[2,7] | Andrés Rojo-Rojo RN, MSN, PhD[2,8] | Rebeca Gomez-Ibañez RN, MSN, PhD[3,9] | Montserrat Lamoglia-Puig RN, MSN, PhD[3,10] | Mariona Farrés-Tarafa RN, MSN, PhD[3,10] | Ignacio Zaragoza-García RN, MSN, PhD[2,4,11]

[1]Department of Fundamental and Clinical Care, Universitat de Barcelona, Barcelona, Spain

[2]Simulation Group of the Spanish Society for Intensive Care and Coronary Unit Nursing (SEEIUC), Madrid, Spain

[3]Member of the GRISimula Research Group (2017 SGR 531), Barcelona, Spain

[4]Department of Nursing, Faculty of Nursing, Physiotherapy and Podology, Universidad Complutense de Madrid, Madrid, Spain

[5]Hospital Clínic de Barcelona, Barcelona, Spain

[6]Simulation Centre, Hospital Universitario 12 de Octubre, Madrid, Spain

[7]Hospital General Universitario de Albacete, Albacete, Spain

[8]Universidad Católica de Murcia, Campus de los Jerónimos, Murcia, Spain

[9]Department of Nursing, Universitat Autónoma de Barcelona, Cerdanyola del Vallès, Spain

[10]Sant Joan de Déu Teaching Campus, Universitat de Barcelona, Barcelona, Spain

[11]InveCuid Group, Research Institute Hospital 12 de Octubre (i+12), Madrid, Spain

Correspondence
Oscar Arrogante, Department of Nursing, Faculty of Nursing, Physiotherapy and Podology, Complutense University of Madrid, Plaza Ramón y Cajal s/n, 28040 Madrid, Spain.
Email: oarrogan@ucm.es

Abstract

Objective: To design, develop and validate a new tool, called NEUMOBACT, to evaluate critical care nurses' knowledge and skills in ventilator-associated pneumonia (VAP) and catheter-related bacteraemia (CRB) prevention through simulation scenarios involving central venous catheter (CVC), endotracheal suctioning (ETS) and mechanically ventilated patient care (PC) stations.

Background: Simulation-based training is an excellent way for nurses to learn prevention measures in VAP and CRB.

Design: Descriptive metric study to develop NEUMOBACT and analyse its content and face validity that followed the COSMIN Study Design checklist for patient-reported outcome measurement instruments.

Methods: The first version was developed with the content of training modules in use at the time (NEUMOBACT-1). Delphi rounds were used to assess item relevance with experts in VAP and CRB prevention measures, resulting in NEUMOBACT-2. Experts in simulation methods then assessed feasibility, resulting in NEUMOBACT-3. Finally, a pilot test was conducted among 30 intensive care unit (ICU) nurses to assess the applicability of the evaluation tool in clinical practice.

Results: Seven national experts in VAP and CRB prevention and seven national simulation experts participated in the analysis to assess the relevance and feasibility of each item, respectively. After two Delphi rounds with infection experts, four Delphi rounds with simulation experts, and pilot testing with 30 ICU nurses, the NEUMOBACT-FINAL tool consisted of 17, 26 and 21 items, respectively, for CVC, ETS and PC.

Conclusion: NEUMOBACT-FINAL is useful and valid for assessing ICU nurses' knowledge and skills in VAP and CRB prevention, acquired through simulation.

Funding information
Spanish Society for Patient Simulation and Safety (SESSEP)

Relevance for Clinical Practice: Our validated and clinically tested tool could facilitate the transfer of ICU nurses' knowledge and skills learning in VAP and CRB prevention to critically ill patients, decreasing infection rates and, therefore, improving patient safety.

Patient or Public Contribution: Experts participated in the Delphi rounds and nurses in the pilot test.

KEYWORDS
catheter-related infections, checklist, clinical skills, critical care nursing, cross infection, high-fidelity simulation training, nursing education, patient safety, validation study, ventilator-associated pneumonia

1 | INTRODUCTION

Bacteraemia Zero (BZ) and Pneumonia Zero (NZ) were two projects designed and implemented in intensive care units (ICUs) in Spain between 2009 and 2012. These projects had a highly positive clinical impact during the implementation period and afterwards, with an on-going reduction in cases of catheter-related bacteraemia (CRB) (Palomar et al., 2013) and ventilator-associated pneumonia (VAP) (Álvarez-Lerma et al., 2018). As a result of these reductions, the related quality standards have been tightened on two occasions by the Spanish Society for Intensive and Critical Care Medicine and Coronary Units (SEMICYUC), working together with nurses from the Spanish Society for Intensive Care and Coronary Unit Nursing (SEEIUC) (SEEIUC, 2017). In February 2021, however, the Advisory Council of the Zero Tolerance Safety Projects (Spanish Ministry of Health) reported that due to the SARS-CoV-2 pandemic, and as a result of structural and organisational changes to ICUs, the incidence rates of VAP and CRB had increased two to threefold. In addition, lengths of stay and intra-ICU mortality also increased (SEEIUC, 2021). One measure that was recommended to address these issues was 'training ICU healthcare staff (including existing, newly recruited and temporary staff) in the Zero projects'.

SEMICYUC and SEEIUC, together with the Ministry of Health, offer online training modules on zero bacteraemia and pneumonia as part of their Critical Patient Safety Programme (Zero projects) (Ministerio de Sanidad, 2022). The modules are comprised of lectures, images, and infographics.

What does this paper contribute to the wider global clinical community?

- Provides a validated tool to assess decision-making skills related to infection prevention in ICU patients.
- Underpins the required decision-making on the most recent evidence on VAP and CRB prevention measures.
- The validated tool standardises simulation-based training in infection prevention skills for ICU nurses, which will allow comparison of infection rates before and after training.

2 | BACKGROUND

Simulation-based learning has grown exponentially in the last 10 years and now forms part of the undergraduate healthcare professional teaching programmes and continuing education levels (El Hussein et al., 2022). This student-centred teaching method promotes immediate, participatory feedback between facilitators and participants, known as debriefing. The aim of simulation-based learning is to develop technical skills (required to accomplish a specific procedure) and non-technical skills (communication, leadership, teamwork, situational awareness, decision-making, resource management, safe practice, and adverse event minimisation) (Lioce et al., 2020). For training in technical skills, low-medium fidelity simulation is used with partial body manikins, for example, a pelvis or an arm, or full-body static manikins that need no programming or computer control. For training in non-technical skills, role players (simulated patients) can be trained or a wide range of high-fidelity manikins can be used that mimic body functions with extreme precision (Lioce et al., 2020). In addition, simulation allows repeated practice to ensure that knowledge and skills are retained (Motola et al., 2013). A scenario needs to be repeated regularly with alterations in bodily symptoms on the same topic to achieve optimal learning outcomes (Hung et al., 2021). This approach is known as deliberate practice in a psychologically safe learning environment. In a positive emotional climate, participants feel at ease taking risks, making mistakes, or extending themselves beyond their comfort zone (INACSL Standards Committee, 2021a).

According to the recommendations of the International Nursing Association of Clinical and Simulation Learning (INACSL), a simulation scenario should include the following: (a) participant preparation, known as prebriefing: learning objectives, information about the patient's condition, environmental conditions (manikin and environment); (b) the functions, expectations, and/or limitations of each participant's role; (c) a progressive outline that includes a beginning

and an ending; (d) a debriefing process and (e) evaluation criteria (INACSL Standards Committee, 2021b). When defining these evaluation criteria in our setting, we identified the need for this research project.

Several studies have demonstrated the effectiveness of checklists for preventing VAP and CRB (Hernández-Aceituno et al., 2020; Kellie et al., 2014; Li et al., 2018; Radhakrishnan et al., 2021; Wichmann et al., 2018), and some have even found a decrease in infection rates after implementing simulation-based training (Balachander et al., 2021; Barsuk et al., 2015; Behzadi et al., 2019; Gerolemou et al., 2014). To date, we have only found one questionnaire that assesses both knowledge and skills in preventing VAP (Jansson et al., 2014). Although this questionnaire can be applied to assess clinical practice and was tested through simulated scenarios, it was neither designed nor validated by experts in clinical simulation methodology and is focused on the knowledge of both pharmacological and non-pharmacological measures related to VAP, rather than technical and non-technical skills acquisition. Even a recent systematic review related to interventions used for VAP prevention (Thapa et al., 2023) does not include simulation-based training among educational strategies to reduce VAP, since simulation methodology has not been used to date for this purpose.

3 | THE STUDY

3.1 | Objective

The main objective of this study was to design and validate a new tool, which we named NEUMOBACT, to evaluate critical care nurses' knowledge and skills in the prevention of VAP and CRB through simulation scenarios.

4 | METHODS

We conducted a descriptive metric study to develop NEUMOBACT and analyse its content and face validity that followed the COSMIN Study Design checklist for patient-reported outcome measurement instruments (Data S1). The content validation phase consisted of checking whether the tool item definitions were understood as intended by the research team and whether the tool explored all the relevant dimensions and domains of the underlying construct. A conventional Delphi technique was used, which consisted of a questionnaire that is sent to a panel of experts for their evaluation. The experts then received the statistical results of the evaluated questionnaire together with a new version of the questionnaire for their evaluation, and the process was repeated until consensus was reached. According to the COSMIN Study Design checklist (Mokkink et al., 2019) at least seven experts are required for a qualitative analysis to ensure that all dimensions or domains of the tool are explored.

The first version of our tool (NEUMOBACT-1) was created from the Pneumonia Zero (https://hws.vhebron.net/formacion-NZero/MedidasBasicas.html) and Bacteriemia Zero (https://hws.vhebron.net/formacion-BZero/intervenciones.html) training modules, drawn up by Advisory Council for Projects on Critical Patient Safety of the Ministry of Health, Consumer Affairs and Social Welfare. The experts conducted a critical review of the literature available for CRB prevention and VAP prevention, separately. They drew up a list of recommended techniques and strategies and then selected and classified recommendations as mandatory or highly recommended.

NEUMOBACT-1 consisted of three checklist-type subscales (correct/incorrect response) to evaluate the performance of ICU nurses at three simulated stations: central venous catheter (CVC) insertion (20 items), endotracheal suctioning (ETS) (29 items) and patient care (PC) (30 items). Table S1 shows the full list of initial items (Column 1: Initial items. NEUMOBACT-1). The learning objectives for each station were (a) the nurse's technical skill of assisting the doctor performing CVC insertion, (b) the technical skill of how to perform open- and closed-system ETS, and (c) the non-technical skill of PC decision-making in a patient with mechanical ventilation and CVC.

4.1 | Validity analysis

Validity was analysed at two levels:

4.1.1 | By relevance

We contacted the members of the Advisory Council for Projects on Critical Patient Safety (Spanish Ministry of Health, Consumer Affairs and Social Welfare), which is composed of critical care nurses and physicians. Seven members agreed to collaborate as expert panellists in the study. These national experts were asked to score item relevance on a Likert scale, where 0 was 'not at all relevant' and 4 was 'totally relevant'. Space was left beside each item to add any comments. The end of this phase resulted in the second version of the tool (NEUMOBACT-2).

4.1.2 | By feasibility for use in simulation-based training

Seven simulation experts at different universities across Spain participated in the analysis to assess the feasibility of each item, that is, whether it is possible to reproduce the item in question in a simulated environment. All these national simulation experts were defined as simulation instructors with postgraduate education in learning and evaluation methods, a minimum of 5 years' experience teaching undergraduate students and 2 years' experience in simulation (Rizzolo et al., 2015). The experts were asked to score feasibility on a scale of 0 to 4, where 0 was 'not at all feasible' and 4 was 'totally feasible'. Space was left beside each item to add any

comments. The end of this phase resulted in the third version of the tool (NEUMOBACT-3).

4.2 | Pilot test

To assess the comprehensibility of NEUMOBACT-3, we contacted 30 ICU nurses, as recommended by guidelines for tool validation (Beaton et al., 2000; Sousa & Rojjanasrirat, 2011), to assess their understanding of the meaning of each item. The aim of the pilot test was to ensure that NEUMOBACT-3 retained its equivalence in an applied situation, that is, to assess ICU-nurse knowledge and skills in VAP and CRB prevention. Each participating nurse was asked to rate each tool item as clear/unclear and suggest how to edit any items they had rated as unclear, and such as the ordering of items to ensure a smooth flow of work.

A review committee was set up, comprised of 10 members from the expert panel who participated in Phases 1 and 2, to evaluate the pilot test responses and make any changes as needed. The end of this phase resulted in the final tool version (NEUMOBACT-FINAL).

4.3 | Data analysis

The criteria for defining level of consensus for relevance and feasibility (Likert scale 0 to 4) (Diamond et al., 2014; Hsu & Sandford, 2007) were: mean >3 and at least 80% of the experts scoring the item with at least 3 points (high consensus), mean equal to or greater than 3 and 70%–79% of the experts scoring the item with at least 3 points (low consensus) or mean less than 3 and less than 70% of the experts scoring the item with at least 3 points (no consensus). Microsoft Excel® was used for the calculations.

4.4 | Ethical aspects

The project was approved by the Bioethics Commission of the University of Barcelona (code number: IRB00003099). The investigators undertook to comply with Organic Law 3/2018 of 5 December on personal data protection and the guarantee of digital rights. Responding to the questionnaires implied consent to participate in the study as an expert panellist. In order to enhance data protection, only the principal investigator had contact with the experts in each phase. Personal data were removed from the results matrix.

5 | RESULTS

For the relevance analysis, the Zero project experts needed two Delphi rounds to reach a consensus. In the first Delphi round, a high consensus was achieved (80% of the experts scoring the item with at least 3 points) in the 85% and 80% of items for the CVC and PC stations. This percentage was lower for the ETS station (58%). See Table S2 (Degree of consensus of the different items and Delphi rounds with the Zero project and simulation experts). In the CVC station subscale, 16 items were retained with their initial wording from NEUMOBACT-1 and 4 items were edited. In the ETS station subscale, 13 items were retained, 10 were edited, 6 were deleted and 1 was added. In the PC station subscale, 25 items were retained, 4 were edited and 1 was deleted. For the outcome of each specific item, see Table S1, column 2 'Zero project experts, NEUMOBACT-2'.

For the feasibility analysis, the simulation experts needed four Delphi rounds to reach a consensus. The highest degree of consensus achieved in the first Delphi round was lower than the consensus achieved with the Zero project experts (65% in the CVC station, 63.6% in the ETS station, and 62.1% in the PC station). See Table S2 (Degree of consensus of the different items and Delphi rounds with the Zero project and simulation experts). In the CVC station subscale, 13 items were retained with their initial wording from NEUMOBACT-2, 3 items were edited, 4 were deleted and 1 was added, leaving 17 items in total. In the ETS subscale, 16 items were retained, 1 was edited, 4 were deleted, 3 items were reorganised (2 items were split into 3 and 1 was split into 2) and 1 item was added, leaving 27 items in total. In the PC subscale, 15 items were retained, 4 were edited, 9 were deleted and 1 was split into 3 items, leaving 22 items in total. For the outcome of each specific item, see Table S1, column 3 'Simulation experts, NEUMOBACT-3'.

In addition, the item order was changed in the ETS and PC subscales to be more consistent with the sequence of actions performed during the simulated scenario. For a list of final items, see Table S1, column 4 'Final items, NEUMOBACT-3'.

The pilot test was then carried out using NEUMOBACT-3, containing the final items. Participants were recruited from the target population in which the checklist would be used. In a session at the 47th National Congress of the SEEIUC, 30 ICU nurses were recruited, who were working in different ICUs all over Spain to represent the possible heterogeneity between them. Most of them were female (92%), with a median [P25-P75] age of 36 [29–41] years, 10 [7–18] years nursing experience, and 6 [4–12] years ICU nursing experience. A postgraduate qualification in critical care was held by 44% of participants. The participating nurses highlighted items that they considered were not nursing competencies or common nursing interventions, such as the catheter insertion site selection and the consideration of closed-system suctioning when PaO_2/FiO_2 is <200 and positive end-expiratory pressure (PEEP) levels are set high.

The expert committee agreed to edit eight items and delete two. Table 1 shows full details. After the last round, NEUMOBACT-FINAL consisted of 17, 26 and 21 items for CVC, ETS and PC, respectively, see Table S3 (NEUMOBACT-Spanish version) and Table 2 (NEUMOBACT-English version).

6 | DISCUSSION

Simulation has been shown to be effective in improving nursing students' self-confidence in their knowledge and skills (Oliveira Silva

TABLE 1 Post-pilot review of the NEUMOBACT-3 items by an expert committee.

Simulated station	NEUMOBACT-3 version	Consensus for NEUMOBACT-FINAL
Central venous catheter (CVC) station	Item 4 Use a single-lumen venous catheter, unless treatment requires multiple lumens. Always use catheters with as few lumens as possible.	Wording changed Always use catheters with as few lumens as possible.
	Item 5 When inserting a thoracic CVC, the patient should remain in the Trendelenburg position.	Wording changed When inserting a thoracic CVC, the patient should remain in the Trendelenburg position if necessary and if not contraindicated.
	Item 15 Use a transparent, semi-permeable dressing to cover the insertion site. A gauze dressing may be used if there is bleeding.	Wording changed Use a transparent, semi-permeable or chlorhexidine-impregnated dressing to cover the insertion site. A gauze dressing may be used if there is bleeding. *Use of chlorhexidine-impregnated dressings is considered correct if they are available and as an optional measure.
	Item 17 Place needle-free connectors only at sites where boluses are to be administered. Needle-free connectors protect staff, but can pose a risk of infection if not used correctly.	Wording changed Place needle-free connectors only at sites where boluses are to be administered. *For infection prevention, it is not necessary to use needle-free connectors in continuous infusion lines, even if they are used to reduce reflux.
Endotracheal suctioning (ETS) station	Item 5 Always suction oral and subglottic secretions before deflating the cuff to move the endotracheal tube (ETT).	Deleted because it is not a routine part of the ETS technique. It is more commonly performed during mouth hygiene.
	Item 10 In very severe respiratory failure, when the oxygenation ratio (paO_2/FiO_2) is <200 and high PEEP levels are required in mechanical ventilation, consider the need to perform closed-system suctioning to prevent alveolar collapse resulting from opening the respiratory circuit and to minimise deterioration in haemodynamic and blood gas parameters.	Wording simplified Consider closed-system suctioning when PaO_2/FiO_2 is <200 and PEEP levels are set high.
Patient care (PC) station	Item 4 Use a single-lumen venous catheter, unless treatment requires multiple lumens. Always use catheters with as few lumens as possible.	Wording changed Always use catheters with as few lumens as possible.
	Item 7 In some selected patients with suspected bacteraemia and limited venous access, the catheter may be changed over a guidewire, always sending the catheter tip for culture.	Wording simplified Only in patients with suspected bacteraemia and limited venous access, the catheter may be changed over a guidewire, always sending the catheter tip for culture.
	Item 10 Change giving sets not before 96 h and not later than 7 days, unless hubs look dirty, they have been accidentally disconnected or catheter-related infection is suspected.	Wording simplified Change giving sets between Days 4 and 7, unless hubs look dirty or they have been accidentally disconnected.
	Item 12 Avoid contact with the insertion site during dressing changes.	Deleted because it is not understood. The insertion site must be touched in order to clean it, although sterile technique should be performed, as already covered in other items.

et al., 2022). The literature refers to bedside checklists for VAP prevention to verify completion of necessary tasks (Kellie et al., 2014; Madhuvu et al., 2021; Parisi et al., 2016), but we have found no studies that apply checklists during simulation, despite this training method being recommended in VAP prevention strategies (Klompas et al., 2022). One study evaluated a training programme for nurses in ETS and oral care through practical training, without specifically mentioning simulation (Jam Gatell et al., 2012). A checklist was used to assess knowledge through direct observation. Another study analysed training and practical instruction for nurses providing oral care

TABLE 2 NEUMOBACT-English version.

	Central venous catheter (CVC) insertion	Correct	Incorrect
1	Select the insertion site by weighing up the risk of infection against the risk of mechanical complications.		
2	Use subclavian vein access unless contraindicated (anatomical deformities, coagulation disorders, kidney disease that might require dialysis).		
3	If jugular vein access is selected, use the right side to reduce non-infectious complications (unless ultrasound-guided insertion is performed).		
4	Always use catheters with the smallest number of lumens possible.		
5	When inserting a thoracic CVC, the patient should remain in the Trendelenburg position if necessary and if not contraindicated.		
6	Prior to skin asepsis, clean the insertion site with chlorhexidine soap and water, then rinse and allow to dry fully.		
7	Perform hand hygiene with soap and water (40–60 s) or alcohol solution (20–30 s).		
8	For skin asepsis prior to catheter insertion, a 0.5%–2% alcohol-based chlorhexidine solution should preferably be used. Use 70° alcohol or povidone-iodine only in the case of hypersensitivity to chlorhexidine. The antiseptic must be completely dry before catheter insertion (if povidone iodine is used, at least 2 min drying time).		
9	Do NOT palpate the puncture site after applying the antiseptic, unless an aseptic technique is used.		
10	Use maximum barrier measures (mask, cap, eye protection and gown, sterile drapes, sheets and gloves) for the CVC insertion.		
11	Insertion assistants must comply with the above measures. They must don a cap and mask, at a minimum.		
12	The sterile field must cover the patient's entire body.		
13	Before connecting any components to a catheter lumen, aspirate blood from the patient through each lumen to prevent air from entering the blood stream.		
14	Apply a sterile dressing to the catheter insertion site before the barrier measures are removed.		
15	Use a transparent, semi-permeable or chlorhexidine-impregnated dressing to cover the insertion site. A gauze dressing may be used if there is bleeding.		
16	Note the catheter insertion date in the nursing records and on the dressing.		
17	Place needle-free connectors only at sites where boluses are to be administered.		
	Endotracheal suctioning (ETS)	**Correct**	**Incorrect**
1	Regardless of whether or not the patient is sedated, inform them of the technique to be performed		
2	Perform hand hygiene with soap and water (40–60 s) or alcohol solution (20–30 s).		
3	Don non-sterile gloves.		
4	Don personal protective equipment: mask and eye protection or mask with face shield.		
5	Do not instil normal saline routinely. Normal saline instillation may increase secretions; use is recommended as an exception only (when secretions need to be thinned or if there is a tendency for plug formation).		
6	Hyperoxygenate the patient before and after suctioning.		
7	Choose to use the ventilator to hyperoxygenate/hyperventilate. It is more recommendable to use the ventilator than a bag valve mask (Ambu®).		
8	Activate the ventilator setting that hyperoxygenates/hyperinflates the patient.		
9	Consider closed-system suctioning when PaO_2/FiO_2 is <200 and PEEP levels are set high.		
10	**Suction technique: OPEN-SUCTION SYSTEM**		
10.1	Select a suction pressure between 100 and 150 mmHg		
10.2	Put a single-use sterile glove on the dominant hand, which will hold the suction catheter.		
10.3	Prevent micro-atelectasis: use a catheter with an appropriate diameter (half the internal diameter of the ETT).		
10.4	Sterile single-use catheter – insert the catheter into the bronchial tree without suctioning and then suction for no more than 15 s at a time. Maximum 3 times.		
10.5	After suctioning, wash out the tube to the suction unit with sterile water		
11	**Suction technique: CLOSED-SUCTION SYSTEM**		
11.1	The first time the technique is performed, prepare the system: choose an appropriate-sized closed-suction catheter considering the ETT diameter.		

TABLE 2 (Continued)

Endotracheal suctioning (ETS)		Correct	Incorrect
11.2	Connect the elbow/T-piece between the ventilator and the ETT connection.		
11.3	Place the sticker showing the date the device was connected in a visible place.		
11.4	Connect the suction system to the closed-suction catheter. Select a suction unit pressure between 100 and 150 mmHg		
11.5	Open the valve system to the ETT and insert the catheter without applying suction to about 2 cm above the carina.		
11.6	Press the suction button for less than 15 s.		
11.7	Withdraw the catheter slowly while continuing to apply suction until you reach the guide mark.		
11.8	Close the valve system between the catheter and the ETT.		
11.9	Clean the suction catheter: connect a 20 mL syringe with sterile water to the washout port. Press the suction button on the catheter and observe how the syringe empties and the catheter is washed out.		
11.10	Close the suction system		
	Items applicable to both suction techniques		
12	Check the cuff pressure after suctioning (and at least once per shift). Pressure should be maintained between 20 and 30 cmH_2O to prevent subglottic secretions moving into the lower airway and to avoid vascular compromise of the trachea. Continuous cuff pressure measurement systems are recommended.		
13	Perform hand hygiene with soap and water (40–60 s) or alcohol solution (20–30 s).		
Patient care (PC)		**Correct**	**Incorrect**
Event no. 1: Patient with cough. Consider whether suctioning is indicated by performing			
1a	**Auscultation of breath sounds during the expiratory phase of the respiratory cycle (with a stethoscope over the trachea, in the sternal area). High specificity/sensitivity**		
1b	Changes in the flow-volume curve shape of the ventilator monitor (accelerations/decelerations from baseline). High specificity/sensitivity		
1c	Decrease in saturation. Low specificity because desaturation can occur in situations other than secretion retention, such patient-ventilator mismatch, patient mobilisation and bronchospasm.		
1d	Increase in peak pressure in volume-controlled systems. Low specificity because desaturation can occur in situations other than secretion retention, such patient-ventilator mismatch, patient mobilisation and bronchospasm.		
1e	Decrease in tidal volume in pressure-controlled systems. Low specificity because desaturation can occur in situations other than secretion retention, such patient-ventilator mismatch, patient mobilisation and bronchospasm.		
Event no. 2: Oral hygiene			
2	Before performing oral hygiene, check that cuff pressure >20 cmH_2O.		
3	Keep the head of the bed raised to perform oral hygiene.		
4	Use 0.12–0.2% chlorhexidine to perform oral hygiene.		
Event no. 3: Catheter change			
5	Always use catheters with as few lumens as possible.		
6	Catheters should not be changed over a guidewire.		
7	Only in patients with suspected bacteraemia and limited venous access, the catheter may be changed over a guidewire, always sending the catheter tip for culture.		
8	If possible, in the case of multi-lumen catheters, select and designate one lumen for lipid emulsions only (parenteral nutrition, propofol).		
9	All catheter replacements and manoeuvres must be recorded.		
Event no. 4: Changing giving sets and connections			
10	Change giving sets between Days 4 and 7, unless hubs look dirty or have been accidentally disconnected.		
11	Do not use antibiotic or antiseptic ointments to protect the insertion site.		
12	Use sterile gloves for dressing changes (one pair of gloves for each dressing).		
13	Note the catheter insertion date in the nursing records and on the dressing.		
14	Wash hands and don non-sterile gloves before handling equipment, connections and valves.		

(Continues)

TABLE 2 (Continued)

Patient care (PC)		Correct	Incorrect
15	Place needle-free connectors only at sites where boluses are to be administered. Needle-free bungs protect staff, but can pose a risk of infection if not used correctly.		
16	Use as few three-way taps as possible and remove them when they are not essential.		
17	Clean injection caps with alcohol-based chlorhexidine before accessing the system.		

in paediatric patients and found that skills improved significantly after the training (Behzadi et al., 2019).

Our checklist covers all the necessary steps for correctly performing ETS, in open and closed systems alike. Jam Gatell's checklist covered only hand hygiene before and after ETS and the use of a sterile catheter, but not sterile gloves specifically (Jam Gatell et al., 2012), as mentioned in the recent update to the Pneumonia Zero project (Arias-Rivera et al., 2022). Similar to our checklist, it also included the need for cuff pressure control. In our case, however, we also recommend using a continuous cuff pressure control device, as mentioned in the aforementioned Pneumonia Zero project (Arias-Rivera et al., 2022). Jam Gatell's checklist specified oral hygiene with chlorhexidine 0.12%, while ours include prior cuff pressure control and the need to raise the head of the bed, which was also included in Behzadi's checklist (Behzadi et al., 2019). Our checklist differs from Behzadi's, however, regarding the need for using a toothbrush. Behzadi found that before the training, nurses did not use a toothbrush. According to the latest updates (Arias-Rivera et al., 2022), in critically ill adult patients, the use of a toothbrush is not associated with a reduction in VAP rates and therefore we did not include it as a recommended measure.

One meta-analysis reported a decrease in the incidence of CRB after the application of care bundles (Ista et al., 2016) and found that use of checklists was the third most-used educational strategy (61%). Some studies applied checklists in simulation scenarios for sterile technique training during CVC insertion procedures (Gerolemou et al., 2014), for drug administration and for CVC dressing changes (Barsuk et al., 2015). Our checklist includes some of the items mentioned in a study by Gerolemou et al. (Gerolemou et al., 2014), such as the requirement for assistants to don a cap and mask, use alcohol-based chlorhexidine solution for skin preparation, and a sterile field that covers the entire patient. By contrast, we did not assess sterile glove donning because nurses are trained in this technique separately, as is the case of hand hygiene. In addition, we provided fewer details than the study by Barsuk et al. (Barsuk et al., 2015) on dressing changes, although we did specify use of sterile gloves. We also considered other items related to the latest recommendations of the Bacteraemia Zero project (Gallart et al., 2022), such as using the subclavian vein as the preferred insertion site, frequency of changing giving sets, extension sets and connectors, and the use of a specific catheter lumen for lipid emulsions.

The Bacteraemia Zero recommendations made no mention of reviewing the evidence for cleaning catheter hubs with 70% isopropyl alcohol prior to venous line access. We agree with Barsuk's recommendation that hubs should be cleaned with alcohol-based chlorhexidine solution. In our setting, however, antiseptic barrier caps and chlorhexidine-impregnated dressings are used only and optionally in ICUs that have high rates of CRB despite compliance with the basic measures in the NEUMOBACT checklist, or for patients at higher risk for CRB (Gallart et al., 2022).

Regarding the participants in the pilot test, they were a representative sample according to the demographic data provided and contrasted with the SEEIUC's database of associated nurses. All of them considered that the NEUMOBACT checklist was relevant to be applied in clinical practice, but they considered that some items did not correspond to nursing competencies (catheter insertion site selection and suctioning system selection based on PaO2/FiO2 and PEEP levels). However, the expert committee maintained these items in the checklist regarding that a critical care nurse is a nurse with an advanced role according to the advanced nurses' definition proposed by the Royal College of Nurses: 'They have the freedom and authority to act, making autonomous decisions in the assessment, diagnosis, and treatment of patients'. (European Specialist Nurses Organisation, 2019).

6.1 | Limitations

Some Pneumonia Zero and Bacteraemia Zero protocols—based on the Zero project recommendations—that are implemented in ICUs in Spain may contradict some of the items agreed by expert consensus in NEUMOBACT-FINAL. We sought to overcome this limitation by piloting the tool with a national sample of 30 nurses, in a session at the 47th National SEEIUC, with the aim of identifying clinical practice diversity in the application of the Zero projects across Spain.

Some of the current items of the tool may be deleted or their order changed in the near future, because having completed the content validation phase of the NEUMOBACT-FINAL checklist, the construct validation phase is pending, along with internal consistency and inter-observer reliability studies.

7 | CONCLUSION

Consensus on a checklist about infection-prevention performance of ICU nurses in simulation-based scenarios was achieved with Zero project experts using two Delphi rounds to evaluate its relevance and with simulation experts using four Delphi rounds to evaluate its feasibility. After a pilot test with 30 ICU nurses to assess the applicability of the evaluation tool in clinical practice, the final checklist

consisted of 17, 26 and 21 items for CVC, ETS and PC, respectively. Therefore, NEUMOBACT-FINAL is useful and valid for assessing ICU nurses' knowledge and skills in VAP and CRB prevention, acquired through simulation. Future research should analyse the construct validation of this checklist, along with internal consistency and inter-observer reliability studies.

8 | RELEVANCE FOR CLINICAL PRACTICE

NEUMOBACT-FINAL is useful and valid for assessing knowledge and skills of intensive and critical care nurses in VAP and CRB prevention. This validated and clinically tested tool could facilitate the transfer of knowledge and skills learning in VAP and CRB prevention to critically ill patients. Therefore, this tool could decrease infection rates for VAP and CRB, improving patient safety.

AUTHOR CONTRIBUTIONS

Marta Raurell-Torredà: Conceptualization, Methodology, Data curation, Formal analysis, Writing–original draft. Oscar Arrogante: Investigation, Resources, Formal analysis, Writing–review & editing. Anna María Aliberch Raurell: Investigation, Validation, Resources. Francisco Javier Sánchez-Chillón: Methodology, Visualisation, Resources. Martín Torralba-Melero: Investigation, Validation, Resources. Andrés Rojo-Rojo: Investigation, Validation, Resources. Montserrat Lamoglia-Puig: Methodology, Writing–review & editing. Mariona Farrés-Tarafa: Software, Project administration, Supervision, Data curation, Writing–review & editing. Ignacio Zaragoza-García: Investigation, Visualisation, Methodology, Supervision, Writing–review & editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

Our dataset is located at https://zenodo.org. Raurell-Torreda, M. (2023). NEUMOBACT checklist about infection-prevention performance of intensive care nurses in simulation-based scenarios [Data set]. Zenodo. https://doi.org/10.5281/zenodo.10134002.

ORCID

Marta Raurell-Torredà https://orcid.org/0000-0003-1369-1915
Oscar Arrogante https://orcid.org/0000-0001-8304-9093
Anna María Aliberch-Raurell https://orcid.org/0000-0003-0517-175X
Martín Torralba-Melero https://orcid.org/0000-0001-5769-4486
Andrés Rojo-Rojo https://orcid.org/0000-0001-8409-1744
Rebeca Gomez-Ibañez https://orcid.org/0000-0002-2049-8630
Montserrat Lamoglia-Puig https://orcid.org/0000-0002-5283-4563
Mariona Farrés-Tarafa https://orcid.org/0000-0001-6151-3844
Ignacio Zaragoza-García https://orcid.org/0000-0002-8606-1415

REFERENCES

Álvarez-Lerma, F., Palomar-Martínez, M., Sánchez-García, M., Martínez-Alonso, M., Álvarez-Rodríguez, J., Lorente, L., Arias-Rivera, S., García, R., Gordo, F., Añón, J. M., Jam-Gatell, R., Vázquez-Calatayud, M., & Agra, Y. (2018). Prevention of ventilator-associated pneumonia: The multimodal approach of the Spanish ICU "pneumonia zero" program. *Critical Care Medicine*, *46*(2), 181–188. https://doi.org/10.1097/CCM.0000000000002736

Arias-Rivera, S., Jam-Gatell, R., Nuvials-Casals, X., Vázquez-Calatayud, M., & equipo Neumonía Zero. (2022). Update of the recommendations of the pneumonia zero project. *Enfermería Intensiva*, *33*(suppl1), S17–S30. https://doi.org/10.1016/j.enfi.2022.05.005

Balachander, B., Rajesh, D., Pinto, B. V., Stevens, S., & Rao, P. (2021). Simulation training to improve aseptic non-touch technique and success during intravenous cannulation-effect on hospital-acquired blood stream infection and knowledge retention after 6 months: The snowball effect theory. *The Journal of Vascular Access*, *22*(3), 353–358. https://doi.org/10.1177/1129729820938202

Barsuk, J. H., Cohen, E. R., Mikolajczak, A., Seburn, S., Slade, M., & Wayne, D. B. (2015). Simulation-based mastery learning improves central line maintenance skills of ICU nurses. *The Journal of Nursing Administration*, *45*(10), 511–517. https://doi.org/10.1097/NNA.0000000000000243

Beaton, D. E., Bombardier, C., Guillemin, F., & Ferraz, M. B. (2000). Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine*, *25*(24), 3186–3191. https://doi.org/10.1097/00007632-200012150-00014

Behzadi, F., Khanjari, S., & Haghani, H. (2019). Impact of an education program on the performance of nurses in providing oral care for mechanically ventilated children. *Australian Critical Care*, *32*(4), 307–313. https://doi.org/10.1016/j.aucc.2018.06.007

de Sanidad, M. (2022). Programa de Seguridad en los Pacientes Críticos. Proyectos Zero https://seguridaddelpaciente.es/es/practicas-seguras/seguridad-pacientes-criticos/

Diamond, I. R., Grant, R. C., Feldman, B. M., Pencharz, P. B., Ling, S. C., Moore, A. M., & Wales, P. W. (2014). Defining consensus: A systematic review recommends methodologic criteria for reporting of Delphi studies. *Journal of Clinical Epidemiology*, *67*(4), 401–409. https://doi.org/10.1016/j.jclinepi.2013.12.002

El Hussein, M. T., Harvey, G., & Bell, N. (2022). The influence of nursing simulation on patient outcomes and patient safety: A scoping review. *Clinical Simulation in Nursing*, *70*, 37–46. https://doi.org/10.1016/j.ecns.2022.06.004

European Specialist Nurses Organisation. (2019). Position statement ESNO 26 April 2019. *The Specialist Nurses in European Healthcare*

Towards, *2030* Retrieved from: https://www.efccna.org/images/stories/news/2019_ESNO_PS_SpecialisedNursing.pdf

Gallart, E., Delicado, M., Nuvials, X., Grupo de Trabajo, & de Bacteriemia Zero. (2022). Update of the recommendations of the Bacteraemia zero project. *Enfermería Intensiva*, *33*(suppl1), S31–S39. https://doi.org/10.1016/j.enfi.2022.06.002

Gerolemou, L., Fidellaga, A., Rose, K., Cooper, S., Venturanza, M., Aqeel, A., Han, Q., Jones, J., Shapiro, J., & Khouli, H. (2014). Simulation-based training for nurses in sterile techniques during central vein catheterization. *American Journal of Critical Care*, *23*(1), 40–48. https://doi.org/10.4037/ajcc2014860

Hernández-Aceituno, A., Vega-Costa, V., Ruiz-Álvarez, M., Figuerola-Tejerina, A., Méndez-Hernández, R., & Ramasco-Rueda, F. (2020). Effectiveness of a bundle of measures for reducing central line-associated bloodstream infections. *Revista Española de Anestesiología y Reanimación (Engl. Ed.)*, *67*(5), 227–236. https://doi.org/10.1016/j.redar.2019.11.014

Hsu, C. C., & Sandford, B. A. (2007). The Delphi technique: Making sense of consensus. *Practical Assessment, Research and Evaluation*, *12*, 1–8. https://doi.org/10.7275/pdz9-th90

Hung, C. C., Kao, H. S., Liu, H. C., Liang, H. F., Chu, T. P., & Lee, B. O. (2021). Effects of simulation-based learning on nursing students' perceived competence, self-efficacy, and learning satisfaction: A repeat measurement method. *Nurse Education Today*, *97*, 104725. https://doi.org/10.1016/j.nedt.2020.104725

INACSL Standards Committee. (2021a). Healthcare simulation standards of best practice™: Simulation glossary. *Clinical Simulation in Nursing*, *58*, 57–65. https://doi.org/10.1016/j.ecns.2021.08.017

INACSL Standards Committee. (2021b). Healthcare simulation standards of best practice™: Simulation design. *Clinical Simulation in Nursing*, *58*, 14–21. https://doi.org/10.1016/j.ecns.2021.08.009

Ista, E., van der Hoven, B., Kornelisse, R. F., van der Starre, C., Vos, M. C., Boersma, E., & Helder, O. K. (2016). Effectiveness of insertion and maintenance bundles to prevent central-line-associated bloodstream infections in critically ill patients of all ages: A systematic review and meta-analysis. *The Lancet Infectious Diseases*, *16*(6), 724–734. https://doi.org/10.1016/S1473-3099(15)00409-0

Jam Gatell, M. R., Santé Roig, M., Hernández Vian, Ó., Carrillo Santín, E., Turégano Duaso, C., Fernández Moreno, I., & Vallés Daunis, J. (2012). Assessment of a training programme for the prevention of ventilator-associated pneumonia. *Nursing in Critical Care*, *17*(6), 285–292. https://doi.org/10.1111/j.1478-5153.2012.00526.x

Jansson, M. M., Ala-Kokko, T. I., Syrjälä, H. P., & Kyngäs, H. A. (2014). Development and psychometric testing of ventilator bundle questionnaire and observation schedule. *American Journal of Infection Control*, *42*(4), 381–384. https://doi.org/10.1016/j.ajic.2013.11.007

Kellie, S. P., Scott, M. J., Cavallazzi, R., Wiemken, T. L., Goss, L., Parker, D., & Saad, M. (2014). Procedural and educational interventions to reduce ventilator-associated pneumonia rate and central line-associated blood stream infection rate. *Journal of Intensive Care Medicine*, *29*(3), 165–174. https://doi.org/10.1177/0885066612467152

Klompas, M., Branson, R., Cawcutt, K., Crist, M., Eichenwald, E. C., Greene, L. R., Lee, G., Maragakis, L. L., Powell, K., Priebe, G. P., Speck, K., Yokoe, D. S., & Berenholtz, S. M. (2022). Strategies to prevent ventilator-associated pneumonia, ventilator-associated events, and nonventilator hospital-acquired pneumonia in acute-care hospitals: 2022 update. *Infection Control and Hospital Epidemiology*, *43*(6), 687–713. https://doi.org/10.1017/ice.2022.88

Li, L., Wang, Q., Wang, J., Liu, K., Wang, P., Li, X., Yang, J., Lu, J., Li, D., Wang, L., Wang, Z., & Peng, F. (2018). Development, validation and application of a ventilator-associated pneumonia prevention checklist in a single cardiac surgery centre. *Intensive & Critical Care Nursing*, *49*, 58–64. https://doi.org/10.1016/j.iccn.2017.10.002

Lioce, L., Lopreiato, J., Downing, D., Chang, T. P., Robertson, J. M., Anderson, M., Díaz, D. A., Spain, A. E., & the Terminology and Concepts Working Group. (2020). *Healthcare simulation dictionary* (2nd ed.). Agency for Healthcare Research and Quality. https://doi.org/10.23970/simulationv2

Madhuvu, A., Endacott, R., Plummer, V., & Morphet, J. (2021). Ventilation bundle compliance in two Australian intensive care units: An observational study. *Australian Critical Care*, *34*(4), 327–332. https://doi.org/10.1016/j.aucc.2020.09.002

Mokkink, L. B., Prinsen, C. A. C., Patrick, D. L., Alonso, J., Bouter, L. M., de Vet, H. C. W., & Terwee, C. B. (2019). COSMIN study design checklist for patient-reported outcome measurement instruments. https://www.cosmin.nl/wp-content/uploads/COSMIN-study-designing-checklist_final.pdf

Motola, I., Devine, L. A., Chung, H. S., Sullivan, J. E., & Issenberg, S. B. (2013). Simulation in healthcare education: A best evidence practical guide. AMEE guide No. 82. *Medical Teacher*, *35*(10), e1511–e1530. https://doi.org/10.3109/0142159X.2013.818632

Oliveira Silva, G., Oliveira, F. S. E., Coelho, A. S. G., Cavalcante, A. M. R. Z., Vieira, F. V. M., Fonseca, L. M. M., Campbell, S. H., & Aredes, N. D. A. (2022). Effect of simulation on stress, anxiety, and self-confidence in nursing students: Systematic review with meta-analysis and meta-regression. *International Journal of Nursing Studies*, *133*, 104282. https://doi.org/10.1016/j.ijnurstu.2022.104282

Palomar, M., Álvarez-Lerma, F., Riera, A., Díaz, M. T., Torres, F., Agra, Y., Larizgoitia, I., Goeschel, C., Provonost, P., & the Bacteremia Zero Working Group. (2013). Impact of a national multimodal intervention to prevent catheter-related bloodstream infection in the ICU: The Spanish experience. *Critical Care Medicine*, *41*(10), 2364–2372. https://doi.org/10.1097/CCM.0b013e3182923622

Parisi, M., Gerovasili, V., Dimopoulos, S., Kampisiouli, E., Goga, C., Perivolioti, E., Argyropoulou, A., Routsi, C., Tsiodras, S., & Nanas, S. (2016). Use of ventilator bundle and staff education to decrease ventilator-associated pneumonia in intensive care patients. *Critical Care Nurse*, *36*(5), e1–e7. https://doi.org/10.4037/ccn2016520

Radhakrishnan, R., Sood, R., Wig, N., Sethi, P., Soneja, M., Kumar, A., Nischal, N., Biswas, A., & Pandey, R. M. (2021). Effect of training and checklist based use of ventilator associated pneumonia (VAP) prevention bundle protocol on patient outcome: A tertiary care centre study. *The Journal of the Association of Physicians of India*, *69*(8), 11–12.

Rizzolo, M. A., Kardong-Edgren, S., Oermann, M. H., & Jeffries, P. R. (2015). The national league for nursing project to explore the use of simulation for high-stakes assessment: Process, outcomes, and recommendations. *Nursing Education Perspectives*, *36*(5), 299–303. https://doi.org/10.5480/15-1639

Sociedad Española de Enfermería Intensiva y Unidades Coronarias (SEEIUC). (2017). Indicadores de calidad del enfermo crítico. https://seeiuc.org/novedades/indicadores-de-calidad-del-enfermo-critico/

Sociedad Española de Enfermería Intensiva y Unidades Coronarias (SEEIUC). (2021). Declaración del consejo asesor del programa de seguridad de pacientes críticos del Ministerio de Sanidad. https://seeiuc.org/wp-content/uploads/2021/02/210218-DECLARACION-DEL-CONSEJO-ASESOR-MODIFICADO_OK.pdf

Sousa, V. D., & Rojjanasrirat, W. (2011). Translation, adaptation and validation of instruments or scales for use in cross-cultural health care research: A clear and user-friendly guideline. *Journal of Evaluation in Clinical Practice*, *17*(2), 268–274. https://doi.org/10.1111/j.1365-2753.2010.01434.x

Thapa, D., Liu, T., & Chair, S. Y. (2023). Multifaceted interventions are likely to be more effective to increase adherence to the ventilator

care bundle: A systematic review of strategies to improve care bundle compliance. *Intensive & Critical Care Nursing*, *74*, 103310. https://doi.org/10.1016/j.iccn.2022.103310

Wichmann, D., Belmar Campos, C. E., Ehrhardt, S., Kock, T., Weber, C., Rohde, H., & Kluge, S. (2018). Efficacy of introducing a checklist to reduce central venous line associated bloodstream infections in the ICU caring for adult patients. *BMC Infectious Diseases*, *18*(1), 267. https://doi.org/10.1186/s12879-018-3178-6

SUPPORTING INFORMATION

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

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