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Nursing technologies for patient safety in intensive care: a systematic review

Tecnologias de enfermagem para a segurança do paciente em terapia intensiva: revisão sistemática

Tecnologías de enfermería para la seguridad del paciente en cuidados intensivos: revisión sistemática

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Abstract
This article aims to demonstrate the evidence that nursing care technologies ensure the safety of patients admitted to Intensive Care Units. Systematic review with search in six databases. Two researchers selected the texts independently in the first stage; and, in the second stage, in a conciliation meeting, the conflicts were analyzed by a third researcher. In order to evaluate the level of agreement, the Kappa coefficient was applied; in order to evaluate the risk of bias and classify the levels of evidence, the Grading of Recommendations, Assessment, Development and Evaluation was adopted. Observational studies were also evaluated with the risk of bias in non-randomized studies of interventions. The 23 included studies were evaluated regarding their quality of evidence, with very low evidence ranking determined for most studies (16/69.6%), moderate evidence for five studies (21.7%), one study with low evidence (4.3%) and one study as high evidence (4.3%). Patient safety is essential, but, despite this commitment, only one study (4.3%), about thermometry assessment, showed high level of evidence that nursing care technologies ensure patient safety in the Intensive Care Unit setting.
Keywords: Technology; Nursing care; Patient safety; Risk; Intensive Care Units.

Resumo
Este artigo teve por objetivo demonstrar as evidências de que tecnologias de cuidado de enfermagem garantem a segurança do paciente internado em Unidade de Terapia Intensiva. Revisão sistemática com busca em seis bases de dados. Dois investigadores selecionaram os textos de forma independente na primeira etapa; e, na segunda, em reunião de conciliação, os conflitos foram analisados por um terceiro pesquisador. Para avaliação da concordância, aplicou-se o coeficiente Kappa; para avaliação do risco de viés e classificação dos níveis de evidência, adotou-se o

Grading of Recommendations, Assessment, Development and Evaluation. Os estudos observacionais também foram avaliados com o risk of bias in non-randomized studies of interventions. Os 23 estudos incluídos foram avaliados quanto a qualidade da evidência, sendo que, o ranqueamento com muito baixa evidência foi determinado para a maioria dos estudos (16/ 69,6%), evidência moderada para cinco estudos (21,7%), um estudo com baixa evidência (4,3%) e um estudo como alta evidência (4,3%). A segurança do paciente é fundamental, mas, apesar desse compromisso, apenas um estudo (4,3%), acerca da avaliação de termometria, apresentou alto nível de evidência de que as tecnologias de cuidado de enfermagem garantem a segurança do paciente na Unidade de Terapia Intensiva.
Palavras-chave: Tecnologia; Cuidados de enfermagem; Segurança do paciente; Risco; Unidades de Terapia Intensiva.

Resumen
Este artículo tiene como objetivo demostrar evidencias de que las tecnologías de atención de enfermería garantizan la seguridad de los pacientes ingresados en las Unidades de Cuidados Intensivos. Revisión sistemática con búsqueda en seis bases de datos. Dos investigadores seleccionaron los textos de forma independiente en el primer paso; y, en el segundo, en una reunión de conciliación, los conflictos fueron analizados por un tercer investigador. Para evaluar la concordancia, se aplicó el coeficiente Kappa; para evaluar el riesgo de sesgo y clasificar los niveles de evidencia, se adoptó el Grading of Recommendations, Assessment, Development and Evaluation. Los estudios observacionales también se evaluaron con el riesgo de sesgo con el risk of bias in non-randomized studies of interventions. Se evaluó la calidad de la evidencia en los 23 estudios incluidos, donde se determinó la clasificación con evidencia muy baja para la mayoría de los estudios (16/69,6%), evidencia moderada para cinco estudios (21,7%), un estudio con evidencia baja (4,3%) y un estudio con evidencia alta (4,3%). La seguridad del paciente es esencial, pero, a pesar de este compromiso, solo un estudio (4,3%), sobre la evaluación de la termometría, presentó un alto nivel de evidencia de que las tecnologías de atención de enfermería garantizan la seguridad de los pacientes en las Unidades de Cuidados Intensivos.
Palabras clave: Tecnología; Atención de enfermería; Seguridad del paciente; Riesgo; Unidades de Cuidados Intensivos.

1. Introduction

An increasingly important aspect of nursing care involves the use of technological resources in the health area. Nurses must develop competencies to be able to use these technologies safely. In short, technological competency is increasingly an integral part of the caring competency (Locsin & Purnell, 2015).

Nurses are not only users but also producers and evaluators of technologies used in health care (Jeleć, et al., 2016). They must therefore demonstrate through research and practice how technologies contribute to care procedures, including those activities necessary for the basic operation and the experience of patients in the health system (Kliger, et al., 2010).

Technology is a passive tool used to accomplish intentions (Beedholm, et al., 2015). It is commonly divided into two broad categories: product technology, whose results are easily identifiable, such as equipment, physical facilities, tools, among others; and process technology, including techniques, methods and procedures (Novaes & Carvalheiro, 2007; Nascimento, et al., 2010; Szczerba & Huesch, 2012). Technologies reflect ideological assumptions about the management and application of scientific resources at work, whose purposes, if not exposed, become underlying and unknown to the users of the product (Asurakkody & Shin, 2018).

Since the publication of "To Err is Human" (Pronovost, et al., 2016), patient safety has been a worldwide commitment; and, in the last two decades, investments have been made to produce and/or apply health technologies to prevent harm. This development has been especially marked in intensive care units (ICU), as they are places where the use of specific diagnostic, therapeutic and care technologies, combined with the clinical complexity of the cases, make ICU patients more vulnerable to adverse events (AE). These events represent a problem in the health assistance provided in intensive care settings and produce impacts on the increase in length of stay and mortality (Roque, et al., 2016).

Paradoxically, care technologies, validated or produced by nurses, at the same time that they subsidize care, may also run the risk of causing harm to patients. Therefore, in this context, nurses are required to minimize the exposure of patients to risks, carrying out the appropriate validation of technologies (Jeleć, et al., 2016).

Given the above, the objective of this study was to demonstrate the evidence that nursing care technologies ensure

patient safety in the ICU setting.

2. Methodology

This is a Systematic Review with the adoption of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), complying with the checklist for reporting the review and the flowchart for presenting the results (Page, et al., 2021). This review was guided by the following research question: "What is the evidence that nursing care technologies ensure the safety of patients admitted to an Intensive Care Unit?". The PIO strategy was used to formulate the question, in which the acronym P (population/participant) was represented by ICU patient; I (intervention/procedure), nursing care Technologies; and O (outcomes/endpoint), patient safety (Eriksen & Frandsen, 2018). The protocol for this study was registered in the PROSPERO – International Prospective Register of Systematic Reviews, under the registration number CRD42020140772, and can be accessed at: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020140772.

A search was performed on the platform of the National Library of Medicine (PubMed), with access to the Medical Literature Analysis and Retrieval System Online (MEDLINE) database, as well as on the Virtual Health Library (VHL) platform, with access to the Latin America and the Caribbean Literature on Health Sciences (LILACS) and the Brazilian Nursing Database (BDENF). To access the Cumulative Index to Nursing and Allied Health Literature (CINAHL) and SCOPUS, the Coordination for the Improvement of Higher Education Personnel (CAPES/Brazil) platform was used. The Scientific Electronic Library Online (SciELO) database was also used. Data collection took place in the period from May 06 to 18, 2019. The Boolean operators AND and OR were used to design the search strategy, which was adapted to each database with the help of a librarian.

The period of searches in the databases was defined as January 1, 1998 to December 31, 2018, covering a 20-year interval, taking as the initial milestone the publication on patient safety, entitled "To Err is Human", in 1999 (Pronovost et al., 2016). The descriptors were defined according to Medical Subject Headings (MeSH) and the *Descritores em Ciências da Saúde* (DeCS) to guide the collection in the databases.

The following criteria were considered for study eligibility: presenting nursing care technology as an intervention; technology development studies; technology application and evaluation studies; studies with an outcome on patient safety; addressing care in adult intensive care units; being randomized or quasi-randomized clinical trials (RCTs) and observational studies, descriptive-analytical studies; having a nurse in (co) authorship; have been published in English, Portuguese or Spanish. On the other hand, we excluded studies on medical technologies; studies with care technologies developed by professionals other than nurses; theses, dissertations, editorials, integrative and systematic reviews, descriptive observational studies and qualitative studies; and studies not located in their entirety.

The publications identified from the search strategies were exported to the EndNote® reference management program to identify and exclude duplicates. Subsequently, two researchers independently read the titles and abstracts to select eligible publications for the study, according to the eligibility criteria. After the selection of the publications, the analysis of the level of agreement between the independent researchers was performed applying the Kappa coefficient, with a confidence interval of 95%, using the IBM SPSS® software, version 21.0. The resolution of conflicts in the selection of studies (18 publications) was performed by a third researcher with research training and experience of more than twenty years.

The Kappa coefficient was adopted to identify the proportion of agreement between the researchers, after removing random concordances (Conger, 2017). In order to classify the values generated by this coefficient, the following classification was adopted: < 0.00, poor agreement; 0.00-0.20, slight agreement; 0.21-0.40, reasonable agreement; 0.41-0.60, moderate agreement; 0.61-0.80, substantial agreement; and 0.81-1.00, almost perfect agreement (Landis & Koch, 1977).

After selecting the studies, the 92 articles were read in their entirety to decide on the final inclusion of the articles.

This step was also performed independently by two researchers, using an electronic tool named Rayyan® (Ouzzani, et al., 2016).

The data were independently extracted and systematized in an electronic spreadsheet, with the following variables: journal name, authors' names, year and country of publication, article title, objective, type of research design, method, technology and its classification. A third researcher was in charge of validating the data extracted and compiled them in tables. To group the results of the studies included in this review, technologies were classified into two groups: product technologies and process technologies (Novaes & Carvalheiro, 2007; Nascimento, et al., 2010; Szczerba & Huesch, 2012), which, in turn, were sub-classified into technologies for clinical interventions and technologies for educational interventions. In addition, technologies developed by nurses and those restricted to their evaluation were identified.

The level of evidence of the studies was obtained from the application of the Grading of Recommendations Assessment, Development and Evaluation (GRADE), using the online tool named GRADEpro GDT (Guyatt, et al., 2008; Zhang, et al., 2019) In this system, the quality of evidence is described in four levels: high, moderate, low and very low, as shown in Table 1. For evidence from randomized clinical trials (RCTs), the level starts high; while, from observational studies, the evidence starts with a low level. Five criteria can reduce the quality of evidence: study limitations, inconsistency of results, indirectness of evidence, imprecision and reporting bias. Conversely, three criteria can increase the quality of evidence, such as the large magnitude of effect, dose-response gradient, and plausible residual confounding (Guyatt, et al., 2008).

Table 1. GRADE categories of the certainty of the evidence.

Quality level	Definition
High	We are very confident that the true effect lies close to that of the estimate of the effect.
Moderate	We are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.
Low	Our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect.
Very Low	We have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

Source: The GRADE approach (Zhang, et al., 2019).

For observational studies, the ROBINS-I tool was used to evaluate the risk of methodological bias with evaluation in seven domains being bias: by confounding; selection of study participants; classification of interventions; due to deviations from intended interventions; due to missing data; measurement of outcomes; and selection of reported outcome. These domains were applied at the pre-intervention, intervention and post-intervention stages (Sterne, et al., 2016).

The characteristics of the articles included in the qualitative synthesis, as well as their quality evaluation, were compiled in three tables. The first presents the characteristics of the studies; the second presents the classification of the studies according to the quality evaluation and the quality level of the studies; and the third presents the classification of the studies regarding care technology, type of care technology, purpose of care technology and nurses' contribution. In addition, a narrative synthesis was performed, as guided in the Synthesis Without Meta-analysis (SWiM) guidelines, due to heterogeneous data regarding the intervention (different care technologies) (Campbell, et al., 2020).

3. Results

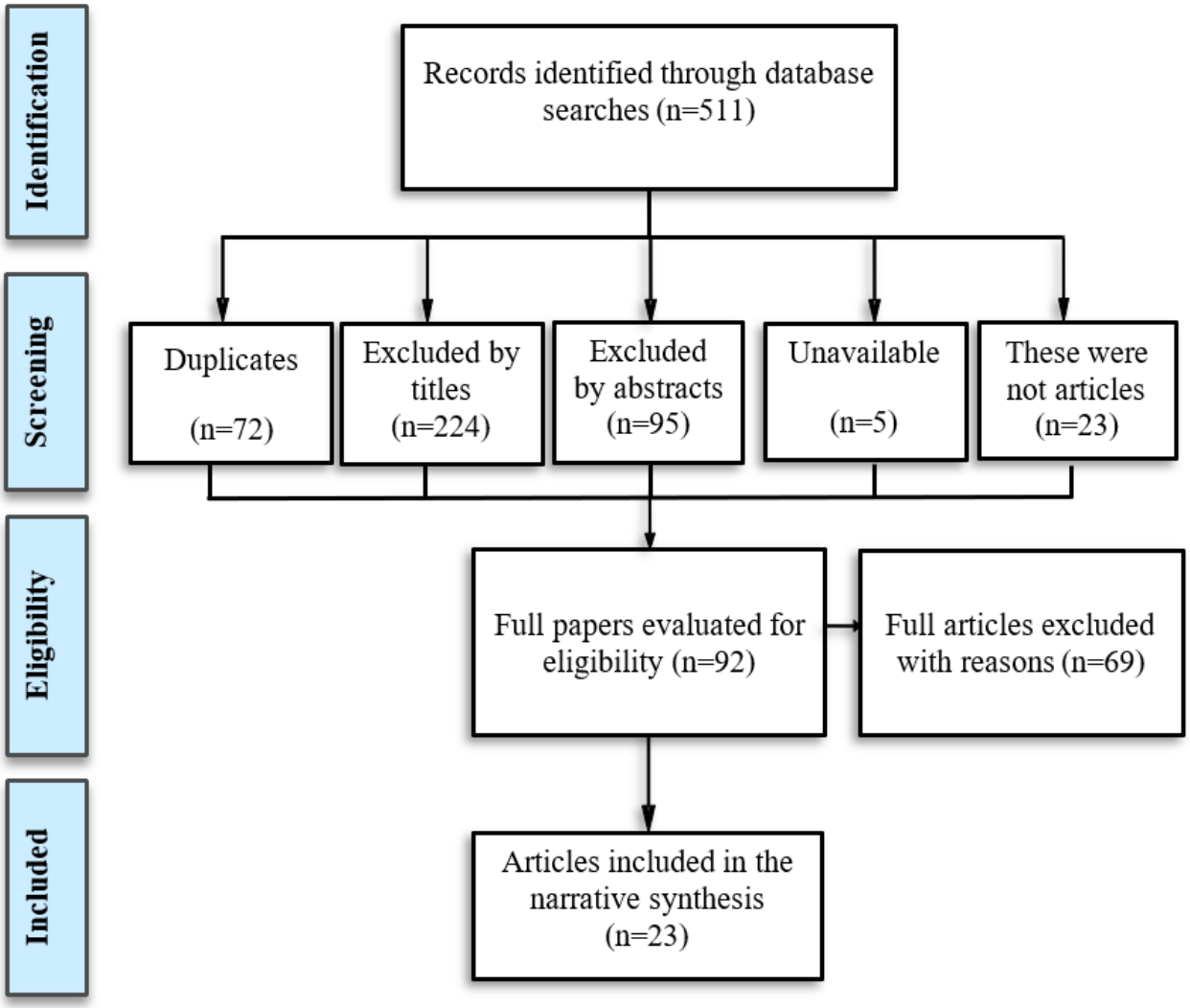
A total of 511 publications were identified, 72 of which were removed for being in more than one database, 224 after reading the titles, 95 after reading the abstracts, 23 for not being original articles, and five for not being available in their entirety. After full reading of the resulting 92 articles, 69 were excluded for not meeting the inclusion criteria (21 did not

present nurses as authors or co-authors; 11 presented a different outcome from that proposed in this study, 27 were outlined differently than expected for rescue in this study); eight were developed with a population other than the critically ill adult patients and two were not developed in/for the ICU setting), thus resulting in 23 articles for quantitative data synthesis, as shown in Figure 1.

The concordance index obtained after applying the Kappa Coefficient in the article selection stages was 0.87 for the reading of the titles and abstracts and 0.69 for the reading of the full texts, representing, respectively, almost perfect and substantial concordance.

The studies are shown in Table 2, of which 13 (56.5%) were observational studies, while six (26.1%) were quasi-experimental and four (17.4%) were randomized clinical trials.

Figure 1. Flowchart of the identification and selection steps of the studies according to PRISMA. Florianópolis, Santa Catarina, Brazil, 2021.



Source: PRISMA (Page et al., 2021)

The places of greatest publication came from the American Continent (65.2%), followed by Oceania (17.4%), Asia (13.0%) and Europe (4.3%). More than half of the publications originated in the United States of America (12/52.2%);

followed by Australia, (4/17.4%) and South Korea (2/8.7%), while in the other countries such as Canada, China, and Italy there was only one publication originated from each country (1/4.3%). There were two articles from Brazil (2/8.7%).

Table 2. Characteristics of the studies according to author, year, series, country, study objective, study design and care technology. Florianópolis, Santa Catarina, Brazil, 2021.

Author/Year	Journal	Country	Study Objective	Care Technology
Observational Studies				
Araújo et al. (2012).	Revista Escola de Enfermagem USP*	Brazil	To identify critically ill patients at risk for pressure ulcers using the Braden scale and digital photographs.	Braden scale and digital photographs to identify the risk of pressure ulcers.
Burk et al. (2014).	American Journal of Critical Care	USA†	To identify predictors of agitation by examining demographic and clinical characteristics of critically ill patients.	Agitation alert system.
Burk et al. (2017).	Advances in Wound Care	USA†	To describe the image quality of ‡HFU, the incidence of ‡HFU image artifacts, and their effect on image quality in critically ill patients.	Evaluation of high-frequency ultrasound imaging.
Cho et al. (2015).	Clinical Nursing Research	South Korea	To implement an automatic prediction system for delirium in intensive care units (APREDEL-ICU§) to investigate its impact on nursing-sensitive outcomes and to evaluate nurses' satisfaction with the system.	APREDEL-ICU§ tool to improve delirium prevention.
Dennis et al. (2016).	Journal of Clinical Nursing	Australia	To evaluate the consistency and safety of manual delivery of hyperinflation by nurses with varying clinical experience using a resuscitation bag during physical therapy treatment.	Evaluation of the consistency and safety of manual inflation of the manual resuscitator.
Gerolemou et al. (2014).	American Journal of Critical Care	USA†	To evaluate the effectiveness of simulation-based training of intensive care nurses in the use of sterile techniques during central vein catheterization and the effect of this training on infection rates.	Evaluation of training effectiveness
Giusti et al. (2017).	Australian Critical Care	Italy	To evaluate the effectiveness and reliability of the palpation method, performed with the operators' fingers, in order to detect the orotracheal tube.	Evaluation of the effectiveness and reliability of the orotracheal tube cuff palpation method.
Goldberg et al. (2004).	Diabetes Technology and Therapeutics	USA†	To investigate the effectiveness and safety of the Continuous Glucose Monitoring System® (CGMS‖) in critically ill patients admitted to an intensive care unit (ICU¶).	Evaluation of the effectiveness and safety of the Continuous Glucose Monitoring System®.
Grap et al. (2016).	American Journal of Critical Care	USA†	To describe the backrest elevation, the anatomical location and the skin pressure intensity across the body in patients receiving mechanical ventilation.	Evaluation of backrest elevation, anatomical location, and skin pressure integrity.
Li et al. (2017).	Medicine	USA†	To evaluate whether the implementation of Failure Mode and Effect Analysis (FMEA**) will significantly reduce the incidence of catheter-related bloodstream infections in the ICU setting¶.	Failure Mode and Effect Analysis (FMEA**).
Ludwig-Beymer et al. (2012).	Journal of Nursing Care Quality	USA†	To examine the verification of medication administration at the bedside in two adult intensive care units, using portable and permanent computers.	Use of portable and permanent computers at the bedside.
Ruesch et al. (2012).	Telemedicine and e-Health	Canada	To examine the impact of the first intensive care unit staffing model implemented by nursing (tele-ICU¶).	Tele-ICU¶ nursing
Williams et al. (2012).	Critical Care Nurse	USA†	To describe the tele-ICU¶ nursing interventions that contributed to the best care in our health system during one year.	Implementation of a Tele-ICU¶ nursing program.
Quasi-experimental studies				
Barakat-Johnson et al. (2019).	International Wound Journal	Australia	To evaluate the clinical conditions, effectiveness and feasibility of the silicone-lubricated positioner (Z-Flo††) in reducing the occurrence of occipital PUs‡‡ in an ICU¶.	Z-Flo†† for prevention of occipital PUs‡‡.
Sowan et al. (2016).	JMIR Human Factors	USA†	To examine whether a change in the default alarm settings of cardiac monitors and nursing education in cardiac monitor use in an ICU¶ would result in a reduction in alarm rate and an improvement in nurses' attitudes and practices toward clinical problems.	Evaluation of the change in cardiac monitor settings.
Coyer et al. (2017).	Journal of Wound Care	Australia	To explore the effects of the type of patient position employed and the body mass index (BMI§§) category on the mapping of interface pressure (IP‖‖) and tissue reperfusion in the critically ill adult patient population.	Mapping of interface pressure (IP) and tissue reperfusion.
Wang et al. (2015).	Therapeutics and Clinical Risk Management	China	To discuss the effectiveness of an intervention to reduce medication administration errors (MAEs¶¶) in hospital assistance and provide some benchmarks for international counterparts.	To evaluate an educational information technology based on process optimization.
Humphrey (2015).	JAVA***|	USA†	To determine the knowledge of nurses working in critical areas with factors that contribute to CLABSIs†††; and assess the influence of an educational intervention on participants' knowledge of the factors that contribute to CLABSIs†††, using a pre- and post-test design.	Educational intervention with simulation.

Author/Year	Journal	Country	Study Objective	Care Technology
Moon et al. (2018).	International Journal of Nursing Studies	South Korea	To develop an Automated Delirium Risk Assessment System (‡‡‡Auto-DelRAS) that automatically alerts health care providers of a patient's risk of delirium based solely on data collected in an electronic medical record system and to assess the clinical validity of this system.	Automated Delirium Risk Assessment System (Auto-DelRAS‡‡‡).
Randomized Clinical Trials				
Pedrolo et al. (2014).	Rev Enferm UERJ§§§	Brazil	To evaluate the effectiveness of chlorhexidine-impregnated dressing for covering central venous catheters.	Evaluation of the effectiveness of chlorhexidine-impregnated dressing.
Schell-Chaple et al. (2018).	American Journal of Critical Care	USA†	To evaluate the agreement and accuracy of a zero heat flow (SpotOn‖‖‖) thermometry system and continuous rectal and bladder thermometry.	Evaluation of the thermometry system and zero heat flux (SpotOn‖‖‖).
Coyer et al. (2015).	American Journal of Critical Care	Australia	To test an interventional skin integrity package, the InSPiRE protocol¶¶¶, in order to reduce pressure ulcers in ICU patients.	InSPiRE protocol (*bundle*), for reducing PUs††.
Drews and Doig (2014).	Human Factors	USA†	To evaluate a configurable vital signs (CVS****) screen designed to support rapid detection and identification of physiological deterioration by graphically presenting patient vital sign data.	Vital signs configuration screen.

*USP = University of São Paulo; †USA = United States of America; ‡HFU = High-Frequency Ultrasound; §APREDEL-ICU = Automatic Prediction of Delirium in Intensive Care Units; ‖CGMS = Continuous Glucose Monitoring System®; ¶ICU = Intensive Care Unit; **FMEA = Failure Mode and Effect Analysis; ††Z-Flo = Silicone-Lubricated Positioner; ‡‡PU = Pressure Ulcer; §§BMI = Body Mass Index; ‖‖IP = Interface Pressure; ¶¶MAEs = Medication Administration Errors; ***JAVA = Journal of the Association for Vascular Access; †††CLABSI = Central line-associated bloodstream infection; ‡‡‡Auto-DelRAS = Automated Delirium Risk Assessment System; §§§UERJ = State University of Rio de Janeiro; ‖‖‖SpotOn = Zero heat flux thermometry system; ¶¶¶InSPiRE = Patient Skin Integrity Care Bundle; ****CVS = configurable vital signs. Source: Authors.

In the 13 observational studies evaluated with the ROBINS-I tool, most (08/61.5) were classified as moderate risk of bias, while the others (05/38.5%) were classified as serious risk of bias (Table 3). All studies were evaluated for quality of evidence using the GRADEpro system, with very low evidence classification being determined for most studies (16/69.6%), while moderate quality of evidence was determined for five studies (21.7%), one study was classified as low evidence (4.3%) and one study as high evidence (4.3%).

The results of the researchers' evaluation for each of the criteria addressed in the GRADEpro system are presented in Table 3, as well as their respective classifications of the level of evidence.

Table 3. Classification of the studies according to the assessment of the quality of the studies. Florianópolis, Santa Catarina, Brazil, 2021.

Author/Year	Quality Evaluation						Level of Quality
	Risk of Bias (ROBINS-I)	Risk of Bias	Inconsistency	Indirect Evidence	Inaccuracy	Others	
Araújo et al. (2012).	Serious	Serious	Very serious	Non-serious	Very serious	None	⊕◯◯◯ VERY LOW
Barakat-Johnson et al. (2019).	NA*	Serious	Non-serious	Non-serious	Non-serious	None	⊕⊕⊕◯ MODERATE
Burk et al. (2017).	Moderate	Non-serious	Very serious	Non-serious	Very serious	None	⊕◯◯◯ VERY LOW
Burk et al. (2014).	Moderate	Non-serious	Very serious	Non-serious	Non-serious	None	⊕⊕◯◯ LOW
Cho et al. (2015).	Moderate	Non-serious	Very serious	Non-serious	Serious	None	⊕◯◯◯ VERY LOW
Coyer et al. (2017).	NA*	Very serious	Very serious	Non-serious	Very serious	None	⊕◯◯◯ VERY LOW
Coyer et al. (2015).	NA*	Very serious	Serious	Non-serious	Non-serious	None	⊕◯◯◯ VERY LOW
Dennis et al. (2016).	Serious	Serious	Very serious	Non-serious	Serious	None	⊕◯◯◯ VERY LOW
Drews and Doig (2014).	NA*	Serious	Very serious	Non-serious	Serious	None	⊕◯◯◯ VERY LOW
Gerolemou et al. (2014).	Moderate	Non-serious	Very serious	Non-serious	Serious	None	⊕◯◯◯ VERY LOW
Giusti et al. (2017).	Moderate	Non-serious	Very serious	Non-serious	Serious	None	⊕◯◯◯ VERY LOW
Goldberg et al. (2004).	Moderate	Non-serious	Very serious	Non-serious	Serious	None	⊕◯◯◯ VERY LOW
Grap et al. (2016).	Moderate	Non-serious	Very serious	Non-serious	Serious	None	⊕◯◯◯ VERY LOW
Humphrey (2015).	NA*	Very serious	Serious	Non-serious	Serious	None	⊕◯◯◯ VERY LOW
Li et al. (2017).	Serious	Serious	Very serious	Non-serious	Very serious	None	⊕◯◯◯ VERY LOW
Ludwig-Beymer et al. (2012).	Serious	Serious	Very serious	Non-serious	Very serious	None	⊕◯◯◯ VERY LOW
Moon et al. (2018).	NA*	Serious	Non-serious	Non-serious	Non-serious	None	⊕⊕⊕◯ MODERATE
Pedrolo et al. (2014).	NA*	Serious	Serious	Non-serious	Serious	None	⊕◯◯◯ VERY LOW
Ruesch et al. (2012).	Moderate	Non-serious	Very serious	Non-serious	Serious	None	⊕◯◯◯ VERY LOW
Schell-Chaple et al. (2018).	NA*	Non-serious	Non-serious	Non-serious	Non-serious	None	⊕⊕⊕⊕ HIGH
Sowan et al. (2016).	NA*	Serious	Non-serious	Non-serious	Non-serious	None	⊕⊕⊕◯ MODERATE
Wang et al. (2015).	NA*	Serious	Non-serious	Non-serious	Non-serious	None	⊕⊕⊕◯ MODERATE
Williams et al. (2012).	Serious	Serious	Non-serious	Non-serious	Non-serious	None	⊕⊕⊕◯ MODERATE

*NA= Not applicable. Source: Authors.

Regarding care technologies, 11 (47.8%) were developed by nurses and 12 (52.2%) were evaluated by them. Among the technologies developed by nurses, six (54.5%) were product technologies and five (45.5%) were process technologies. In contrast, the care technologies that underwent the evaluation process by nurses in clinical practice were all process technologies and, consequently, there was no product technology evaluated (Table 4).

Among the product technologies, all were directed to clinical interventions and none were directed to educational interventions. Conversely, of the 17 process technologies, 11 (64.7%) were directed to clinical interventions and six (35.3%) to educational interventions.

Table 4. Classification of the studies according to care technology, type of care technology, purpose of care technology and nurses' contribution. Florianópolis, Santa Catarina, Brazil, 2021.

Study	Care Technology	Type of Care Technology	Purpose of Care Technology	Nurses' Contributions
Araújo et al. (2012).	Joint use of the Braden scale and digital photographs to identify pressure ulcer risk	Process	Assistance	Development
Barakat-Johnson et al. (2019).	Silicone microsphere lubricated head positioner, called Z-Flo*, to prevent pressure ulcers in the occipital region	Product	Assistance	Development
Burk et al. (2014).	High-frequency ultrasound imaging evaluation	Process	Assistance	Evaluation
Burk et al. (2017).	Agitation alert system.	Product	Assistance	Development
Cho et al. (2015).	APREDEL-ICU† tool to improve delirium prevention.	Product	Assistance	Development
Coyer et al. (2015).	Mapping of interface pressure and tissue reperfusion	Process	Assistance	Development
Coyer et al. (2017).	InSPiRE‡ protocol for reducing pressure ulcers	Product	Assistance	Development
Dennis et al. (2016).	Consistency and safety evaluation of manual inflation of bag-valve-mask.	Process	Education	Evaluation
Drews and Doig (2014).	Screen for configuring vital signs	Product	Assistance	Development
Gerolemou et al. (2014).	Evaluation of training effectiveness	Process	Education	Evaluation
Giusti et al. (2017).	Evaluation of the effectiveness and reliability of the orotracheal tube cuff palpation method	Process	Education	Evaluation
Goldberg et al. (2004).	Evaluation of the effectiveness and safety of the Continuous Glucose Monitoring System®.	Process	Assistance	Evaluation
Grap et al. (2016).	Evaluation of backrest elevation, anatomical location, and skin pressure integrity.	Process	Assistance	Evaluation
Humphrey (2015).	Educational intervention with simulation	Process	Education	Development
Li et al. (2017).	Failure Mode and Effect Analysis	Process	Assistance	Evaluation
Ludwig-Beymer et al. (2012).	Use of portable and permanent computers	Process	Assistance	Evaluation
Moon et al. (2018).	Auto-DelRAS§ for assessing delirium risk	Product	Assistance	Development
Pedrolo et al. (2014).	Evaluation of the effectiveness of the chlorhexidine-impregnated dressing	Process	Assistance	Evaluation
Ruesch et al. (2012).	Telemedicine intensive care unit staffing model implemented by nurses	Process	Assistance	Development
Schell-Chaple et al. (2018).	Non-invasive, continuous temperature monitoring system with zero heat flux technology to measure core temperature, called SpotOn‖	Process	Assistance	Evaluation
Sowan et al. (2016).	Evaluation of the change in default alarm settings for cardiac monitors and nursing education	Process	Education	Evaluation
Wang et al. (2015).	Evaluation of organizational, measures related to an educational information technology based on process optimization.	Process	Education	Evaluation
Williams et al. (2012).	Implementation of a Tele-ICU nursing Program	Process	Assistance	Development

*Z-Flo = Silicone-lubricated positioner; †APREDEL-ICU = Automatic Prediction of Delirium in Intensive Care Units; ‡InSPiRE = Bundle for the patient's skin integrity (Patient Skin Integrity Care Bundle); §Auto-DelRAS = Automated Delirium Risk Assessment System; ||SpotOn = Zero heat flux thermometry system. Source: Authors.

4. Discussion

Most surveys were conducted in developed countries, regardless of whether it was product or process technology. The

process technologies were evaluated by nurses, which was expected, since these professionals have an ethical and legal responsibility for the care and safety of patients, especially those in the ICU setting. In addition, their daily experience with practical problems related to nursing care also enables them to understand and evaluate possibilities of technological contributions to improve patient safety and assistance.

The findings of this SR constitute a paradox. Since patient safety is required in all fields of care practice, for this very reason, the research that gives rise to product and process technologies, whose articles were examined, should be supported by a high level of evidence, which did not happen. This is because the designs chosen, as presented in the method of the examined articles, did not correspond, for the most part, to those whose analyses and propositions, when registered, result in a high level of evidence.

Only one RCT after the evaluation was classified as a high level of quality of evidence. In this study, the author evaluated a zero-heat flux thermometry system (SpotOn) and continuous urinary and rectal bladder thermometry during fever in adult ICU patients. The evaluation was directed towards measurement accuracy and system agreement (Schell-Chaple et al., 2018). The high level of quality of evidence indicates that this is a technology that does not compromise patient safety.

The design of RCT-type studies contributes to greater reliability in the results, due to the requirement of rigor, an aspect attributed especially by the randomization process (Sterne, et al., 2016). Randomization ensures that these studies start with a high level of evidence in the GRADE system (Zhang, et al., 2019; Schünemann, et al., 2019). Nevertheless, when an RCT is not adequately described in the method, it can especially be evaluated with a low or very low level of evidence, despite the technologies being focused on important issues for the provision of safe care to patients. The studies on the InSPiRE Protocol – bundle for reducing pressure ulcers (Coyer, et al., 2015) and proposing a screen for vital signs configuration to support the rapid identification of physiological deterioration of ICU patients (Drews & Doig, 2014), were evaluated as very low quality of evidence. Both studies, although essential products in the ICU routine, due to the very low level of quality of evidence, emphasize that patient safety may be compromised with the use of these technologies during assistance. Moreover, the study that evaluated the effectiveness of the chlorhexidine-impregnated dressing is not recommended for use due to the very low level of quality of evidence (Pedrolo, et al., 2014).

The quasi-experimental studies that were evaluated in this SR were mostly classified as a moderate quality level of evidence because the risk of bias was considered serious. Among these, the studies developed that resulted in product technologies such as Z-Flo (lubricated silicone microspheres positioner) for preventing occipital pressure ulcers (occipital PUs) (Barakat-Johnson, et al., 2019) and the Automated Delirium Risk Assessment System named Auto-DelRAS (Moon et al., 2018). The articles on the educational process were also classified as a moderate level of quality of evidence: evaluated the change of configurations of cardiac monitors (Sowan, et al., 2016) and the one that evaluated the information and educational technologies based on process optimization (Wang et al., 2015). In addition to these, the articles on the development of the assistance process of mapping interface pressure (IP) and tissue reperfusion were classified as very low level of evidence, as they present a very serious risk of bias, inconsistency and inaccuracy, causing the technology is not recommended (Coyer, et al., 2017). The other study, also a development study, but for the educational process/educational intervention with simulation, had its classification downgraded, as it presented a very serious risk of bias (Humphrey, 2015).

Most observational studies had very low levels of evidence because they presented very serious inconsistencies; for this reason, they were downgraded or not upgraded. The analyzed manuscripts with a focus on the assistance process developed a combination of the use of the Braden scale with photo for identifying risk of injury, the skin care of patients in the ICU (Araújo, et al., 2012) setting and the study of the development of the Tele-ICU nursing, to examine the impact of the first model created and implemented by nurses (Ruesch, et al., 2012). These studies provide innovation for nursing care, but the quality of evidence presented showed a very low level of evidence due to very serious inconsistencies, because the authors did

not provide enough data to allow this assessment (Zhang, et al., 2019). The evaluation studies of the assistance process found were related to the evaluation of the high-frequency US imaging (Burk, et al., 2017); the effectiveness and safety of the Continuous Glucose Monitoring System® (Goldberg, et al., 2004); the backrest elevation, anatomical location and skin pressure integrity (Grap, et al., 2016); the Failure Mode and Effect Analysis (FMEA) (Li, et al., 2017); and the use of portable and permanent computers at the bedside (Ludwig-Beymer, et al., 2012). Taking into account the study theme and the technological focus, these articles could improve the assistance process. However, considering that they presented inconsistencies and obtained very serious scores, they may compromise patient safety, when applied in the ICU setting.

The studies focused on evaluating the educational process were related to the evaluation of the consistency and safety of manual insufflation of the ambu-bag (Dennis, et al., 2016), the effectiveness of training (Gerolemou, et al., 2014) and the effectiveness and reliability of the palpation method performed by the operators' fingers, for detecting endotracheal tube cuff pressure (Giusti, et al., 2017). Although these studies were aimed at evaluating the educational process, they presented very serious inconsistencies, downgrading the level of evidence.

The observational study that developed an assistive product technology, consisting of an agitation alert system (Burk et al., 2014), obtained a low level of evidence, as it presented very serious inconsistency, because there is not enough data available in the study to carry out this evaluation. Only the observational study that developed an assistance process for implementing a Tele-ICU nursing program managed to raise the level of evidence to moderate (Williams, et al., 2012)

Several themes and technologies were found in this SR, aiming at the nursing care in the ICU setting, demonstrating a positive potential for innovation. Nevertheless, considering the objective defined for this SR "to demonstrate evidence that nursing care technologies ensure patient safety in the ICU setting" and having adopted GRADE and ROBINS-I to evaluate the content of the articles, we should consider as a relevant issue the fact that only one article obtained a high level of evidence. Therefore, when conducting research and producing technology, nurses must decide on the type of study design, its planning and the description of the procedures in the published articles, so that the evidence is of a high level of quality, since patient safety, especially in the ICU setting, must be ensured.

5. Conclusion

The level of evidence evaluated in most articles is related, in large part, to flaws in the description of the designs and reports of the evaluated studies. More rigor is needed in the design and description of the studies, and the reports of the methods and results should be rigorously documented.

Therefore, as important as knowing how to propose and produce a technology, is knowing how to validate it. Consequently, using theoretical references and adequate methods to evaluate the outcomes is a researcher's commitment, both for the development and validation of technologies, whether related to products or processes. This is because the patients' safety, especially those in the ICU setting, must be ensured.

The results of this study may contribute to nursing professionals deciding, in the light of science, when and with which technology changes will be proposed in the clinical practice of nurses, particularly in the ICU setting. Therefore, the level of evidence, when evaluated with the support of appropriate tools, is an indicator of the quality of research and technological production.

Accordingly, it is necessary to encourage experimental research in nursing, appropriately proposing projects, to obtain evidence with the least possible bias and to become able to incorporate the findings into direct patient care with maximum safety.

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