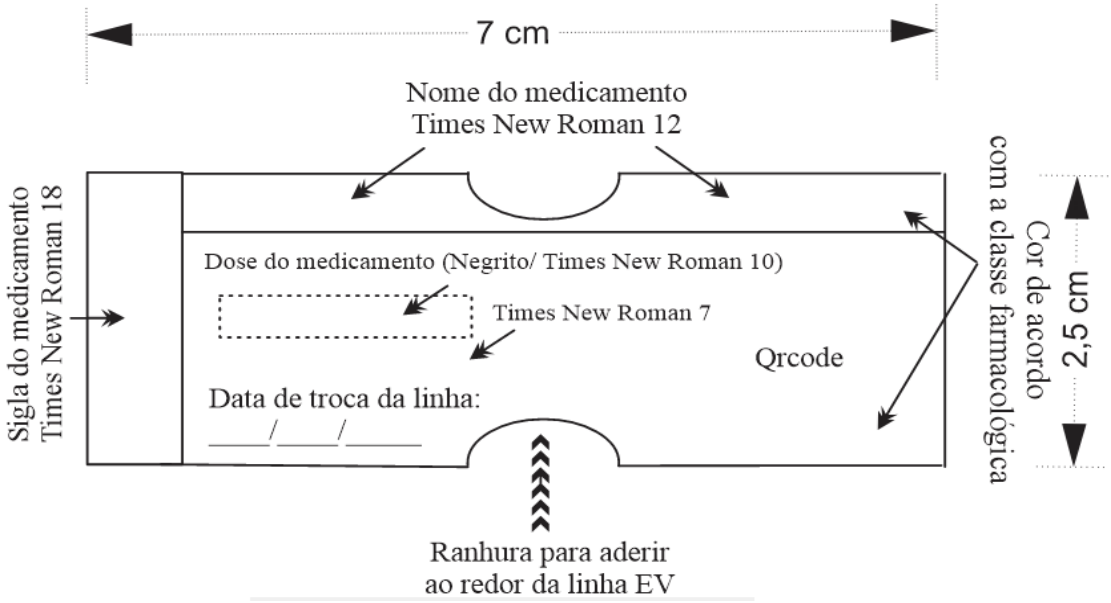

Figura 1 - Protótipo definitivo utilizado para construção dos rótulos de linhas EV.

Fonte: Os autores, 2023.

Figura 2 - Protótipo final do rótulo de Midazolam.

Fonte: Os autores, 2023.

Figura 3 - Protótipo final do rótulo de Norepinefrina.

Fonte: Os autores, 2023.

Figura 4 - Protótipo final do rótulo de Vasopressina.

Fonte: Os autores, 2023.

Figura 5 - Protótipo final do rótulo de Fentanil.

Fonte: Os autores, 2023.

Figura 6 - Protótipo final do rótulo de Heparina.

Fonte: Os autores, 2023.

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CLINICAL TRIAL

Intravenous Line Labels For High-Alert Drugs Administered To Critically Ill Patients: A Simulated Experimental Assessment

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ABSTRACT

Aims and Objectives: Evaluate the effect of IV line labels on nurses' identification of high-alert medications in a simulated scenario of multiple infusions for critically ill patients.

Design: Randomised crossover simulation experimental study.

Methods: A study was conducted on 29 nurses working in intensive care for over 6 months. They were given two critical scenarios in a simulated environment, one with labels and the other without labels, involving multiple intravenous infusions. The nurses had to identify the medications infused into the critical patients' intravenous lines and disconnect a specific line. The data were collected and analysed to evaluate the errors made by the nurses in identifying and disconnecting the medications and the time they spent carrying out the tasks. The Wilcoxon test was used to analyse the variation in outcome before and after the intervention.

Results: Approximately one-third of the study participants incorrectly identified the intravenous lines in both scenarios. There was no significant difference in the average number of errors between the scenarios with and without labels. However, the time taken to perform the tasks in the scenario with labels was 1 min less than in the scenario without labels, suggesting a potential efficiency gain.

Conclusions: The labels on the intravenous lines allowed for quick drug identification and disconnection. The professionals performed similarly in correctly recognising the high-alert medication intravenous lines, in the scenarios with or without labels.

Relevance to Clinical Practice: The label can be used as a technology to prevent misidentification of high-alert medications administered to critically ill patients through intravenous lines, thereby enhancing medication safety in healthcare institutions.

No Public Contribution.

1 | Introduction

Medication errors involving high-alert drugs administered intravenously are a significant concern in critically ill patients. These errors increase the risk of causing significant harm to the patient (Kuitunen et al. 2021). One reason for these errors is intensive care professionals' difficulty identifying these drugs in intravenous (IV) lines (Pinkney, Fan, Chan et al. 2019).

Summary

- What does this paper contribute to the wider global clinical community?
  - Intertwining of intravenous lines of multiple infusions administered to critically ill patients increases the chances of drug administration errors;
  - There is a lack of knowledge regarding the best labelling standards for intravenous lines of high-alert medications administered to critically ill patients and the impact of labelling on patient safety;
  - Our research provides practical insights, revealing that labels with specific characteristics can significantly reduce the time nurses spend identifying drugs in intravenous lines and minimise errors related to identifying high-alert drugs. These characteristics include labels printed on resistant material, with differences in font colour and size, and containing the following information: the name of the drug, its dose, time of preparation, date of line change and expiration date of the drug.

It can be challenging to identify IV lines due to visual clutter and the entwining of lines that occur when multiple medications are used simultaneously. In intensive care settings, a multi-lumen central venous catheter can be used to administer multiple infusions, which can increase the risk of drug administration errors in critically ill patients. This population often requires urgent and frequent changes in medication therapy (Pinkney, Fan, Koczmara, and Trbovich 2019; Smith and Litman 2017; Fan et al. 2019).

Implementing preventive strategies to ensure the safety of critically ill patients with multiple IV infusions is increasingly essential. One such strategy is to use IV line labels with drug information attached to each infusion line. Drug information is typically only found on labels attached to infusion bags. However, IV lines are handled close to the patient's vascular access point during drug administration or when disconnecting infusions. Since the lengths of IV lines are visually similar, proper identification is necessary to avoid medication errors (Pinkney, Fan, Koczmara, and Trbovich 2019; Souza et al. 2019; Rodziewicz, Houseman, and Reduction 2023).

There are no general recommendations or guidelines on using IV line labels in practice. Furthermore, the existing standard for label standardisation—International Organization for Standardization (ISO) number 26825/2021—is limited to single-dose drugs used in the anaesthetic area and for syringe-type devices (International Organization for Standardization 2022).

Given this context, it is relevant to consider the development and integration of technologies aimed at increasing patient safety, especially in light of the Global Action Plan for Patient Safety 2021–2030, proposed by the World Health Organization. This plan aims to achieve the maximum possible reduction in avoidable harm due to unsafe health care worldwide in 2021–2030 (World Health Organization 2021).

2 | Background

Errors with high-alert medications are a problem of significant magnitude. A systematic review of five studies on the prevalence of harm caused by medication errors involving high-risk medications illustrates this. The combined prevalence of harm was 16.3%, and 0.01% of harms resulted in patient death. The highest prevalence of harm occurred following the use of potassium chloride, insulin and epoprostenol (Alves et al. 2021).

A 2015 study analysed medication errors reported in a safety record system at a tertiary hospital in Saudi Arabia. The study found 624 medication errors, with 281 (45%) attributed to high-alert drugs, which were identified as the leading cause of safety failures. Chemotherapeutic agents accounted for the highest percentage, 23.6%, followed by anticoagulants at 7.5% and narcotics at 4.8% (Aseeri et al. 2020).

A study investigated medication errors within intensive care units, specifically focusing on those involving high-alert medications. The study identified 305 incidents of medication errors involving 73 different drugs in 33 classes. High-alert medications were responsible for 37 occurrences (12%), with venous anaesthetics (midazolam and fentanyl) and anticoagulants (heparin) being the main culprits, with a frequency of 43% and 27%, respectively (Bohomol 2014). Another study also found that errors with high-alert drugs in intensive care units ranged from 14% to 50%, with most errors occurring during drug administration (Sessions et al. 2019).

In a simulated scenario, a study found a 7.7% error rate when handling multiple IV infusions, specifically during the screening of IV lines to identify infusions (Pinkney, Fan, Chan, et al. 2019). Another investigation analysed medication error reports from 2004 to 2013 in Pennsylvania, USA, and found 907 errors related to IV line manipulations. These errors occurred mainly during the inclusion of infusion rates in infusion pumps, the manipulation of IV lines with unintended medications and the lack of connection of IV lines to patients. It was observed that high-alert drugs were involved in 71% of the errors associated with IV lines, with heparin being the drug that caused the most frequent errors (Wollitz and Grissinger 2019).

In 2015, the Emergency Care Research Institute listed the top 10 hazards related to health technologies. One of the hazards on the list was errors in handling IV lines for high-alert medications. These errors included connecting the infusion line to the wrong device, administering inappropriate medication to the patient and titrating doses incorrectly or through an inappropriate route. Intertwining lines can make distinguishing one IV line from another difficult, compromising the correct tracing of the line to the bag (Emergency Care Research Institute 2014).

Studies have shown that labelling errors, including non-labelling and incorrect or incomplete intravenous (IV) line labelling, are common in intensive care units. However, no studies have adequately recommended labelling IV lines (Nunes, Campos, and Silva 2022). This highlights the importance of the current study, which aims to evaluate the effectiveness of labels designed for high-alert drug lines in reducing medication errors.

Clinical simulation is a technique that replicates real-life situations to evaluate skills and competencies in a safe environment. It is considered a meaningful learning strategy in which learners actively construct their knowledge (Kim, Park, and Shin 2016). Therefore, simulation can be used to examine the professionals' performance regarding the IV line labels suggested in this study.

3 | Objective

Evaluate the effect of IV line labels on nurses' identification of high-alert medications in a simulated scenario of multiple infusions for critically ill patients.

4 | Method

4.1 | Study Design

It was a randomised, crossover, experimental simulation study. The experiment evaluated the effect of IV line labels on nurses' performance in the identification of high-alert medications. The study took place in two simulated scenarios with multiple IV infusions in critically ill patients. One scenario involved IV line labels, while the other did not. The researchers followed the extended Consolidated Standards of Reporting Trials (CONSORT) checklist, adapted for simulation research, to guide the presentation of the research report (Cheng et al. 2016). As this was a simulated experimental study, there was no requirement for clinical trial registration.

4.2 | Construction of the IV Line Label Prototype

The prototype of the IV line label was constructed based on a scoping review using the Joanna Briggs Institute methodology. According to a prospective protocol registered with the Open Science Framework, the review aimed to identify existing knowledge on labelling devices for administering IV drugs to critically ill patients. The findings were mapped to synthesise the ideal labelling characteristics and standards to prevent medication errors associated with IV line labelling. This review identified 715 scientific articles in various databases and 10 materials from other sources. After the selection process, eight documents specifically addressed intravenous line labels. The primary evidence mapped is presented in Table 1:

The results guided the selection of materials, content and visual structure for the prototype label. The medications chosen were based on the 'High-Alert Medications in Acute Care Settings' list from the Institute for Safe Medication Practices (Institute for Safe Medication Practices 2018). Medications commonly used in critically ill patients, such as vasoactive drugs (noradrenaline/vasopressin), sedatives (midazolam) and analgesics/tranquillisers (fentanyl), were selected from this list. Additionally, heparin was included due to a high error rate identified in a previous study (Wollitz and Grissinger 2019).

The label prototype includes the following key characteristics: (a) Information: It includes the name of the drug and the dose and date of the IV line change. The dose of the drugs is in mg/ml for midazolam, fentanyl and noradrenaline, and in IU/ml for heparin and vasopressin; (b) Visual structure: The label measures 7 cm in length and 2.5 cm in width. The text is in Times New Roman font, size 12. It uses Tall Man Lettering strategies and colour coding according to ISO 26925:2021; (c) Physical material: The label is made of vinyl due to its good durability, adhesiveness and low cost. It allows the use of marker pens without smudging; (d) Safety features: It adopts acronyms for the drug names on the white part of the label in size 18 to reduce the chance of intra-class medicine errors due to colour. A QR code is used for each drug, redirecting to the websites of the Brazilian National Health Surveillance Agency (Agência Nacional de Vigilância Sanitária—Brasil) and the Brazilian Institute for Safe Medication Practices (Instituto para Práticas Seguras no Uso de Medicamentos ISMP—Brasil), providing technical information on the use of each drug.

A graphic designer used Corel Draw21 software to create the prototype and organise the label template. The templates were then printed and applied to the IV lines for evaluation before the investigation. Feedback from the evaluation led to adjustments, resulting in the final template and prototype evaluation. Figures 1 and 2 display the final prototype:

4.3 | Setting Study

The prototype evaluation was conducted in a Nursing Clinical Simulation Laboratory at a public university in Rio de Janeiro, Brazil. This laboratory was equipped with advanced technological resources that simulated a variety of clinical situations that could occur in a hospital. This mannequin allowed the researchers to perform various nursing procedures, such as administering IV medication, applying dressings and inserting probes. The simulation included multiple IV infusions, and the researchers used various materials to set up the scenario, including infusion pumps, solution bags, IV catheters, connectors and other equipment used for administering medication.

4.4 | Participants, Selection Criteria and Sample

The study included nurses who had at least 6 months of practical experience in intensive care or emergency units, which was considered enough to manage IV therapy for critically ill patients. Nurses who were not currently working in these settings were excluded from the study.

The authors carefully considered the sample size because this was a study that evaluated the use of labels constructed in a simulated environment. They decided not to perform sample calculations because it is difficult to gather large samples of intensive care nurses outside the ICU. Instead, they relied on the literature's recommendation of using a group of 30–40 participants and considered the behaviour of this group as an estimate for the population (Miot 2011).

The participants were intentionally selected from a specialised intensive care nursing course in Rio de Janeiro, which nurses from various health institutions in the city attended. Initially, the postgraduate course had 50 applicants divided into two

TABLE 1 | Evidence mapped in the scoping review.

Year/country	Document types/ Scenarios	Types of labels	Content and structure of labels
2009/USA	Article: experimental study, quantitative, conducted in a simulated environment. Scenario: Simulated ICU	- Colour-coded labels with printed and handwritten content and standardised design for IV lines. - Labels without colour coding, with handwritten and printed contents, standardised design for IV lines. **Impacts of labels regarding error prevention**: Colour-coded labels provided greater drug administration safety, allowing devices to be labelled correctly in less time and facilitating visual identification, avoiding errors.	-Information on labels: Name of medication; date and time of preparation -Colour coding.
2019/Canada	Article: experimental quantitative study in simulated environment Scenario: Simulated ICU	- Labels without colour coding, printed content, standardised design for IV lines. **Impacts of labels regarding error prevention**|: Labels without colour coding, with printed content, enabled correct and more timely identification.	-Information on labels: Name of the medication.
2017/Chile	Article: quasi-experimental, quantitative study Scenario: ICU	- Labels without colour coding, handwritten, unspecified design for IV lines. - Colour-coded labels, with printed content, standardised design for IV lines. **Impacts of labels regarding error prevention**: Adopting labels with pre-established colour codes increased drug administration safety. The risk of errors for patients who received drugs without colour coding and in a handwritten format was four times greater.	-Information on labels: Name of the medication; Date and time of preparation; Dose; Patient identification; Identification of who prepared the drug; -Colour coding.
2019/ Brazil	Article: survey, quantitative Scenario: ICU	- Colour-coded labels, with printed content, standardised design for IV lines. **Impacts of labels regarding error prevention**: Colour-coded labels and printed content helped prevent errors by improving the continuous monitoring of administered infusions, providing greater accuracy in identifying medications in high-stress situations and reducing the average time required to label medications.	-Information on labels: Name of the medication; date and time of preparation; -Colour coding; -Label size (length x width): 5 × 1.5 cm; Type of font for drug name: Times New Roman; Different-sized letters
2013/South Korea	Article: controlled, quantitative clinical trial Scenario: Emergency department	- Colour-coded labels, printed, unspecified design for IV lines. **Impacts of labels regarding error prevention** The colour-coded labels provided faster and more accurate handling of infusions individually and relative to other fluids; greater assertiveness in connecting and disconnecting fluids; and faster administration of medications in emergencies.	-Colour coding.

(Continues)

TABLE 1 | (Continued)

Year/country	Document types/ Scenarios	Types of labels	Content and structure of labels
2017/United Kingdom	Guideline Scenario: Anaesthesia unit	- Labels without colour coding, handwritten, unspecified design for bags, syringes, and IV lines. **Impacts of labels regarding error prevention:** In the absence of pre-printed labels, handwritten labels can be used, but they must be labelled with permanent markers. Infusion lines should be labelled at both ends near the connectors for easy verification and to reduce erroneous connections.	-Information on labels: Name of the medication; -Labelling method: Permanent marker for handwritten information.
2012/Australia	Guideline Scenario: Anaesthesia unit	- Labels without colour coding, printed, standardised design for IV lines **Impacts of labels regarding error prevention:** The main means of identifying the route of administration for IV lines is reading the written content containing information about the drug. Strategies such as using capital letters and colours help differentiate drugs.	-Information on labels: Route; -Label size (length × width): 7 × 2.5 cm; -Type of font for drug name: Sans Serif; - Different-sized letters; -Colour coding.
2015/Australia	Guideline Scenario: Anaesthesia unit	-Colour-coded labels, printed, standardised design for IV lines **Impacts of labels regarding error prevention**: The labels must be pre-printed, and contain the name of the drug and the additive, a capital initial letter for each word, and lowercase for other letters. Uppercase letters interspersed with lowercase letters to differentiate drug names should be used for drugs with similar names.	Information on labels: Name of the medication; Dose; Route; -Label size (length × width): 7 × 2.5 cm; -Type of font for drug name: Sans Serif (11–20); - Different-sized letters; -Colour coding.

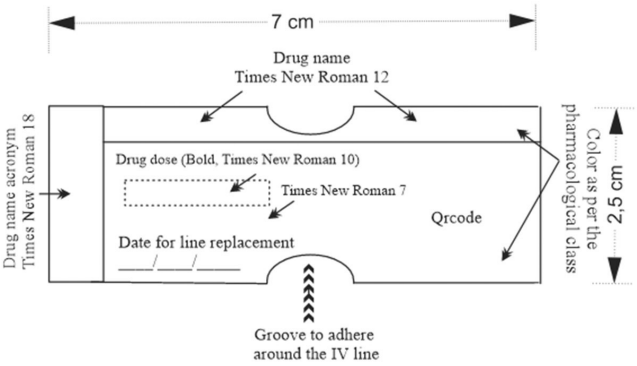

FIGURE 1 | Template used to label IV lines of high-alert medications.

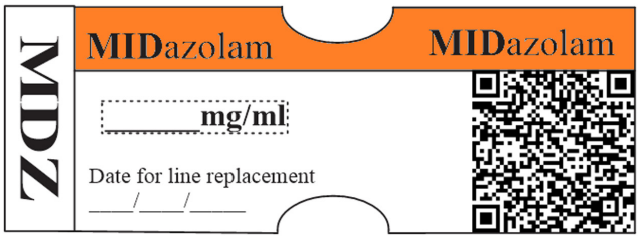

FIGURE 2 | Midazolam IV line label prototype.

classes of 25 students. After assessing compliance with the selection criteria, 29 participants met the requirements and agreed to participate, forming the final research sample.

4.5 | Intervention

A clinical scenario was set up to develop procedures for managing multiple intravenous infusions. The scenario involved a patient mannequin with a three-lumen central venous access and a two-way peripheral intravenous access. Continuous infusions of drugs commonly used in critically ill patients (such as noradrenaline, vasopressin, midazolam, fentanyl and heparin) were given through the central venous access lumens. Two gravity infusions of simple Ringer's or saline solution were administered through the peripheral intravenous access to simulate a situation where IV lines were tangled. The order in which the drugs were distributed in the infusion lines differed in the two scenarios.

The central venous access connections were labelled with proximal, distal and medial lumens to help users identify the drugs infused through each IV line. The infusion pumps were mounted vertically on the supports, and the solution bags of the high-alert drugs were hung on the respective hooks of the support. Each infusion bag had a drug label with the name of the drug, dose and infusion speed. Each solution bag was connected to a channel of the infusion pump, providing the desired scenario for the IV line.

Before the intervention, the nurses received a presentation on the safe use of medications for treating critically ill patients, providing an overview of the research's general context. In the next stage, groups of three potential participants visited the laboratory's anteroom. They were presented with the research proposal and given an informed consent form to sign. Those who agreed to participate completed the proposed scenario individually and only once, as shown in Figure 3.

Scenario without IV line labels (*Scenario 1*): The researcher instructed the participants to identify the drugs infused into continuous infusion lines for high-alert medications installed in proximal, medial and distal lumens of the patient's central venous access. We asked them to record the identified drug names on a written form in their respective routes. Finally, we instructed them to disconnect the midazolam infusion line from the central venous access inlet connection.

Scenario with IV line labels (*Scenario 2*): The researcher instructed the participants to identify the drugs infused into continuous infusion lines for high-alert medications installed in the proximal, medial and distal lumens of the patient's central venous access in the presence of IV line labels. We asked them to record the drug names in written form on each lumen. Finally, we instructed them to disconnect the noradrenaline infusion line from the central venous access inlet connection.

The choice of variables for the experiment's design was based on studies that showed that errors in identifying the lines for administering IV drugs and interrupting the infusion, as well as the time spent identifying them, are the main factors that interfere with the safety of professionals' performance in handling continuous infusions (Pinkney, Fan, Koczmara, and Trbovich, 2019; Porat et al. 2009).

4.6 | Randomisation

Upon agreeing to participate, each nurse was assigned a number based on their arrival at the laboratory to receive information about the research. The participants were then divided into two groups—odd and even—and were randomly assigned to either scenario one or two. Odd-numbered participants started with the scenario without labels, while even-numbered participants started with the scenario containing labels. After completing the first scenario, participants proceeded to the second scenario. This means that both groups were exposed to the two scenarios sequentially.

After receiving the handouts, researchers escorted the participants to the internal area of the laboratory and briefed them about the upcoming activity. They received an overview of the various scenarios and instructions regarding the tasks they needed to complete. Researchers reminded them of the significance of maintaining an authentic and realistic approach while completing the assigned tasks.

4.7 | Data Collection

The study aimed to assess how item labelling affected the participants' performance in scenarios that involved identifying medication infused IV lines, disconnecting a line and completing two additional tasks.

We gathered data from September to October 2022. Each participant received an alphanumeric code based on their selection order. The participants filled out a form provided by the researcher, where they recorded the name of the medication infused in each IV line. The researcher recorded the time taken to complete the tasks and the name of the drug in the disconnected IV line. The form also included a section recording the participants' personal and professional characteristics, such as age, gender, sector of work, time since graduation and length of professional experience.

The evaluation process timer started when the participants indicated they were ready to begin the activity. It ended when they raised their hand, indicating that they had identified all infusions and disconnected the requested line. We used a digital stopwatch on equipment with an iOS operating system for precise and reliable timing measurements.

The researchers closely monitored the participants' completion of tasks in each scenario. These were experienced researchers in managing multiple infusions in intensive care settings. Before data collection, we conducted a pilot test with two nurses with profiles similar to the research participants. This test helped us adjust the process of identifying the infusion route, which

FIGURE 3 | Illustration of the scenarios evaluated in the study.

reduced any potential biases related to the participants' better performance in identifying IV lines through cognitive resources (memory) when moving from one scenario to another.

4.8 | Data Analysis

For this analysis, we compiled and reviewed a database. We performed all analyses using the Statistical Package for the Social Sciences (IBM SPSS, v. 23.0). We used descriptive statistics and measures of central tendency to describe personal and professional variables and the frequency of errors in evaluated scenarios. To assess the results, we compared errors in identifying the IV lines and the time it took to perform the tasks between scenarios using the Wilcoxon test. This test analysed the variation in outcomes before and after the intervention.

We used the Mann–Whitney U-test and Spearman's correlation for bivariate inferential analyses between the study's covariates (personal and professional variables) and the outcomes. The Mann–Whitney U-test was used to evaluate the differences in mean values of participants' performance in outcomes (errors and time) depending on the sectors in which professionals worked. Spearman's correlation analysed the correlation between professionals' performance in scenarios and their personal and professional characteristics (e.g., age, time since graduation and time of experience). We considered strong correlation (>0.7), moderate correlation (between 0.5 and 0.7), weak correlation (between 0.3 and 0.5) and very weak correlation (<0.3). For all tests, we adopted a 5% significance level.

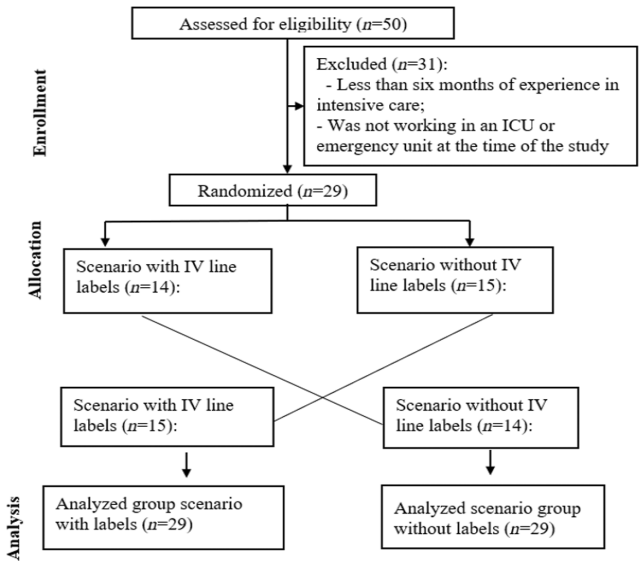

FIGURE 4 | Flowchart of study participants.

4.9 | Ethical Considerations

The study followed national ethical standards for research involving human subjects. It was approved by the institution's research ethics committee, where the lead researcher is based, on 21 July 2021. The committee issued an opinion number of 5.656.699 and provided an Ethics Appreciation Certificate with reference number 43137721.9.0000.5238. Before participating, we informed participants about the research objectives and procedures, and they signed an informed consent form. The data were processed numerically to ensure participant anonymity.

5 | Results

Out of the 50 nurses enrolled in an intensive care nursing specialisation course, 31 were excluded from the study because they had less than 6 months of experience in intensive care or were not working in such environments at the time of the study. As a result, the research's methodological procedures were carried out on 29 nurses, as shown in Figure 4.

5.1 | Sample Characteristics

The data in Table 2 indicate that most participants were women (96.6%), young, recent graduates and had limited professional experience in intensive care settings.

In the study, participants identified medications in the IV lines in both scenarios similarly. Seven participants made fewer errors with labels, four made more errors, and 18 showed no significant difference in their performance compared to the scenario without labels.

The overall analysis of the two scenarios revealed that 31% of the participants incorrectly identified the IV lines. Two participants incorrectly identified the five high-alert medications in

TABLE 2 | Characteristics of the study sample.

	N (%)	Average (±SD)[a]	Min-Max
Age (years)		29.3 (5.6)	23–47
Department			
ICU	20 (69.0)		
Emergency + ICU	9 (31.0)		
Time since graduation (years)		3.6 (±3.6)	0.7–17.0
Length of professional experience (years)		2.3 (±3.8)	0.5–20.0

Abbreviations: ICU, Intensive care unit; SD, Standard deviation.

the scenario without labels. However, in the scenario with label technology, the maximum number of misidentifications was three, and no participant misidentified all the drugs.

In this study, the highest number of misidentifications occurred with fentanyl (27%) and vasopressin (24%) in the scenario without labels. However, in the scenario with labels, all participants correctly identified midazolam, while fentanyl (20%) and vasopressin (20%) remained the medications with the highest number of misidentifications. The study also found only one error in disconnecting an unintended medication (midazolam) from the multiple infusions underway in the simulated critical patient in the scenario without labels.

Furthermore, as indicated in Table 3, the study's findings confirm no significant difference between the scenarios regarding the number of errors the participants made during the IV lines' drug identification activities.

The time evaluation showed that in the scenario with IV line labels, 24 participants completed the task faster, four took longer, and one had the same time as in the scenario without labels. In the scenario without labels, the fastest completion time was 1 min and 51 s, while the slowest was 9 min and 15 s. In the labelled scenario, the fastest completion time was 49 s, and the slowest was 9 min and 20 s. According to Table 4, the time taken to identify and disconnect the IV line was significantly shorter in the scenario with the label prototype.

According to Table 5, only age was significantly correlated with the time participants took to complete tasks in the labelled scenario. As the participants' age increased, the average time to complete the activity also increased, showing a moderate correlation.

Table 6 compares the average number of errors made by professionals who exclusively worked in the ICU and those who worked in both ICU and emergency departments. The study shows differences in both scenarios. Professionals who worked solely in the ICU made fewer medication identification errors in IV lines.

6 | Discussion

In the evaluation of the label prototype, it was found that the participants in the scenario with labels made similar medication identification errors to those without labels. Interestingly, the average error rate in both scenarios (with and without labels) was 31%. However, using the label designed for the IV lines decreased the time taken to identify the drugs by an average of 1 min compared to the scenario without labels.

Numerous studies have shown the importance of IV line labels in healthcare settings. These studies have consistently demonstrated that implementing standardised medication identification decreases error rates, reduces time spent on labelling tasks and increases professional satisfaction (Pinkney, Fan, Koczmara, and Trbovich, 2019; Souza et al. 2019; Porat et al. 2009; Morales-González and Galiano Gálvez 2017; Stevens et al. 2015; Moreira et al. 2015).

In a study, the impact of interventions in a simulated ICU scenario was evaluated in four different conditions: current practice, with the use of IV line labels and infusion organisers, with smart infusion pumps, and with an infusion path lighting system. Forty participants had to identify and disconnect an infusion in each condition correctly. The study found that participants were able to identify infusions with fewer errors when using labels/line organisers (0%) compared to current practice (7.7%) and smart pump conditions (6.4%) ($p < 0.01$). Moreover, participants were significantly faster at identifying infusions when using line labels/organisers (0:31) compared to current practice (1:20), smart pumps (1:29) and a lighting system (1:22) ($p < 0.001$) (Pinkney, Fan, Koczmara, and Trbovich 2019).

A study compared the effectiveness of a colour-coded label with the current practice of not labelling IV lines for high-alert medications. The study involved 61 participants who performed tasks in a simulated ICU scenario. Participants had to describe all the drugs and lines, estimate the time needed to identify and describe each drug and line, identify errors, and estimate the time needed to identify a mismatch between the

TABLE 3 | Comparison of the total number of errors in the scenarios evaluated.

Scenarios evaluated	Mean of errors (±SD)	Median	Interquartile range	Min-Max	Z	p^a
Scenario without labels	0.9 (±1.5)	0	0.0–2.0	2–5	−0.673	0.501
Scenario with labels	0.7 (±1.1)	0	0.0–1.5	1–3		

Abbreviations: SD, Standard deviation; Z, significance test (from the test itself).
[a]Probability according to the Wilcoxon test.

TABLE 4 | Comparison of task completion time in the tested scenarios.

Scenarios	Mean time (±SD)	Median	Interquartile range	Min-Max	Z	p^a
Scenario without labels	3:55 (1:32)	3:27	2:58–4:34	1:51–9:15	−3.598	**< 0.001**
Scenario with labels	2:40 (1:38)	2:16	1:29–3:32	0:49–9:20		

Abbreviations: SD, Standard deviation; Z, significance test (from the test itself).
[a]Probability according to the Wilcoxon test. Bold values indicates $p \leq 0.05$.

TABLE 5 | Comparisons of the characteristics of the sampled studied and task execution time.

Personal and professional characteristics	Time in the scenario without labels		Time in the scenario with labels	
	Correlation Coef.[b]	*p*	Correlation Coef.	*p*[a]
Age	0.272	0.154	0.575	**0.001**
Time since graduation	0.254	0.184	0.335	0.076
Length of experience	−0.124	0.521	0.180	0.350

[a]Probability according to the Spearman correlation test. Bold values indicates $p \leq 0.05$.
[b]Significance value is $p \leq 0.05$.

TABLE 6 | Comparison of sample characteristics and error count in each simulated scenario.

Department	N	Mean number of errors			
		Scenario without labels		Scenario with labels	
		Mean (±SD)	*p*[a]	Mean (±SD)	*p*
Only ICU	20	0.45 (±0.9)	**0.035**	0.35 (±0.8)	**0.035**
Emergency + ICU	9	1.9 (±2.1)		1.3 (±1.3)	

Abbreviations: ICU, Intensive care unit; SD, Standard deviation.
[a]Mann–Whitney *U*-test. Bold values indicates $p \leq 0.05$.

labelling on the syringe pump and its line. The study found that the use of colour-coded labels reduced the time needed for a general description of drugs and lines ($p = 0.04$), improved error identification ($p = 0.03$) and reduced the average time taken to perform general tasks ($p = 0.0001$) (Morales-González and Galiano Gálvez 2017).

A survey was conducted in Brazil to analyse the opinions of 42 nursing professionals working in a paediatric intensive care unit. The survey aimed to evaluate the design, practicality and usefulness of a standardised colour-coded labelling system implemented for lines, infusion pumps, syringes and serum bottles. The results showed that the labelling technology was highly agreed upon among the participants. They found it to be well-designed and practical for all devices and helpful in preventing medication errors by reducing the time spent on labelling tasks (Souza et al. 2019).

After comparing our results with those of other studies, we observed that the evaluation did not show any differences between the scenarios in the number of errors or correct answers in identifying high-alert drugs. However, it is essential to note that the simulated laboratory environment minimises the influence of other factors that can contribute to errors, such as environmental factors inherent to intensive care. These factors can impact the professionals' daily management of IV therapy.

We allowed the professionals enough time to identify the drugs in the IV lines in two scenarios. This may have improved their performance, especially when there were no labels, which was assumed to be more challenging. This statement is based on the understanding that the intensive care environment is characterised by systemic factors that can lead to errors, including time pressure, high workload, noise, interruptions and distractions. These factors are considered risk factors for medication errors and are highlighted in the scientific literature (Sassaki, Cucolo, and Perroca 2019; Freitas et al. 2019; Johnson et al. 2017; Raja, Sajid, and Sherali 2019; Bonafide et al. 2020; Schroers 2018).

The absence of certain variables in the laboratory environment may have reduced errors in identifying how multiple infusions are managed in scenarios without labels. Additionally, completing tasks in less time is particularly important in intensive care, where time management directly affects the availability of medical professionals and prioritises certain care activities (Sassaki, Cucolo, and Perroca 2019; Diniz et al. 2021). When multiplied by the frequency of medication administration per critically ill patient, the average difference of 1 min between scenarios can save professional working time. This is a crucial cost indicator that can help to improve care.

This analysis examines the advantages of using labels verified by research on medical devices like infusion bags and syringes. Researchers studied the impact of the design of safety labels in simulated high-stress clinical situations. In the study, anaesthesiologists were asked to select a medication requested by a surgeon during a bleeding emergency from a drawer containing various fluids in two hypothetical situations: one with standardised labels for medication bags and one without. In the scenario with standardised labels, the success rate in choosing the medication was 63%, while in the scenario without identification labels, it was 40% (Estock et al. 2018).

A research study in Switzerland examined the impact of standardised labels on syringe identification in a critical care environment. Intensive care nurses participated in the study and used eye-tracking glasses to assess the Tall Man Lettering feature adoption. The study found that this feature increased visual attention, leading to nurses spending more time looking at the medication names. As a result, the error rate decreased from 5.3% to 0.7% when using the labelled syringes (Lohmeyer et al. 2022).

Understanding the errors that happen in medication systems is crucial. It is essential to see errors as both individual actions and organisational processes. To ensure patient safety, we must systematically consider the active failures and underlying conditions that lead to errors. It is based on the idea that humans make mistakes, so we need to anticipate and prevent errors by understanding how they happen, identifying system weaknesses and implementing safety measures (Seshia et al. 2018).

In patient safety studies, it has been observed that personal factors such as experience, professional training and age can affect the occurrence of errors, especially in intravenous therapy (Porat et al. 2009; Di Fine et al. 2018; Norton et al. 2019; Ribeiro et al. 2023). The results of our study showed that younger professionals were quicker at identifying multiple intravenous lines, similar to findings in another study. Age is a factor that should be explored further in more extensive studies, as time plays a vital role in complications in intensive care. Therefore, quickly identifying multiple intravenous lines for medication administration can improve the effectiveness of interventions during critical moments in the care of severely ill patients. Understanding the identified errors and contributing factors can help in developing safety measures.

6.1 | Limitations

A limitation of the study was the small number of nurses with more than 6 months of experience at the research site. This limited the ability to interpret and apply the findings more broadly. Additionally, the simulation did not account for all variables in the intensive care environment that could affect professionals' performance in identifying drugs in IV lines. This limits the analysis and interpretation of nurses' performance. We suggested that the labels be evaluated in a real environment with a larger sample size of nurses to assess their effectiveness in reducing medication errors and strengthening the findings' validity.

7 | Conclusion

According to the results, IV line labels can help identify and disconnect high-alert drugs in less time. Professionals' performance was similar in correctly recognising intravenous infusion compared to a standard scenario without labels.

Adopting the proposed standards for IV line labels of high-alert drugs is recommended to enhance patient safety and healthcare efficiency. These standards include a pre-established design, printed format, size and fonts suitable for reading, differentiation in the size of the letters, resistant materials in label composition and colour coding. The labels should also include essential information such as the name of the drug, dose and time of preparation, as well as the specification of the date on which the line should be changed and the drug's expiration date.

8 | Relevance To Clinical Practice

Our technology can be used in critical patient care settings based on current knowledge of errors associated with high-alert drugs administered through IV lines. The research demonstrates that labelling IV lines is effective, and if implemented in routine clinical practice, it can potentially decrease medication errors and save lives. When coupled with an organisational safety culture that prioritises continual education and safety, this approach can improve medication system safety in healthcare institutions and reduce the chances of errors when identifying high-risk IV drugs administered to critically ill patients.

Author Contributions

Made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data: Geovane de Kassio Nunes, Bruna Gonçalves Ribeiro Araújo, Letícia Braga Portes Alves Rentz, Flávia Giron Camerini, and Sabrina da Costa Machado Duarte, Juliana Faria Campos and Rafael Celestino da Silva. Involved in drafting the manuscript or revising it critically for important intellectual content: Geovane de Kassio Nunes, Bruna Gonçalves Ribeiro Araújo, Letícia Braga Portes Alves Rentz, Flávia Giron Camerini, and Sabrina da Costa Machado Duarte, Juliana Faria Campos and Rafael Celestino da Silva. Given final approval of the version to be published. Each author should have participated sufficiently in the work to take public responsibility for appropriate portions of the content: Geovane de Kassio Nunes, Bruna Gonçalves Ribeiro Araújo, Letícia Braga Portes Alves Rentz, Flávia Giron Camerini, and Sabrina da Costa Machado Duarte, Juliana Faria Campos and Rafael Celestino da Silva. Agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: Geovane de Kassio Nunes, Bruna Gonçalves Ribeiro Araújo, Letícia Braga Portes Alves Rentz, Flávia Giron Camerini, and Sabrina da Costa Machado Duarte, Juliana Faria Campos and Rafael Celestino da Silva.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Peer Review

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/jan.16529.

Statistics

The statistics were checked prior to submission by an expert statistician—PhD Luciana Portela—luportela@yahoo.com

Trial Registration

Since this was a simulated experimental study, there was no need for clinical trial registration.

References

Alves, B. M. C. S., T. N. G. Andrade, S. C. Santos, et al. 2021. "Harm Prevalence due to Medication Errors Involving High-Alert Medications: A Systematic Review." *Journal of Patient Safety* 17, no. 1: e1–e9. https://doi.org/10.1097/PTS.0000000000000649.

Aseeri, M., G. Banasser, O. Baduhduh, S. Baksh, and N. Ghalibi. 2020. "Evaluation of Medication Error Incident Reports at a Tertiary Care Hospital." *Pharmacy* 8, no. 2: 69. https://doi.org/10.3390/pharmacy8020069.

Bohomol, E. 2014. "Medication Errors: Descriptive Study of Medication Classes and High-Alert Medication." *Escola Anna Nery* 18, no. 2: 311–316. https://doi.org/10.5935/1414-8145.20140045.

Bonafide, P. C., J. M. Miller, A. R. Localio, et al. 2020. "Association Between Mobile Telephone Interruptions and Medication Administration Errors in a Pediatric Intensive Care Unit." *JAMA Pediatrics* 174, no. 2: 162–169. https://doi.org/10.1001/jamapediatrics.2019.5001.

Cheng, A., D. Kessler, R. Mackinnon, et al. 2016. "Reporting Guidelines for Health Care Simulation Research: Extensions to the CONSORT and STROBE Statements." *Advances in Simulation* 25, no. 1: 25. https://doi.org/10.1186/s41077-016-0025-y.

Di Fine, G., G. Centini, D. Gavetti, et al. 2018. "Best Practices in the Management of Central Vascular Access Devices: An Observational Study in Areas With a High Prevalence of Trained Nurses." *Journal of Infusion Nursing* 41, no. 5: 319–325. https://doi.org/10.1097/NAN.0000000000000297.

Diniz, S. O. S., E. M. Costa, I. P. Ferreira, P. S. Silva, and T. Tonini. 2021. "Time Management in the Work Process of Nurses in the Intensive Care Unit." *Revista Enfermagem UERJ* 29: e61926. https://doi.org/10.12957/reuerj.2021.61926.

Emergency Care Research Institute. 2014. "Top 10 Health Technology Hazards for 2015." USA: ECRI; November 16, 2021. https://www.ecri.org/Resources/Whitepapers_and_reports/Top_Ten_Technology_Hazards_2015.pdf.

Estock, J. L., W. A. Murray, M. T. Miszah, M. P. Mangione, J. S. Goode Jr., and D. E. Eibling. 2018. "Label Design Affects Medication Safety in a Operating Room Crisis: A Controlled Simulation Study." *Journal of Patient Safety* 14, no. 2: 101–106. https://doi.org/10.1097/PTS.0000000000000176.

Fan, M., C. Koczmara, C. Masino, A. Cassano-Piché, P. Trbovich, and A. Easty. 2019. "Multiple Intravenous Infusions Phase 2a: Ontario Survey." *Ontario Health Technology Assessment Series* 14, no. 4: 1–141. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4522693/.

Freitas, W. C. J., V. C. Alves, J. S. Ramos, et al. 2019. "Distractions and Interruptions in Medication Preparation and Administration in Inpatient Units." *Revista Eletronica de Enfermagem* 21: 53621. https://doi.org/10.5216/ree.v21.55516.

Institute for Safe Medication Practices. 2018. "ISMP List of High-Alert Medications in Acute Care Settings." EUA: ISMP Cited February 17, 2022. https://www.ismp.org/recommendations/high-alert-medications-acute-list.

International Organization for Standardization. 2022. "Anaesthetic and Respiratory Equipment -User-Applied Labels for Syringes Containing Drugs Used During Anaesthesia – Colours, Design and Performance." EUA: ISO; cited February 17, 2021. https://www.iso.org/obp/ui/#iso:std:76678:en.

Johnson, M., P. Sanchez, R. Langdon, et al. 2017. "The Impact of Interruptions on Medication Errors in Hospitals: An Observational Study of Nurses." *Journal of Nursing Management* 25, no. 7: 498–507. https://doi.org/10.1111/jonm.12486.

Kim, J., J. H. Park, and S. Shin. 2016. "Effectiveness of Simulation-Based Nursing Education Depending on Fidelity: A Meta Analysis." *BMC Medical Education* 16, no. 1: 1–8. https://doi.org/10.1186/s12909-016-0672-7.

Kuitunen, S., I. Niittynen, M. Airaksinen, and A. R. Holmström. 2021. "Systemic Causes of In-Hospital Intravenous Medication Errors: A Systematic Review." *Journal of Patient Safety* 17, no. 8: e1660–e1668. https://doi.org/10.1097/PTS.0000000000000632.

Lohmeyer, Q., C. Schiess, P. D. W. Garcia, et al. 2022. "Effects of Tall Man Lettering on the Visual Behaviour of Critical Care Nurses While Identifying Syringe Drug Labels: A Randomised In Situ Simulation." *BMJ Quality and Safety* 0: 1–8. https://doi.org/10.1136/bmjqs-2021-014438.

Miot, H. A. 2011. "Sample Size in Clinical and Experimental Trials." *Jornal Vascular Brasileiro* 10, no. 4: 275–278. https://doi.org/10.1590/S1677-54492011000400001.

Morales-González, M. F., and M. A. Galiano Gálvez. 2017. "Predesigned Labels to Prevent Medication Errors in Hospitalized Patients: A Quasi-Experimental Design Study." *Medwave* 17, no. 8: e7038. https://doi.org/10.5867/medwave.2017.08.7038.

Moreira, M. E., C. Hernandez, A. D. Stevens, et al. 2015. "Color-Coded Prefilled Medication Syringes Decrease Time to Delivery and Dosing Error in Simulated Emergency Department Pediatric Resuscitations." *Annals of Emergency Medicine* 66, no. 2: 97–106.e3. https://doi.org/10.1016/j.annemergmed.2014.12.035.

Norton, C. B., H. Á. Lauria, D. Baker, P. Hauser, and C. A. Smith-Miller. 2019. "Nurses' Short Peripheral Catheter Flushing Practices: Implications for Patient Care, Nursing Education, and Policy." *Journal of Infusion Nursing* 42, no. 5: 228–236. https://doi.org/10.1097/NAN.0000000000000337.

Nunes, G. K., J. F. Campos, and R. C. Silva. 2022. "Intravenous Therapy Device Labeling in Intensive Care Units: An Integrative Review." *Revista Brasileira de Enfermagem* 75, no. 6: e20220049. https://doi.org/10.1590/0034-7167-2022-0049pt.

Pinkney, S., M. Fan, K. Chan, et al. 2019. "Multiple Intravenous Infusions Phase 2b: Laboratory Study." *Ontario Health Technology Assessment Series* 14, no. 5: 1–163. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4549602/.

Pinkney, S. J., M. Fan, C. Koczmara, and P. L. Trbovich. 2019. "Untangling Infusion Confusion: A Comparative Evaluation of Interventions in A Simulated Intensive Care Setting." *Critical Care Medicine* 47, no. 7: e597–e601. https://doi.org/10.1097/CCM.0000000000003790.

Porat, N., Y. Bitan, D. Shefi, Y. Donchin, and H. Rozenbaum. 2009. "Use of Colour-Coded Labels for Intravenous High-Risk Medications and Lines to Improve Patient Safety." *Quality & Safety in Health Care* 18, no. 6: 505–509. https://doi.org/10.1136/qshc.2007.025726.

Raja, B., A. Sajid, and S. Sherali. 2019. "Association of Medication Administration Errors With Interruption Among Nurses in Public Sector Tertiary Care Hospitals. Pak." *Journal of Medical Sciences* 35, no. 5: 1318–1321. https://doi.org/10.12669/pjms.35.5.287.

Ribeiro, G. S. R. R., J. F. Campos, F. G. Camerini, P. M. S. D. Parreira, and R. C. Silva. 2023. "Flushing in Intravenous Catheters: Observational Study of Nursing Practice in Intensive Care in Brazil." *Journal of Infusion Nursing* 46, no. 5: 272–280. https://doi.org/10.1097/NAN.0000000000000516.

Rodziewicz, T. L., B. Houseman, and J. E. Hipskind. 2023. "Medical Error Reduction and Prevention." In *StatPearls*, 2023. Treasure Island (FL): StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK499956/.

Sassaki, R. L., D. F. Cucolo, and M. G. Perroca. 2019. "Interruptions and Nursing Workload During Medication Administration Process." *Revista Brasileira de Enfermagem* 72, no. 4: 1001–1006. https://doi.org/10.1590/0034-7167-2018-0680.

Schroers, G. 2018. "Characteristics of Interruptions During Medication Administration: An Integrative Review of Direct Observational Studies." *Journal of Clinical Nursing* 19-20: 3462–3471. https://doi.org/10.1111/jocn.14587.

Seshia, S. S., G. B. Young, M. Makhinson, P. A. Smith, K. Stobart, and P. Croskerry. 2018. "Gating the Holes in the Swiss Cheese (Part I): Expanding Professor Reason's Model for Patient Safety." *Journal of Evaluation in Clinical Practice* 24, no. 1: 187–197. https://doi.org/10.1111/jep.12847.

Sessions, L. C., L. S. Nemeth, K. Catchpole, and T. J. Kelechi. 2019. "Nurses' Perceptions of High-Alert Medication Administration Safety: A Qualitative Descriptive Study." *Journal of Advanced Nursing* 75, no. 12: 3654–3667. https://doi.org/10.1111/jan.14173.

Smith, V. I., and R. S. Litman. 2017. "Staying Connected: How to Prevent Wrong Route Medication Errors in the Operating Room." *Current Anesthesiology Reports* 7: 119–124. https://doi.org/10.1007/s40140-017-0205-x.

Souza, M. G. N., V. M. Silva, M. V. O. Lopes, C. M. Diniz, and G. L. Ferreira. 2019. "Evaluation of Color-Coded Drug Labeling to Identify Endovenous Medicines." *Revista Brasileira de Enfermagem* 72, no. 3: 715–720. https://doi.org/10.1590/0034-7167-2018-0242.

Stevens, A. D., C. Hernandez, S. Jones, et al. 2015. "Color-Coded Prefilled Medication Syringes Decrease Time to Delivery and Dosing Errors in Simulated Prehospital Pediatric Resuscitations: A Randomized Crossover Trial." *Resuscitation* 96: 85–91. https://doi.org/10.1016/j.resuscitation.2015.07.035.

Wollitz, A., and M. Grissinger. 2019. "Aligning the Lines: Analysis of IV Line Errors." *Pennsylvania Patient Safety Advisory* 11, no. 1: 1–7. http://patientsafety.pa.gov/ADVISORIES/Pages/201403_01.aspx.

World Health Organization. 2021. *Global Patient Safety Action Plan 2021–2030: Towards Eliminating Avoidable Harm in Health Care [Internet]*. Geneva: WHO. https://www.who.int/teams/integrated-health-services/patient-safety/policy/global-patient-safety-action-plan.