Review Article

The Influence of Nurses' Characteristics on Medication Administration Errors: An Integrative Review

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Ali Kerari, PhD, MSN, BSN, RN[1] and Adnan Innab, PhD, REM, MSN, BSN, RN[2]

Abstract

Background: Medication administration errors (MAEs) are a frequent cause of morbidity and mortality in acute care settings and can result in a prolonged hospital stay. The WHO estimated that medication errors cost up to $42 billion globally per a year. Therefore, MAEs was among the most common medical errors to occur in acute care settings. Studies of medication error usually focus on system factors, thus creating a gap between what researchers know about the causes of MAEs, and what frontline nurses actually do in the clinical setting. The purpose of this review is to fill a gap in the existing literature by focusing on the relationship between nurses' characteristics and MAEs.

Methods: Online databases were accessed, including CINAHL, PsycINFO, PubMed, Scopus, and Google Scholar from 2007–2020 period. This review was guided by the methods described by Whittemore and Knafl. Studies that addressed the occurrence of medication errors based on RN demographics were included in this review. The included studies were reviewed and analyzed by the two authors.

Results: Of the 1141 publications retrieved, 19 studies met inclusion criteria. The result provided strong evidence that nurses' level of education, length of experience, and attendance at training courses, are directly associated with the occurrence of MAEs. There is weak evidence of MAEs being influenced by the age and gender of nurses. Other nurse characteristics, such as cognitive load, frustration with technology, negligence, lack of attentiveness, and nurse ethnicity, are not adequately examined across the reviewed studies necessitates further research.

Conclusion: Focusing on nurses' characteristics might facilitate other researchers to suggest appropriate interventions that may reduce the incidence of MAEs. Interventional studies may provide convincing evidence as to whether one variable has a causal effect on another variable, and control the influence of confounding variables to enhance the generalizability of the findings.

Keywords

Patient safety, nursing, medication errors, medical errors/adverse events

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Medication errors, especially medication administration errors (MAEs), are a frequent cause of morbidity and mortality. MAEs have been identified as a priority issue among hospitalized patients and can result in a prolonged hospital stay. A number of studies have reported that MAEs are among the most common medical errors to occur in acute care settings (Samsiah et al., 2020; Vrbnjak et al., 2016).

The Institute of Medicine estimates that medication errors in the U.S. cause between 44,000 to 98,000 deaths per year (Shahrokhi et al., 2013). The World Health

[1]Medical Surgical Department, School of Nursing, King Saud University, Riyadh, Saudi Arabia
[2]Nursing Administration and Education Department, School of Nursing, King Saud University, Riyadh, Saudi Arabia

Corresponding Author:
Adnan Innab, Nursing Administration and Education Department, School of Nursing, King Saud University, Riyadh 11451, Saudi Arabia.
Email: ainnab@ksu.edu.sa

Organization (2017) estimated that medication errors cost up to $42 billion globally per a year. Therefore, MAEs was among the most common medical errors to occur in acute care settings (Vrbnjak et al., 2016). Generally, medication errors can occur at any stage in the medication process, but a substantial number of these errors occur during medication administration, thus implicating nurses as the Registered Nurse (RN) plays a significant role in the administration medications in the clinical setting.

Since the IOM report (1999), a vast number of research studies have described medication errors in clinical settings. These studies have evaluated the role of medication education in conforming to new medication policies (Sluggett et al., 2017), improving medication calculation to decrease medication errors (Latimer et al., 2017), and determining barriers to reporting medication errors (Vrbnjak et al., 2016).

Although MAEs in acute care settings are generally thought to occur due to human error, there is growing recognition of the role of system errors as a contributing factor in the occurrence of medication errors (Asad, 2015). The U.S. IOM reported that a fundamental revision of systems of work was required in order to provide safe and holistic care (Hajibabaee et al., 2014). Medication errors are seldom the product of a singular cause, and in fact the true cause of the problem is often difficult to identify (Hajibabaee et al., 2014). Understanding the causes behind medication errors might help to predict and control the risks for such errors.

In the course of the last two decades, two reviews have found that organizational factors, such as nursing staffing levels and heavy workloads, were strongly associated with medication errors in acute care settings (Brady et al., 2009; O'Shea, 1999). There is also strong evidence indicating that the psychological factors among nurses, such as burnout and compassion fatigue, were associated with medication errors (Zarea et al., 2018). Studies that examine the influence of system factors and psychological factors on MAEs are extensively documented in the literature. However, to our knowledge, no recent reviews concerning the relationship between nurses' characteristics and medication errors have been published recently.

Based on Reason's human error model, errors occur because of a multifaceted interaction between how individuals act, and the systems under which the individual works (Reason, 1990, 2000). The system approach contributes to only one part of the error, while the person approach constitutes the other part of the error (Reason, 2000). Studies of medication error usually focus on system factors, thus creating a gap between what researchers know about the causes of MAEs, and what frontline nurses actually do in the clinical setting. Therefore, given the focus of previous studies on system factors, the purpose of this review is to fill a gap in the existing literature by focusing on the relationship between nurses' characteristics and MAEs.

Methods

In order to ensure a rigorous review and valid outcomes, this review was guided by the methods described by Whittemore and Knafl (2005). There are five stages to this review: problem identification, literature search, data evaluation, data analysis, and presentation (Whittemore & Knafl, 2005).

Data Search

Online databases were accessed, including CINAHL, PsycINFO, PubMed, Scopus, and Google Scholar. The search terms included: *medication administration errors*, *reasons for medication errors*, *nurses' characteristics*, *individual contributory factors*, and *nurse-related factors*. Each online database provided a vast number of results, thus making it challenging to review all of them.

A subsequent search was conducted of specific databases, such as CINAHL and PubMed, using major headings to include only relevant studies that could answer the research question. Also, the search was limited to research studies published in the English language and that were published between 2007 and 2020. We focus on this 2007–2020 period because the last review that examined the nurses' characteristics and medication errors was published in 2009. Most of the studies included in that review were conducted prior to 2007 (Brady et al., 2009). Furthermore, four additional research studies were included via tracking references and hand searches.

The initial search yielded 1141 studies. Following the removal of duplicated studies, 890 studies were retrieved. The remaining studies were reviewed for significance using a four stage process. In the first stage, titles were scanned to determine their relevance, with studies that obviously did not address RN characteristics and medication errors being excluded. In the second stage, abstracts were scanned to ensure that the research studies were focused specifically on nurses rather than pharmacists or physicians. In stage three, the methods and findings were scanned to ensure that the studies were concerned with factors contributing to MAEs by RNs. And in the fourth stage, the studies were assessed based on the inclusion and exclusion criteria.

Inclusion Criteria

All the research studies must meet the following criteria: (a) quantitative, qualitative, or mixed methods studies;

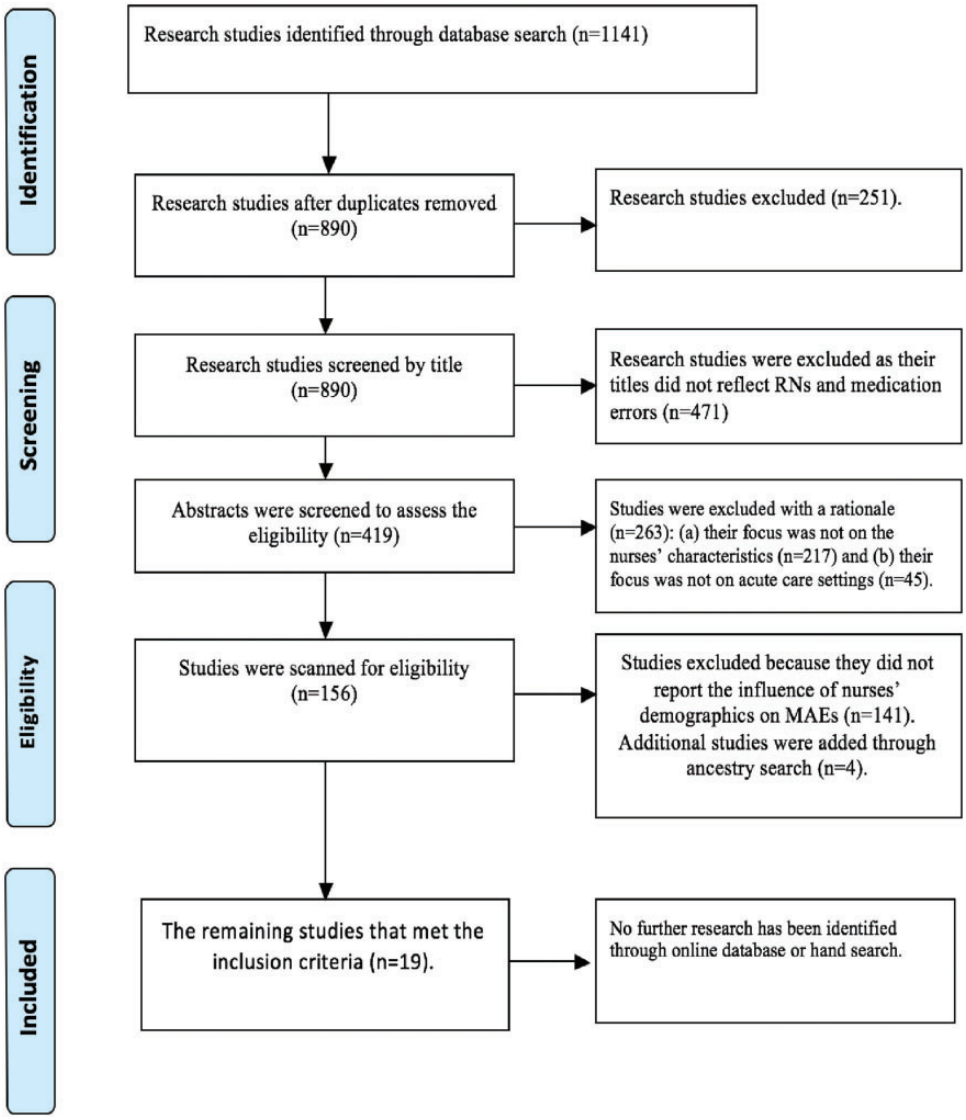

Figure 1. PRISMA flow diagram for included and excluded studies.

(b) research studies published in English describing nurses' characteristics and MAEs; (c) studies were published between 2007 and 2020; and (d) studies specifically addressing patient safety or adverse events, and reporting the occurrence of medication errors based on RN demographics.

Exclusion Criteria

The exclusion criteria include the following: (a) non-research studies; (b) literature reviews; (c) research studies focusing on pharmacists or physicians; (d) research studies focused on nursing medication errors in home care or ambulatory care (i.e., because this review is concerned with acute in-patient care); and (e) books, theses, dissertations, and conferences.

Level of Evidence

Cooper (2016) suggested that the degree of correspondence between methods and inferences in research studies should be the primary criterion for evaluating the level of evidence of a study. The Johns Hopkins Nursing Evidence-Based Practice grading scale was used to measure the level of evidence of the selected studies. The level of evidence for each study is determined based on the following domains: adequacy of sample size; reliability and validity of the instruments; generalizability of the results; and consistency between methods, findings and conclusions (Newhouse et al., 2007). High quality studies are graded as level A, good quality studies level B, and low quality studies level C (Table 1). The included studies were reviewed and

Table 1. Characteristics of Included Studies.

Authors (year)	Design and purpose	Sample characteristics and setting	Measurements	Findings and conclusion	Strengths & Limitations	Level of evidence
Soori et al. (2019)	-Cross-sectional design The purpose of the study was to determine the relationship between nurses' characteristics and occurrence of medication errors.	220 nurses from 35 hospital wards in a teaching hospital in Iran.	A questionnaire.	Nurses' characteristics (gender, employment status, and job experience) were significantly correlated with the occurrence of medication errors.	**Strengths:** -Large sample size from different wards. **Limitations:** -No information regarding the reliability or the validity of the questionnaire. -The design may not be appropriate to determine the causality	Level III and good quality B
Lan et al. (2014)	-Cross-sectional design. No theory included. -The purpose of this study was to evaluate the pediatric nurses' knowledge toward the pharmacological medications.	$N = 262$ pediatric nurses working in pediatric wards, Taiwan. All participants were women. The average age was 31 The average experience: 7.4 Years. Level of education: 106 (40.5%) of participants had undertaken additional training courses in pediatric medications.	They developed their own scale. The questionnaire consisted of 20-items. They piloted the questionnaire. They concluded that this tool is valid. They reported only the content validity: .88	61% of participants had insufficient knowledge about the pediatric medications. More than 60% of medication error was related to the wrong dose. Length of Experience, age, and attending training courses were statistically significant with the medication error. The level of education was not statistically significant.	**Strengths:** Adequate sample size. - Reasonably consistent recommendation for future studies. **Limitations:** -Although the questionnaire was piloted, it was used for the first time in a research study. -The design may not be appropriate to determine the causality.	Level III and good quality B
Asad (2015)	-A cross-sectional study -No theory **-Purpose:** To examine nurses' perception toward medication errors based on their individual characteristics (gender,	-Snowball sampling method Settings: General hospital and a private hospital. Sample size: $n = 89$	-Questionnaire -No information whether the questionnaire was tested or not.	**Finding:** Female nurses were better than male nurses ($p < .01$). Nurses with higher degrees scored higher than nurses with diploma degrees ($p < .01$). Staff nurses scored significantly higher than the	**Strengths:** - Sufficient sample size. - Reasonably consistent recommendation for future studies **Limitations:** -It was not clear how the authors measured participants	Level III and good quality B

(continued)

Table 1. Continued.

Authors (year)	Design and purpose	Sample characteristics and setting	Measurements	Findings and conclusion	Strengths & Limitations	Level of evidence
	knowledge, experience, level of education, position, and nationality).			head nurses. Foreign nurses scored significantly higher than aboriginal nurses. Age and length of experience were not statistically significant.	scores. -The research design may not adequately predict the causality.	
Fahimi et al. (2015)	-Experimental: educational sessions. The pharmacists did a direct observation on nurses during medication preparation To determine the correlation between medication preparation, medication administration, and nurses' demographics.	$N = 460$ participants working in different medical surgical wards (random selection). Male to female ratio was 2:30. The average job experience was 7.5 years. All the nurses participated in this study held a bachelor degree. Employment status: 61.7% official nurses, 13.7% were one-year contract, 21.1 % were three-year contract.	Questionnaire. No information about the validity and reliability of the scale.	Age, gender, level of education, and work experience were not statistically significant with the rate of the medication errors ($p > .05$). Temporary 1-year contract nurses were statistically significant with medication error rates ($p < .0001$). -33% of medication errors were related to incorrect infusion rate.	**Strengths**: -Sufficient sample - The results were consistent for this study. **Limitations**: -The sampling method and the duration of the intervention was not provided. - All the participants were recruited from one hospital.	Level I and high quality A
Vatankhah et al. (2017)	Cross-sectional descriptive study -No theory Purpose: -To determine the relationship between nurses' characteristics (gender and work experience) and rate of medication error in a university hospital.	$N = 540$ nurses. -76% of participants were female. Average length of experience: 5 to 10 years. Settings: Teaching hospital.	Self-report using questionnaire. Reliability was calculated to be averagely 0.69.	There was a significant relationship between gender and the accuracy of medication dose $p < .0001$. The length of experience was not significantly predicting medication errors $p = .81$.	**Strengths**: - Good details for power size based on the sample. -A reliable scale - Appropriate explanation for the search **Limitations**: -The female to male ratio (76% female) may influence the result to reflect that female participants were more likely to	Level III and high quality A

(continued)

Table 1. Continued.

Authors (year)	Design and purpose	Sample characteristics and setting	Measurements	Findings and conclusion	Strengths & Limitations	Level of evidence
					commit medication errors than males. No available data about the sampling methods.	
Treiber and Jones (2010)	Qualitative: interpretive analysis. Theory: Benner's (1985) interpretive model was used to guide the analysis. **Purpose:** To understand and describe the perceived causes of medication error based on nurses' perspectives.	-The surveys were distributed randomly to participants in all over the state. -87% of participants were female. The length of experience ranged from 1 to more than 40 years of experience. The average of experience was approximately 20 Years.	Nurses described medication errors in their own words "self-descriptions of errors" Interview: the codes and themes used to interpret the transcribed verbatim.	Four themes emerged: 1-External contributing factors, 2-Lack of experience "being new", 3-Fear of making errors 4-Frustration with technology: lack of knowledge due to lack of training courses in using advanced technological devices).	**Strengths:** -Adequate explanations. -Using a theory to guide the analysis. **Limitations:** - Low response rate (8.2%) -No information on the sample size. -There was no homogeneity; 87% of participants were female. -It is challenging to generalize the results to different settings.	Level III and low quality C
Rodriguez-Gonzalez et al. (2012)	-Prospective observational study -No theory **Purpose**: To determine the relationship between potential risk factors and medication errors as a way to identify potential causes.	The total sample size was not provided. Setting: two gastroenterology units in a teaching hospital in Spain. Average ages: 42 Average experience: 2 years.	Disguised Observation Technique. Computerized prescription order entry program was used to determine the frequency of medication error rates, accuracy of medication preparation, and frequency of medication used in the department.	There was no significant association between nurses' characteristics (age, type of nurse, and length of experience in medical/surgical wards) and medication administration errors.	**Strengths:** - Sufficient sample size. - Consistent recommendation based on the results. - Reliable scale used. - Reasonable results and conclusions **Limitations:** -Sample size was not provided. -No enough information about participants' demographics.	Level III and high quality A

(continued)

Table 1. Continued.

Authors (year)	Design and purpose	Sample characteristics and setting	Measurements	Findings and conclusion	Strengths & Limitations	Level of evidence
Sheu et al. (2009)	- Correlation-descriptive design. To understand the reasons behind medication errors.	Sample size: 85. Demographic information was not presented. -Snowball sampling method.	A semi-structured questionnaire.	**Finding**: -328 medication administration errors were reported. -51.2% of medication errors were committed by participants who hold associate degree. -53% of errors were committed by nurses with less than 2 years of experience. . -The wrong dose was the most frequent medication error reported by nurses.	**Strengths**: -Results were reasonably sufficient for this study. -Adequate sample size. - Consistent recommendations and conclusion. -Adequate explanations. **Limitations**: -No demographics available	Level III and high quality A
Cheragi et al. (2013)	-Cross-sectional descriptive study. **Purpose:** To investigate the types and causes of medication errors, and their relationship with nursing characteristics.	$N = 237$ Random selection from one hospital in Iran. Demographics: -67.1% of participants were female. -51.1% were under 30 years, -54.85% were contract nurses, -43.5% of participants had attended drug administration courses. -64.55% of participants reported medication errors.	Self-made questionnaire. The reliability of the questionnaire was tested and approved by t-test ($r = .9$).	-The most common error was wrong dose. - Lack of pharmacological knowledge was the most common cause of medication error. -There was no statistical relationship between years of experience and age of nurses with medication errors. There was a significant relationship between the frequency of IV (dose route) and gender.	**Strengths**: - Consistent results and sufficient sample size. - A reliable scale -Appropriate methods **Limitations**: -The researchers did not report the mean age and length of experience of participants.	Level III and high quality A
Thomas et al. (2017)	-Hierarchical design -To examine the impact of individual nurses' characteristics and work environmental factors	$N = 79$ RNs. The majority (93.67%) were female, the mean age was 38.14 years, the average length of	1-Structured observation sheet 2- NASA Task Load Index to measure mental workload	Nurses' ages and medication administration errors ($p < .043$). Inadequate skills to deal with electronic documentations were the	Strengths: -Adequate sample size -Provided a clear direction for future research. -Cognitive load and	Level III and high quality A

(continued)

Table 1. Continued.

Authors (year)	Design and purpose	Sample characteristics and setting	Measurements	Findings and conclusion	Strengths & Limitations	Level of evidence
	(interruptions and distractions, and cognitive load) on medication administration errors (MAEs).	experience was 9.59 years. Educational level: 5.06% masters, 62.03 bachelors, 31.65% associate, and 1.27% diploma.	(Cronbach $\alpha = 0.72$).	most frequent causes of medication errors. There was a significant relationship between Interruption, and distraction and cognitive load (all results yielded $p<.05$).	MAEs was not included in other studies. -First study shows a significant relationship between age and MAEs. **Limitations:** -little evidence with inconsistent results.	
Kendall-Gallagher & Blegen (2009)	-Secondary data analysis. -To explore the relationship between the proportion of certified nurses in a unit and medication administration errors.	Settings: a random sample of registered nurses working in 48 ICUs in 29 hospitals.	Two questionnaires that addressed nurse staffing, rates of adverse events, individual and organizational characteristics. No information about the reliability of the scale.	There was a significant correlation between level of education and medication errors ($p<.01$). The years of experience did not predict the medication administration errors ($p>.05$).	**Strengths:** -Adequate sample size -Consistent results and recommendations. **Limitations:** -Missing data affects both the power to detect effects and the stability of Hierarchical linear modeling parameter estimates. -No information about the scale.	Level III and good quality B
Chang & Mark (2009)	Longitudinal study (6-months) To investigate the association between nurses' characteristics and the severity of medication errors.	$N = 4954$ Data were collected for 6 months from 146 hospitals randomly selected in the United States. 286 nursing units (different medical surgical units).	Communication with physician was measured by Relational Coordination Scale (Cronbach's alpha = 0.82). Nurses experience was measured by Nursing Expertise and Commitment to Care Scale (Chronbachs α=.92)	The length of experience had a statistically significant relationship with non-severe medication errors. The greater the length of experience, the fewer non-sever medication errors ($p < .01$). Nurses' level of education was statistically significant with sever medication errors. The more BSN nurses in the unit, the lower percentage of	**Strengths:** -The sample was homogeneous. -Consistent results -Included thoughtful reference to scientific evidence. -Reliable scale **Limitations:** -Large sample size may lead to overestimate the effect size. - -	Level III and high quality A

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Table 1. Continued.

Authors (year)	Design and purpose	Sample characteristics and setting	Measurements	Findings and conclusion	Strengths & Limitations	Level of evidence
				sever medication errors.		
Manojlovich & DeCicco (2007)	Cross-sectional descriptive study To examine the impacts of communication skills between nurses and physicians, and medication adminstration errors.	$N = 462$ Nurses working 25 ICUs in 3 hospitals in Michigan hospitals. Demographics: 84% female, mean age: 39.3 years, The average length of experience: 13 years. Education: 59% of participants had baccalaureate.	ICU-Nurse-Physician Questionnaire was used to measure nurse-physician communication. Validity was assessed through factor analysis. The reliability was reported, Cronbach α was .92.	Nurse's age was significantly associated with nurse-physician communication. Nurse-physician communication was significantly predicted medication errors ($R^2 = .11$). Years of experience was significantly associated with medication errors ($p < .0001$).	**Strengths:** -Adequate Sample -consistent result -reliable scale **Limitations:** -Non-experimental design may fail to predict the causality.	Level III and high quality A
Pazokian et al. (2014)	-Qualitative study Theory: [Reason's human error model]. -To identify nurses' experiences regarding medication error [ME] and it's factors.	$N = 20$ Purposive sampling Teaching hospital in Iran Average of 11 years of experience. Average ages: 34.89	Codes and themes	Two themes: 1- Individual Approach [nurses' characteristics]. Low attention level among managers to nurses personal issues in prescribing medications lead to increase the chance of the ME among nurses. Also, nurses' knowledge has a big contribution in the medication errors. 2-organizational approach such as work environment and risk management strategies.	**Strengths:** -Using a theory - Adequate sample size; reached the saturation **Limitations:** The data may not be generalizable due to the research design.	Level III and good quality B
Fasolino & Snyder (2012)	Mixed method-descriptive and correlational study. To examine the relationship between nurses'	$N = 199$ Length of experience: 12.11 Years. Education: 8% Diploma, 62%	Professional Practice Environment Survey (Cronbach alpha= .92) and TME survey (Cronbach alpha= .98) .	There was a sig. relationship between nurses with BSN age ($r = -.13$, $p = .03$) and experience and MEs ($r = -0.16$, $p = .001$).	**Strengths** -Adequate sample -Reliable scale -Consistent results and recommendations.	Level III: and good quality B

(continued)

Table 1. Continued.

Authors (year)	Design and purpose	Sample characteristics and setting	Measurements	Findings and conclusion	Strengths & Limitations	Level of evidence
	characteristics, clinical environment and team member effectiveness (TME), and medication errors (ME).	associate degree, and 30% RNs).		Also, young nurses were more likely to make MEs than RNs. Education level was not related to the MEs incidence.	**Limitations:** -Lack of homogeneity; most participants have Diploma (62%).	
Ndosi & Newell (2008)	Causal comparative and correlational design. To assess nurses' pharmacology knowledge regarding medication administration.	$N = 43$ All nurses were working in surgical units. Participants experience median was 10.87	They designed their own questionnaire. They examined its validity and reliability. But did not report the result.	There was a relationship between pharmacology knowledge and years of experience ($rp = 0.326$, $p = .035$). Regarding nurses' grades (juniors and senior) the junior nurses (5.3) has lower score than senior nurses (6.4). Also, postgraduate nurses scored (>8) higher than other undergraduate nurses.	**Strengths:** Fairly conclusion. **Limitations:** -Small Sample size. -Did not report reliability and validity of the instrument.	Level III and low quality C.
Di Muzio et al. (2017)	Cross-sectional study. No theory **Purpose:** To describe the relationship of nurses' knowledge, attitude, behavior, and training needs on medication errors.	$N = 529$ Nurses work in ICU. 14 Italian hospitals. The average nurses' age was 39.9 years. 68.1% female. level of education: 56.9% with BSN and 43.1% with no university degree.	The authors constructed a survey with 19 items that cover three main areas (Knowledge, Attitudes and Behaviors). The overall Cronbach alpha was (0.776).	BSN or MSN spend more than an hour in training to stay updated. There was a significant relationship between education level and medication knowledge ($p < .05$). 62% of the participants had a good knowledge regarding medication preparation and administration.	**Strength:** -Adequate sample size. -Reliable scale -Consistent result and recommendations for future research. -definitive conclusion **Limitations:** -Research design may fail to determine the causality.	Level III and high quality A
Björkstén et al. (2016).	Qualitative content analysis: Secondary data analysis **Purpose:** To enhance comprehending level regarding	$N = 585$	Codes and Themes The codes were categorized into subcategories and main categories. Three main categories: medication error type,	The total MEs: 615 MEs. The wrong dose (41%). . 68% of the cases reported that "Negligence, forgetfulness or lack of attentiveness" were the most common	**Strengths:** -Adequate sample size -Clear interpretations of the result fairly definitive conclusions.	Level III and good quality B

(continued)

Table 1. Continued.

Authors (year)	Design and purpose	Sample characteristics and setting	Measurements	Findings and conclusion	Strengths & Limitations	Level of evidence
	medication errors focusing on nurses individual factors, error kind, experience, and workplace factors.		individual factor, and system factor. These main subcategories: Wrong drug due to mix-up of drugs, negligence, forgetfulness or lack of attentiveness, and role overload.	individual factors that lead to MEs. There was a significant relationship between nurses experience and MEs. The most MEs is related to wrong patient and rout especially among nurses who have less than 2 years of experience.	**Limitations:** -Missing data. -No demographics.	
Sulaiman et al. (2017)	Observational study. **Purpose:** 1-To determine the frequency and severity of medication administration errors. 2-To explore factors associated with medication administration errors.	Patients= 283 Nurses = 15 Teaching hospital on Amman, Jordan with 54 medical beds. The authors did not present the demographics of the participants	Disguised direct observation and chart review methods. Participants were not informed that they were being observed..	The authors found 803 MEs. Years of experience among nurses, number of doses for each patient, patients-nurse's ratio, and length of stay in hospital have a significant relationship with the MEs	.Strengths: -Using two different data collection methods: unrecognizable observation and review charts. - Consistent result and recommendation. **Limitations:** -Inadequate sample size of nurses. -Demographics were not provided. -No information about the scale.	Level III and low quality C.
Phua & Tan. (2011).	Cross sectional, exploratory study. To examine medication knowledge among nurses in Alexandra, Singapore and examine its impact on medication errors.	$N = 238$ RNs working in inpatient units, Alexandria hospital, Singapore. Around 86% of the participant were RNs and 14% senior RNs. Average length of experience: 3 years.	Developed their own questionnaire Pharmacists independently reviewed the test questions. A pilot study was conducted to assure the validity of the questionnaire.	Senior staff (score $M = 66.5\%$) has a significant high scores than junior staff (score $M = 59.6\%$). There was a positive relationship between nurses' experience and medication knowledge. -Nurses with less than one-year experience has insufficient knowledge that related to the medications.	**Strengths:** -adequate sample size -Consistent result and recommendations. **Limitations:** -Inadequate information about the validity of the scale.	Level III with good quality B

analyzed by the two authors using the framework of Whittemore and Knafl (2005). In order to avoid the selection bias, all research studies that met the inclusion criteria were included in this review regardless their level of evidence (Figure 1). The researchers addressed the level of evidence for all included studies (Table 1).

Findings

Profile of Selected Studies

Of the 1141 publications retrieved, 19 studies met inclusion criteria. All of the included studies, except for one (Kendall-Gallagher & Blegen, 2009), was a primary study. All studies were published between 2007 and 2020, with most published between 2013 and 2017 (Table 1). Studies were set in various countries, including the United States, Canada, England, Sweden, Italy, Taiwan, Saudi Arabia, and Iran.

A literature matrix was used to synthesize essential information about the included studies. Research designs ranged from quantitative, descriptive and observational designs, to mixed methods, with the majority of studies ($n = 14$) being quantitative, non-experimental designs. Each of the studies aimed to identify nurses' characteristics and their relationship with MAEs. After analyzing the methods and findings of the included studies, themes related to the MAEs were identified. Four themes emerged: pharmacological knowledge (i.e., level of education and attendance at training courses), clinical experience and expertise (i.e., length of experience and employment status), demography (i.e., age and gender).

Theme 1: Pharmacological Knowledge and Management Skills. In relation to pharmacological knowledge, two subthemes emerged: level of education and attendance at medication administration training courses.

Level of Education. Seven studies, with varied research designs and measurements, explored the relationship between the level of education of RNs and MAEs (Asad, 2015; Chang & Mark, 2009; Di Muzio et al., 2017; Fahimi et al., 2015; Fasolino & Snyder, 2012; Kendall-Gallagher & Blegen, 2009; Sheu et al., 2009). There was moderate consensus across two studies that participants' level of education was not a significant predictor of MAEs ($p > .05$). These studies were different in terms of research designs: Fahimi et al. (2015) being an experimental study, and Fasolino and Snyder (2012) being a mixed methods descriptive and correlational study. They also differed in terms of their selection of participants: random selection (Fahimi et al., 2015) versus convenience sampling (Fasolino & Snyder, 2012). Both studies used self-report and surveyed a wide range of participants who held diplomas, BSN, and master's degrees. However, the majority of participants (40–65%) had BSN degrees in both studies, which could influence the results.

On the other hand, there was strong agreement across five studies using univariate analysis, finding that the higher the level of education of nurses, the lower the rate of MAEs (Asad, 2015; Chang & Mark, 2009; Di Muzio et al., 2017; Kendall-Gallagher & Blegen, 2009; Sheu et al., 2009). Despite the fact that these studies had different research designs: cross-sectional (Asad, 2015; Di Muzio et al., 2017; Sheu et al., 2009) and a longitudinal study (Chang & Mark, 2009), they all used self-report instruments for data collection. In a 6-months longitudinal study, Chang and Mark (2009) found that the greater the number of BSN-prepared nurses in the unit, the lower the frequency of severe medication errors ($p < .01$). In a cross sectional study, Sheu et al. (2009) identified 328 MAEs in a teaching hospital, finding that 68.3% of these medication errors had been made by associate degree-prepared nurses as opposed to BSN degree-prepared nurses (26.2%). Similarly, in other cross-sectional studies: (a) Asad (2015) found that nurses with higher degrees (e.g., bachelors and masters) were less likely to make MAEs than nurses with associate degrees ($p < .01$), and (b) Di Muzio et al. (2017) found that nurses' attitudes and awareness with respect to medication errors varied based on their level of education. Most studies consistently demonstrated that level of education was a significant predictor of MAEs among RNs. This result is consistent with Shahrokhi et al. (2013), who found that the educational level of the RNs is strongly correlated with MAEs.

Attendance at Training Courses. Four studies addressed the influence of attending training courses on MAEs (Cheragi et al., 2013; Lan et al., 2014; Thomas et al., 2017; Treiber & Jones, 2010). Two studies had cross-sectional designs and used questionnaires to examine the effectiveness of attending training courses with the frequency of MAEs in acute care settings (Cheragi et al., 2013; Lan et al., 2014). These studies were similar in terms of the ratio of nurses who attended training courses; 40.5–43.5% of participants had attended hospital-based drug administration courses. Each of these studies agreed that attending training courses on medication administration reduced the incidence of MAEs ($p < .05$).

In one qualitative study, Treiber and Jones (2010) interviewed participants and concluded that many participants lacked knowledge with respect to the use of advanced technological devices (e.g. infusion pumps) as they had not attended training courses in the clinical setting. While in a hierarchical quantitative study, Thomas et al. (2017) found that inaccurate documentation and inadequate electronic documentation skills were

often the result of having not attend appropriate training courses and were the most frequent causes of medication errors ($p < .05$).

Theme 2: Clinical Experience and Expertise. Two subthemes emerged: employment status and length of experience.

Employment Status. Only two studies reported findings related to employment status. The researchers used random sampling techniques and recruited a wide range of participants working in different hospitals with different employment status (Asad, 2015; Fahimi et al., 2015). The samples included: staff nurses (Asad, 2015; Fahimi et al., 2015), those working on a temporary 1-year contract, temporary 3-year contract (Fahimi et al., 2015), and head nurses (Asad, 2015). Both studies reported a significant relationship between employment status and MAEs. Specifically, researchers found that: (a) staff nurses scored significantly higher than head nurses in medication administration (Asad, 2015), and (b) temporary 1-year contract nurses were statistically significantly correlated with medication error rates ($p < .0001$) (Fahimi et al., 2015). The influence of employment status on MAEs was not addressed in previous reviews (O'Shea, 1999).

Length of Experience. The majority of studies, 15 studies, explored the relationship between the RN's length of experience and the occurrence of MAEs in acute-care settings. Research designs included cross-sectional ($n = 8$), secondary analysis ($n = 2$), observational ($n = 2$), longitudinal ($n = 1$), and experimental study ($n = 1$). Eight studies had cross-sectional designs and used questionnaires to measure the influence of nurses' length of experience on MAEs (Asad, 2015; Cheragi et al., 2013; Lan et al., 2014; Manojlovich & DeCicco, 2007; Di Muzio et al., 2017; Phua & Tan, 2011; Soori et al., 2019; Vatankhah et al., 2017). Five cross-sectional studies (Fasolino & Snyder, 2012; Lan et al., 2014; Manojlovich & DeCicco, 2007; Sheu et al., 2009; Soori et al., 2019) examined the frequency of medication errors for RNs with different length of experiences (7–13 years), and reported that the greater the number of years of experience, the lower the rate of MAEs ($p < .05$). Sheu et al. (2009) reported that over 50% of MAEs were committed by nurses with less than 2-years of experience.

The other two cross-sectional studies (Di Muzio et al., 2017; Phua & Tan, 2011) examined the pharmacological knowledge of RNs based on their length of experience. Both studies indicated that nurses' pharmacological knowledge and length of experience were correlated; the greater the length of experience, the greater pharmacological knowledge, and the lower rate of MAEs. Phua and Tan (2011) found that senior staff ($M = 66.5\%$) had significantly high medication knowledge scores than junior staff ($M = 59.6\%$).

The two observational studies examined nurses' experiences, as measured by way of the disguised observation technique, to determine the correlation between potential risk factors and MAEs in teaching hospitals (Rodriguez-Gonzalez et al., 2012; Sulaiman et al., 2017). Rodriguez-Gonzalez et al. (2012) reported that there was no significant relationship between length of experience and MAEs. It has been argued in the literature that teaching hospitals provide specific medication programs for nurses that might positively influence the frequency of medication errors (Rodriguez-Gonzalez et al., 2012; Sheu et al., 2009). However, Sulaiman et al. (2017) conducted a study in a teaching hospital and reported that the frequency of medication errors was associated with the length of experience ($r^2 = .456$, $p < .042$).

On the other hand, three cross-sectional studies (Asad, 2015; Cheragi et al., 2013; Vatankhah et al., 2017) and the experimental study (Fahimi et al., 2015) used questionnaires and reported that length of experience was not a significant predictor of medication errors. Nevertheless, with the exception of Fahimi et al. (2015), none of these studies reported the length of experience of participating nurses. Most studies (10 out of 15) demonstrated that the nurse's length of experience was a significant predictor of MAEs. This result is consistent with a review by Shahrokhi et al. (2013), who focused on addressing the contributing factors involved in medication errors.

Themes 3: Demography. Only eight studies were found that addressed nurses' age and gender as independent variables (Asad, 2015; Cheragi et al., 2013; Fahimi et al., 2015; Lan et al., 2014; Thomas, Donohue-Porter, & Fishbein, 2017; Rodriguez-Gonzalez et al., 2012; Soori et al., 2019; Vatankhah et al., 2017). In four cross-sectional descriptive studies, researchers (Asad, 2015; Cheragi et al., 2013; Soori et al., 2019; Vatankhah et al., 2017) used questionnaires and found a significant relationship between the gender of the nurse and medication dosage accuracy ($p < .0001$). Each of these three cross-sectional studies reported that participants' age was not statistically significant ($p > .05$), but they all agreed that female nurses were less likely to make medication errors than males. One major limitation in these studies was that the majority of participants (67.1–76%) were female. The samples may not have been representative of the population of interest, which may threaten the internal and external validity of these studies.

In the experimental study, Fahimi et al. (2015) reported no statistically significant correlation between the age and gender of nurses and the rate of MAEs

($p > .05$). In the two observational studies, researchers found: (a) participants' age did not predict medication errors (Rodriguez-Gonzalez et al., 2012), and (b) younger nurses were more likely to commit medication errors ($p < .043$) (Thomas, Donohue-Porter, & Fishbein, 2017). Despite significant difference in terms of research designs and instruments, six out of eight studies provided strong evidence with which to indicate that participants age was not a significant predictor of MAEs (Asad, 2015; Cheragi et al., 2013; Fahimi et al., 2015; Lan et al., 2014; Rodriguez-Gonzalez et al., 2012; Vatankhah et al., 2017). On the other hand, there was a weak evidence that participants' gender was a significant predictor for MAEs ($p < .05$) (Asad, 2015; Vatankhah et al., 2017), warranting further research with more homogeneous samples and stronger designs.

Discussion

Although there is a wealth of literature concerning MAEs in acute care settings, literature specified to nurses' characteristics is only a recent area of scholarly interest. Numerous studies have focused on environmental and psychological factors, creating a gap with respect to nurses' characteristics and their influence on MAEs. The current integrative review examined research on nurses' characteristics and MAEs, addressing a gap in the prior research literature. Despite the 13-year time frame for inclusion in this review, most of the studies that we reviewed were published in the last 5 years, most likely due to the increased interest in understanding the personal characteristics of RNs in acute care settings.

Nurses Characteristics and MAEs

The result of this review showed some consistency with older literature reviews and reported approximately similar factors contributing to MAEs (Brady et al., 2009; O'Shea, 1999). These reviews explained the occurrence of MAEs and presented unidirectional relationships between the contributing factors and MAEs. Other recently published reviews have primarily focused on presenting both organizational and individual factors, their findings suggesting that nurse-related factors were the dominant factors in MAEs (Shahrokhi et al., 2013, Innab, 2019). However, this integrative review focused specifically on nurses-related factors, identifying several contributing factors not examined in previous reviews.

In this integrative review, the main contributing factor identified among nurse characteristics was the length of experience, which was similarly identified by Innab (2019), and Shahrokhi et al. (2013). Level of education was the second most prevalent factor in MAEs from perspective of nurses in these studies, which again was something that other researchers had identified as a factor complicit in the incidence of MAEs (Asad, 2015; Chang & Mark, 2009; Di Muzio et al., 2017; Shahrokhi et al., 2013; Sheu et al., 2009). Stronger evidence was found in this integrative review than in the review by Parry et al. (2015), who reviewed studies with a broader scope of contributing factors related to medication errors. The evidence included experimental, cross-sectional, and longitudinal designs; used a wide range of sampling methods and instruments; and reported that nurses' level of education was predictive of MAEs.

Inadequate pharmacological knowledge due to having not attended training courses was another factor that influenced the incidence of MAEs (Cheragi et al., 2013; Lan et al., 2014; Thomas et al., 2017; Treiber & Jones, 2010). Attending training courses in medication administration was not addressed in reviews by Parry et al. (2015). Various researchers have subsequently recommended attendance at medication administration training courses to enhance nurses' pharmacological knowledge because of the necessity of learning the indications of old drugs and the continuous supply of various drugs in the drug market (Cheragi et al., 2013; Innab, 2019; Thomas et al., 2017).

There was weak evidence of MAEs being influenced by the age and gender of nurses. Only four studies showed a significant relationship between gender and MAEs (Asad, 2015; Cheragi et al., 2013; Soori et al., 2019; Vatankhah et al., 2017). Also, only one study found that younger nurses had more MAEs than older nurses (Thomas, Donohue-Porter, & Fishbein, 2017). However, most of these studies had an issue with the sample homogeneity, which could influence the result. Further research with more homogeneous sample is needed.

Other factors contributing to the incidence of MAEs was noted, but not adequately addressed across studies. These factors include: cognitive load (Thomas et al., 2017), negligence (Björkstén et al., 2016), frustration with technology (Thomas et al., 2017; Treiber & Jones, 2010), nurse ethnicity (Asad, 2015), and forgetfulness or lack of attentiveness (Pazokian et al., 2014). Because these factors were not adequately examined, further research is needed.

In this integrative review, most studies employed a cross-sectional design and relied on self-report, indicating a need for further research with stronger designs to determine causality between variables, thus determining appropriate interventions to reduce MAEs in acute-care settings. Despite these limitations, most research studies reviewed here examined the frequency of MAEs and their relationship with nurse characteristics, which provided new insights for future research.

There was some inconsistency with respect to the attention given to factors contributing to MAEs in acute care settings. Three studies focused exclusively

on environmental factors, and did not pay adequate attention to nurse-related factors (Björkstén et al., 2016; Di Muzio et al., 2017; Sulaiman et al., 2017). A further three studies, while exploring both nurse-related factors and environmental factors, failed to consider the interaction between nurse-related factors with environmental factors with respect to the causes of MAEs (Ndosi & Newell, 2009; Pazokian et al., 2014; Treiber & Jones, 2010). In contrast, the reset of studies focused solely on nurse characteristics and MAEs (Asad, 2015; Björkstén et al., 2016; Chang & Mark, 2009; Cheragi et al., 2013; Fahimi et al., 2015; Kendall-Gallagher & Blegen, 2009; Lan et al., 2014; Manojlovich & DeCicco et al., 2007; Phua & Tan, 2011; Rodriguez-Gonzalez et al., 2012; Sheu et al., 2009; Thomas et al., 2017; Vatankhah et al., 2017). Because these 13 studies endeavored to account for this dynamic relationship, their results present an uncomplicated relationship between the variables.

Strengths and Weaknesses of the Studies

Several strengths and weaknesses were identified in the selected studies. The strengths of these studies include: (a) each study, except one, had an adequate sample size (Ndosi & Newell, 2009); (b) all studies, except two, used reliable and valid scales (Ndosi & Newell, 2009; Phua & Tan, 2011); (c) in six studies, participants were recruited randomly from different departments or hospitals (Asad, 2015; Chang & Mark, 2009; Cheragi et al., 2013; Fahimi et al., 2015; Kendall-Gallagher & Blegen, 2009; Treiber & Jones, 2010); and (d) nine studies were marked as high quality studies (Chang & Mark, 2009; Cheragi et al., 2013; Di Muzio et al., 2017; Fahimi et al., 2015; Manojlovich & DeCicco, 2007; Rodriguez-Gonzalez et al., 2012; Sheu et al., 2009; Thomas et al., 2017; Vatankhah et al., 2017).

Weaknesses include: (a) a number of studies had an issue with sample homogeneity, with over 60% of participants being female (Asad, 2015; Cheragi et al., 2013; Lan et al., 2014; Vatankhah et al., 2017), and over 75% of participants had associate degrees (Lan et al., 2014) or BSN (Fahimi et al., 2015; Fasolino & Snyder, 2012); (b) two studies did not report participant demographics (Asad, 2015; Vatankhah et al., 2017); (c) three studies were considered low quality (Sulaiman et al., 2017; Ndosi & Newell, 2009; Treiber & Jones, 2010), (d) only two studies incorporate theories (Pazokian et al., 2014; Treiber & Jones, 2010); and (e) none of the studies implemented an intervention for nurses. As such, these studies reflect the growing interest in understanding the personal characteristics of RNs in acute care settings.

Limitations

The first limitation of this review was the inclusion of English language papers only. Other non-English papers could provide insightful and meaningful results. Secondly, limiting the search to five databases was another limitation. Other databases may have yielded relevant studies that had been missed. Third, focusing only on studies of acute care settings may have limited the exploration of nurse-related factors on MAEs. A large number of studies had cross-sectional designs and used self-report measures, which may have influenced the determination of causality between variables. Fifth, there was a lack of consistency with respect to the definition of nurse characteristics; due to this discrepancy, factors associated with MAEs were open to interpretation.

Also, most studies did not report the type or severity of the MAEs, or link these with the nurses' characteristics. Consequently, there was some ambiguity in interpreting the most and least factors associated with particular types or the severity of MAEs. Furthermore, this review included studies from various countries. This diversity may diminish the generalizability of the findings; thus there is a need for caution in interpreting the findings of these studies. A lack of similarities with respect to nurses' characteristics in most studies can reduce the value of the evidence for this integrative review.

Recommendations

Because there were few studies focusing on organizational or psychological factors, there were few details with respect to the influence of nurses' age, gender, cognitive abilities, and employment status on MAEs, thus revealing a gap in the current review. Future studies should look to focus on these factors. Also, more than one third of these studies were cross-sectional studies. As such, the design of these studies makes it difficult to answer the research question by demonstrating which of these characteristics makes the largest contribution to MAEs. This result indicates a need for future research with stronger designs.

This integrative review indicated that nurse's level of education, length of experience, and attendance at training courses in clinical settings were the factors most strongly associated with the incidence of MAEs in acute care settings. However, this review did not provide a definitive answer to the question of what other nurse-related factors influence MAEs. Future research might emphasize nurses' characteristics and their relationship with the severity of MAEs. Focusing on nurse's characteristics might facilitate other researchers to suggest appropriate interventions that may reduce the incidence

of MAEs. Interventional studies, such as RCTs, provide convincing evidence as to whether one variable has a causal effect on another variable, and control the influence of confounding variables in terms of randomization (Polit & Beck, 2017; Shadish et al., 2002).

Conclusion

Administering medication is a high-risk task routinely performed by RNs in clinical settings. The current review confirms that the occurrence of MAEs is a multi-dimensional phenomenon, which was seen from organizational and personal perspectives. Despite a number of empirical studies over the last two decades, there is still a gap in the research literature with respect to how these medication errors occur. Using the Whittemore and Knafl (2005) framework for integrative reviews, the result provided strong evidence that nurses' level of education, length of experience, and attendance at training courses, are directly associated with MAEs. Other nurse characteristics not adequately examined across the reviewed studies necessitates further research.

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A. K. participated in reviewing the literature, created the inclusion and exclusion criteria, designing the PRISMA chart, summarizing the selected studies, and drafting the work. A. I. participated in writing the background, methods, and discussion sections and revise the content. Selecting the appropriate journal and assigned to be the corresponding author.

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ORCID iD

Adnan Innab https://orcid.org/0000-0002-9527-1078

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