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Effectiveness of an Educational Program Regarding Vasoactive Drugs at the Level of Knowledge and Practices among Nurses Working in Critical Care Units

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ABSTRACT

Background: Critical care-unit nurses have the responsibility of medication preparation and administration. Vasoactive drugs are lifesaving drugs that are commonly used in critical-care units. However, the inappropriate administration of vasoactive drugs may lead to poor patient outcomes and complications. ***Purpose*:** The present study aimed to evaluate the effectiveness of an educational program of vasoactive-drug administration in critical care-unit nurses' knowledge and practice. ***Methods*:** A one-group pre-test-post-test design was used for this study. A convenience sample of 102 registered nurses working at different critical-care units at a university-affiliated hospital was recruited. The researchers provided the study participants with a valid educational program on knowledge and practices related to the administration of vasoactive drugs. Three tools were used to collect data; a demographics form, a vasoactive-drug knowledge questionnaire and a vasoactive-drug observational checklist. ***Results:*** There were significant differences in the nurses' vasoactive-drug knowledge and the total vasoactive-drug observational checklist scores before and after the implementation of the educational program with $p \leq 0.001$. Experiences in the current critical-care unit and course-related vasoactive drugs were significant predictors of the pre-knowledge test scores. Experience in the current critical-care unit was a significant predictor of the pre-practice test scores. ***Conclusion:*** The implemented educational program significantly improved critical care-unit nurses' knowledge and practice related to the administration of vasoactive drugs. ***Implications for Nursing:*** The educational program increased nurses' knowledge, competence and confidence regarding vasoactive-drug administration.

Keywords: Nurses' knowledge, Nurses' practice, Vasoactive medication, Educational program.

What does this paper add?

1. Critical-care nurses have an insufficient level of knowledge and poor practices regarding VAD administration.
2. The proposed educational program significantly improved the participating CCU nurses' professional knowledge and practices related to VAD administration.

3. The provision of educational programs for CCU nurses can enhance the safe and high-quality administration of medications.

Introduction

Patients in critical-care units (CCUs) are often hemodynamically unstable and in critical need of treatment (Dos et al., 2019); therefore, CCUs contain different machines used to monitor patients and administer special medications to recover patients' hemodynamic instability, such as vasoactive drugs (VADs). Vasoactive drugs play an essential role in restorating the tissue perfusion of vital organs, enhancing the cardiac output (CO) to prevent organ dysfunctions (Pei et al., 2015) and saving the patients' lives (Bangash et al., 2012).

Hence, it is important that CCUs have professional nurses that have comprehensive knowledge and practices related to the administration of VADs in order to ensure the quality of care, reduce the adverse effects and ensure patient safety (Dos et al., 2019; Júnior & Gasparino, 2017). Several studies have shown that CCU nurses are responsible for medication preparation, administration, monitoring, weaning and titration (Abo El-Ata et al., 2019; Dos et al., 2019; Hunter et al., 2020; Melo Mesquita et al., 2016; Júnior & Gasparino, 2017; Youssef et al., 2014).

Furthermore, inadequate nurses' knowledge and practice related to drug administration can lead to negative patient outcomes and negatively impact care quality, leading to medication errors, increased hospital length of stay, patient disability and even death (Youssef et al., 2014; Abo El – Ata et al., 2019). Medication errors can occur in healthcare settings and have negative impacts on the patients and the healthcare setting, causing increased rates of mortality and morbidity (Abdalla et al., 2020). The rates of medication errors are higher in ICUs than in other wards (Di Muzio et al., 2016; Tan et al., 2017). The World Health Organization (WHO) has emphasized that medication errors cause at least one death every day and approximately 1.3 million people annually being injured in the United States of America, while low- and middle-income countries are estimated to have higher rates of medication-related adverse events compared to high-income countries. Furthermore, the WHO evaluated the global annual cost of medication errors at $42 billion (World Health Organization. 2017). Factors related to healthcare professionals, such as errors in dose calculation, lack of double-checking, low adherence to protocols and inadequate knowledge of drugs, can significantly increase the rate of medical errors (Escrivá Gracia et al., 2019).

Types of VADs include: (1) Vasopressors, which can be used to improve the systemic vascular resistance (SVR) and blood pressure by activating the alpha-1 adrenergic receptors in the vasculature of the body that produces vasoconstriction (Allen, 2014), (2) Inotropes are another type of VADs that can be used to increase the cardiac output (CO) by activating the beta-1 adrenergic receptors in the heart which increase contractility and heart rate (Allen, 2014) and (3)Vasodilators are another type of VADs. Nitroglycerin is a vasodilator, which is used in cases of acute heart failure, angina pectoris and hypertensive emergency. The common VADs used in CCUs that were explored in the present study were noradrenaline, adrenaline, dopamine, dobutamine and nitroglycerin.

Background

Studies which have assessed VAD-related knowledge and practices among nurses have reported that critical-care nurses have inadequate knowledge and practices related to VADs, which may lead to medication errors (Abo El-Ata et al., 2019; Dos et al., 2019; Melo Mesquita et al., 2016; Hroub & Khalil, 2016; Youssef et al., 2014). Nurses with low levels of experience are more likely than experienced nurses to commit medication errors. Common medication error causes include selecting incorrect infusion device settings, incorrect labeling of medication, administering the medication to the wrong patient or at the wrong time, working at night shifts and heavy workload (Salami et al., 2019). Further, 28% of medication errors are underreported by nurses due to fear of being dismissed (Alrabadi et al., 2020). Moreover, nurses require continuous monitoring while administrating vasopressors in order to prevent the occurrence of complications to patients, which may include tachyarrhythmia and ischemia (Fadale et al., 2014). The extravasation of VADs can cause injury to the tissues around intravenous access and lead to the amputation to the affected area in the worst situation (Sisan et al., 2018).

Dos et al. (2019) investigated the nurses' knowledge regarding VADs. They found high percentages of correct

answers in the areas of classification, indication and contraindication, whilst they identified low percentages of correct answers in the areas of mechanisms of action, administration and adverse effects. The researchers emphasized the importance of educational programs and training sessions in resolving the problem of nurses' knowledge deficits regarding VADs.

A previous experimental study that used an educational intervention related to parenteral medication preparation and administration among CCU nurses found out that the intervention decreased the rate of medication errors and enhanced nurses' medication-related practices (Tan et al., 2017). Further, the studies of Gogri (2018) and Elsayed et al. (2020) highlighted the importance of VAD-related educational programs in improving CCU nurses' knowledge. The implementation of VAD-related educational programs can improve the levels of knowledge and practices among nurses in CCUs. In addition, these programs may reduce healthcare costs, minimize patients' hospital length of stay and increase healthcare providers' confidence and competence. To prepare professional nurses to provide safe care to patients, there is a need to regularly assess and evaluate the effect of VAD-related educational programs on CCU nurses' knowledge and practices concerning VADs. The aim of the current study is to evaluate the effectiveness of an educational program in improving CCU nurses' knowledge and practices related to VADs.

Methods

Study Design

A one-group pre-test-post-test design was used. The one-group pre-test-post-test design is considered a type of quasi-experimental design that lacks randomization and control group, but uses intervention. The advantages of one-group pre-test-post-test design include: (1) The researcher can compare between two sets of data before and after the intervention, (2) It is considered one of the simplest research designs being easy to implement and (3) Adopting only one group with no need to match between groups (Skinner, 2020). The design of this study involved two dependent variables (DVs) and several independent variables (IVs). In this study, the dependent/outcome variables were VAD knowledge and practice scores. All participants were tested on the outcome variables two times. Participants were tested once before the intervention and again after the intervention. The continuous dependent variables were the mean VAD-knowledge score and the mean VAD-practice score on an instrument.

In this investigation, the independent variables were the educational (knowledge and practice) program and the predictors of VAD knowledge and safe VAD administration among CCU nurses, including age, gender, education, years of experience as a nurse, years of experience in the current unit, VAD courses and working area.

Setting and Participants

The present study was conducted in an affiliated teaching hospital. One healthcare setting was selected to minimize variability in regard to the sample and medication-administration protocols/guidelines. A convenient study sample that included 110 registered nurses, who worked in different critical-care units and met the inclusion criteria, was recruited. The sample of the study was calculated by G*Power 3.1.9 software, using a medium effect size of 0.15, while power and alpha thresholds were set at 0.80 and 0.05, which revealed that the required sample size to answer the study research questions is n=103. As the sample was a convenient one, all registered nurses (110) were asked to sign the informed consent and complete the demographics form. Eight nurses withdrew from the study for different reasons. So, 102 nurses completed the study, with a response rate of 92%. The inclusion criteria in this study were being registered nurses working in critical-care units, with more than three months of experience, administering VADs in three shifts and holding at least a bachelor's degree in nursing. All study raters, as well as critical-care unit supervisors and heads were excluded from this study. The process of recruitment of participants, conducting the study intervention and collecting the study data took place between August and October 2020.

Study Tools

The questionnaire consisted of three tools: (1) Demographics form which includes age, gender, academic qualification, years of experience as a nurse, years of experience in the current unit, special courses related to VADs and working area; (2) A structured questionnaire called "assessment of knowledge on administration of vasoactive drugs" which was developed by Júnior and Gasparino (2017) to evaluate

nurses' knowledge about the preparation, installation and maintenance of vasoactive-drug infusion (e.g. noradrenaline, adrenaline, dopamine, dobutamine and nitroglycerin). This tool consists of 14 multiple-choice questions on VADs. The score ranges from 0 to 14, with higher scores indicating a higher level of knowledge about VADs. Permission was obtained from the author who developed the questionnaire "Gasparino" to replace sodium nitroprusside in the questionnaire with nitroglycerin for its common use in critical-care units. The overall content validity index (CVI) of the previously developed questionnaire was (0.80); (3) An observational checklist called "the observed practices of the positive inotropic medication checklist" to measure CCU nurses' practice during VAD administration (Hroub & Khalil, 2016). This tool generally consists of 30 items with three rating scales (missed/not done, done correctly and done incorrectly). Checking the "missed" or "done incorrectly" boxes indicates that a nurse did not master a task of VAD administration correctly or performed it in a way that could cause harm to a patient, missed a task or needed practice, consequently counted as 0. Checking the "done correctly" boxes indicates that a nurse had mastered the procedure of VAD administration correctly, consequently counted as 1 point. The score ranges from 0 to 30, with higher scores indicating a higher skill level in VAD administration and consequently lower number of errors. The checklist is psychometrically sound with Cronbach's alpha being (0.62) (Hroub & Khalil, 2016).

Ethical Considerations and Data Collection

Ethical approval was obtained from the Institutional Review Board of the affiliated university (IRB # 193/132/2020) prior to data collection. Then, permission to conduct the study was gained from the selected hospital. After obtaining the Institutional Review Board approval, the researchers approached the head nurses of CCUs to get their permission to recruit participants. The participants were notified that their participation is voluntary and that they can withdraw at any time without penalties. Confidentiality of data was maintained by giving each participant a unique identifier in the form of letters and numbers. The consent form was obtained from each participant who participated in the study. Participants who met the inclusion criteria received information about the study purpose and procedure, as well as about the risks and benefits of participation.

The data-collection procedure includes: First, demographics and clinical data of the study participants was collected. After that, participants were pre-tested regarding VAD knowledge using the assessment of their knowledge on the administration of vasoactive drugs questionnaire. Then, participants were also pre-tested on VAD administration through their observation by trained raters—who were assessed for inter-rater and intra-rater reliability—using a valid and reliable observational checklist concerning VAD administration. The raters visited the study participants at their critical-care units during the times of medication administration and asked the participant to give the scheduled time for VADs (e.g. noradrenaline, adrenaline, dopamine, dobutamine and nitroglycerin) to the patient. The rater used the VAD observational checklist to rate the participant's VAD administration. The raters took approximately 10 days to finish this measurement.

After conducting the pre-test for knowledge and practice, the researchers provided the study participants with a 3-hour educational intervention on VAD knowledge and administration. The educational program was developed by the researchers based on a comprehensive review of the literature concerning the theoretical and practical CCU nurses' needs about VADs (Bangash et al., 2012; Benken, 2018; Hroub & Khalil, 2016; Jentzer et al., 2015; Parry, 2015; Pei et al., 2015; Sacha et al., 2019; Saric et al., 2017; Zhang & Chen, 2016; Zimmerman et al., 2018). The educational program consists of a PowerPoint presentation and videos concerning (a) the effect of VADs on the cardiovascular system and on the $\alpha 1$, $\alpha 2$, $\beta 1$ and $\beta 2$ adrenergic receptors; (b) the aseptic technique for VAD preparation and administration procedure; (c) information on VAD dilution according to JUH guidelines; (d) dose calculation; (e) the equipment needed for VAD infusion; (f) hemodynamic monitoring before, during and after VAD administration; (g) VAD side effects, complications and follow-up interventions. Training on safe and aseptic VAD administration was also provided. Three doctoral-prepared nurses with an expertise in critical-care nursing confirmed the face validity and content validity of the entire content presented in the educational program. The expert team reviewed all the videos and made some suggestions that focused on the addition of some aspects of violation during the administration process. The addition of such

violation aspect in VAD preparation, dilution, dose calculation, aseptic technique, documentation and administration would increase the accuracy of the raters when using the checklist to rate the videos. The researchers made the recommended changes raised by the expert team to the videos. After the proposed edits were made, the expert team members again reviewed the videos and their comments were positive as they agreed to use all the revised videos. They noted that the educational program adequately addressed the 14 multiple-choice questions on VAD knowledge and that all the videos adequately addressed the 30 items of the VAD observational checklist. Then, the researchers provided the study participants with a 3-hour educational intervention on VAD knowledge and administration practices according to the times available to the participants. The participants were divided into four groups to attend the educational VAD program session. The educational program was completed in two weeks.

Finally, participants were then post-tested about VAD knowledge and administration by trained raters using the same study instruments. Confidentiality of data was maintained during the course of the study by giving each participant a unique identifier (the first letter of his/her first name plus the last 3 digits of his/her job number).

Analysis

All data was analyzed using the Statistical Package for Social Sciences (SPSS), version 25. Descriptive statistics (mean, standard deviation, percentage and frequency) were used to describe the demographic information of the study participants, as well as their level of VAD knowledge and practice. A paired-sample t-test was conducted on mean differences in the levels of VAD knowledge and practice among CCU nurses before and after the administration of the educational program. Multiple linear-regression analysis was used to assess which of the demographic characteristics of the study participants (age, gender, academic qualification, years of experience as a nurse, years of experience in the current unit, special courses related to VADs and working area) significantly predicted their VAD knowledge and safe administration. The inter-rater reliability and intra-rater reliability were assessed using Intra-class correlation coefficients (ICCs). The alpha threshold for statistical significance was set at (0.05).

Results

The researchers utilized descriptive statistics to describe the demographics of the 102 critical-care registered nurses. Of the 102 total subjects, most of the participants were males (63, 61.8%,), with an average age of 32.03 years (ranging from 25- 40 years). Regarding the participants' level of education, most of them hold a bachelor's degree (92, 90.2%). Regarding the participants' work unit, 25 (24.5%) work in CCUs, while the rest of participants were distributed as follows: 24 (23.5%) work in SICUs, 24 (23.5%) in MICUs, 17 (16.7%) in GICUs and 12 (11.8%) in CICUs. The participants' mean overall experience as a nurse was 8.22 years (SD=3.27) and their mean overall experience in the current critical unit was 3.87 years (SD=3.39). Finally, most of the participants (98, 96.1%) answered that they did not receive any courses concerning VAD education and practice.

Paired-sample t-test was applied to evaluate the effectiveness of the educational program in enhancing the CCU nurses' knowledge concerning VADs. Several assumptions must be fulfilled before conducting a paired-sample *t*-test: (1) the dependent variable must be continuous (must be measured at the interval or ratio level). In this study, the pre-test knowledge score and post-test knowledge score were produced from the same instrument and the instrument produces continuous data; (2) independence of observations; in this study, the observations within the study group were independent of one another; (3) the differences between dependent variables (pre-test and post-test) should be approximately normally distributed and not contain significant outliers. This assumption was considered satisfactory in this investigation, as the skew and kurtosis levels were estimated at -0.31 and 0.49, respectively, being less than the maximum allowable values for *t*-test (skew ± 2 and kurtosis ±7) (Hair et al., 2010). Furthermore, the boxplot did not show any outliers. It is also noted that the correlation between the two paired measurements (pre-test and post-test) was estimated at $r = 0.88$, $p \leq 0.001$, suggesting that the paired-/dependent-sample t-test is appropriate in this case.

Table 1. Demographic and baseline characteristics of study participants (N=102)

Sample Characteristics	M	SD	F	%	Range
Age in years	32.03	3.71			(25- 40)
Gender					
Male			63	61.8	
Female			39	39.2	
Level of education					
BSN			92	90.2	
MSN			10	8.8	
Years of experience as a nurse	8.22	3.27			
Years of experience in the current unit	3.87	3.39			
Courses related to VADs					
Yes			4	3.9	
No			98	96.1	
Working area					
CICU			12	11.8	
GICU			17	16.7	
MICU			24	23.5	
SICU			24	23.5	
CCU			25	24.5	

M: mean; SD: standard deviation; F: frequency; BSN: baccalaureate science nursing, MSN: master science nursing, VADs: vasoactive drugs, CCU: cardiac-care unit, CICU: cardiac intensive-care unit, GICU: general intensive-care unit, MICU: medical intensive-care unit, SICU: surgical intensive-care unit.

The analysis of paired-sample *t*-test revealed a significant increase in VAD knowledge score from pre-test (M = 9.28, SD = 2.31) to post-test (M = 12.30, SD = 1.43), t (101) = -24.07, $p \leq 0.001$ (two-tailed). The mean increase in VAD knowledge score was 3.02 at a 95% confidence interval for the difference ranging from 3.26 to 2.76. Eta squared was calculated using the following formula [Eta squared = $t^2 / (t^2 + N - 1)$] and revealed a value of (0.85), indicating a large effect size (Cohen, 1988), with a substantial difference in VAD knowledge scores before and after the intervention.

Paired-sample *t*-test was conducted to evaluate whether statistically significant differences existed between VAD practice scores among CCU nurses before and after the intervention. Assumption testing indicated no gross violation of assumptions. The skew and kurtosis levels were estimated at 0.34 and -0.14, respectively, being less than the maximum allowable values for *t*-test (skew ± 2 and kurtosis ±7) (Hair et al., 2010). Furthermore, the boxplot did not show any outliers. It is also noted that the correlation between the two paired measurements (pre-test and post-test) was estimated at r = 0.82, $p \leq 0.001$, suggesting that the paired-/dependent-sample *t*-test is appropriate in this case. The result of the paired-sample *t*-test was significant, t (101) = -34.33, $p \leq 0.001$, indicating a significant increase in VAD practice score from the pre-test (M = 18.62, SD = 2.27) to the post-test (M = 23.04, SD=1.76). The mean increase was 4.42 at a 95% confidence interval for the difference ranging from 4.17 to 4.68.

Standard multiple linear-regression analysis was conducted to find out the factors that predict VAD knowledge and safe VAD administration among CCU nurses regarding the demographic and clinical characteristics. Preliminary analysis was conducted to ensure no violation of the assumptions of normality, linearity, multi-collinearity and homoscedasticity. The demographic and clinical characteristics (age, gender, level of education, years of experience as a nurse, years of experience in the current unit and courses related to VADs) were regressed as independent variables (predictors). One independent variable (working area) was coded as a dummy variable. The total pre-test VAD knowledge scores and the total pre-test VAD practice scores were entered as dependent variables (outcomes) in separated regressions. As shown in Table (3), for the pre-test knowledge of VADs, the predictors explained

significantly 28.4% of the variance (R^2_{Adj} = 0.284, F (10, 91) = 5.01, p ≤ 0.001), whereby years of experience in the current unit and VAD courses significantly predicted the pre-test knowledge of VADs among critical-care nurses (28% and 24% of explained variance, respectively). Participants with more working experience in critical-care units and who received VAD courses tend to have more knowledge about VADs.

Table 2. Paired- sample t-test for the differences in VADs' practice scores before and after the intervention (N=102)

					Confidence interval (CI)				
		M	SD	SEM	Lower	Upper	t	df	P
Pair1	Pre-practice test total score- Post-practice test total score	-4.42	1.30	0.13	-4.68	-4.17	-34.33	101	0.000

M: mean; SD: standard deviation; SEM: standard error of mean; t: t-test value.

Table 3. Regression analysis for the predictors of the pre-test knowledge of VADs (N=102)

Independent Variable	B	St. B	T	Sr^2	Tolerance	VIF
Age	0.01	0.02	0.18	0.02	0.44	2.29
Gender (0/Female, 1/Male)	-0.27	-0.06	-0.57	-0.05	0.69	1.45
Level of education (0/BSN, 1/MSN)	-0.27	-0.04	-0.37	-0.03	0.80	1.25
Years of experience as a nurse	0.18	0.26	1.92	0.16	0.40	2.52
Years of experience in the current unit	0.19	0.28	2.44*	0.21	0.53	1.89
VADs' course (0/No, 1/Yes)	2.79	0.24	2.46*	0.21	0.78	1.29
Working area (0/CCU, 1/CICU)	-1.32	-0.19	-1.92	-0.16	0.76	1.32
Working area (0/CCU, 1/GICU)	-0.68	-0.11	-1.03	-0.09	0.63	1.60
Working area (0/CCU, 1/MICU)	-0.74	-0.14	-1.25	-0.11	0.60	1.67
Working area (0/CCU, 1/SICU)	-1.19	-0.22	-2.01	-0.17	0.60	1.69
$R^2_{Adjusted}$	0.284					
F	5.01**					

* p ≤ 0.05; **p ≤ 0.01.

B: beta coefficient (non-standardized); St. B: beta coefficient (standardized); t: t-test value; Sr^2: semi-partial correlation squared, BSN: baccalaureate science nursing, MSN: master science nursing, VADs: vasoactive drugs, CCU: cardiac-care unit, CICU: cardiac intensive-care unit, GICU: general intensive-care unit, MICU: medical intensive-care unit, SICU: surgical intensive-care unit.

As shown in Table (4), for the pre-test of VAD administration, the predictors explained significantly 16.6% of the variance (R^2_{Adj} = 0.166, F (10, 91) = 3.01, p ≤ 0.01), whereby only years of experience in the current unit significantly predicted 36% of the pre-test of VAD administration. Participants with more working experience in critical-care units tend to be more skillful in VAD administration.

Discussion

Most CCU patients require VADs in order to recover from their hemodynamic instability. Vasoactive drugs should be administrated relying on evidence-based guidelines to ensure therapeutic effect and safety. Nurses in CCUs must have comprehensive knowledge and practices related to the administration of VADs in order to ensure good quality of care and effective treatment of patients. Therefore, CCU nurses should be

competent and qualified in the performance of medication administration to prevent medication errors (Abo El – Ata et al., 2019). Sohair and Mahmoud (2017) stated that studies are inadequate in discussing nurses' competency regarding safe medication practices, especially in critical-care units. Therefore, there is a need to evaluate the effect of a VAD-related educational program on critical-care nurses' knowledge and practices. On the other hand, when nurses have inadequate knowledge regarding VADs, this may lead to complications for the patient and errors in medication administration. Therefore, nurses need to have adequate knowledge regarding the safe administration of VADs to ensure safe practice and patient safety (Dos et al., 2019; Melo Mesquita et al., 2016; Júnior & Gasparino, 2017).

Table 4. Regression analysis for the predictors of the pre-test of VAD administration (N=102)

Independent Variable	B	St. B	t	Sr^2	Tolerance	VIF
Age	0.07	0.11	0.82	0.07	0.44	2.92
Gender (0/Female, 1/Male)	0.35	0.08	0.70	0.06	0.70	1.45
Level of education (0/BSN, 1/MSN)	-1.31	-0.17	-1.70	-0.16	0.80	1.25
Years of experience as a nurse	-0.06	-0.08	-0.55	-0.05	0.40	2.52
Years of experience in the current unit	0.24	0.36	2.86**	0.26	0.53	1.89
VADs' course (0/No, 1/Yes)	-0.96	-0.08	-0.80	-0.07	0.78	1.30
Working area (0/CCU, 1/CICU)	-.47	-0.07	-0.64	-0.06	0.76	1.32
Working area (0/CCU, 1/GICU)	-0.33	-0.06	-0.48	-0.04	0.63	1.60
Working area (0/CCU, 1/MICU)	-0.83	-0.16	-1.32	-0.12	0.60	1.67
Working area (0/CCU, 1/SICU)	-1.20	-0.23	-1.91	-0.17	0.59	1.69
$R^2_{Adjusted}$	0.166					
F	3.01**					

* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$.

B: beta coefficient (non-standardized); St. B: beta coefficient (standardized); t: t-test value; Sr^2: semi-partial correlation squared, BSN: baccalaureate science nursing, MSN: master science nursing, VADs: vasoactive drugs, CCU: cardiac-care unit, CICU: cardiac intensive-care unit, GICU: general intensive-care unit, MICU: medical intensive-care unit, SICU: surgical intensive-care unit.

In the present study, the majority of the participants were males. This is inconsistent with previous studies which have had predominantly female participants (Júnior & Gasparino, 2017; Youssef et al., 2014). The mean age of the participants was 32.03 years, which is within the age ranges reported by previous studies (Abo El – Ata et al., 2019; Elsayed et al., 2020). The mean number of years of experience in nursing was 8.22 years. Meanwhile, the mean number of years of experience in the current unit was 3.87 years, which is lower than the mean reported by a previous study conducted by Youssef et al. (2014). This may be explained by the fact that there are no special requirements for nurses to work in CCUs in the targeted hospital. The majority of the participants were bachelor-degree holders and it was found that most of the participants had not received courses related to VADs before or after starting their job in the CCU, which is in accordance with two previous studies conducted by Abo El-Ata et al. (2019) and Elsayed et al. (2020).

In the present study, pre-test findings showed that the mean total VAD knowledge score among participating nurses indicates insufficient knowledge, which comes consistent with previous studies (Dos et al., 2019; Melo Mesquita et al., 2016). This inadequate knowledge may be explained by the nurses' lack of participation in VAD-related courses and references to VAD-related policies and guidelines. It may also be explained by the insufficient pharmacology courses in nursing curricula related to VADs (Hroub & Khalil, 2016). A previous study reported similar findings regarding low levels of knowledge about medications among CCU nurses (Escrivá Gracia et al., 2019), whilst other studies have reported satisfactory levels of VAD-related knowledge

(Júnior & Gasparino, 2017). Hroub and Khalil (2016) and Youssef et al. (2014) also highlighted the need for educational programs aimed at improving VAD-related knowledge and practice among nurses.

Furthermore, the results showed that the nurses' mean total VAD knowledge score after the implementation of the educational program was greater than their mean total score before the program, indicating improvement in the nurses' VAD-related knowledge. Hence, the educational program may be considered effective in improving nurses' VAD-related knowledge. In turn, this may improve the quality of nursing care, decrease patients' hospital length of stay, increase nurses' competence and confidence, improve CCU nurses' knowledge and practices, decrease medication errors in healthcare settings and decrease healthcare costs. This is in line with the findings of previous similar studies which confirmed the importance of educational interventions in decreasing medication errors and improving nurses' knowledge related to high alert medications (Ali & Sheikh, 2021; Elsayed et al., 2020; Gogri, 2018; Lu et al., 2013). The educational program in the current study incorporated more than one teaching method, including a PowerPoint presentation, educational videos and demonstrations of VAD administration. This may have motivated the participating nurses and reinforced their VAD knowledge, resulting in improved VAD knowledge scores after the educational program. In addition, after the CCU nurses were given the VAD-related educational program, the qualification of professionals through this program promotes the achievement of knowledge and motor skills, making them more competent and effective in performing their tasks when dealing with VADs.

Moreover, the mean total VAD observational checklist score prior to the educational program indicated poor VAD-related practices among the participating nurses, which is in accordance with the findings of previous studies (Abo El-Ata et al., 2019; Hroub & Khalil, 2016; Youssef et al., 2014). This may be explained by the low levels of VAD-related knowledge identified among the participating nurses, as nurses' practices are a practical reflection of their knowledge. These poor practices may also be attributed to the lack of demonstrations, training and continuing education on medication preparation and administration for nurses. Previous studies have suggested the need for interactive educational programs aimed at enhancing nurses' VAD-related practices (Abo El – Ata et al., 2019; Hroub & Khalil, 2016; Youssef et al., 2014).

The nurses' mean total VAD observational checklist score after the educational program was greater than their mean total score prior to the educational program, indicating an improvement in the nurses' VAD administration practices. The interactive educational program comprised video demonstrations of the aseptic technique for the preparation and administration of intravenous medications and VADs. Further, a demonstration of VAD preparation and administration was also included to reinforce correct VAD procedures among the nurses and decrease the medication error rate.

The current study findings are in line with previous studies which indicated improvements in nurses' medication administration practices after their participation in educational programs (Allawy et al., 2020; Bahar et al., 2017; Tan et al., 2017). In addition, when administering VADs, CCU nurses use the VAD-related educational program that helps them in administering VADs in a correct manner, avoiding mistakes when preparing and administering VADs and preventing complications that affect patients. Thus, this will increase CCU nurses' competence, safety and effectiveness of VAD administration.

It should be emphasized that demographic variables of the participants contributed significantly to their total pre-test knowledge scores. The variables years of experience in the current unit and previous participation in special courses related to VADs were identified as significant predictors of total pre-test knowledge scores. The fact that CCU nurses are familiar with VAD indication, mechanisms of action, side effects, complications and preparation may have led to experience in the current unit being a significant predictor of VAD knowledge scores, which shows that the experience time assists in the acquisition of knowledge. Likewise, nurses' participation in VAD-related courses increases their VAD-related knowledge, which explains why previous participation in VAD-related courses significantly predicted the participating nurses' total pre-test knowledge scores. This finding is consistent with the finding of Abo El-Ata et al. (2019), which indicated the importance of VAD-related courses in improving the quality of care and increasing the effectiveness of inotropic medications. In a Brazilian study, total VAD knowledge scores were found to

correlate significantly with years of professional experience, experience in the institution and experience in the working unit (Júnior & Gasparino, 2017). This supports the current study finding regarding the association between experience in the current unit and total pre-test knowledge scores. Contrary to the current study findings, Hroub and Khalil (2016) found no significant correlation between nurses' knowledge scores and age, years of nursing experience or years of ICU experience. The current study findings are also inconsistent with an Egyptian study that found no correlation between total knowledge of selective inotropic medication scores and ICU experience or working area (Youssef et al., 2014). In the present study, different demographic variables of the participants contributed significantly to their total pre-practice test scores, with experience in the current unit found to be a significant predictor of the nurses' scores. This finding may be explained by the fact that CCU nurses are required to prepare and administer VADs on a frequent basis and hence have practical VAD-related experience.

The present study had the limitations of using a convenient sample method to recruit participants from only one healthcare setting and using a small sample size, which might affect the generalizability of the results. Also, the present study used a one-group pre-test-post-test design which lacked a control group and randomization. Hence, there is a need for further studies which use stronger designs, such as randomized control trials and a combination of qualitative and quantitative methods, to obtain more generalizable findings. However, this study had a strength point through using the observational methodology which aids in collecting valid and objective data compared to the self-report method.

Implications for Nursing

The study has several implications. The interactive educational program implemented in the current study was found to lead to improvements in the participating CCU nurses' VADrelated knowledge and practices as it was evident from post-test knowledge and practice scores when compared with pre-test scores. In turn, this may increase nurses' confidence, competence and professionalism, in addition to improving quality of care and medication effectiveness. The interactive educational program, which included videos and PowerPoint presentations, was uploaded onto the computer system with the collaboration of the nursing training center and nurses were provided with access to the educational content at any time. Thus, CCU nurses can administer these drugs with a high degree of understanding and supported with evidence-based practice guidelines regarding VAD administration. Moreover, interactive educational programs could be used as reference to enhance the teaching purpose for junior nurses in CCUs. Moreover, it is also suggested to investigate the systematic reviews of studies to apply the best type of VAD- related educational programs to improve nurses' knowledge and practice in critical-care units. Hence, in practice, it is endorsed to increase educational programs, upgrading courses and training sessions on medication indications, mechanisms of action, dosage, side effects, preparation and administration. This raises the emphasis to incorporate pharmacology courses in general and VADrelated courses in particular in the curricula of educational systems in nursing schools. This study recommends that the administration system must highlight the importance of medication safety by creating and applying a specific policy for administration of VADs in critical-care units to be a guide for nurses. So, dealing with VAD safely leads to maintain and improve the patient safety. The used educational program could be a part of the requirements of continuous professional development hours, especially for nurses working in critical-care units. In addition, the study recommends to create a follow-up monitoring system to be sure that the staff became competent. Finally, it is recommended that CCU nurses are required to reapply for a license every two years to ensure that they are well qualified to work in CCUs. Future studies are encouraged to apply experimental research designs to investigate the best type of VADrelated educational programs to improve nurses' knowledge and practice in critical-care units. Thus, CCU nurses can administer these drugs with a high degree of understanding and a standardized administration procedure.

Conclusion

The results showed that nurses lacked knowledge and had poor practices regarding VADs. Further, the demographic variables experience in the current unit and previous participation in VAD-related courses were found to predict the nurses' VAD knowledge and practice scores prior to their participation in the educational

program. The educational program used in the current study significantly improved the participating CCU nurses' knowledge and practices related to VAD administration. This indicated that educational programs remain an effective tool for staff nurses to enhance their knowledge and practice to perform high-quality administration of vasoactive drugs.

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Conflict of Interest

The authors have no conflict of interest to declare.

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