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Drop Factor and Infusion Dose Calculation Discrepancies among Nurses in Southern Nigeria: A Cross-Sectional Study

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Abstract

Nurses must deliver infusions as prescribed since too slow or fast a dose could be deleterious to patients. Nurses experience challenges with infusion dose calculations, making them vulnerable to errors. The research team examined drop factor and infusion dose calculation discrepancies among nurses in southern Nigeria. Five university teaching hospitals were involved in this cross-sectional study conducted in 2019. To establish the drop factor of commonly available macro drip sets, the team randomly sourced 25 macro drip sets from the hospitals' pharmacies. A sample of 291 nurses was selected using a proportionate random sampling technique. The team collected data using the Adult Infusion Dose Calculation Quiz and analyzed it at a 5% significance level. Twenty (80%) of the sampled macro drip sets displayed a drop factor value of 20 drops per milliliter (gtt/ml) on their packaging. When measured experimentally, 25 (100%) of the macro drip sets delivered exactly 20 gtt/ml. Only 36 (12.4%) respondents calculated macro drip infusion doses using the correct drop factor of 20 gtt/ml. Non-attendance of infusion administration training updates significantly increased the risk of error by 38% ($p \leq 0.001$). In conclusion, the drop factor of macro drip sets used in southern Nigeria is 20 gtt/ml; nurses were prone to infusing patients at a lower dose than prescribed. Special training in infusion therapy might remedy this concern.

Keywords

Adult, Infusions, Intravenous, Pharmacies, Nigeria

1. Introduction

Medication errors are the seventh most common cause of death in healthcare globally [1] [2]. Among the various medication error-related risks, intravenously administered infusions pose the highest risk [3]. These errors are preventable and can arise from some unintentional misapplication of medication by healthcare providers [4]. Regarding hospital-admitted patients, intravenous infusions are frequently prescribed for fluid replacement and the administration of medicines [5]. This valuable medical intervention proves especially beneficial for patients with insufficient oral fluid intake and excessive fluid loss [6]. However, inherent risks are evident when errors occur during its administration process [7]. To ensure patient safety, healthcare professionals must adhere to prescribed guidelines when administering infusions to avoid the potential harm of administering intravenous infusions too slowly or too quickly [8] [9]. Notably, recent trends indicate that errors in infusion flow rate have emerged as a common type of medication error [10]. Thus, comprehensive efforts are needed to address and mitigate the risk and enhance patient safety in healthcare settings.

Infusion prescriptions are often not written in drops per minute (gtt/min) flow rate [11]. As a result, nurses have the responsibility of calculating the required flow rate using a complex formula: Drip flow rate in drops per minute = ((volume of infusion × drop factor)/(Time duration in minutes)) [12]. This complexity can be particularly problematic for nurses with limited mathematical ability, especially during clinical emergencies [13]. Consequently, advanced countries have taken significant steps by adopting Smart intravenous infusion pump technologies with preset drops per minute calibration for regulating infusion dose delivery [10]. Unfortunately, such advanced technology is not widespread in the developing countries of West Africa [14] [15].

The drop factor of a drip set refers to the number of drops in the drip chamber that produce 1 ml of fluid into a receptacle [12]. The UK literature has documented drop factors of 10 and 15 drops per milliliter (gtt/ml) for Travenol/Baxter and Abbott/McGraw brands of macro drip sets, respectively [16]. In contrast, American literature has documented a drop factor of 20 gtt/ml [17]. Additionally, Indian and African authors have documented drop factor values of 15, 16, and 20 gtt/ml [15] [18] [19]. The variation creates some confusion among nurses and other healthcare providers. In developing countries, where governments and regulatory bodies do not strictly monitor manufacturer labels of drip sets, discrepancies between prescribed and administered infusion rates may exist between physicians and nurses [2] [8]. The confusion in drop factor creates a chance for misapplication of drop factor values in infusion-related calculations, thus predisposing nurses to infusion dose errors. Therefore, it is essential to establish the drop factor value of commonly available macro drip sets and estimate the risk of infusion dose delivery errors. This study examined drop factor and infusion dose calculation discrepancies among nurses in southern Nigeria.

2. Materials and Methods

2.1. Study Design and Sampling

The research team adopted a cross-sectional design for this study in five university teaching hospitals in southern Nigeria between September and December 2019. The hospitals were Lagos State University Teaching Hospital Idi-Araba, the University of Nigeria Teaching Hospital Enugu, the University of Port Harcourt Teaching Hospital Alakahia, the University of Benin Teaching Hospital Ugbowo, and Abia State University Teaching Hospital Aba. The target population consisted of nurses working in the Teaching Hospitals, estimated to be 3186 individuals. Fisher's (1988) sample size calculation formula ($n = (Z^2 \times p(1 - p)/e^2)$) determined the minimum sample size to be 288 and the final sample size to be 320 after accounting for a 10% potential non-response [20] [21]. The team used the following values for the sample size calculation: Z distribution constant = 1.96; the prevalence of moderate level $p = 0.25$, $1 - p = 0.75$; and tolerable error $e = 0.05$.

The research team used proportionate random sampling with a balloting technique to select consenting respondents. The research team approached the nurses in the selected hospitals and instructed them to randomly draw a tally from a bag containing red and blue cubes without peering into the bag. Individuals who drew a blue cube were enrolled in the study, while those who drew a red cube were not. The criteria for inclusion into the study were individuals willing to participate, capable of using an electronic calculator, and physically and mentally stable enough to respond to questionnaire items. This study excluded nurses on leave and those in administrative or non-clinical roles.

To determine the drop factor of available macro drip sets, researchers randomly selected five (5) macro drip sets from each of the five selected hospitals' pharmacies ($n = 25$ drip sets). The research team then experimentally measured the drop factor of these selected sets.

2.2. Instrument and Data Collection

The data collection instrument comprised three parts. In Part 1, the research team used a 4-item checklist to document the drop factor value seen on the label of the macro drip sets and experimentally counted and measured the drop factor values of the same macro drip sets. Part 2 consisted of a 7-item semi-structured Adult Infusion Dose Calculation Quiz questionnaire. Items 1 - 4 aimed to extract demographic data such as age, sex, educational qualification, and attendance at intravenous therapy training. Item 5 inquired about the commonly used drop factor of the macro drip set in their hospital. Item 6 asked about the formula for calculating infusion flow or drop rate (gtt/min) when given the infusion bag volume and duration time. Item 7 requested respondents to calculate, using an electronic calculator, the required flow or drop rate of infusion into an adult if 100 ml of Metronidazole should flow for 50 minutes. Part 3 of the instrument consisted of a marking scheme checklist used by the research team to assess var-

ious parameters, including the ability to state the correct formula, correctly substitute the right drop factor into the formula, apply the correct drop factor value, demonstrate arithmetic computation ability, and arrive at the correct answer. Five nursing research experts from two Nigerian Universities validated the instrument (Agreement index of 83%) and confirmed its validity [22] [23].

After the research team explained the aim of the study to the respondents, they submitted the questionnaires to the respondents, who then filled in their space of choice and returned them to the research team within 15 minutes.

2.3. Data Analysis

The research team statistically analyzed the data using the Statistical Products and Service Solutions (SPSS) version 21 (IBM Inc, Chicago, IL, USA). The team summarized categorical variables using descriptive statistics (frequencies and percentages) and compared differences between the categorical variables with Chi-square and Relative-risk tests. A significance level of $p < 0.05\%$ was considered statistically significant.

2.4. Ethical Consideration

The research team obtained ethical approval from the Health Research and Ethics Committee of the Federal Medical Centre, Umuahia, with the approval number FMC/QEH/G.596/Vol.10/417 on 4th September 2019. This study followed the Helsinki Declaration guidelines (revised in 2013) for the study protocol. Each respondent gave informed consent to ensure their voluntary participation.

3. Results

The respondents filled out 291 out of 320 administered questionnaires (76.6%). The respondents had a mean age of 36.7 years. The majority was female (90.7%), held a Bachelor of Nursing degree (51.9%), and had not attended any training update on intravenous administration (82.5%). **Table 1** presents the socio-demographic profile of the respondents.

The researcher team examined 25 macro drip sets from different brands. **Table 2** presents the characteristics of the macro drip sets. Among these macro drip sets, the majority (20; 80%) displayed a drop factor value of 20 gtt/ml on the packaging. When manually measured, all (20; 100%) of the macro drip sets delivered exactly 20 gtt/ml.

About 255 (87.6%) respondents demonstrated palpable errors in infusion dose calculation and failed to arrive at the desired infusion dose. Only 81 (27.8%) stated the correct infusion calculation formula. Among them, 36 (12.4%) correctly substituted the drop factor in the stated formula. In contrast, many (48.1%) applied a drop factor value of 15 gtt/ml in their calculation. **Table 3** shows the infusion dose calculation ability of the respondents.

There was a significant relationship between attendance of special training

Table 1. Socio-demographic profile of the respondents (n = 291).

Variable	Category	f	%	Mean (SD)
Age	Mean age			36.7 (11.2)
	20 - 29	99	34.0	
	30 - 39	64	22.0	
	40 - 49	82	28.2	
	50 - 59	46	15.8	
Biological Sex	Female	264	90.7	
	Male	27	9.3	
Highest Educational Qualification	Diploma	84	28.9	
	Bachelors	151	51.9	
	Masters	44	15.1	
	Doctorate	12	4.1	
Attended training on infusion administration	No	240	82.5	
	Yes	51	17.5	

% = percent, f = frequency, SD = standard deviation.

Table 2. Drop factor values of brands of macro drip sets in southern Nigeria (n = 25).

Brand Name	Drop factor displayed on the packaging	Drop factor value on packaging	Experimentally measured drop factor
	f (%)	gtt/ml	Mean (SD)
Dolphin	5	20	20.0 (0.0)
Life Sign	0	-	20.0 (0.0)
PHH	5	20	20.0 (0.0)
Agary	5	20	20.0 (0.0)
Fantastic	5	20	20.0 (0.0)
Summary	20 (80%)	20	20.0 (0.0)

% = percent, f = frequency, gtt/ml = drops/milliliter, SD = standard deviation.

updates on intravenous fluid administration and infusion dose calculation errors (*Fisher* = 14.50, $p \leq 0.001$). Non-attendance of such training increased the risk of infusion dose calculation errors by 38%. Table 4 presents a summary of the test of association between training and infusion dose calculation.

4. Discussion

This study found that the drop factor of the most commonly used macro drip infusion sets in southern Nigeria is 20 gtt/ml. It means that 20 drops into the drip chamber will infuse 1 ml into a patient. This finding supported another Nigerian author who reported the same drop factor for macro drip sets used in Nigeria [19]. Similarly, the Royal College of Nursing in the UK affirmed that a

Table 3. Infusion dose calculation ability of the respondents (n = 291).

Variable	Detail	f	%
Ability to state reqired formula	Correct	81	27.8
	Incorrect	159	54.6
	Not attempted	51	17.5
Drop factor value inputted into formula	10 gtt/ml	17	5.8
	15 gtt/ml	140	48.1
	18 gtt/ml	1	0.3
	20 gtt/ml	36	12.4
	>20 gtt/ml	26	8.9
	Not attempted	71	24.4
Infusion dose calculation error	No error	36	12.4
	Error present	255	87.6

% = percent, f = frequency, gtt/ml = drops per milliliter.

Table 4. Test of association between training and infusion dose calculation error (n = 291).

	Infusion dose calculation error		df	Fisher	RR (95%CI)	*p* value
	Present	*Not present*				
Training				25.06	1.38 (1.13 - 1.68)	<0.001
No	221	19	1			
Yes	34	17				
Qualification			3	3.89		0.273
Diploma	75	9				
Bachelors	139	12				
Masters	43	1				
PhD	10	2				

RR = relative risk, CI = confidence interval, df = degree of freedom, $p < 0.05$ = significant.

macro drip drop factor of 20 gtt/ml is for infusion dose calculations involving clear fluids [24]. However, this finding contrasts with the macro drip drop factor value of 15 gtt/ml documented in the Nursing and Midwifery Council of Nigeria's recommended textbooks used in nursing colleges within Nigeria [16] [18], as well as the macro drip drop factor value of 16 gtt/ml documented in India [5]. It indicates a need for revising textbooks used in Nigerian nursing colleges to align with existing facts in the Nigerian clinical setting, bridging the gap between theory and practice. Additionally, authors have recommended that nurses regularly examine the drip sets used in their wards for drop factor values to protect patients from complications and avoid litigation resulting from unintended un-

der and over-delivery of infusion doses [1] [16].

This study revealed that about 20% of the macro drip infusion sets in circulation within southern Nigeria had no drop factor value indicated on the packaging. Attitudinal indifference among regulatory bodies and hospital administrators may explain why such omission exists even in university-teaching hospital pharmacies. Such irregularity can lead to infusion-related errors, which accounted for 50.1% of clinical errors reported in a study in Canada [13]. Inaccurate infusion rates can have disastrous consequences for patients, and healthcare providers like nurses are accountable for the dose of infusions they administer [6]. Based on these findings, there is a need for government authorities to regulate and cross-check the labelling of intravenous drip sets for drop factor value.

This study observed varying difficulties with infusion dose calculation among respondents, with most (87.6%) demonstrating errors despite good arithmetic skills. This finding differs from a study conducted in Saudi Arabia that found that 13.9% of nurses were prone to medication errors in drug calculation [7]. However, it is somewhat similar to a study in Pakistan, which found that 58.5% of nurses were prone to infusion dose delivery errors [15]. The larger sample size of this study enhances its validity compared to the study in Pakistan [22]. Nevertheless, the findings largely support a British study, which found that 89% of registered nurses failed a drug calculation test, even though 55% passed arithmetic [25].

Furthermore, the study showed that non-attendance of special training programs on intravenous fluid administration was significantly associated with infusion dose calculation error. This finding aligns with a study conducted in Ethiopia that proposed knowledge and practical skills enhancement for clinical nurses to reduce intravenous fluid administration errors. It also supports two other studies, which found that training nursing staff substantially reduces the probability of intravenous infusion errors [1] [11]. Nonetheless, this study did not find a significant association between educational qualification and infusion dose calculation error. It suggests that statistically speaking, the educational qualification of nurses does not significantly affect their tendency for infusion dose calculation error. This finding is consistent with a study conducted in the USA that found that 75% of faculty members demonstrated errors in infusion dose calculation, and their error rates increased with years of faculty experience [25]. It further supports an article that noted how nurses' infusion calculation competence can decrease over time to suboptimal levels [25].

5. Study Limitation

This study's limitation relates to a time maturation threat to validity, as the study participants were allowed to fill the instrument at their chosen pace, potentially exposing them to interactions with colleagues that could have influenced their responses. Therefore, the findings of this study should be interpreted with caution when generalizing outside this study's population.

6. Conclusion

This study confirms that the most accurate drop factor for macro drip infusion sets used in southern Nigeria is 20 gtt/ml. Nurses are prone to infusion dose calculation errors, but attending training on infusion therapy might reduce the risk of such errors. To address this concern, Nurse Educators should consider more seminars and workshops on infusion therapy and revision of clinical pharmacology textbooks used in nursing colleges.

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Informed Consent

The authors obtained verbal and written informed consent from each respondent before data collection.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this article.

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Appendix A

QUESTIONNAIRE

TOPIC: Macrodrip infusion dose calculation for clinicians and interns.

Instruction: Please write or tick your honest response to the questionnaire items.

Section A: Socio-demographic Profile

1) How old were you on your last birthday? ……. (please write)

2) What is your gender?

a) Female [ ]

b) Male [ ]

3) What is your highest educational qualification in Nursing Sciences?

a) Diploma [ ]

b) Bachelors [ ]

c) Masters or equivalent [ ]

d) Ph.D or MD [ ]

4) Have you attended any continuing education programme on intravenous fluid administration?

a) No [ ]

b) Yes [ ]

Section B: Intravenous fluid calculation

5) Do you know the drop factor of the adult macrodrip set mostly used in your ward or hospital?

a) No [ ]

b) Yes [ ]

6) What is the formula for calculating infusion flow or drop rate (gtt/min) when given the infusion bag volume and duration time? Write the formula legibly below.

7) Using a calculator solve the following. A prescription order reads Rx: infuse 100 mls of metronidazole over 50 mi-nutes using the adult macrodrip mostly used in the ward. At what drop rate (in drops per minute) will you set the infusion? (Show clearly all working).

Appendix B

Part 2: Observation checklist for Macrodrip sets used in hospitals in Nigeria.

Macrodrip Set Profile

1) Manufacturer…….. (please write)

2) Is drop factor clearly indicated on the macrodrip set label?

a) No [ ]

b) Yes [ ]

3) What is the average drop factor of the macrodrip set?

a) First count [ ]

b) Second count [ ]

c) Third count [ ]

d) Mean count [ ]