*The Turkish Journal of Pediatrics 2018; 60: 277-285*
*DOI: 10.24953/turkjped.2018.03.007*

*Original*

# High alert medications administration errors in neonatal intensive care unit: A pediatric tertiary hospital experience

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Received: 28th July 2017, Revised: 27th August 2017, 30th August 2017,
Accepted: 30th October 2017

**SUMMARY: Labib JR, Youssef MRL, Abd El Fatah SAM. High alert medications administration errors in neonatal intensive care unit: A pediatric tertiary hospital experience. Turk J Pediatr 2018; 60: 277-285.**

**Changing nurses' culture of safety and increasing error reporting, then investigating the common causes of error, particularly those associated with high-risk medications, will finally improve medication safety at neonatal intensive care units (NICU). This study aims to assess nurses' knowledge and practices during the administration of high alert medications (HAM).**

**This is a hospital-based descriptive cross sectional study, implemented in the NICU, at Cairo University Pediatric hospital. A convenient sample of 33 bedside NICU nurses, who agreed to participate was recruited.**

**A valid, reliable questionnaire was used to measure NICU nurses' general and specific knowledge regarding five therapeutic HAM. An observational checklist was used to assess nurses' administration practices. Both revealed that the mean percentage score of the nurses' knowledge (76.2±11.6) was higher than the mean percentage score of their total practice (69.1±13.3). Analysis of types of nurses' errors, showed that the most common error type was the wrong dose (15%), followed by wrong drug type (13.6%).**

**Nurses' knowledge and training are not mandatorily interpreted into improved implementation practices. Interventions highlighted for preventing HAM errors were developing specific training on HAM for nurses and establishing neonate centered, multidisciplinary teams formed of physicians, nurses, and pharmacists.**

***Key words: Neonatal Intensive Care, nurses, high alert medications.***

Safe, effective and ethical medical practice is an important component of clients' care. Medication administration is one of the primary functions of healthcare providers (HCP) especially nurses in the health care settings, so they need to ensure that drug therapy achieves maximum benefit without any complications. Medication administration errors are often used as indicators of patient safety in hospitals because of their common occurrence and potential risk to patients.[1] Prevention of medication errors has become a high priority worldwide since they're costly to healthcare systems, to patients, their families, and to clinicians.[2] This process depends on multiple disciplines working collaboratively to ensure safe delivery from the time the order is placed to when the medication is administered. According to the Institute for Safe Medication Practices (ISMP 2003), high-alert medications (HAM) are drugs that have a heightened risk of causing significant patient harm when used in error.[3]

Medication administration process in Neonatal Intensive Care Unit (NICU) is uniquely risky because of vulnerable nature of neonates, the complexity of medications used, and challenges of the high-stress NICU environment. Stresses include workload, unpredictable workflow, rapidly changing patient acuity, poor lighting, loud noise, and frequent distractions and interruptions during the

medication administration process.[4] Neonatal medications are universally weight based, requiring calculations for each dose.[5] Very few medications are available in neonatal dosage forms or concentrations from pharmaceutical manufacturers.

Meanwhile, human factors also contribute to medication errors occurrence. Examples include fatigue, burnout, and complacency, a false sense of security with technology, poor team communication.[6]

Improving medication safety, particularly for high-alert medications, remains a major concern of health care professionals. Owing to the incidence and consequences of medication errors in the NICU, evidenced based safety procedures and guidelines for drugs administration are pivotal.[7] So standardization of medications especially HAM and documentation should be incorporated into the electronic medication administration record system. Standardized monitoring tools including administrative policies and procedures, education and training materials, validation tools, staff competencies and documents with frequently asked questions ensure the portability of sound HAM practices implementation and commitment by the NICU staff.[8]

This study aims to evaluate current medical practices and eliminate medication errors that cause neonatal harm through assessing nurses' knowledge and practices during HAM administration in Cairo University NICU.

## Material and Methods

### *Study design, period and setting*

A hospital-based descriptive cross-sectional study, conducted in NICU at Cairo University Pediatric Hospital (CUPH), in Egypt. The included unit is located on the third floor with 31 incubators. The study took place over a 3 month period that started January 2017.

### *Working definitions*

According to USA "MEDMARX reporting system", a medication error is any preventable event that may cause or lead to inappropriate medication use or potential harm while the medication is in the control of the healthcare professional, patient or consumer. Various errors may occur related to professional practice, healthcare products, and/or procedures applied, like prescription errors, order communications errors, product labeling, packaging and nomenclature errors, compounding and dispensing errors, administration errors, monitoring and usage errors.[9]

High Alert Medication (HAM) are drugs that have a high risk of causing significant adverse events to patients when used erroneously.[10] The Institute for Safe Medication Practices (ISMP) defines and annually updates a list of all the medicines classified as high-alert, with a special focus on agonists and adrenergic antagonists, antiarrhythmics, antithrombotic drugs, opioids, sedatives, concentrated electrolytes and others.[3]
*Study sample*: A convenient sample of 33 bedside NICU nurses, who agreed to participate were recruited. Inclusion criteria were: 1-Nurses working at the previously mentioned setting. 2- Nurses exceeding one year of experience. The total number of the neonates, served by these nurses, during the study period were 87 newborns. Accordingly, one nurse served more than one child.

### *Study tools and data collection*

*I) A self-administered Questionnaire:*

The questionnaire started with instructions, aiming at briefly introducing study purposes and the method to fill in the questionnaire. The first part included background information on the nurses enrolled in the current study as age, occupation, education, work-related experience, number of working years in NICU and hospital, qualifications and training that contributed to nurses' knowledge of HAM. The second part was adopted from the study done by Mohammed et al.[11] to test NICU nurses' general knowledge regarding HAM such as drug administration questions focusing on drug delivery routes and dosage and drug regulation questions focusing on how HAM should be stored, regulated and written. Also, specific knowledge regarding five therapeutic sub-groups was chosen, being the most commonly used HAM in the NICU of Cairo university hospital. They included: agent beta-blocker (as epinephrine), anxiolytic muscle relaxant (as dormicum), cardiac therapy (as dopamine), medication used in diabetes (as insulin), plasma substitutes and perfusion solutions (as potassium chloride). The indications, preparation, action, reaction, and the overdose

of the mentioned five HAM were inquired upon. Examples of inquired questions were: appropriate clinical use for epinephrine and intravenous infusion guide lines - Dormicum effect on heart rate - Dopamine dose and dilutions - conditions treated by Insulin and administration guidelines- potassium chloride (KCI) rate of infusion and extra dose side effects.[11-14]

The scoring system was as follows; the total score is 29 for 29 questions. Right answer has taken one score, incorrect answer or doesn't know have taken zero scores.[11]

The third part was adopted from the study done by Karen et al.[14] to demonstrate causes of medication administration errors from NICU nurses' perspectives. Nurse respondents were asked to select the two most important of 14 potential reasons that medication errors occurred on the NICU, in addition to transcription error and physician handwriting.

II) *An observational checklist of HAM administration practices, in order to assess nurses' practices related to administration of the selected high alert medications*; filled and observed by the researchers. The checklist consisted of 50 steps.[11] It was divided into three main parts as follows:

1-Pre administration phase (6 steps): checking basic infection and safety regulation when preparing HAM and injections (example: washing hands) before administering medication.

2-During administration phase: checking practices regarding:

General administration practices related to all selected drugs (9 steps): checking adherence to the five rights of medication safety (right medication, right dose, right patient, right route and right time.)

Specific administration practices: checking selected administration of each of the selected 5 HAM. Literature and manufacturer leaflets represented the basis used for preparing the chosen drugs' checklists.[15-16] They included: each step in proper product preparation and delivery as described by the references in addition to administration guidelines and evaluation parameters of dosages like the proper selection of diluents, amount of diluents and recommended rate of infusion.

Epinephrine (7 steps e.g. Validate the adrenaline concentration and ordered infusion rate).

Dormicum (5 steps e.g. Assess peripheral circulation prior to starting infusion).

Dopamine (7 steps e.g. Carefully monitor blood pressure and urine output).

Insulin (4 steps e.g. Document blood glucose level hourly, monitor fluid balance intake and output).

Potassium chloride (5 steps e.g. Administer potassium infusion using a rate-controlled infusion pump).

3- Post administrations phase (7 steps): checking practices related to adherence to drug administration record protocols (examples: recording the nurse who administered the drug, the accurate time of administration and the event is recorded only after the administration is completed).[17]

Scoring system: Each nurse was observed several times during administration of HAM. The complete practice has taken two scores (adherence to guidelines during all observations times), the incomplete practice has taken one score (adherence to guidelines during some observations times) and non-adherence to guidelines during observations has taken zero scores.[11]

A pilot study was carried out on 5 nurses to test feasibility, objectivity, and applicability of the study tools. Content validity of the tools was reviewed by a panel of three experts in critical care nursing specialty and pharmacology. Internal consistency reliability for the general and specific knowledge tool (29 items) using Cronbach's alpha ranged from 0.788 -0.827. Internal consistency reliability for the practice tool (50 items) with Cronbach's Alpha ranged from. 0.75-0.86.[11] Minimizing the observation effect (Hawthorne effect) on nurses was much regarded, as it causes an increased rate of adherence to guidelines, and affect the outcome of the research. Therefore, observation days and shifts were alternated i.e. randomly selected from all shifts and during all hours. One nurse per shift was randomly selected. If an error was presumably to cause impending harm, the observer would interpose during the observation process.[18]

All procedures followed were in accordance with regulations of the responsible Research

Ethics Committee. The study was approved in December 2016 with the report number N-56-2016.

Informed consent was obtained directly from each nurse before data collection and after explanation of the study objectives. All procedures for data collection were treated with confidentiality according to the Helsinki declarations of biomedical ethics.

### *Statistical analysis*

Collected data were entered and analyzed using the Statistical Package for Social Science Software (SPSS) program, version 21.0 IBM. Data were summarized using the mean, median and inter-quartile range for quantitative variables and frequency and percentage for qualitative variables. Comparison between groups was performed using Mann Whitney test for quantitative variables and Chi-square test for qualitative variables. P values below 0.05 were considered statistically significant. Correlation between HAM knowledge score and administration practices score with NICU experience years was done using Spearman correlation test. Pareto diagram was constructed to prioritize the causes of medication errors from nurses' perspectives.

## Results

Participant nurses' age ranged from 21 to 43 years. Their average total hospital experience years, was14 years while their average NICU experience years, was 10 years. The mean percent score of the nurses' knowledge (76.2±11.6) was higher than the mean percentage score of their total practice (69.1±13.3). The highest practice mean percent score was for the insulin administration (82.6±14.3), followed by dopamine, KCL, dormicum and finally adrenaline administration. The mean percent score of the nurses' post-administration practices (74.5±14.2) was higher than the mean percentage score of their pre-administration practices (68.2±19.4). (Table I)

Nurses with a higher educational degree (Bachelor) had significantly higher mean percent score in all knowledge and practice administration aspects (P-value<0.05) except the post-administration practices mean percent score, where there was no significance in performance on the basis of nurses' qualifications whether diploma or bachelor. (Table II)

Comparing the mean percentage score of nurses' knowledge and practice between nurses who attended HAM training courses and those who didn't; revealed that nurses with previous HAM training courses had significantly, the highest mean percent score in all knowledge and practice administration aspects above (85%) (P-value <0.001). (Table II)

Similarly, nurses with previous NICU training courses had significantly higher

**Table I.** Age, Experience, and Training Courses that Contributed to NICU Nurses' Knowledge and Practices Regarding HAM.

| | Range | Mean±SD | Median | IQR |
|---|---|---|---|---|
| Age | 21.0-43.0 | 29.2±5.7 | 28.0 | 25.0-32.0 |
| Total Exp. Years | 6.0-28.0 | 14.1±5.7 | 14.0 | 10.0-18.0 |
| NICU Exp. Years | 4.0-18.0 | 10.1±4.6 | 10.0 | 6.0-13.0 |
| Total K*% score | 51.7-96.6 | 76.2±11.6 | 75.9 | 65.5-82.8 |
| Pre-administration (P†) % score | 33.3-100.0 | 68.2±19.4 | 75.0 | 50.0-83.3 |
| Adrenaline administration (P†) % score | 35.7-100.0 | 60.0±20.4 | 50.0 | 42.9-78.6 |
| Dormicum administration (P†) % score | 40.0-100.0 | 61.2±16.7 | 60.0 | 50.0-70.0 |
| Dopamine administration (P†) % score | 42.9-92.9 | 71.2±12.4 | 71.4 | 64.3-78.6 |
| Insulin administration (P†) % score | 50.0-100.0 | 82.6±14.3 | 87.5 | 75.0-87.5 |
| KCL administration (P†) % score | 30.0-100.0 | 64.8±18.2 | 60.0 | 50.0-80.0 |
| Post-administration (P†) % score | 50.0-100.0 | 74.5±14.2 | 71.4 | 64.3-85.7 |
| Total P† % score | 50.0-91.0 | 69.1±13.3 | 64.0 | 59.0-83.0 |

(P†): Practice guidelines
(K*): Knowledge

**Table II.** Comparison of Knowledge and Practice Regarding Nurses' Qualifications, NICU and HAM Training Courses.

| Knowledge and Practice% score | Qualifications | | | NICU training courses | | | HAM training courses | | |
|---|---|---|---|---|---|---|---|---|---|
| | Diploma n= 19 | Bachelor n=14 | P value | Yes n= 28 | No n=5 | P value | Yes n=12 | No n= 21 | P value |
| Total K% score | 70.6±11.0 | 83.7± 7.5 | 0.001 | 78.2± 11.1 | 64.8±6.6 | 0.014 | 87.9±4.8 | 69.5±8.5 | <0.001 |
| Pre-administration (P†) % score | 61.0±18.0 | 78.0± 17.2 | 0.008 | 72.0± 18.2 | 46.7±9.5 | 0.011 | 88.2±5.6 | 56.7± 14.3 | <0.001 |
| Administration (P†) % score | 62.8±11.6 | 75.5± 12.5 | 0.017 | 70.9± 12.6 | 52.7±4.1 | 0.001 | 84.8±3.6 | 58.7±4.4 | <0.001 |
| Post-administration (P†) % score | 70.7±13.9 | 79.6± 13.4 | 0.068 | 76.8± 13.8 | 61.4±8.1 | 0.025 | 86.9±8.0 | 67.3± 11.9 | <0.001 |
| Total P†% score | 63.7±11.5 | 76.4± 12.4 | 0.01 | 71.9± 12.4 | 53.2±2.4 | 0.001 | 85.5±2.9 | 59.7±5.0 | <0.001 |

(P†): Practice guidelines
(K*): Knowledge

mean percent score in all knowledge and practice administration aspects above (70%) (P-value<0.05) (Table II).

Non-significant, negative relationships were observed when correlating knowledge and practice scores with nurses' age, total and NICU experience years. Only a positive, moderate, relationship was found between the post-administration practices score and nurses' age (r=0.042), total (r=0.036) and NICU (r=0.218) experience years (P >0.05). (Data not shown).

The total number of newborns who were served by the participating nurses was 87. Along the study period, 66 of them were exposed to medical error, also among those 29 recorded having more than one error. Error occurrence was significantly related to qualifications, HAM training experience (P value<0.05) more than NICU experience (Table III).

Analysis of types of nurses' errors observed during the study period, showed that the most common error type was the wrong dose (15%), followed by wrong drug type and drug omission error (13.6%) for each. Then, wrong time and wrong infusion velocity (12.1%) for each. Finally, the following errors were recorded respectively: wrong diluents, wrong administration technique, extra dose, wrong patient, wrong drug preparation (Fig.1).

Highlighting the most common causes of errors from the nurses' perspectives was done using Pareto Chart, where 14 causes of errors were arranged in descending order from the most

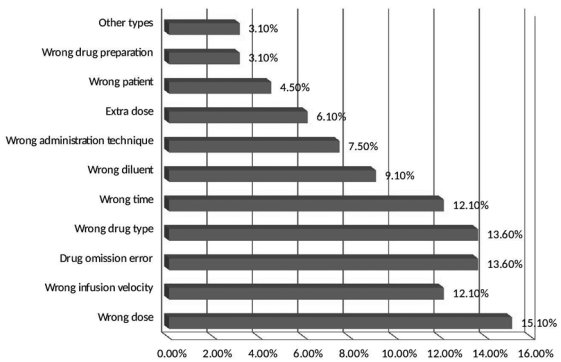


**Fig. 1.** Distribution of Nurses' Errors during the Study Period.

common cause mentioned to the least one in a relative frequency as selected and reported by NICU nurses'. The mentioned vital six causes which were cumulatively responsible for about (80%) of nurses administration errors were (20.4%) related to decrease in HAM knowledge, (19%) related to lack of sufficient nurses' numbers, (17.1%) related to nurses fatigue, (16.4%) related to low dose calculation skills, (3.9%) related to illegible physician handwritten orders, (3.9%) related to nurses forgetfulness and inattention, respectively (Fig. 2).

## Discussion

The risk of neonatal harm due to HAM involves clinically complex situations that demand a high level of competence among nurses to identify and minimize risk. In this study, NICU nurses' average total hospital experience years, and average NICU experience

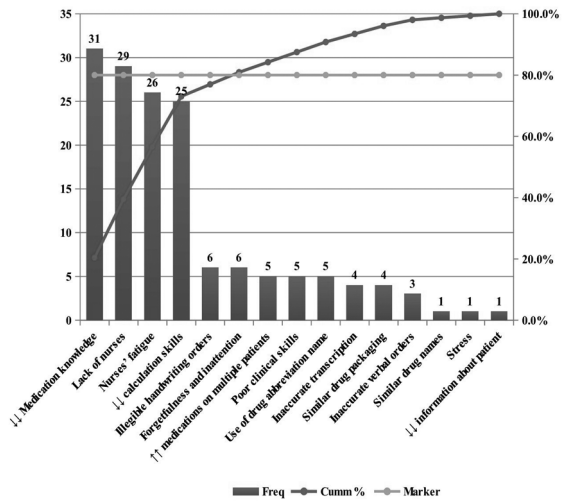


**Fig. 2.** Pareto Chart Representing the Cumulative Relative Frequencies of Nurses' Errors (from Nurses' Perspectives).

years, were[14] years and 10 years respectively. Relationships when correlating nurses' total and NICU experience years whether negative with knowledge and practice scores or positive with the post-administration practice score, represent discrepancies with others that proved that nurses' experience contributed significantly to higher scores of various knowledge questionnaires and practical aspects and vice versa.[13] Also, nursing expertise and competence have been associated with specialty certification including NICU specialty. On the other hand, our results, go in accordance with similar studies where no significant relationships between NICU errors and nurses' years of experience were reported.[19] This could be explained within the context that older nurses usually adapt less easily than younger ones to information technology applications in medication administration, and continuous education should be provided to them.[20] Most studies recommend larger samples to clarify relationships, if any, among variables. In small samples, only large differences, if exist, can be detected. In the current study, the score of the nurses' knowledge regarding HAM was higher than their total practice. This supports the evidence that NICU nurses cognitive knowledge against preset principles and standards, does not necessarily translates to better bedside care practices.[19] Even in studies where measuring the level of knowledge was done using specialty certification, yet passing a cognitive certification examination neither validates nor ensures competency at the bedside because nursing certification programs are not a unified construct, accredited certification programs vary in standards, and eligibility requirements.[21]

Consistent practical training is needed to implement intact safety NICU practices regarding standardized HAM list, drug concentrations, and management requirements.[8] Nurses' post-administration practices were better than their pre-administration practices. This could be attributed to the fact that post administration steps are fewer, mostly consisting of observation and documentation activities less complicated, than pre-administration precautions and detailed administration steps for each of the

**Table III.** Distribution of Errors according to Nurses' Qualifications, NICU and HAM Training Courses.

| | Errors occurrence | | | | | Number of errors | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Yes (n=66) | | No (n=21) | | P value | One error (n=37) | | > one error (n=29) | | P value |
| Nurses* | N | % | N | % | | N | % | N | % | |
| Qualifications | | | | | | | | | | |
| Diploma | 48 | 72.7 | 0 | 0.0 | <0.001 | 21 | 56.8 | 27 | 93.1 | 0.002 |
| Bachelor | 18 | 27.3 | 21 | 100.0 | | 16 | 43.2 | 2 | 6.9 | |
| NICU training courses | | | | | | | | | | |
| Yes | 53 | 80.3 | 21 | 100.0 | 0.032 | 36 | 97.3 | 17 | 58.6 | <0.001 |
| No | 13 | 19.7 | 0 | 0.0 | | 1 | 2.7 | 12 | 41.4 | |
| HAM training courses | | | | | | | | | | |
| Yes | 12 | 18.2 | 19 | 90.5 | <0.001 | 12 | 32.4 | 0 | 0.0 | 0.001 |
| No | 54 | 81.8 | 2 | 9.5 | | 25 | 67.6 | 29 | 100.0 | |

*One nurse served more than one neonate.

HAM. Moreover, the 5 rights of medication administration are not properly done, as these tasks have become routine and also many interruptions happen during drug preparation, verification, and administration.

The best practice score was for the insulin administration, followed by dopamine, KCL, dormicum and finally adrenaline administration. This could be explained in light of different policies and procedures followed with each of the HAM lists like drug concentrations, and management requirements.[8] Insulin requirements have the advantage of fewer, easier administration instructions. The rest of the drugs, require more steps and more precautions during their administration, thus increase the likelihood of incomplete practice scores. Analysis of common HAM error types in NICU, helps researchers to organize priorities for developing educational plans, drug, and clinical practice guidelines.[3]

Nurses with the higher educational degree (Bachelor) had a far better knowledge and practice administration aspects except for the post-administration practices, where there was no significance in performance on basis of nurses' qualifications. Many studies illustrated that highly qualified NICU nurses have core competencies in their education, especially in medication safety principles as; medication administration, policy review and medication processes like dose calculation, preparation, and safe medications administration mostly for neonates. Nursing Bachelor educational programs encompass various medication safety efforts focusing on problem prone processes and prevention efforts.[22] Certified nurses perform better than do noncertified nurses when tested on the level of specialty knowledge.[19]

Meanwhile; most of newborns' reported errors were significantly performed by nurses holding a diploma degree. This points out to drawbacks in those nurses' educational pattern. Since diploma degree lacks pharmacology teaching and big theory-practice gap, those nurses suffer from lack of ongoing annual education and training on medication administration best practices.[23]

Nurses with previous NICU and HAM training courses had significantly upgraded accomplishment, in all knowledge and practice administration aspects. This reflects the importance of training and continuous professional education that should be ongoing among all NICU nurses. NICU training supports information on all items of medication safety, collaborative neonate-centered care by both nursing and pharmacy staff. It provides strategies to prevent human factor errors and system weaknesses.[24] HAM training focuses on rapidly changing new medications, the most recent knowledge regarding prescribing, dispensing, and administration of HAM, medication administration technology and strategies to reduce risk.[20]

Nurses who had NICU training courses recorded newborns' errors occurrence once or more. While nurses who had HAM training courses did fewer errors. HAM training courses are superior to NICU training courses as they are more focused and detailed to assure safe medication practices and to seclude medication errors.[8]

Information technology (IT) and its applications in clinical processes are required to be implemented during training courses with the actual use by the NICU nurses during routine clinical care.[25] Negative consequences of IT include more work or new work for nurses, increasing workflow, and technical errors.[26]

Medication errors are common in our NICU. Fortunately, actual harm to a neonate is rare. Analysis of types of nurses' errors during the study period, were mostly; wrong dose, wrong drug type, drug omission error, wrong time and wrong infusion velocity. The Egyptian (ME) reporting system, disclosed that the most frequent administration errors were extra dose, dose omission, and medication omission.[27] Many interesting explanations have been trying to clarify this frequency order in NICU. Starting with the wrong dose, drugs are usually found in the unit dose for adults (e.g.1 vial, 1 ampoule equals 1 adult dose). This necessitates repackaging and diluting drugs to make an accurate neonatal dose.

The factor of 10 errors or decimal place errors is common in NICU, as neonates weigh from 0.5 kg up to 5 kg, a 10-fold difference in dosing within the same neonatal care unit. Large differences in neonatal weights can result in errors with decimal points and units of measure: microgram (μg), milligram (mg).[28] Pediatricians usually stress on preventing

errors of commission (e.g. wrong dose, route, medication), disregarding that medication errors of omission have an equally significant wedge, especially with clear medical benefit.[29]

Misidentification errors are not only restricted to diagnostics and therapeutics but also includes documentation. Factors contributing to misidentification errors: NICU environment (e.g. high workflow, materials used in the identification process,) and neonatal population themselves; since neonates can't participate actively in the identification process. Also, methods used to identify adults or children in everyday life, like physical appearance (size, age, hair color, and gender), are not immediately apparent or distinguishable within neonates. As such, NICU nurses solely depend on standardized patient wrist bands for identification purposes.[30]

In this study, most common causes of errors from NICU nurses' perception represented a combination of system errors and human factor errors. Human factor errors came in first place, including insufficient HAM knowledge (in the form of lack of nursing training, experience, and attention). While practice deficits were (deficient nurses' drug calculation skills, unclear prescriptions, and personal neglect) second. In regard to system errors, resulting in this error-prone environment included: shortage in nurses numbers, increased numbers of high-acuity neonates, many complicated technologies, using HAM with a minimal therapeutic index and the need to reduce costs at the same time as the demand to improve quality of care.

Similarly, the Egyptian (ME) reporting system displayed that the most common causes reported were lack of knowledge and experience, environmental factors (e. g. work overload and diversions), deficiency of drug information sources, and incomplete prescribing commands.[27]

Rates of reported errors calculated from voluntary self-reported data are usually biased because of the selective or underreporting, but, it reflects the state of science and provides valuable information for designing effective interventions to reduce neonatal harm risk.[28] Limited generalizability of results due to the small sample of NICU nurses at Cairo University Pediatric hospital, resulted in a limited diversity of reporting NICU nurses in addition to inter-individual differences in assessment of error outcomes.

Nurses' knowledge and training aren't mandatory interpreted into improved implementation practices. Although the most common errors contributing to HAM neonatal harm are human related, correction of system errors are equally vital. It will be cost saving by NICU administration, that would support improved implementation practices and minimize HAM errors, to assign a full-time dedicated clinical pharmacist in NICU, who can review and recommend medication orders and changes, provide pharmacokinetic monitoring information, and provide staff education. It is a substantial necessity to developing neonatal-specific training on HAM for NICU nurses comprising epitomized and value-added message and implanting accountability for the medication use process.

**Acknowledgement**

The authors are thankful to Dr. Mohammed YS lecturer of nursing for his valuable, reliable instruments. Special thanks to all nursing staff at the NICU at CUPH who fully cooperated with the researchers during data collection process.

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