Original Research Article

Medication errors and Root Causes Analysis: emerging views and practices in King Saud Medical City, Riyadh, Saudi Arabia

Running Title:

Medication Errors and Root Cause Analysis

Abstract

Background: Medication errors (MEs) are associated with significant morbidity and mortality, and huge cost worldwide. Medication errors are multifactorial and present in different forms with variable severity. Many tools are developed to analyze MEs for knowing the main etiological factor and preventing their occurrence. **Objective:** This minireview narratively describes the emerging views and practices concerning MEs and root cause analysis (RCA) in King Saud Medical City (KSMC) supported by relevant international literature. **Methods:** Electronic searches of PubMed and Google Scholar using keywords were made to identify relevant articles published in English literature of the past 10 years. For illustrative purpose, three case scenarios of MEs with step-wise process of RCA were presented in this research. **Results:** A number of programs, orientation sessions, policies and procedures, ME reporting system, guidelines and action plan were developed to identify and prevent MEs, and RCA of MEs was the most important assessment tool to recognize the main causes underlying MEs in KSMC. **Conclusion:** Several programs, developed and implemented in KSMC over the past few years match with international evidence-based data, and RCA is an effective tool to detect, analyze and prevent MEs in this medical city. This minireview calls for further research on MEs and root cause analysis in other hospitals of Saudi Arabia.

Keywords: Medication errors, root cause analysis, prevention, medication error reporting system.

Introduction

Medication errors (MEs) are an important cause of significant morbidity and mortality and financial burden on public health around the world. MEs are multifactorial, present in different forms and severity, and are observed in all age groups of people. The etiologies of MEs include unsafe management of medications, wrongly written prescriptions and dispensing of

incorrect medications, non-existence of medication safety and quality assurance programs, and lack of health information technology (HIT) integration into the healthcare system [1-5].Most medication errors are preventable and electronic prescribing system [EPS], a powerful tool to prevent MEs, is in place in KSMC since 2006 [6-8]. Surprisingly, recent reports suggest that electronic reporting systems may create some barriers against reporting medication errors especially access problems to system and time constraints. This study suggested some steps including training and education of concerned professionals, technology acceptance, feedback reports, supportive organizational structure, blame-free culture, and appropriate policies in place in healthcare organizations [9]. Notably, handwritten prescription errors are prevented by 50% using EPS [10].

Medication errors are reported more in an integrated blame free culture compared to blame supported culture, though the reporting rate between two cultures is marginal [9].Therefore, blame free culture needs to be fostered in the healthcare settings because early reporting of medical incidents including medication error is associated with patient safety, learning of causes and their remediation and prevention [11]. In fact, MEs and adverse events using multimodal approach [12] can be reduced considerably leading to cost reduction and substantial decrease in morbidity, mortality, and disabilities around the world [11]. Multiple factors lead to the occurrence of MEs [12, 13]. Healthcare providers need to know prohibited abbreviations and should never use them in their practice as these are frequently linked with MEs, and avoidance of their use often lead to enhanced patient safety and quality of care [6,7,11,13]. Similarly, prescribers need to handle look-alike and sound-alike (LASA) and high alert medications (HAM) drugs carefully, because they are the major cause of MEs [6-8,11-13]. Medication management system needs to be error free including processes and behaviours that determine the way that medications are safely used or handled by patients [6-8,12,13]. Safe medication management, a critical component of healthcare system guarantees patient safety and quality of life [14]. Notably, appropriate medication prescribing, dispensing, administration, and proper use of prescribed medications by patients contribute substantially to an environment associated with low incidence of MEs [14]. Furthermore, consideration of patients' perceptions about safe medication management while planning annual action plan of medication safe use contribute considerably to enhance patient safety issues, quality of care and enhanced satisfaction both of healthcare providers and users[11,14]. Medication errors are the major

concern of health professionals, patient and public and need to be prevented in healthcare organizations using powerful tools such as root cause analysis.

The root causes analysis is one of the elements of risk management strategies [15]. Prior to RCA, multidisciplinary team considers what criteria should be used to find out factors causing ME (or performance variance) and the impact of their differential (or performance) reporting by professionals. In addition, the team looks for reasons underlying variable reporting of MEs and recommends remedial measures. In KSMC, the team forwards the recommendations to the hospital manager who decides about the best action to be taken against defaulters of ME reporting and ME makers. RCA has several critical steps [Figure 1] and is an in-depth process for identifying the most basic factor (s) underlying a variation in performance, such as detection and reporting of medication errors, and the focus is on systems and processes but not on individuals [15-18]. In other words, RCT reflects a process of determining the causes of active and latent errors [19] that led to a nonconformance, event or undesirable condition. RCT identifies corrective actions to prevent recurrence of events which, when solved restores the status quo or establishes a desired effect. The Joint Commission (JC) Root Cause Analysis and Action Plan tool has 24 analysis questions that facilitate RCA in finding the main cause of the problem [20]. Furthermore, RCA is a retrospective, structured method and involves thorough review of the problem/error in order to identify and verify the underlying prime cause of ME or symptoms [19, 21].Thus, identified root causes are controlled by risk management team by specifying workable corrective measures, and allow for the generation of charts, recommendations and their implementation. RCA is carried out in case of significant or consequential events, occurrence of repetitive human errors and system failures during a specific process, and low performance contrary to desired quality standards. RCA prevents problems from recurring, reduces possible injury to personnel, increases competitiveness and efficiency, promotes customers safety and outcome, improves communication about patient care, team work and stability of profession, and reduces cost [22]. According to some researchers, a thorough understanding of RCA is a key component in promoting safety within the healthcare setting, and risk reduction strategies make RCA more meaningful and efficient that impact safety of healthcare systems [23].Several RCA-related tools useful in healthcare settings are identified and those are "five whys" approach, cause-and-effect diagrams (Ishikawa), causal tree mapping, affinity diagrams, interrelationship diagram, and Pareto charts and other tools [16, 18].

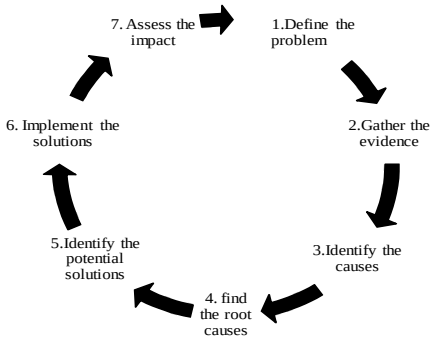

Figure 1: The Critical steps of RCA adapted from [17].

Root cause is a harmful factor that results in the production of problem/adverse outcome in business organizations including health industry. Root cause is usually used to describe the depth in the causal chain where an intervention could reasonably be implemented to improve performance or prevent an undesirable outcome [24].These adverse events/outcomes may result from medication errors or near misses/close calls or medicinal incidents. Causes or causal factors determine a condition or event that results in an effect reflecting cause-effect relationship [25].In RCA, one should always see beyond obvious [Figure 2] and the initial response is usually the symptom, not the root cause of the problem [26]. To fix a problem, it must be clearly defined and corrected by using RCA tools which are very useful and productive. Doggett (2004) compared three tools, the cause-and-effect diagram (CED), the interrelationship diagram (ID), and the current reality tree (CRT) to find out the differences but could not find the best tool among them [24]. Most times root cause turns out to be much more than expected such as: process or program failure, system or organization failure, poorly written work instructions including illegible prescriptions, and lack of training and others [27,28].In an editorial, Vincent (2004) criticized RCA based on its notion of single root cause and instead used the term system analysis [28].

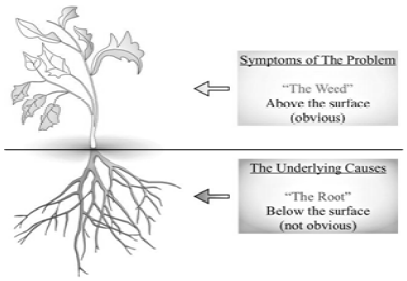

Figure 2 Root Cause Analysis – obvious and beyond obvious causes [26].

The rationale of this minireview is to familiarize health professionals with medication errors, related programs, policies, procedures, action plan, and RCT. The RCA is routinely conducted in King Saud Medical City; however, a discussion with local pharmacists revealed knowledge gap about RCT, which is not used in most other general hospitals in Saudi Arabia. The significance of this study is that MEs are a major cause of morbidity and mortality, burden on public health, and are associated with a variety of adverse consequences around the world. MEs are caused by multiple factors and RCT is a powerful tool to detect the prime cause of ME. Based on identified factors in individual MEs, preventive strategies and action plan are developed for implementation. The overall purpose is to prevent the occurrence of new and recurrence of old MEs in healthcare settings. Other healthcare organizations may adopt the process of conducting RCA in order to identify the root causes of ME and, accordingly, develop preventive strategies and recommendations for implementation that could lead to reduction in MEs [10, 14, 20]. The objective of this review narratively describes the medication errors and steps of root causes analysis in light of emerging views and practices in KSMC, and supported by international data.

Methods and Results

Search Method

The relevant literature published in English since the year 2007 was searched in PubMed and Google Scholar databases. The Boolean operators and keywords used in multiple electronic searches were medication errors in hospitals “AND” root cause analysis OR RCA tools, “AND”

adverse effects of MEs OR disadvantages of RCA "AND" prevention of MEs by RCA. The search strategy and the keywords were modified as appropriate according to the searched database. In addition, the studies listed in relevant articles were hand searched. More than 12400 articles (n=11025) were retrieved, which were reviewed by two independent reviewers (NAQ & DSAD). Our main focus was on full articles describing MEs and RCA in healthcare organizations. After removal of duplications [n=7241], no full articles [n=1203], no abstracts [n=721], non-English articles [n=161], and not accessible papers [n=1601], only 98 papers were left for further review. Finally both reviewers agreed to include 53 published studies in this minireview [Figure 3 Prisma Chart].

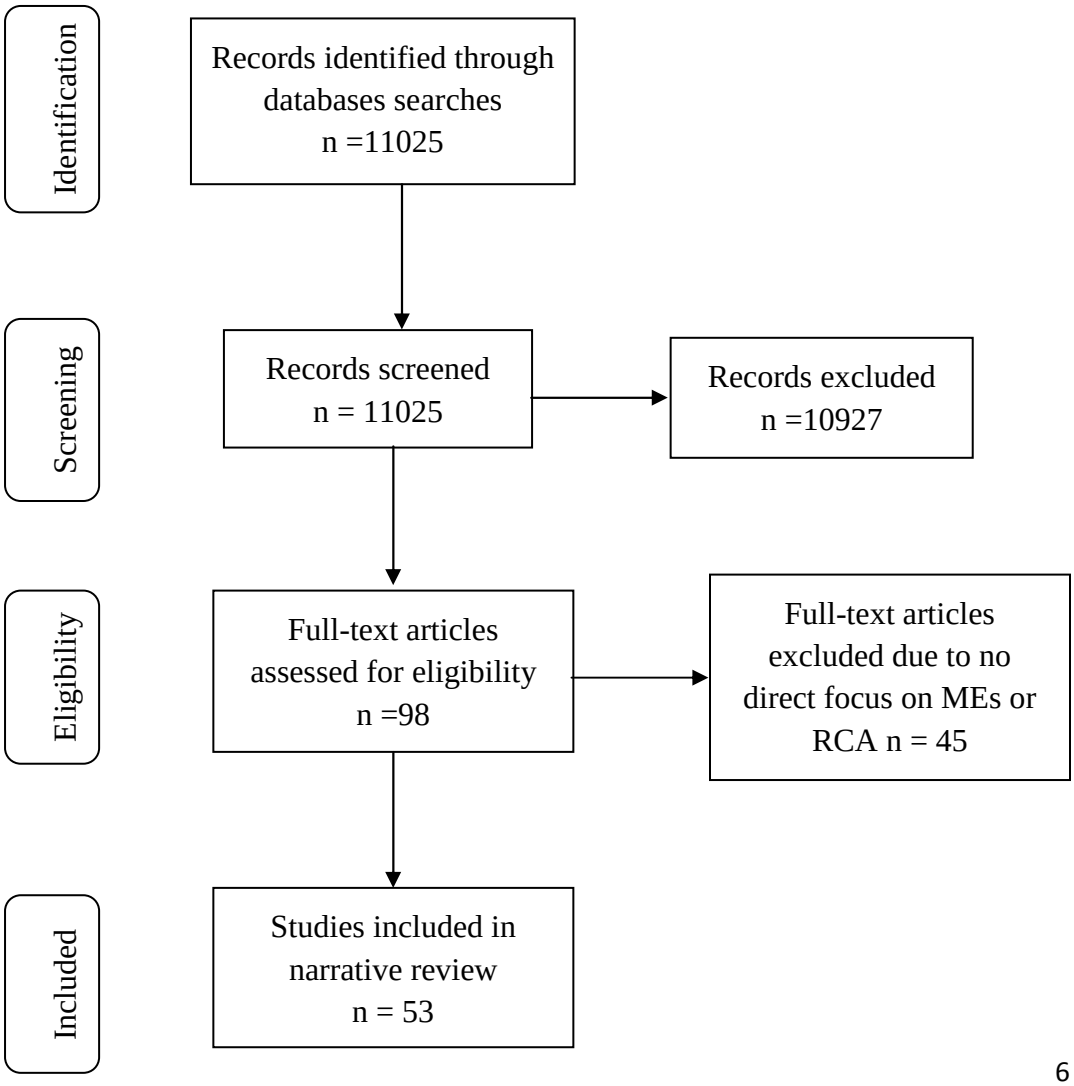

Figure 3 Prisma Chart

Setting

King Saud Medical City is a tertiary care and referral hospital in Riyadh, Saudi Arabia. This medical city has 1400 bed capacity and comprises of general, pediatric and maternity hospitals. It also has intensive care unit (ICU), artificial kidney unit (AKU), human immunodeficiency virus (HIV) centre and dental clinics. The campaign for safe medication management and patient safety in KSMC was formally started in January 2012. Pharmaceutical care staff carried out SWOT (strength, weaknesses, opportunities, and threats) [29] analysis of pharmacy services in KSMC for suggesting some reforms. This exercise was designed to help healthcare professionals to identify potential risks to medication safety, prevent medication errors, regularly conduct root cause analysis, ensure patient safety, and improving overall quality of healthcare. Medication Safety Coordinators [MSCs] especially pharmacists from Pharmacy Department and Drug Poisoning and Information Center (DPIC) used relevant materials and tools to pinpoint specific system weaknesses in terms of lack of awareness campaigns about electronic prescribing system, barriers against error reporting, medication errors makers and interceptors, and the role of health information technology (HIT) in the medication-use processes in order to provide a starting platform for organizational improvements. The newly formed team started initiatives to improve medication safety by collaborative approach [30] based on multidisciplinary stakeholders including physicians, nurses, pharmacists, managers, and healthcare users. Baseline assessment of pharmacy practices helped to safely manage medication at KSMC [14].Notably, medication therapy management service model 2.0 have five core elements in version 1.0 including medication therapy review, a personal medication record [PMR], a medication-related action plan [MAP], intervention and referral, and documentation and follow-up with redesigning of the PMR and MAP to be more patient friendly, effective, and efficient for patients to use in medication self-management [30].The important thing about this model is that it is equally applicable to all hospital pharmacies.

The pharmacy team, drug information and poisoning center workers and administrators developed a step-wise process for reporting trend of MEs and near misses (NMs) in KSMC [6-8,14]. The salient feature of this system includes voluntary reporting of MEs to medication safety unit (MSU) in a blame free culture that consequently leads to safe management of medications

[Figure 3]. For this purpose, a special medication error/near misses (ME/NMs) reporting template was developed and available in all departments of KSMC. In addition, medication safety unit regularly collect data related to MEs and NMs from pharmacy and inpatient care units [6,7,14]. The data are analyzed monthly with a focus on knowing the epidemiological pattern, and stages and settings involved in MEs or NMs for further improving MEs scenario. Following root cause analysis of each medication error, an action plan is developed and executed to prevent the occurrence of MEs, and NMs or close calls (CCs) across multiple stages of drug dispensing [14]. In addition, the concerned professionals collaboratively develop educational posters to demonstrate the trend in MEs and NMs. This is to share important drug information among all healthcare providers for further improving medication management, reduction in MEs and enhancing patient safety. Every reported ME is investigated by a multidisciplinary team that uses RCA for identifying main cause of ME. Furthermore, for dissemination purpose research team from KSMC published a number of papers on MEs and NMs or Close Calls in open access international journals [6-8, 10, 14].

Conceptual Framework of MEs

Medication error reporting informs about epidemiological trend of MEs and helps in tailoring safe medication management plan. The development of conceptual framework for identifying risk factors for medication error should consider the following; error producing conditions; likelihood of error occurring; environment including setting and processes of care; medication(s) involved; stage of medication process; patient characteristic(s); nature (seriousness) and type of error; contributing factors; mitigating and ameliorating factors; patient outcome; and pharmacovigilance system [31, 32,33]. However, any or all characteristics of a drug product can increase or decrease risk, and should be considered in risk assessment: generic name, brand name; dose, strength(s), dose form, packaging, labeling; route, frequency, instructions; storage requirements; indications and patient's demographic; care environment and others. Medication errors occur in predictable ways to allow risk assessment, risk reduction and error prevention. Notably, the error prevention strategies include but are not limited to patient education, prior authorization, electronic technology including bar coding, electronic prescription record, e-prescribing, electronic drug utilization reviews, automated medication dispensing, and internal quality control procedures [34]. Similarly, drug product interacts with healthcare

environment and system processes in identifiable but often surprising and predictable fashion. These interactions are determined by specific characteristics of the product and specific healthcare processes. Medication error reporting system is an important tool in a healthcare setting. Similarly, at the national level, healthcare providers, patients and public can report medication errors to the pharmacovigilance system. ME reporting has the following steps; 1) OVAR Flow chart [Figure 4], 2) reporting and documentation, 3) analysis of MEs, 4) Root Cause analysis and 5) action plan. Root Cause analysis is an important tool of medication safety unit (MSU) in King Saud Medical City.

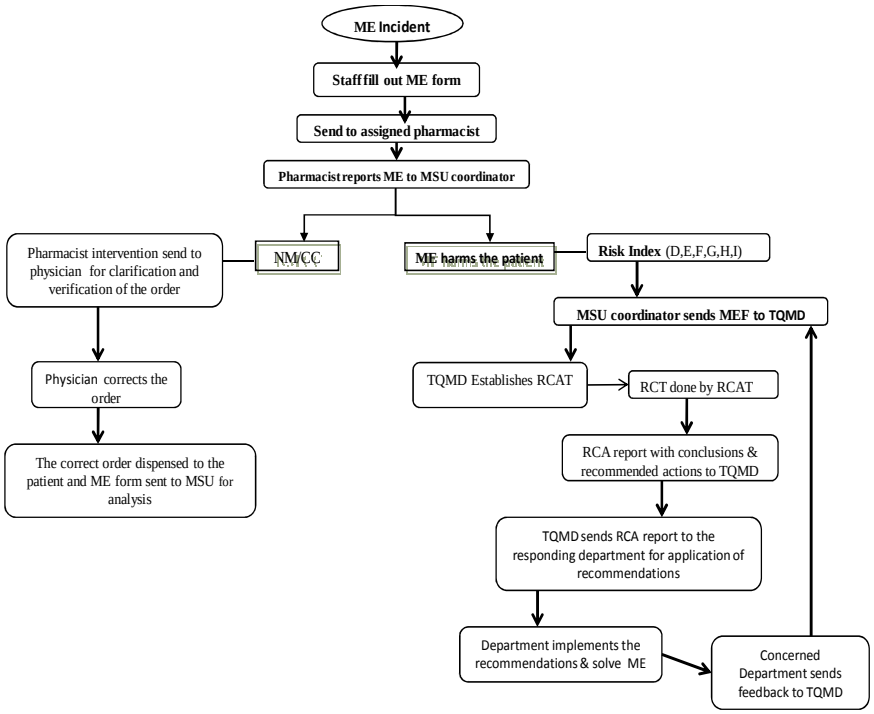

Figure 4 ME Reporting and RCA Flow Chart

Clinical Case Scenarios of MEs

1. One patient diagnosed with ischemic toe was prescribed Nexium (esomeprazole) 40 mg orally but transcribed and entered wrongly as Nexavar (sorafenib) 200 mg which is a chemotherapy drug. This was because of un-upgraded EP system, and medications are entered in formulary

alphabetically. It was sound-a-like error that happened last week. RCA is in progress with documentation and action plan.

2. One patient came to ER with bronchial asthma and physician entered wrongly prendopril 5 mg tablet five times/day (antihypertensive drug) instead of prednisolone 20 mg tablet once. RCA was carried out and documented and action plan was considered.

3. A female patient with acute coronary syndrome (ACS) in surgery department was on multiple beta blockers: Metoprolol 50 mg tab; Carvidelol 25 mg tab; and Bisoprolol 10 mg tab as found by pharmacist on ward round, attributed to non-implementation of related medication reconciliation (MR) form, the policy and procedure. RCA was done, cardiac consultant discontinued first two drugs with continuation of Carvidelol and action plan included regular orientation of this policy to concerned healthcare workers.

MSU and Orientation Programs (OPs)

Orientation programs address many pharmacy practice topics including MEs and RCAin KSMC. These programs have been conducted monthly by professionals of MSU for new employees in collaboration with academic affairs since January 2012. MSU shares with DPIC in giving lectures on awareness day. There are weekly sessions for pharmacy employees and first line staff. Orientation sessions both for the HAM and LASA drugs policy for all medical sections are done by the members of MSU. Topics addressed by MSU during OP include but not limited to unit dose system, prescribing privilege, verbal & telephone order, stat - Prn - routine orders, administration time, prohibited abbreviations, high alert medications, drug recall, adverse drug reactions (ADRs), home brought medications, medication dispensing stage, and medication reconciliation (MR) policy & procedures. Orientation about MSU to all newly employed staff is a priority and an integral part of safe medication management, patient safety and quality of care. Professionals of MSU, DPIC and quality assurance unit carry out quality rounds of all medical sections regularly to ensure full implementation of pharmaceutical policy & procedures. Notably, the awareness of all staff of risks and medication errors through orientation programs in medication system and other related perspectives such as system processes and medication

dispensing stages, and their ability to identify MEs and take appropriate action is vital in improving patient safety and reducing harms [14,35].

MSU and Harm Reduction Policies

High alert and LASA medications (Table 1 & 2) have an increased risk of causing medication errors and significant harm to a patient when prescribed, dispensed, prepared and administered wrongly. These medications are reported to cause most MEs, up to 15% to 29% [36, 37, 38]. Notably, one of the most common causes of MEs is a failure to accurately identify LASA drug names [39].Institute for Safe Medication Practices maintains a list of confused drug names and also suggested strategies to deal with such medications, which are using both the brand and generic names on prescriptions and labels, including the purpose of the medication on the prescriptions, configuring computer selection screens to prevent look-alike names appearing consecutively, and changing the appearance of look-alike product to draw the attention to their dissimilarities [40]. LASA names are most commonly confused at drug storage, pharmacy, care areas, automatic dispensing cabinets (ADC), floor stock, and packaging and labelling [14].Therefore, the policy followed in KSMC is that pharmacy personnel and nursing staff must identify the potential HAM and outline appropriate steps to administer these medications for preventing serious medication errors [14]. HAMs related MEs jeopardize the life of healthcare consumers, and hence, healthcare providers should handle HAM properly. Notably, "Patient*Safety* First" is connected to five evidence-based interventions including reducing harm from high risk medicines [41], and, hence, safe medication management strategies need to be in place in high risk healthcare settings including intensive care units and emergency departments.

Table 1 Names of common LASA medications

LASA Medications	
Losec(Omeporazole)	Lasix (Frusemide)
Reminyl(Galantamine)	Amaryl(Glimepiride)
Diamox (Acetazolamide)	Zimox(Amoxicillin)
Lamisil (Terbeniafen)	Lamictal(Lamotrigine)
Taxol (Paclitaxel)	Taxotere (Docetaxel)
Celebrex(Celecoxib)	Celexa(citalopram)
Four most common LASA drugs involved in MEs	
Sarafem® (fluoxetine hydrochloride)	Serophene®(clomiphene citrate tablets,

	USP)
Lantus® (insulin glargine [rDNA origin] inj.)	Lente® Iletin® II (insulin zinc suspension, USP purified pork)
Serzone® (nefazodone HCl)	Seroquel®(quetiapine fumarate)
Depakote® (Divalproex Sodium)	DEPAKOTE® ER(Divalproex Sodium)

Table 2 Names of common HAM

Common High Alert Medications	
Potassium chloride (20 meg/vial)	Concentrated Electrolytes
Potassium phosphate (3 mol/ml)	
Sodium chloride (>0.9%)	
DOPamine(200mg/vial)	Inotropic sympathomimetic
DOBUTamine (200mcg)	
EPInephrine [(1:1000) (1:10000)]	
NORepinephrine (2mg/ml)	
Heparin, Warfarin & low mol. wt heparin (ENOxaparin, DALtaparin, TINzaparin)	Anticoagulants
Atracurium (100mg/ml), Suxamethonium, Rocuronium, Propafol, and Pancuronium	Neuromuscular blocking agents

Root Cause Analysis Done in KSMC

In KSMC, root cause analysis is carried out in all cases with serious to fatal injuries caused by prescribed medications and this technical step is supported by other studies [15-19]. RCA provides multiple leads: knowledge gain; help in knowing main cause underlying fault or problem or event or error; finding the best solution for not repeating the same mistake or occurrence of new errors; about health system failure; trends in serious MEs, and guiding health authorities and committees for taking legal actions against those who make medication errors [15-21].

Purpose of RCA

The purpose of RCA is to analyze and record index 2 and 3 medication errors, which reached the patient and required monitoring. So this step can be taken to prevent re-occurrence of such errors that would eventually lead to a medical incident. Such medication errors usually happen at prescribing, dispensing and administration stage, and choice of dose [42,43].A

balanced prescribing can mitigate MEs to a greater extent [42,43].The several steps of RCA done in KSMC are briefly described.

1. Incident Report Investigation

1.0 Incident Description

Three incidents were reported in KSMC at different times in year 2015. Two of them were index 3 errors, one was index 2 error, and dispensing and administration stages were involved. These are briefly described below:

Case 1: This patient, a case of malaria was on Artesunate. The prescribed dose to be given was 120mg twice daily but the patient received only 2 Amps of Artesunate but not the same as recommended by physician. The pharmacist who received the order prepared and dispensed only 2 amps. Also the nurse who rechecked the trolley did not ask the pharmacist about the missing dose. This compromised the patient because she is suffering from Malaria and was febrile till next day to receive the missing dose of Artesunate.

Case 2: A female patient with psychogenic seizures was admitted to Medical Section 4 floor right wing. She was on Levetracetam 500mg tab, Carbamazepine 400mg tab., Topiramate 100mg tab., Quetiapine 300mg tab., Esomeprazole 20mg tab and Cholecalciferol 5000 unit/cap. The treating physician prescribed all these medications. When the prescription sent to pharmacy for dispense, the medications entered as usual by pharmacist as per policy then prepared by assistant pharmacist. During the preparation process, Quetiapine 300mg prepared wrongly as Quinine Sulfate 300mg. It was dispensed without double check by assistant pharmacist and the nurse. This event happened in the afternoon duty when one pharmacist and one assistant pharmacist were there for the entire shift. The wrong medicine dispensed to the patient by the Nurse on the day the patient was discharged. Two days later, the patient came to ER of KSMC, with complains of vomiting, diarrhea, screaming and overwhelming anxiety. The patient was treated and referred for followup at Al-Amal Mental Health Complex, because she followed up psychiatric medications there.

Case 3: The third incident is about a patient for whom the physician recommended potassium chloride 40meq in 500cc of normal saline/6hrs. Instead the nurse gave potassium chloride 10ml, one vial IV push at once without dilution. The treating team directly reported the error. This

procedure compromised the patient who developed cardiac arrest, urgent ECG was done together with cardiopulmonary resuscitation (CPR) and intravenous fluids were given. The patient was successfully revived; however this incident entailed a series of other investigations and procedures. Patient was kept in the hospital for close monitoring for 24 hours.

1.1 Person Directly Involved

The following persons were involved in MEs; 1) physician who prescribed the order and enter it, 2) pharmacist who assigned and prepared the trolley, 3) nurse who checked the trolley, [Malaria drug] 4) patient, 5) pharmacist and assistant pharmacist, 6) nurse who picked up medications [Quetiapine medication], 7) two collaborating nurses, physician, and CPR team [Potassium chloride HAM medication].

1.2 Root Cause Analysis Team

RCA multidisciplinary team comprises of the following; 1) medication safety unit officer, 2) pharmacist who involved in the incident, 3) assistant pharmacist, 4) nurse, and 5) quality representative. The team remained same in both types of errors, i.e., index 2 and index 3.

1.3 Sources of Evidence

The sources of information were as follows; 1) physician original order, 2) entered order-print out-MediSystem, 3) patient medication chart, 4) OVAR form, 5) medication error form, 6)related policies and procedure and additional discharge summary (discharged patients in index 3 error).

2. Type of Investigations Regularly Done

2.0 Method Used During the Investigation

The following methods are used while conducting enquiry; 1) contributing factors diagram, 2) cause and effect diagram, and 3) affinity diagram.

2.1 Special Tools and Techniques Used in Root Cause Analysis

1) Brainstorming- it helps generate radical solutions to medication errors, and encourages participating members, six to nine in numbers, to commit to solutions, because they have provided input and played a role in developing them. The best approach combines individual and

group brainstorming. During the process, committee members ensure no criticism of ideas, and creativity is encouraged, 2) 5 whys - this technique does not involve data segmentation, hypothesis testing, and regression or other advanced statistical tools. The 5 whys approach can be completed without a data collection plan. Its benefits include help identify the root cause of a problem, determine the relationship between different root causes of a problem, and easy to complete without statistical analysis, 3) Sequence Analysis [Table 3], 4) Flow Chart [Figure 5]

Table 3 Sequence Analysis

Date & time	Event or Activity	Variation	What should have happened	Recommendation
9/2/2015 7:45am	Physician prescribed Artesunate 120mg/twice	As per policy		
	Entered by physician using computer.	As per policy		
	Ordered sent to pharmacy by the Nurse who also to collect the Medication	As per policy		
	Pharmacist dispensed 2 amps. Instead of 4 amps.	Pharmacist should compare the original order with the entered one.	As per policy independent double check should be done bythe pharmacist, assistant pharmacist and the nurse who collected the medicine.	Recommendation to adhere to policy and procedure regarding dispensing process. For pharmacist and nurses.
4/2/2015 5:15pm	Physician prescribed the medicine (Quetiapine 300mg tab)	As per policy		
	Entered by physician via computer.	As per policy		
	Order sent to pharmacy by Nurse to collect the medicines.	As per policy		
	Pharmacist entered the order via computer.	As per policy		
	Assistant pharmacist prepared the order.	As per policy		
	Assistant pharmacist dispensed the prepared order.	Pharmacist did not make double check with the nurse who picked up medications.		
28.01.215 9.20pm	Physician ordered KCl 40 meq as infusion and given wrongly as IV push.	---------	Physicians should have written complete order with infusion time.	Physicians should write complete order with infusion timewith entry in the computer system
	Order sent to pharmacy to be entered and dispensed.	As per policy	As per policy	As per policy
	The order dispensed by pharmacist as per policy of HAM	As per policy KCl vials not to be kept in the unit. Labeled as HAM	As per policy	The KCl order should be prepared as IV by the IV unit pharmacy.

		when it is dispensed to the Nurse.		
	Nurse gave the medicine as wrong dose without dilution	Given the KCl without dilution	Dilution for the KCl 40meq as per the order	Nurse should coordinate with other nurse to double check HAM for preventing errors regardless of availability of barcode or smart infusion pump

helps understand complex processes, bring together perspectives across units or departments, identify breakdowns and redundancies, highlight possible interventions, and shape further questioning during the root cause analysis, 5) Common Factors Check List – includes dependent/outcome variable related to medication error occurred during any dispensing stage, independent/exposure variables - socio-demographic characteristics of the ME maker including age, educational level, year of working experience, idea of workload, shift of medication administration, i.e., night time or working time, route of medication administration, time of drug administration, interruption of the involved professional during medication administration such as like talking phone, other staffs, attendants, and patients and age of the patient [44]., 6) Cause and Effect Diagram/Fishbone Diagram/Ishikawa -the fishbone diagram helps explore all potential or real causes that result in a single defect or failure or ME, and once all inputs are established on the fishbone, the 5 Whys technique could be used to drill down to the root causes. One drawback to the fishbone diagram is that this tool cannot tell researcher how important or common a particular issue is, and problem ranking matrix solve this weakness of fishbone diagram, 7) Contributing Factors Diagram – these are the modified versions of cause and effect diagrams and take into account several factors related to environment (high noise level), equipment and system (unavailability of automated dispensing cabinets), leadership (financial constraints), communication (transcription error), people (staff working overtime) and policy and procedures (double check not done by pharmacists before dispensing) and others [45]. , and 8) RCA Report Form Template.

Another RCA tool not used in KSMC is a Pareto chart/histogram used for quantifying the frequency of common causes of the problem such as MEs. By quantifying the frequency, the RCA team focuses on the biggest issues first. Pareto charts include specific categories along the x-axis. Histograms are like Pareto charts, but instead use continuous variables along the x-axis.

Histogram and Pareto analysis provides a useful representation of data that allows team members to prioritize the causes of medication errors. This analysis also helps generate alternative approaches and provides a tool for showing progress. Notably, RCA is not without problems. Peerally and colleagues (2016) have discussed many pros and cons of RCA including the questionable quality of many RCAs, their tendency to produce poor risk controls, poorly functioning feedback loops, and failure to aggregate learning across incidents and confusion about blame and responsibility [46]. The researchers recommended implementation and evaluation of risk

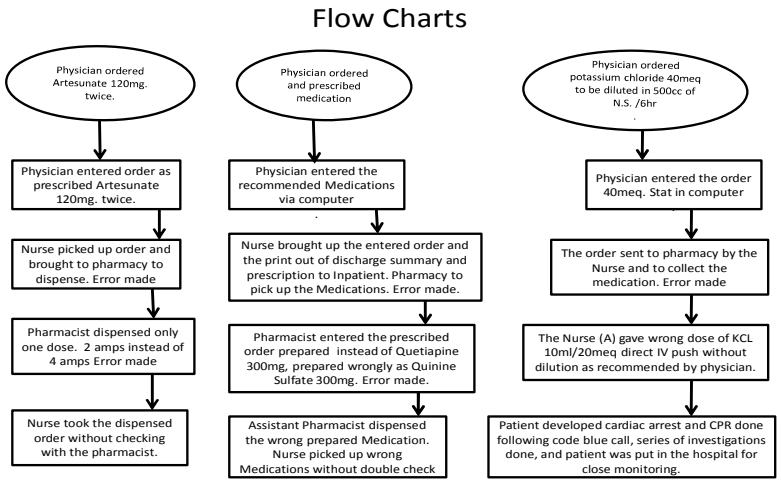

Figure 5: Flow Chart of MEs

controls to eliminate or minimize identified hazards need to become a more visible feature of the RCA process, and to maximize learning, lessons learnt from incidents, descriptions of implemented risk controls and their effectiveness need to be shared within and across organizations [46].We will further describe briefly how brainstorming is done, common factors checklist is prepared, contributing factors are identified, cause-effect exercise is completed, training and education is conducted, implementations recommended, and harm reduction plan is prepared annually in KSMC. Overall, our steps of conducting RCA are supported by other researchers [44-46].

Brainstorming

The open frank discussion among RCA committee members identifies most probable factors that contribute to the error, and recommended the following steps: 1) Implementation of and compliance with administrative rules, regulation, policies and procedures [14], 2) electronic prescribing system should be updated and all health care providers especially physicians, nurses and pharmacists should be trained continuingly as how to operate medication prescribing system [6-8], 3) Implementation of independent double check of ordered medication by pharmacist and nurse at the time of collecting medications form the pharmacy [6,7].

Common Factors Checklist

This list is for identifying critical causes and contributory factors related to system and medication dispensing processes: 1) **staff** - Lack of adherence to the policy of independent double check, 2) mandatory for the pharmacist to re-check all doses ordered by the physician, 3) Check list form should be co-signed by pharmacist and nurse, and 4) Patient medication chart should be followed by the endorsed nurse (for inpatients), 2) **Process and System** -Lack of implementation of double check and update of electronic prescribing and dispensing of medications, 3) **Policies and Procedure-** All health care providers especially who are closely in contact with the patient should double check physicians' orders and medications [6-8, 14].

Contributing Factors

Ideally, common factors checklist include most contributing factors related to professionals involved in making MEs, process and system failures, patients, policies and procedures, medications, and leadership [44-46]. In tandem with international data, contributing factors to MEs are regularly identified during the process of RCA in KSMC, and these factors concern staff, patients, process and system, education and training [ET], and policy and procedures. However, more focus is on system and processes rather than individual, and blame free culture is strongly promoted in KSMC.

Fish bone Diagram

It is a tool to represent the relationship between an effect (problem) and its potential causes by category type and is carried out when a root cause needs to be determined. It helps ensure that a balanced list of ideas have been generated during brainstorming. Fish bone diagram

[Figure 6] determines the real cause of the problem versus a symptom and refines brainstormed ideas into more detailed causes. Cautionary note about cause and effect analysis is that it cannot get past existing knowledge - must have either observed or considered that the cause produced the effect in the past. So this is a retrospective exercise.

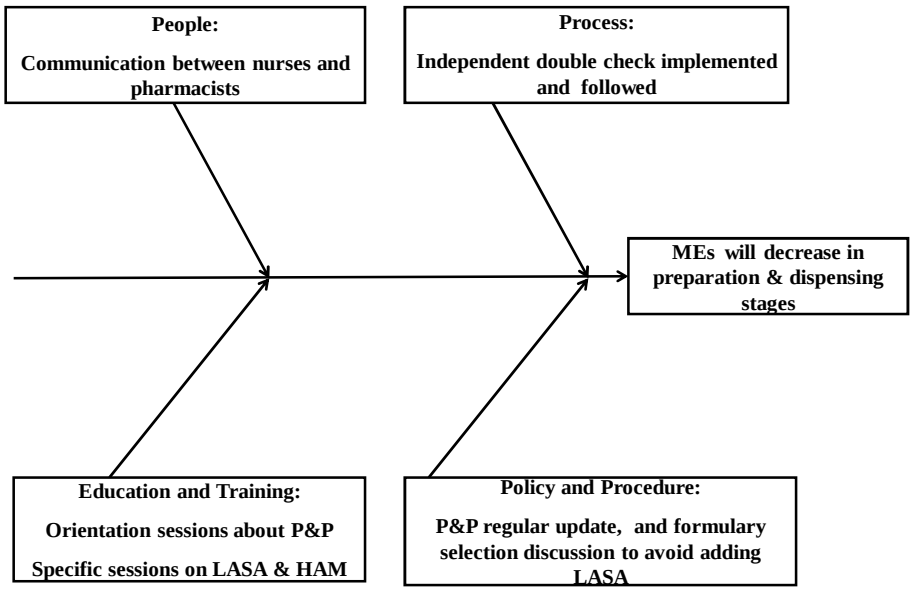

Figure 6 Fish Bone Diagram equally applies to both index 2 and 3 errors.

Education and Training [ET]

All concerned staffs should have regular training in safe medication management especially about LASA and HAM in order to prevent medication errors, because these are the medications involved in most of MEs [47,], a comprehensive lists of LASA and high alert medications is available here [38,40]. It was observed that majority of the staff especially pharmacist and assistant pharmacist are not present during the orientation sessions conducted by MSU. This was attributed to work load and busy schedule. Similar findings were reported in a review, and accordingly workload issues impact nurses' ability to attend continuing professional development with multiple adverse consequences including competence to practice and job satisfaction [48]. Organizational leadership plays an important role in supporting attendance at

continuing professional development as an investment for the future. We suggested that the pharmacy administrators should arrange their release for attending orientation programs on RCA, MEs, and their prevention. In addition, training of patients in safe management of medications, i.e., how to use prescribed medication at home contributes to the reduction in MEs across healthcare settings [49].

Ethical Considerations

This is a minireview and does not involve any human participation, and, hence, no risk of injury. However, from ethical perspective, the identification information of six illustrative cases was anonymized, and they gave verbal consent for reporting their clinical data. Furthermore, two authors (DSAD & IAAZ) coordinated with Academic Department of KSMC and obtained permission to publish data concerning six cases.

Results

Recommendation by RCA Committee

The concerned staff must adherence fully to the policy of independent double check [50] and formulary selection in order to prevent medication errors attributed mostly to LASA and HAM [47]. Adherence to dug formularies tends to improve medication safety and efficiency [51]. Motivate the concerned staffs to attend the orientation sessions conducted by MSU to learn more about independent double check and policy and procedures.

Risk Reduction Plan

The risk reduction plan is prepared by Medication Safety Unit on 4-2-2015 [Table 4]. This plan mainly focusses on education and training, independent check by two trained individuals, adherence to hospital drug formulary (HDF), regular update of pharmacy policy and procedures, preparation of HAM carefully, update of electronic prescribing system, electronic reporting of MEs and pharmacy leaders need to give time space to their staff for attending orientation education and training programs in safe medication management.

Table 4 Risk reduction plan

Risk Reduction Strategies	Measures of effectiveness	Targeted staff	Responsible persons	Date of implementation
Training orientation as how to handle independent double check for preventing MEs	Regular presentation of the orientation program	Physicians, nurses and pharmacists	Medication Safety Unit staff	Currently
Orientation concerning implementation of independent double check	Do	Do	Do	Done on Jan. 2015
Recommendation for drug formulary selection to decrease MEs related to LASA and HAM.	Decrease in HAM & LASA MEs	Do	Pharmacy & Therapeutic Committee members	Done on Feb. 2015
Medication Error policy and procedure updating	Increase in ME reporting	Do	Medication Safety Unit staff	Done on March 2015
Preparation of potassium chloride doses	Ongoing	Nurses and pharmacists	IV room pharmacists	Ongoing
Regular system upgrading for reporting of MEs.	Increase in ME reporting	Professionals	IT staff	Done
Absenteeism (non-attendence)	Under recording	Legal Affairs persons	Administrative persons	Ongoing process

Discussion

This minireview briefly highlighted the salient features of medication errors, presented clinical scenarios of medication errors and incidents, training programs and steps of conducting root cause analysis in King Saud Medical City, and these perspectives were supplemented by international data. Despite most MEs are preventable [6-8], they cause a significant morbidity and mortality, huge cost and disabilities around the world [11, 12]. As majority of MEs are preventable, healthcare providers using preventive strategies including patient education [49] need to make concerted efforts to minimize their occurrence and recurrence to an acceptable, minimum rate, which is about less than 7% [14]. MSU contribute largely to safe medication management which is associated with enhanced patient safety and good quality healthcare [14]. Medication safety unit follow and implement recommendations of RCA multidisciplinary team concerning MEs, and also update strategic medication action plan every year in KSMC [14]. Medication safety unit with the help of interdisciplinary team also develop medication safety program yearly which relate to prevention of harm from HAM, LASA and abbreviation related MEs and ADE, control and monitor of concentrated electrolytes, develop guidelines or implementation toolkits for individual program including reporting of MEs [template available upon request from DSAD], develop mechanisms for clarification and variation of orders, and develop educational and training programs for concerned staff. Overall, medication safety unit supported by state of the art of EPS with clinical decision support system and electronic

medical/health record system streamlines safe medication management using its programs [8, 10, 14]. Furthermore, annual action plan with implementation of its recommendations across all settings in KSMC also enhances patients' safety, minimize the costs, patient outcomes, and help deliver better quality of care – noble goals of healthcare system across the world. Interprofessional collaboration and cooperation is a key and so crucial to achieve these goals including specifically educational and training of healthcare professionals [52]. Another policy is that electronic prescribing system needs to be updated regularly in order to reduce medication errors. It is reported that about 50 % of hand-written prescription errors [like 14%] especially illegible hand writing are reduced to [7%] by electronic prescribing [10].

Root cause analysis of index 2 and 3 medication errors as done in KSMC and supported by international data helps healthcare providers to identify the causes and also help prevent MEs and ultimately assist them in reducing various MEs related adverse consequences including morbidity, mortality, cost burden on public health, and indirect costs in healthcare settings [15-21,24]. Every medication error needs to be reported to pharmacovigilance system at national level or internally to medication safety unit in hospitals. This will necessitate healthcare provider change attitudes towards reporting MEs and, hence, help in their prevention [49]. Similarly, every ME needs evaluation and RCA for identifying their underlying primary causes including institutional, system and process factors [15-19, 49, 53]. Correction of contributing causes of MEs [44-46] prevents its recurrence as well as occurrence of new MEs [49]. Overall, RCA gives several important leads to healthcare professionals and administrators for the prevention of medication errors in healthcare system [15-21].

Some of them need special focus; patient education, the collection of error data and analysis in the healthcare delivery process [49] as done regularly in KSMC [6-8], creation of blame free culture [14], defaulters of error reporting require proper, disciplinary action, and healthcare system and processes need regular update. All these preventive strategies will lead to patient safety, public confidence building in healthcare organizations, reduction in MEs, good outcomes, and delivery of good quality care to patient population [49]. In the words of Albert Einstein, "It's impossible to solve significant problems using the same level of knowledge that created them!". Therefore, we suggest that continuous education and training of healthcare

professionals concerning medication errors and root cause analysis need to be in place in all hospitals of Saudi Arabia and other Gulf countries.

In conclusion, medication errors are preventable, associated with significant morbidity and mortality, burden on public health, and caused by system processes, human factors and medications. Every medication error needs comprehensive analysis using several tools of root cause analysis in order to identify their root causes and develop preventive strategies, medication-related plan and educational programs for the prevention of medication errors in healthcare organizations. This narrative minireview calls for adoption of root cause analysis by other public and private hospitals in Saudi Arabia.

Consent

Verbal consents were given by six cases included in this work.

Ethical Approval

This mini review does not involve human participation and, hence, no risk of any injury. However, two authors coordinated with the Academic Department of KSMC and obtained permission for its publication.

Abbreviation List

ADRs – Adverse Drug reactions, AKU- Artificial Kidney Unit, ADC - Automatic Dispensing Cabinet, CPR-Cardiopulmonary resuscitation, CC - Close calls, ET – Education & Training, EPS - Electronic Prescribing System, HIT– health Information Technology, *HAM – High Alert Medications, HIV- Human Immunodeficiency virus, HDP - Hospital Drug Formulary, ICU - Intensive care unit, *ISMP – Institute of Safe Medication Practice, *JC – Joint Commission, KSMC – King Saud Medical City, *LASA – Look alike and Sound alike, MAP - Medication-related Action Plan, MEs - Medication errors, MR - Medication Reconciliation, MSU - Medication Safety Unit, MSC - Medication Safety Committee, MSCs - Medication Safety Coordinators, MUS – Medication Use System, NMs - Near misses, PMR - Personal Medication Record, P&TC - Pharmacy and Therapeutic Committee, RCA - Root Cause Analysis,

Reference

1. Aljadhey H, Mahmoud MA, Hassali MA, Alrasheedy A, Alahmad A, Saleem F et al. Challenges to and the future of medication safety in Saudi Arabia: A qualitative study. Saudi Pharm J. 2014; 22: 326–32.
2. Al-Dhawailie AA. Inpatient prescribing errors and pharmacist intervention at a teaching hospital in Saudi Arabia. Saudi Pharm J. 2011; 19: 193–6.
3. Al-Jeraisy MI, Alanazi MQ, Abolfotouh MA. Medication prescribing errors in a pediatric inpatient tertiary care setting in Saudi Arabia. BMC Res Notes. 2011; 4:294. doi: 10.1186/1756-0500-4-294.
4. Alkhani S, Ahmed Y, Bin-Sabbar N, Almogirah H, Alturki A, Albanyan H et al. Current practices for labeling medications in hospitals in Riyadh, Saudi Arabia. Saudi Pharm J. 2013; 21: 345–9.
5. Aljadhey H, Alhossan A, Alburikan K, Adam M, Murray MD, Bates DW. Medication safety practices in hospitals: A national survey in Saudi Arabia. Saudi Pharm J. 2013; 21:159–64.
6. Al-Zaagi IA, Al-Dhwaihi KA, Al-Dossari DS, Salem SO, Qureshi NA. Analysis of reported e-prescribing near misses in King Saud Medical City, Riyadh. Integrated Pharm Res Pract. 2013:217–24.
7. Al-Dossari DS, Al-Zaagi IA, Al-Saud SD, Al-Bedah AM, Qureshi NA. A Comparative Analysis of Electronic Prescribing Near Misses in King Saud Medical City, Riyadh, Saudi Arabia. Brit J Pharm Res. 2014; 4(9):1088-104.
8. Qureshi NA, Al-Dossari DS, Al-Zaagi IA, Al-Bedah AM, Abdualli A, Koenig H. Electronic Health records, electronic prescribing and medication errors: A systematic review of literature, 2000-2014. Brit J Med Medical Res 2015; 5: 672-704.
9. Lederman R, Dreyfus S, Matchan J, Knott JC, Milton SK. Electronic error-reporting systems: A case study into the impact on nurse reporting of medical errors. Nurs Outlook. 2013; 61(6), 417-426 e5.
10. Qureshi NA, Al-Bedah A, Koenig HG. Handwritten to Electronic prescribing: emerging views and practices. Brit J Med Medical Res. 2014; 4: 4607-26.
11. Larizgoitia I, Bouesseau M-C, Kelley E. WHO Efforts to Promote Reporting of Adverse Events and Global Learning. J Public Health Res. 2013; 2(3):e29. doi:10.4081/jphr.2013.e29.

12. Kruer RM, Jarrell AS, Latif A. Reducing medication errors in critical care: a multimodal approach. Clin Pharmacol. 2014; 6:117-26.
13. Alsulami Z, Conroy S, Choonara I. Medication errors in the Middle East countries: A systematic review of the literature. Eur J Clin Pharmacol. 2013; 69: 995-1008.
14. Al-Zaagi IA, Al-Dossari DS, Salem SO, Qureshi NA. Medication Safety Unit Programs in King Saud Medical City, 2012 – 2013: Safe Medication Management and Use with a Focus on Patient Safety 2015. Brit J Med Medical Res. 2015; 8: 384-407.
15. Garcia-Hejl C, Chianéa D, Dedome E, Sanmartin N, Bugier S, Linard C et al. Internal audit in medical laboratory: what means of control for an effective audit process? Ann Biol Clin (Paris). 2013; 71 (5): 615-24.
16. Brook OR, Kruskal JB, Eisenberg RL, Larson DB. Root Cause Analysis: Learning from Adverse Safety Events. Radiographics. 2015; 35(6): 1655-67.
17. Quraishi SA, Kimatian SJ, Murray WB, Sinz EH. High-Fidelity Simulation as an Experiential Model for Teaching Root Cause Analysis. J Grad Med Educ. 2011; 3(4): 529-34.
18. Williams PM. Techniques for root cause analysis. Proceedings (Baylor University Medical Center). 2001; 14(2): 154-57.
19. AHRQ Patient Safety Network. Available at https://psnet.ahrq.gov/primers/primer/10/root-cause-analysis. Accessed on December 12, 2015.
20. The Joint Commission. Framework for conducting a root cause analysis and action plan. http://www.jointcommission.org/Framework_for_Conducting_a_Root_Cause_Analysis_and_Action_Plan/. Retrieved on October 8, 2015.
21. Hellebek A, Skjoet P. Aggregated review of route cause analyses related to medication. Stud Health Technol Inform. 2010; 157: 15-7.
22. Braithwaite J, Westbrook MT, Mallock NA, Travaglia JF. Experiences of health professionals who conducted root cause analyses after undergoing a safety improvement programme. Qual Safe Health Care. 2006; 15(6): 393-99.
23. Boyer MM. Root cause analysis in perinatal care: health care professionals creating safer health care systems. J Perinat Neonatal Nurs. 2001; 15(1): 40-54.

24. Doggett AM. A Statistical Comparison of Three Root Cause Analysis Tools. J Indust Technol. 2004; 20(2): pp9. Available at: http://c.ymcdn.com/sites/www. atmae.org/ resource/resmgr/JIT/doggett010504.pdf. Retrieved on October 12, 2015.
25. Saferpak.com. Basic tools for process improvement. Available at: http://saferpak.com/ cause_ effect_articles/howto_cause_effect.pdf. Retrieved on November 17, 2015.
26. Chung KC, Kotsis SV. Complications in Surgery: Root Cause Analysis and Preventive Measures. Plast Reconstr Surg. 2012; 129(6):1421-27.
27. Uberoi RS, Gupta U, Sibal A. Root Cause Analysis in Healthcare. Apollo Med. 2004; 1 (1): 60–63.
28. Vincent CA. Analysis of clinical incidents: a window on the system not a search for root causes. Qual Saf Health Care. 2004; 13: 242-43.
29. Helms MM, Moore R, Ahmadi M. Information Technology (IT) and the Healthcare Industry: A SWOT Analysis. Int J Healthc Inf Syst Inform. 2008; 3(1): 75-92.
30. American Pharmacists Association; National Association of Chain Drug Stores Foundation. Medication therapy management in pharmacy practice: core elements of an MTM service model (version 2.0). J Am Pharm Assoc. 2008; 48(3): 341-53.
31. World Health Organization. Reporting and learning systems for medication errors: the role of pharmacovigilance centres. Available at: http://apps.who.int/iris/bitstream/10665/ 137036/1/9789241507943_eng.pdf. Retrieved on July 25, 2016.
32. Solberg LI. Improving Medical Practice: A Conceptual Framework. Ann Fam Med.. 2007; 5(3): 251-56.
33. European Medicines Agency. Good practice guide on recording, coding, reporting and assessment of medication errors. Available at :http://www.ema.europa.eu/ docs/en_GB/ document_library/Regulatory_and_procedural_guideline/2015/11/WC500196979.pdf. Retrieved on June 20, 2016.
34. Academy of Managed Care Pharmacy. AMCP's Framework for Quality Drug Therapy. Available at: http://www.fmcpnet.org/index.cfm?p=132D8447.Retrieved on June 20, 2016.
35. Coombes ID, Heel ACY, Stowasser DA, Reid CM, Henderson A, Mitchell CA. Identification of medication errors by nurses during a simulated ward, medication safety orientation program. J Pharm Pract Res. 2005; 35: 190-94.

663 36. Chadwick M. Look-alike sound-alike health product names. Health Canada Workshop,
664 2003, October 20.
665 37. The Joint Commission on Accreditation of Healthcare Organizations. The Joint
666 Commission Announces the 2007 National Patient Safety Goals and Requirements. Joint
667 Commission Perspective 2006; 26: 1-31.
668 38. The Institute of Safe Medical Practices. ISMP's List of High Alert Medications. 2012.
669 Available at: www.ismp.org/tools/highalertmedications.pdf. Retrieved on May 21.
670 39. Leape LL. Preventing adverse drug events. Am J Health Syst Pharm. 1995; 52: 379–82.
671 40. Institute for Safe Medication Practice. ISMP's List of Confused Drug Names. Available
672 at: http://www.ismp.org/Tools/confuseddrugnames.pdf. Retrieved on June 10, 2016.
673 41. Patient Safety First. Available at: http://www.institute.nhs.uk/safer_care/general/ patient_
674 safety_first.html**.** Retrieved on May 30, 2016.
675 42. Aronson JK. Medication errors: definitionsand classification. Brit J Clin Pharmacol.
676 2009; 67 (6): 599–604.
677 43. Aronson JK. Medication errors: what they are, how they happen,and how to avoid them.
678 Qual J Med. 2009; 102: 513–21.
679 44. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The
680 Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)
681 Statement: guidelines for reporting observational studies. Bull World Health Organ.
682 2007; 85: 867–72.
683 45. Reason J. Beyond the organisational accident: the need for “error wisdom” on the
684 frontline. Qual Saf Health Care. 2004; 13(Suppl II): ii28-33.
685 46. Peerally MF, Carr S, Waring J, Dixon-Woods M. The problem with root cause analysis.
686 BMJ Qual Saf. 2016. pii: bmjqs-2016-005511.doi: 10.1136/bmjqs-2016-005511.
687 47. Ciociano N, Bagnasco L. Look alike/sound alike drugs: a literature review on causes and
688 solutions. Int J Clin Pharm. 2014; 36 (2): 233-42.
689 48. Coventry TH, Maslin-Prothero SE, Smith G. Organizational impact of nurse supply and
690 workload on nurses continuing professional development opportunities: an integrative
691 review. J Adv Nurs. 2015; 71(12): 2715–27.

49. Academy of Managed Care Pharmacy. The Academy of Managed Care Pharmacy's Concepts in Managed Care Pharmacy. Academy of Managed Care Pharmacy Medication errors.pdf. Retrieved on June 12, 2016.
50. White R, Cassano-Piché A, Fields A, Cheng R, Easty A. intravenous chemotherapy preparation errors: Patient safety risks identified in a pan-Canadian exploratory study. J Oncol Pharm Pract. 2014; 20(1): 40–46.
51. Helmons PJ, Coates CR, Kosterink JGW, Daniels CE. Decision support at the point of prescribing increases formulary adherence. Available at: http://www.rug.nl/research/ portal/files/3668356/Helmons_thesis.pdf!null#page =78. Retrieved on July 17, 2016.
52. Bridges DR, Davidson RA, Odegard PS, Maki IV, Tomkowiak J. Interprofessional collaboration: three best practice models of interprofessional education. Med Educ Online. 2011; 16: 10.3402/meo.v16i0.6035. doi:10.3402/meo.v16i0.6035.
53. Clifford SP, Mick PB, Derhake BM. A Case of transfusion error in a trauma patient with subsequent root cause analysis leading to institutional change. J Investig Med High Impact Case Rep. 2016: 1–4. DOI: 10.1177/2324709616647746.