|| ISSN(online): 2589-8698 || ISSN(print): 2589-868X ||
International Journal of Medical and Biomedical Studies
Available Online at www.ijmbs.info
NLM (National Library of Medicine ID: 101738825)
Index Copernicus Value 2019: 79.34
Systematic Review Volume 5, Issue 6; June: 2021; Page No. 26-43

THE IMPACT OF BARCODE MEDICATION ADMINISTRATION ON PATIENT SAFETY: A SYSTEMATIC REVIEW

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Article Info: Received 07 February 2021; Accepted 20 May 2021
DOI: https://doi.org/10.32553/ijmbs.v5i6.1951
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Conflict of interest: No conflict of interest.

Abstract
Patient safety is considered as an essential feature of healthcare system. Many trials have been conducted in order to find ways to improve patient safety, and many reports indicate that medication errors pose a threat to patient safety.
Thus, some studies have investigated the impact of bar code medication administration (BCMA) system on medication error reduction during the medication administration procedure.
This systematic review (SR) reports the impact of BCMA system on reducing medication errors to improve patient safety; it also compares traditional medication administration with the BCMA system. The review concentrates on the effectiveness of BCMA technology on medication administration errors, and on the accuracy of medication administration. This review also focused on different designs of quantitative studies, as they are more effective at investigating the impact of the intervention than qualitative studies.
The findings from this systematic review show various results depending on the nature of the hospital setting. Most of the studies agree that the BCMA system enhances compliance with the 'five rights'' requirement (right drug, right patient, right dose, right time and right route) of medication administration. In addition, BCMA technology identified medication error types that could not be identified with the traditional approach which is applying the 'five rights' of medication administration. The findings of this systematic review also confirm the impact of BCMA system in reducing medication error, preventing adverse events and increasing the accuracy of the medication administration rate. However, BCMA technology did not consistently reduce the overall errors of medication administration.
Keyword: Patient Safety, Impact, BCMA, eMAR

1. Introduction:

Losing someone is a traumatic and overwhelming event, yet realising that their death was not inevitable makes it even more upsetting. Mistakes in medication can lead to injuries or, in certain cases, can even cause death, and they are avoidable (Wittich, Burkle and Lanier 2014).
Medication errors are frequently defined as an avoidable event, which can bring about or result in unsuitable medications being used or patients being harmed while healthcare professionals or consumers are in charge of their medication (Hughes and Blegen 2008). These events can be linked to several factors: professional procedures and practices; healthcare products; systems and processes, including prescribing; communication issues; labelling, packaging and classification of products; dispensing, distributing and administrating of products; and poor education and supervision (Ibid).
The figures concerning medication error in England are shocking; more than 22,000 deaths each year are a direct result of medication error (Gallagher 2018). Moreover, The Institute of Medicine 2000 (US) and the National Patient Safety Agency 2004 (UK), both report that medication errors harm patient safety and risk their lives (Williams 2007). Medication errors have many potential consequences, including far longer hospital stays, higher economic costs and a greater likelihood of death (Classen et al. 1997). The National Quality Forum and the National Priorities Partnership state that medication errors cost the US healthcare system more than $21 billion each year (Andel et al. 2012).
According to the World Health Organisation, the most straightforward definition of patient safety is the avoidance of mistakes and their harmful effects on patient's health. Patient safety is a sensitive domain, which concerns cultural, practical and psychological issues that require careful consideration; it is a fundamental goal of healthcare providers (Aggrawal et al. 2010). Despite this, patient safety presents a challenge for all countries that provide healthcare services, and a large number of patients have been harmed as a result of receiving healthcare (WHO 2016).
There are various initiatives concerning patient safety in the UK, one of which is the concept of 'the Never Events', which includes the administration of medication by the wrong rote (NHS 2018).
Medication errors can happen for a wide range of reasons; for example, the medications could have names or packaging which resembles each other.
Moreover, they may not be frequently prescribed or used; they could provoke allergic reactions in significant numbers of people (antibiotics, opiates, non- steroidal anti-inflammatory drugs). Also, medications which must be tested, to make sure that the correct (non-toxic) therapeutic levels are kept up (Warfarin, lithium, theophylline and

digoxin) (Hughes and Blegen 2008). However, these factors can be eliminated by applying the 'five rights' of medication administration: right patient, right drug, right dose, right route (Jones 2009).

Despite these rights, medication administration errors still occur, often because the 'five rights' are procedural goals for safe medication administration practice; they focus on the performance of the individual practitioner but do not consider the multidisciplinary efforts in the medication administration process (Grissinger 2010). This will be explained in detail in the background section.

Technology plays a crucial role in reducing medication administration errors and improving patient safety (Kaushal et al. 2001). Some studies have shown that the BCMA technology can improve patient safety by reducing medication errors (Johnson et al. 2002; Koppel et al. 2008; Marini and Hasman et al. 2009).

Therefore, the following chapter provides background information relating to BCMA technology as well as the aim and justification for this systematic review.

1.1 Background literature

One of the most common threats to patient safety issues is medication error, according to the Agency for Healthcare Research and Quality (Citty et al., 2017). In order to ensure that medication is administered safely, the five rights have to be checked: right patient, right dose, right drug, right time and right route (Grissinger 2010). However, a significant number of mistakes, including lethal errors, continue to occur when practitioners think that they have checked the five rights prior to administering the medication (HealthIT 2014). This raises the question how this can be the case, given the five rights that healthcare professionals must check. However, this argument overlooks the fact that drug safety is subject to a process, which involves a number of professionals from different disciplines; thus, both healthcare professionals, as well as the health care system, are involved in ensuring the safety of drug administration.

Sometimes, the medical team does not check the five rights accurately, and this can occur if there is poor lighting, an insufficient number of staff, badly designed medical devices, handwritten information, missing trailing zeroes (for example

2.0 vs 2), and missing initial zeros (for example .2, rather than 0.2). If these orders are not understood correctly, it could result in doses being ten times higher; drug labels could be confused; and in ineffective double-check system for drugs subject to a high alert, which should be independently checked (Grissinger 2010).

Recently, some projects and studies have focused on a technology called the BCMA system which can help to reduce medication errors and increase patient safety (Thompson et al. 2018; Koppel et al., 2008; Johnson et al. 2002). The Veterans Affairs VA Medical Centre in Topeka, Kansas, developed the BCMA system in 1995, and this was rolled out across the US in 2000 (Johnson et al. 2002; Department of Veterans Affairs 2004).

Since the BCMA was first developed, the Veterans Healthcare Administration (VHA) continuously modified and upgraded the BCMS to meet the general needs of users (Ibid). Health IT (2015) defined the BCMA system as an inventory control system for hospitals, which distributes prescription medication according to barcodes in order to make sure that patients are given the right medication. According to Agrwal and Glasser (2009), using the BCMA system is important to supporting medication safety, since it ensures that medication is not administered until the five rights have been checked.

The system can ensure the five rights because it verifies that the right medication was ordered, it was administered at the right time, the right dosage was measured, and the actual administration of the medication was documented appropriately (Gummper et al. 2009). The medication administration process using BCMA technology starts when the nurse scans the patient's ID, and their profile shows up on the screen, which shows all of the patient's medications, the time they should be taken and the dosage amount. Once the medications are given to the patient, the nurse will record it (Holden et al. 2013).

According to Wideman, Whittler and Anderson (2005), the BCMA system upgrades the accuracy of medication administration, since users can record and update medication records electronically.

The work of Keohane et al. (2008) reveals that BCMA technology can reduce specific types of errors, such as prescribing unauthorised drugs, administering the wrong medication, using the wrong medication forms, mistakenly administering an extra dose, or making an omission.

The Institute of Medicine has drawn attention to the fact that between 44,000 and 98,000 Americans die each year because of medical mistakes (Wideman, Whittler and Anderson 2005). Therefore, in 2004, the US Food and Drug Administration (FDA) demanded that medication manufacturers apply barcodes to medications (Marini et al. 2010). The FDA suggested that the aim was to prevent nearly 500,000 adverse events (ADEs) and transfusion errors (FDA, 2004).

Medication management standards and the national patient safety goals set by the joint commission require hospitals to have a plan for implementing barcode technology for matching patient identification to their medications (Foote and Coleman 2008). Sakowsik and Ketchel (2013) calculated the cost of applying the BCMA system over five years and found that including electronic pharmacy management and drug repackaging the cost was $40,000 per BCMA per bed and

$2000 per harmful error prevented. Therefore, they concluded that BCMA is an effective and cost-saving tool for avoiding patient harm and costs associated with medication errors.

Some studies have utilised a BCMA system alongside other tools or technologies to achieve better results in terms of reducing medication errors. For instance, Paoletti et al. (2007) used BCMA technology and a medication

observation methodology, plus electronic medication administration records (eMAR), as a multidisciplinary, collaborative approach for safer medication administration; they observed a 54% reduction in medication administration errors after implementation. Similarly, Franklin et al. (2007) carried out a direct observation study, based on comparing before and after findings, in a 28-bed surgical ward of a London teaching hospital. The authors assessed the effectiveness of a closed- loop medication administration computerised prescriber order entry (CPOE), automated dispensing devices (ADDs) and BCMA on medication administration errors and prescribing errors. They found a statistically significant fall in non-IV medication administration errors—from 7.0% to 4.3% (an absolute difference of 3.7%, 95% CI-0.9% to -4.5% p=0.005)—once a closed-loop medication administration system had been put in place.

All of the medication errors leading to adverse drug events place patients at risk, and this increases the patient's length of stay by approximately four to six days (Bates et al. 1997). Luckily, it is possible to prevent a large number of medication errors from occurring, and healthcare information technology systems, such as the BCMA system, are becoming more widespread and are increasingly being seen as practical and feasible (Bates and Gawande 2003). The BCMA system is highly recommended to reduce the medication administration error rate (Cummings et al. 2005). This study has been designed to consider the effectiveness of BCMA in preventing medication errors.

1.2 Justification of the review

Recently, a number of researchers have evaluated the experience of implementing a BCMA system (Johnson et al. 2002; Koppel et al., 2008; Marini and Hasman et al., 2009). However, unfortunately, the studies have not been integrated and amalgamated, which would allow for important conclusions to be drawn from the studies. A preliminary search of databases—including CINAHL, Web of Science, MEDLINE and EMBASE—was undertaken to look for relevant reviews.

Very few reviews looking into the BCMA's effectiveness at improving patient safety were found. Nevertheless, all of the reviews targeted a specific sample or specific design and achieved different outcomes. In addition, the latest systematic review evaluated the BCMA system alongside other technology, such as CPOE and ADDs, but it excluded any studies that did not include the specified complementary technologies (CPOE and ADD). Conversely, this systematic review includes all studies that focus on the BCMA system in isolation. Therefore, this review is needed to summarise all of the studies that investigate the effect of the BCMA system in different hospital settings and among different populations. The reviewer believes that, to date, no systematic review has been produced on the experiences of implementing the BCMA in terms of its impact on patient safety.

The author sets out to investigate this subject and bases this systematic review on evidence which will be useful to clinicians as well as to individuals or teams involved in creating guidelines for the BCMA.

1.3 Identifying the research question

This review aims to answer the following question: Does the BCMA system improve patient safety? The findings and conclusions of the review, as well as its detailed and comprehensive information, will be of help to anyone considering implementing BCMA technology, with the aim of improving patient safety.

1.4 The systematic review protocol

Korhonen et al. (2013) and Yoshii, Plaut and McGraw (2009) state that a review protocol has to be established before undertaking a review and searching for sources, since helps reduce potential bias at the selection stage. A protocol for this review was created before the review, see Appendix I.

1.5 Dissemination of Result

The findings of this dissertation are valuable and will be published as it highlights a number of helpful studies conducted in various clinical setting. However, before publishing the review, a second reviewer will be included to increase the validity and reliability of the study, which was not possible currently as it is a master's thesis.

1.6 Overview of the dissertation

This systematic review is a synthesis of empirical quantitative studies that cover the impact of the BCMA technology on patient safety by reducing medication administration errors. By utilising a variety of databases, this systematic review evaluates 10 quantitative studies that identify the effectiveness of the BCMA system in terms of reducing the rate of medication administration in order to improve healthcare quality and patient safety. The review is divided into five chapters. Chapter one presented the background to the review—namely, information on the BCMA system, the justification for the research and the study's aims and objectives. Chapter two sets out the methodology chosen for this systematic review. Chapter three illustrates the search results, and chapter four discusses the findings of the review and identifies its strengths and limitations.

Finally, chapter five concludes the review and makes a number of recommendations based on the findings.

Methodology:

2.1 Overview

According to the Joanna Briggs Institute (JBI), the study of the effectiveness of any implementation should be based on quantitative evidence, which is acquired by research based on typical scientific methods that result in numerical data (JBI, 2009). Furthermore, the methods of quantitative evidence in healthcare have been developed by studying the natural and social sciences (Ibid). Therefore, the following

section will discuss the methods and processes utilised for conducting this systematic review.

According to the JBI (2019), there are seven stages involved in conducting a systematic review: 1/review question, 2/inclusion and exclusion criteria, 3/search strategy, 4/selection of the studies, 5/critical appraisal, 6/data extraction and 7/data synthesis. This strategy was adopted in this review because JBI is one of the international leaders in evidence-based healthcare (Pearson et al. 2007).

2.2 Review question

Framing a research question is the first step in a systematic review, and it should be a clear and an explicit statement of the review question (Journal of the Royal Society of Medicine 2003; JBI 2019). Moreover, the interest of the review should be clear for the reader. According to the literature, there are some factors that stimulate the attention of practitioners in identifying a researchable question, which includes data evaluation, patients' concerns and satisfaction (Rosswurm and Larrabee 1999; Fineout et al. 2005). The most imperative is the review question, which is important for helping to get the best evidence relative to the clinical problem (MacPhee and Pratt 2005). Subsequently, the research question should be well structured and apply the PICO framework.

According to Stone (2002), 'a clear answerable question' has four elements that are widely used: the patient, population or problem (P); the intervention or independent variable (I); the comparison I; and the dependent variable or outcome (O). These four basics are known by the abbreviation of PICO. According to the BMJ (2009), the PICO framework should help the readers of the review, as often it is time-consuming to find the required studies; thus, this technique can make it easy for the busy practitioner to keep up to date with the literature, as well as help this kind of paper to find the way to clinical practice as soon as possible. Since this paper seeks to uncover the effect of BCMA on patient safety, the PICO will be used in the following way:

P(Population): inpatients I(Intervention): BCMA technology

C(Comparison): usual medication administration practices
O(Outcome): improve patients' safety and reduce harm
This step connects to the next step, which is the inclusion and exclusion criteria; thus, if this step is performed in a systematic way, it will make the next step clearer.

2.3 Inclusion criteria

The inclusion and exclusion criteria are an important element of any systematic review because all of the following steps rely on the determined eligibility of these criteria. The inclusion and exclusion criteria are based on the population, the intervention and the outcome. This means that all studies should meet the PICO outlined in the previous section (JBI 2009). In addition, the search should be conducted in written studies in the English language, considering the date of publication of the articles or journals. Consequently, this systematic review looks at quantitative studies published between 2000 and 2019; studies published prior to 2000 were excluded. According to Hanney et al., this time period is sufficient for health studies, as health and science experiments can take a long time. As well from 2000 onwards, many hospitals have adapted and developed the BCMA system (Patterson et al. 2004: Wideman et al. 2005).

In addition, all quantitative studies were included. According to Haase (2011), effectiveness questions are best answered with the use of quantitative studies. Therefore, in this systematic review, a range of random quantitative studies regarding improving patients' safety through BCMA was considered—for example, cohort studies as well as cross-sectional, randomised and non-randomised control trials. The search focused on articles focusing on BCMA as an intervention and its results relative to patient safety; any studies looking at BCMA as an intervention but with a different interest of outcome were excluded. In addition, all qualitative study designs were avoided because this paper aimed to determine the effect of the intervention by reflecting on the measures. Mixed-method studies were also included but only for their quantitative data in order to avoid mixed results, since this review focused only on pure statistical findings to seek a more rigorous result and conclusion.

The inclusion principles covered the healthcare professionals who administer medication to a population or to participants since according to Aronson (2009), the probability of patient harm increases from the point of medication administration. Besides that, hospitalised patients of any age and gender were considered as participants in this study because of their need for medication administration. In addition, all inpatient health settings were included. However, the focused intervention was limited to introducing BCMA. The outcome of the included studies focused on medication error rate, adverse effects, and preventing patient harm, all of which aimed to improve patient safety.

Furthermore, the inclusion criteria were not limited to any health setting in any country. The inclusion criteria are summarised in Table 2.1. Papers are included if they met all the inclusion criteria and if it is not met the inclusion criteria will be excluded.

Table 2.1: Summary of the inclusion criteria

Population or participants and conditions of interest	Healthcare professionals who administer medication Hospitalised patients Patients of any age or gender
Interventions or exposures	Implement BCMA
Comparisons or control groups	Anyone who has been admitted to a hospital or any health clinic without a barcode wristband
Outcomes of interest	Medication error rate
Setting	Hospital Health clinic Secondary care
Study design	Any quantitative studies

2.4 Search strategy

Numerous studies have highlighted that systematic reviews should adapt all evidence related to the research question by using reproducible search strategy (Erwin et al. 2011; Thorme et al. 2004; Baroso et al. 2003). Therefore, this systematic review utilised all reasonable search strategies—for example, conducting manual searches in different books and looking for all published evidence that met the inclusion criteria regarding the impact of BCMA on patient safety. This section will highlight the search process, key terms, information source and chosen limits.

In order to conduct a comprehensive search strategy, the key terms and MesH headings were used in the important databases—MEDLINE, OvidSP and CINAHL Plus—to get an idea and look for synonyms as well to develop the key terms.

Then, the search was expanded to other databases so that a total of four databases were searched: MEDLINE, OvidSP, CINAHL Plus, EMBASE and web of science. Electronic searches were performed in all these databases, with manual searching of articles to confirm that all relative evidence was involved. In addition, grey literature was also searched to increase the range of evidence.

Thus, ProQuest and Mednar were utilised to search for E-dissertations and unpublished papers. These databases were used because they contain a huge number of international medical and health science articles and journals and they are continuously updated and added to (Chapman 2009).

Articles published between 2000 and 2019 were searched for in the databases. The key terms were chosen according to the inclusion criteria and PICO; different spellings were also considered (British and American English) and as were abbreviations, for example, bar code, barcode or bar-code. The terms were linked together by "OR" if they had a similar meaning or by "AND" to link the terms with another keyword. The search strategy regarding the impact of BCMA on patient safety-focused not only on the article's title but also on the abstract to get an idea about the article's aims. Details of the search strategy of the databases are provided in Appendix II. In addition, the reference sections for the chosen studies were also searched to look for any studies that met the inclusion criteria but were not identified during the search strategy. Furthermore, EndNote was utilised to save all the search results.

2.5 Selection of studies

According to the work of Meline (2006), the selection of studies for a systematic review is a complex process comprising of many steps; the most important step in this process is to determine the inclusion and exclusion criteria. Based on that, the study selection was performed with the inclusion eligibility criteria discussed above (Table 1). The Preferred Reporting Items for Systematic Review and Meta- Analysis (PRISMA) framework was utilised to explain the plan for selecting the studies. According to Moher et al. (2009), PRISMA is used as a recording strategy in systematic reviews to reflect on other studies. This approach was used to organise and to display the details of the selection method.

First, the titles and abstracts found through the database search or the manual search were screened, and any study that did not match the inclusion eligibility was excluded. Furthermore, any duplicate studies were removed at the eligibility stage. The duplication studies were removed using EndNote and to make sure they were reviewed again; decisions concerning the inclusion or exclusion of articles were recorded on an Excel sheet. Then, the text of all the remaining studies was assessed in detail. Afterwards, any studies that did not match the inclusion outlined (Table 2.1) were excluded, and the reasons for exclusion were provided, with all other papers that met the inclusion eligibility selected for review. The following PRISMA flowchart (Figure 1) was used to conduct this systematic review. Referring to the JBI (2009), the study selection should be performed by two or more independent researchers.

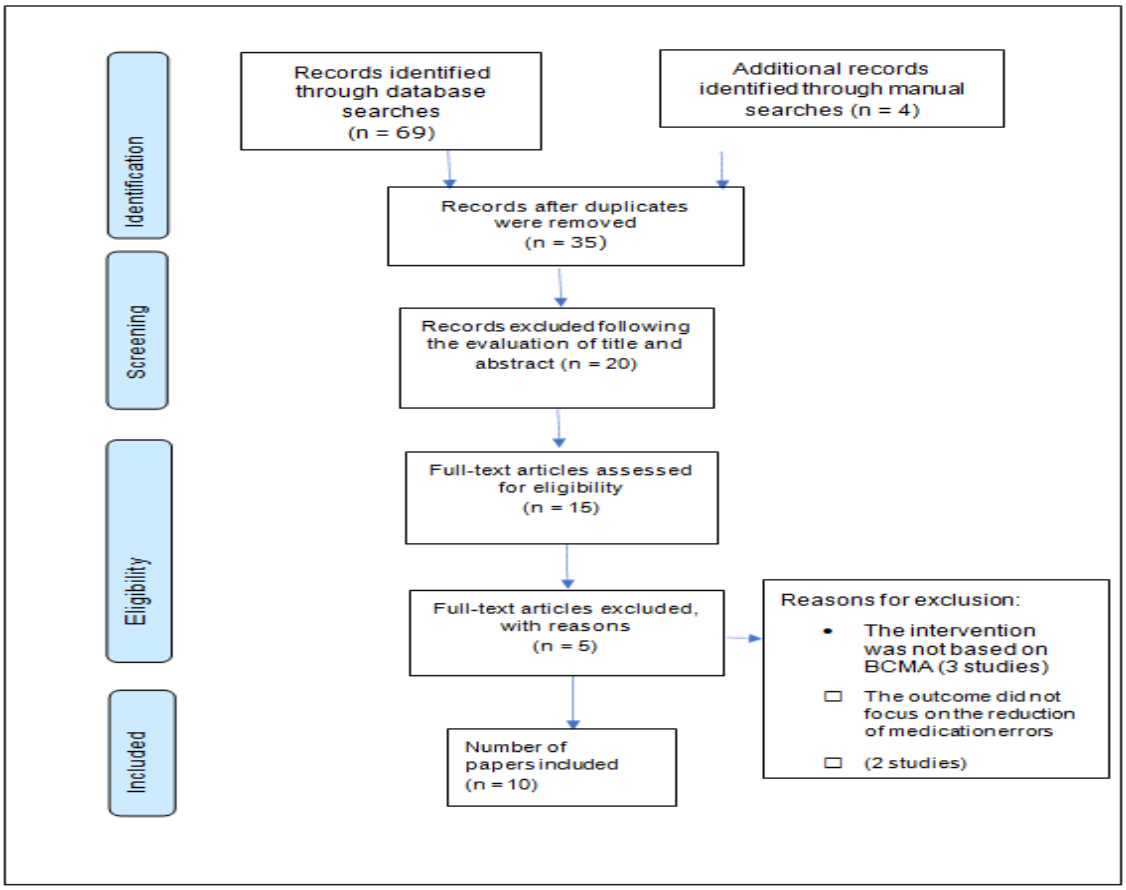

Figure 1: PRISMA flow diagram

2.6 Assessment of the methodological quality of the selected study

The critical appraisal of the studies contained within a systematic review should be performed with the explicit goal of classifying the risk of diverse systematic errors in the design, conduct and evaluation of quantitative literature that could affect the validity of the results of the selected studies (JBI, 2009). The quality and reliability of evidence provided from systematic reviews are dependent on the quality and results of the contributing primary studies (Growther and Cook, 2007; Garg, Hackam and Tonelli 2008). The assessment of the methodological quality of studies is a controversial topic, as the debate surrounds what criteria should be applied and whether a quality assessment is even suitable (Seale, 1999; Sparks, 2001; Hannes, Lockwood and Pearson, 2002; Walsh and Downe, 2006; Noyes et al. 2011).

However, there are many approaches to assessing the quality of quantitative studies. For instance, the critical appraisal skills programme (CASP) uses various tools for different studies, such as systematic reviews, randomised controlled trials, cohort studies, case-control studies, qualitative studies, clinical prediction rules and economic evaluation (Butler, Hall and Copnell, 2016). The Jadad scale is another critical tool for reporting randomised controlled trials (Halpern and Douglas, 2005). However, it was not used for this review due to the inclusion eligibility, which is not limited to randomised controlled trials but for all types of quantitative designs. Another tool that is widely used in quantitative studies is known as the JBI tool. According to Hannes et al. (2010), the JBI tool appears to be more sensitive to aspects of validity than CASP because it includes an evaluation plus outcome criterion and facilitates the evaluation of interpretive and theoretical validity. For this reason, the JBI tool was utilised in this review to critically appraise the quality of the selected studies, as it is best to evaluate all studies by the same scale. Moreover, the JBI was selected as it was considered to be better than other appraisal tools in assessing the methodological quality (Hannes, Lockwood and Pearson, 2010).

There are several sorts of JBI critical appraisal tools, and the appropriate types have been chosen to critique the selected quantitative studies under consistent criterion. Specifically, the studies involved in this review have used various methods; therefore, five different JBI checklists were used for these studies—for example, checklists for prevalence studies, cross-sectional analytical studies, cohort, non-randomised controlled trials and randomised control trials (JBI, 2009).

Each checklist consists of eight to 11questions regarding the methodological quality, measurements and results and findings of the primary studies, with ‘yes’, ‘no’, ‘unclear’ or ‘not-applicable’ answers for these questions. The 'yes'

answer receives a score, and then the scores for each paper are totalled to give a grade of the overall paper quality. In general, the methodological quality assessment aims to determine the quality of the selected paper and to identify the strengths and limitations of the included evidence rather than to exclude any studies (JBI,2019). However, this assessment led to a more transparent discussion and analysis; it also highlighted any major defects in the quality of the selected study quality. In addition, the appraisal of the methodological quality of studies is helpful to identify the level of confidence in the review findings (Noyes et al.
2018). The assessment of the methodological quality of the selected studies was performed by one assessor, which was checked by the supervisor, who provided an independent review of the ratings; an agreement was then reached. There are examples regarding the JBI checklist for cohort studies provided in appendix III.

2.7 Data extraction

The process of extracting data from the included studies is one of the most important steps, as the systematic review extends beyond the subjective traditional literature review (Munn, Aromataris and Tufanaru, 2014). In this step, all of the key methodological elements of the evidence affecting the findings of evidence evaluation were extracted. Therefore, the data extracted were related to the impact of BCMA as an intervention to reduce patient harm by preventing ADEs or by reducing medication errors to improve patient safety. This was done after reading the full text of the selected studies several times to identify the crucial information and by utilising a consistent, pre-piloted method to extract data from quantitative evidence to evaluate the quality of the studies and their synthesis of information (Free et al. 2010).

Thus, the JBI summary tool was used as a standardised data extraction tool to abstract specific details about the included evidence (please see Appendix IV). The most important information of the quantitative studies should be significantly classified in the extraction form—for instance, the aim of the study, the implementation of BCMA to enhance patient safety, the study design, the sample size (either inpatient number, medication administration or rate of error reports for prospective studies) and the information showing how these studies measure the impact of BCMA among different health settings. In addition, the data collection technique and the results of the intervention should be considered in the data extraction form.

The data should be extracted to assist researchers in determining the generalisability of the results (Munn, Aromataris and Tufanaru, 2014). In addition, it helps the reviewers to organise the information and refer to similarities and differences in the data in order to interpret the findings during the data synthesis step (Ibid). The extracted data should include the reliability and validity of the methods used to obtain the outcome of the selected study. These extracted data have been reviewed by two people individually. In Appendix V, there is a table presenting the data extraction form used in this review.

2.8 Data synthesis

According to the JBI (2009), there are two ways to effectively synthesise data in a systematic review: one is a meta-analysis, and the other is a narrative approach. A meta-analysis combines the statistical results of multiple studies that address the review using the same measurement method. However, this procedure was not used in this systematic review because the quantitative studies need to be similar, and the data need to have a high degree of homogeneity. This review uses different types of studies, so a meta-analysis is not appropriate. The other method for data synthesis is a narrative approach. The narrative review is acknowledged as the best approach to synthesise all of the evidence and findings using a written language summarisation (Popay et al.
2006). Furthermore, by comparing the meta-analysis with a narrative one, it is evident that the narrative synthesis delivers an organised summary of several methods of evidence; the meta-analysis, in contrast, requires similar methods or types of study (Ibid).

The selected data were assessed according to the set criteria and JBI tool. All the extracted data were summarised together in a descriptive way to answer the review question (Pearson, Rittenmeyer and Robertson-Malt, 2011). For example, similar results were integrated, identifying the way that led these studies to this result, as well as any differences in these studies which have similar results, for instance, if they had a different study design or data collection method. The participant (sample), data collection, how the data were analysed and the results of critical appraisal were also considered in the data syntheses process. Popay et al. (2006) rightly point out four main elements that need to be mentioned in narrative data syntheses, which are the concept of the intervention which means how the intervention works, why and what are the benefits of the intervention; the finding of the included studies; data relationship and assess the strength of the evidence.

2.9 Summary

This chapter has illustrated the methodology of conducting a systematic review. It has discussed the review findings through the search strategy, described and the rationale for using a narrative approach instead of meta-analysis and concluded with the method of data synthesis. The next chapter will discuss the results of this review in detail.

Results:

3.1 Overview

The findings of the systematic review are presented in this chapter by sectioning the findings into the intervention and hospital setting. The reason for this is because it is helpful to determine the effects of BCMA in various units. For example, paediatric nursing wards are different to adult nursing units because the injection drugs procedure is different to the one involving oral drugs. As well, injecting medication into inpatients is a primary task that requires a specific technique and skills for a safe procedure; thus, there is a possibility of medical errors occurring (Hunter 2008; Greenway 2014, Clancy and Furyk 2012).

Therefore, such a sectioning approach allows all of the hospital settings to be examined to evaluate the effectiveness of BCMA system.

Moreover, this chapter contains a summary of the critical appraisal tool completed to determine a paper's quality. Figures and tables are used where necessary to provide a pictorial presentation of the findings.

3.2 Characteristics of the studies

Ten published quantitative primary studies were included in this review to evaluate BCMA's impact on patient safety. None of these articles were published more than 10 years ago. The majority of the studies (8) were undertaken in the United States of America, whereas the study by Tsai, Sun and Taur (2010) was conducted in Taiwan and the study by Sakushima et al. (2015) was from Japan. Furthermore, different study designs were used in the studies: four prospective cohort studies, two prevalence studies, two quasi-experimental (non-randomised) studies and one cross-sectional study. All of the results and characteristics of these studies are broken down into sectors in the following section.

There are three distinct studies that focus on paediatric units. Two of them were conducted by Morriss et al., the first in 2009 and the second in 2011. These are prospective cohort studies, and the study by Hardmeier et al. is classified as a prevalence study. In these prospective cohort studies, the participants were followed for 19 weeks.

All of these studies sought to investigate the effect of BCMA in reducing harm to neonatal intensive care unit patients (NICU). However, they used various sample sizes. For instance, Morriss et al. (2009) assessed the role of BCMA on 92,398 doses for 958 subjects in NICU, whereas, in Morriss et al. (2011), 618 hospitalised patients in the neonatal NICU were included. The authors here considered the neonates needing opioid drugs because the specific interest of this study was to evaluate the effect of BCMA in ADEs in neonates treated with opioids. Meanwhile, Hardmeier et al.(2014) included three units: two acute care units (ACU) with 36 and 29 beds and one intensive care unit (ICU) for neonates with 51 beds. They utilised the direct observational method to collect their data among other methods. As such, a structured daily audit of each patient's paper and electronic medical records for the preceding 24 hours was used alongside direct observation. Hardmeier et al. (2014) used an incidence reporting system with direct observations to identify different medication administration errors. In addition, the studies found that the observers were specialists or well trained in direct observation. The data were analysed differently in each study. Morriss et al. (2009) utilised SAS statistical software version 9.1.3 (SAS Institute, Cary, North Carolina) as well as Poisson distribution to analyse targeted and preventable ADEs. Meanwhile, in Morriss et al.'s (2011) study, the data were analysed using stratified frequency distribution and Cox proportional hazards.

However, Hardmeier et al.(2014) analysed their data by reviewing medication administration records. All of these records were made using a data collection tool adapted from an observation code sheet developed by the California Nursing Outcomes Coalition (CalNOC). According to Aydin et al. (2004), CalNOC is currently the largest statewide nursing quality database and includes around 150 hospitals. In addition, it also helps to recode and record all the activities which form part of the medication administration process (Ibid).

Similarly, Helmons et al. (2009) have pointed out that CalNOC tool is valuable to reflect on different types of errors because it contains six indicators of medication accuracy. Several of these six indicators have already been validated in other studies which analyse the quality of medication administration once BMCA has been set up and implemented (Greengold et al. 2003; Pattreson et al. 2002; Pattreson et al. 2006).

DeYoung et al. (2009) introduced the BCMA system in an adult medical ICU with 38 beds located in a 744-bed community teaching hospital in order to evaluate its effectiveness in preventing medication errors. The direct observation technique involved 24 hours of collecting the data, and a total of 1,465 medication administrations were observed in 92 patients (775 medications administered in 47 patients before introducing BCMA and 690 administrations in 45 patients after introducing BCMA). Two senior elevators autonomously reviewed the medication errors; data analysis was performed using SPSS version 13.0 for Windows (SPSS, Inc., Chicago, IL), and the inter-rater reliability was assessed using Cohen's Kappa coefficient (k) statistic.

There are a number of studies that have been based on the whole hospital framework to assess the effect of BCMA on patient safety. This review included a non-randomised and two cohort studies that took place in public hospitals.

Thompson et al.'s (2018) study assessed the BCMA's effectiveness in 50 inpatient nursing units, and 500,000 medications were administered during the study period. Similarly, the study by Seibert et al. (2014) took place in two community hospitals with 644 beds and 22,807 annual patients in order to study the effect of the BCMA system with eMARs on the medication accuracy rate. In Seibert et al., the follow-up period was approximately six to twelve months in three phases; phase one was before implementation of the BCMA system, and phases two and three were after the implementation. However, in Thompson et al.'s(2018) study, the intervention was followed-up for 33 months, which was the longest follow-up among all of the cohort studies. In addition, Poon et al. tracked 14,041 medication administrations and reviewed 3,082 order transcriptions because they wanted to study the effect of the BCMA on the safety of medication administration. The three studies used direct observation methods to examine the effectiveness of the BCMA in terms of medication administration error rates.

Thompson et al. (2018) applied the observational technique and collected data monthly through the Midas+ system, which included all events that were reported by nursing staff alongside an observational methodology concerning medication administration errors among the nursing unit.

Seibert et al. and Poon et al. analysed their data by utilising chi-square, and the Yates correction was used to compare the accuracy rate of medication administration before and after implementation of the BCMA-eMAR system. In the study by Thompson et al. (2018), interrupted time series analysis (ITSA) was applied; it incorporated a step-wedge design for barcoding, which was introduced to evaluate the effect on medication-related ADEs.

FitzHenry et al. (2011) assessed the effect of the BCMA in terms of detecting medication error alerts for warfarin orders. This prevalence study was conducted on 2,404 patients that had 18,393 warfarin doses during the study period.

FitzHenry et al. is the only selected study that used a vendor's BCMA log file to track medication error alerts displayed when the nurse administered warfarin. However, adding an observation method can be valuable in tracking medication error alerts (Cronenwett et al. 2007). The data were analysed using R project version 2.10.1 (Institute for Statistics and Mathematics Resources, Wien, Austria) to determine Cronbach's alpha, and Excel 2007 (Microsoft Corporation, Redmond, WA) was used for descriptive analysis. Cronbach's alpha measures reliability and internal consistency (Tavakol et al. 2008). Cronbach's alpha is the most widely used instrument for measuring reliability (Fogg et al. 2001; Tavakol et al. 2011).

However, DeYoung et al. (2009) utilised Cohen's Kappa coefficient to assess inter-rater reliability. Cohen's Kappa measure the inter-reliability when the data rater gives the same score to the same data element (Beker 2000; Blackman and Koval 2000).

A non-randomised study was conducted by Tsai et al. (2010) to compare the working time between the BCMA system and the traditional medication administration system. The study collected data for 51 nurses from neurosurgical wards that were using the BCMA system and 51 nurses from three neurological wards that were using a traditional medication administration record.

A cross-sectional study by Sakushima et al. (2015) was included in this review to evaluate the BCMA system regarding errors associated with injection medication administration based on 2,867 injection drug error reports (1,550 before the BCMA system was implemented and 1,317 after) submitted between 2003 and 2012. A retrospective analysis was conducted on these data. The BCMA's effectiveness was appraised by the number of error reports per year utilising the Mann-Whitney U test. All statistical analyses of this study were conducted using STATA version 12.0 (STATA Corporation, College Station, TX, USA). In addition, the effect of the BCMA was assessed by comparing the rate of annual injection error reports before introducing the BCMA (2003 to 2007) and after (2008 to 2011).

3.3 Summary of quality assessment

There are some factors that affect the quality of the evidence, such as the risk of bias, inconsistent results, imprecision, publication bias, the sample size and indirectness of evidence (Guyatt et al. 2011; Lewin et al. 2015).

In this review, the quality of the studies has been assessed using the JBI tool, and none of the studies were excluded because the purpose was only to highlight the flaws. For all of the included studies, they scored between high and moderate in terms of quality. There was a clear link between the aim of the studies, the utilised methods and the analysis of the data. None of the evidence scored poorly.

However, the confounding factors were not clear in the cohort and cross-sectional studies, but some studies identified these factors as a limitation of the studies, which was the in Thompson et al. (2018), a study which scored 11 out of 11 and was classified as high quality. Yet the questions related to confounding factors had an effect on the score that was given to the quality of the cohort and cross-sectional studies. For example, Seibert et al. received a score of nine out of 11 due to their unclear confounding factors, which was similar in Morriss et al.'s studies (2009 and 2011).

However, in the quality assessment, no weaknesses were identified that could affect the interpretation of these studies in this review. All the prevalence studies were classified as high quality due to the answers. As well, the non-randomised studies got full marks and were also considered as high quality. However, the cross- sectional study got six out of eight due to the lack of clarity surrounding their confounding factors. The quality assessment tables are given in Appendix VI.

3.4 Findings of the study

This section presents the finding of BCMA effectiveness in these areas: paediatric hospital settings, ICU hospital settings and whole hospital settings. It also looks at the effectiveness of BCMA on detecting medication errors for warfarin orders and on the working time of oral medication administration.

3.4.1 The effect of BCMA in paediatric hospital settings

Overall, the paediatric studies reflect the positive outcome of BCMA in terms of improving patient safety. Morriss et al. (2009) found that before the implementation of the BCMA system, unadjusted medication errors rates were 69.5/1000 doses and a mean of 0.53 (SD 0.98)/subject/day. The number of unadjusted medication errors increased after the implementation to 79.7/1000 doses and a mean of 0.60 (SD 0.99)/subject/day ($p < 0.001$). The growth in medication errors was associated with a 117% increase in detecting wrong time errors from 1,412 before the BCMA intervention to 3,075 after the intervention. However, more serious medication errors decreased. After the BCMA system was operational, the rates of unadjusted potential ADEs declined from 15.1/1000 doses to 4.4/1000 doses and from a mean of 0.11 (SD 0.47) to a mean 0.033 (SD 0.20)/subject/day ($p < 0.001$). In addition, the targeted, preventable, ADEs reduced significantly from 0.86/1000 doses and a mean of 0.0065 (SD 0.082) ADE/subject/day to 0.43/1000 doses and a mean of 0.0032 (SD 0.060) ADE/subject/day. It was concluded that BCMA technology

reduces targeted and preventable ADEs by 47%. The following table 3.1 summarises these findings.

Table 3.1 Medication errors, potential ADEs and unadjusted, targeted and preventable ADEs

	No BCMA system	BCMA system	p*
Medication errors, total (n)	3204	3690	
(n/1000 doses)	69.5	79.7	
(n/subject/d)	0.53 (0.98)	0.60 (0.99)	
median (IQR) (n/subject/d)	0 (0-1)	0 (0-1)	
< .001			
Potential ADEs, total (n)	694	202	
(n/1000 doses)	15.1	4.4	
(n/subject/d)	0.11 (0.47)	0.033 (0.20)	
median (IQR) (n/subject/d)	0 (0-0)	0 (0-0)	
< .001			
Unadjusted targeted, preventable ADEs, total (n)	39	20	
(n/1000 doses)	0.86	0.43	
(n/subject/)	0.0065 (0.082)	0.0032 (0.060)	
median (IQR) (n/subject/d)	0 (0-0)	0 (0-0)	0.008

Furthermore, Hardmeier et al. (2014) also focused on medication administration errors in paediatric units and concluded that 95% of the observed doses administered were classified as the correct medication administration and 5% were identified as medication administration errors (MAEs). The study found that the most common MAE type was the (1) wrong route, followed by the (2)wrong technique and medication being unavailable, (3) wrong time and (4)error of omission. The process measures compliance with six safety processes compares medication to the eMAR system at least twice, minimises distractions, keeps medications labelled, checks two patient identifiers (IDs), explains drug to patient and documents the record immediately after administration. This was achieved 86% of the time, ranging from 23% to 100%.

Morriss et al. (2011) reported that opioid administration during hospitalisation was associated with preventable ADEs; the odds ratio (the measure of the link between the intervention and the outcomes (Montreuil et al. 2005) for any preventable ADE incidence in a patient treated with an opioid was 4.74 (95% confidence interval [CI], 1.73-12.97) compared with an infant who was not treated with an opioid. After a high odds ratio associated with postoperative and opioid administration was found, a separate stratified analysis was performed to assess the link between opioid administration and the occurrence of a preventable ADE while managing the potential confounding effect of supported ventilation status. Subsequently, the result of this examination revealed a significant outcome (p = 0.0007). However, when opioid administration status defined the strata in a restructured analysis, the supported ventilation was not significantly linked to the occurrence of a preventable ADE (p = 0.3011). This finding is illustrated in the following table 3.2.

Table 3.2 Stratified Associations with Preventable Adverse Drug Events (ADEs) in Neonatal ICU Patients (n = 616)

Stratum	*Opioid Administered?*	*No. (%) Preventable ADEs*	*pa Within Stratum (Opioid vs. No Opioid)*	*pb Overall (Opioid vs. No Opioid*
Postoperative status				
Postoperative		7 (17.5)	0.0316	
Postoperative	Yes (n = 40)	1 (2.6)		
Not postoperative	No (n = 38)		0.0233	
Not postoperative	Yes (n = 32)	4 (12.25)		
All patients	No (n = 506)	20 (4.0)		0.0019c
Ventilation status		32 (36.6)		
Ventilated			0.0283	
Ventilated		8 (13.8)	0.0002	
Not Ventilated	Yes (n = 58)	12 (4.5)		0.0007d
Not Ventilated	No (n = 221)	3 (21.4)		
All patients	Yes (n = 14)	9 (2.8)		
	No (n = 323)			
		32 (43.4)		

a: Mantel-Haenszel chi-square test. b: Cochran-Mantel-Haenszel statistic. c: Controlling for postoperative status. d: Controlling for ventilation status.

Patients who were treated with an opioid in the absence of a BCMA system had a 10% probability of experiencing an ADE after being hospitalised for six days. However, being equipped with a BCMA system can extend the period of ADEs occurring to 13 days because the BCMA system has a significant protective effect in reducing the risk of a preventable ADE by 50%. The following table (Table 3.3) provides more details.

Table 3.3 Proportional Hazards Model for Risk of First Preventable ADE in NICU Patients, Stratified by Opioid Administration and Adjusted for BCMA System and Cumulative Number of Medication Doses Administered (n = 616)

Variable	Hazard Ratio (95% Confidence Interval)	*P*
Opioid administration during Hospitalisation	3.98 (1.88–8.41)	0.0003
Cumulative doses before event	0.997 (0.994–1.000)	0.0310
BCMA system present	0.48 (0.23–0.98)	0.0450

3.4.2 The effect of BCMA in adult ICU hospital settings

The study by DeYoung et al. (2009) found the medication error rate dropped by 56% with the BCMA system. The incidence of medication errors before and after the implementation of the BCMA system was 19.7% (153 of 775) versus 8.7% (60 of 690), respectively ($p < 0.001$). This reduction was associated with the reduction in the rate of wrong time administration errors from 18.8% during pre- implementation to 7.5% post-implementation ($p < 0.001$), with no significant differences in other error types, as shown in the following table. A high level of inter-rater reliability was noted for classifying observations as medication errors ($k = 0.88$). The following table clarifies the frequency of errors by type of medication administration error.

Table 3.4: Frequency of Medication Administration Errors by Drug Class

	No. (%) Errors During All Administrations		
Drug class	Total(n=213)	pre-implementation(n=153)	post implementation (n=60)
Gastrointestinal agent	62(29.1)	39(25.5)	23(38.3)
Cardiovascular agent	35(16.4)	29(19.0)	6(10.0)
Electrolytes or vitamins	22 (10.3)	20(13.0)	2(3.3)
Anticoagulant	17(8.0)	14(9.2)	3(5.0)
Neurologic agent	16(7.5)	12(7.8)	4(6.7)
Antibiotics	14(6.6)	10(6.5)	4(6.7)
Insulins	9(4.2)	9(5.9)	0
Pain relievers or narcotic	3(1.4)	3(2.0)	0

3.4.3 Effect of BCMA in whole hospital settings

Poon et al.'s study suggested that a BCMA system with eMAR has a positive impact on the safety of medication administration. The results of their study revealed a reduction in the rate of medication errors (excluding wrong-time errors) from 11.5% to 6.8%, which is a 41.4% relative risk reduction (RRR) (95% confidence interval [CI] –34.2% to –47.1%; $p< 0.001$). Wrong medication errors were reduced from 1.0% to 0.4% (RRR 57.4%, 95% CI –39.2% to –79.3%; $p < 0.001$) the RRR figure is positive because it measures a reduction (i.e. a change of -57.4%) so is consistent with being within the 95% confidence interval. Also, wrong dose errors reduced from 2.0% to 1.1% (RRR 41.9%, 95% CI –27.9% to –

58.7%; $p < 0.001$), wrong route of administration errors from 0.3% to 0.1% (RRR 68%, 95% CI –37.4% to –97.7%;

p < 0.001) and administration documentation errors reduced from 2.9% to 0.6% (RRR 80.3%, 95% CI –73.7% to –87.0%; p< 0.001). Subsequently, potential ADEs decreased from 3.1% to 1.6% (RRR 50.8%, 95% CI –39.1% to –61.7%; p < 0.001). There were RRRs of
48.5% (95% CI –33.9% to –64%; p < 0.001) and 54.1% (95% CI –36.8% to –
70.4%; p < 0.001) for 'significant' and 'serious' potential ADEs, as decided by a multidisciplinary panel of physicians, nurses and pharmacists. Also, the errors associated with medication administration timing decreased by 27.3%. However, there was no significant reduction in potential ADEs that were classified as life- threatening.

The study by Thompson et al. (2018) revealed a significant reduction of over 17% in the number of medication errors. The mean rate for BCMA related events decreased from 37.25 at baseline to 21.03 reported errors/100,000 administered medications. Thus, the number of errors decreased by 43.5%. Similarly, the rates of events related to harm reduced from a baseline mean of 0.65 reported errors/100,000 administered medications to 0.29 after the BCMA system was introduced.

Seibert et al. (2014) split their findings into three sections. The first concerned medication administration accuracy; the accuracy rate at hospital one changed substantially after implementing the BCMA-eMAR technology from 89% to 90% (p
= 0.0015). Nevertheless, if wrong time errors are excluded, the accuracy rate improved from 92% to 96% (p = 0.000008). However, at hospital two the accuracy rate did not change considerably after the implementation of the BCMA- eMAR system, and when wrong times were excluded, the accuracy rate increased from 93% before BCMA-eMAR implementation to 96% after (p = 0.015).

The second finding concerned the target-error analysis. The results of the target- error analysis in comparing before and after the implementation of the BCMA- eMAR system and the number of target errors at both facilities did decrease for hospital one. This analysis was completed in the emergency department, but the outpatient oncology units were excluded because these were classified as special interest units.

The third finding related to the accuracy rate in special care units. The medication accuracy rate reduced significantly after the implementation of the BCMA-eMAR system in the ICU at hospital two, which resulted in an accuracy rate of 94% and 83%, respectively (p = 0.004). The analysis showed a large increase in technical errors: one before BCMA-eMAR and 13 after. The accuracy rate for hospital one's outpatient oncology unit continued to be steady even when wrong time errors were excluded. The reason for this was because most chemotherapy and support medications are for a single dose and wrong-time errors are not as relevant in this unit as in other practice settings. In the emergency department at hospital one, the accuracy rate increased from 86% to 95% (p = 0.0015). When wrong time errors were excluded, the accuracy rate improved from 87% to 99% (p = 0.000002). In addition, the number of wrong-dose errors reduced from eight to zero after the implementation of BCMA-eMAR technology.

3.4.4 The effect of BCMA in detecting medication errors for warfarin orders

FitzHenry et al. (2011) determined that there were 99 warfarin dose errors that were linked to error alerts. (They indicated that this was clinically meaningful but did not justify this assertion). The alerts' mean ± SD severity rating was low (2.93 ± 1.42) with a standardised Cronbach's coefficient alpha of 0.845. The mean ± SD warfarin dose attempted when the nurse received an alert was 4.10 ± 2.48 mg. It was also found that 70% of the doses with alerts were for patients with an active warfarin order. This shows that there was an unexpected high rate of false-positive alerts, which could result in alert fatigue as well as errors.

3.4.5 The effect of BCMA on the working time of oral medication administration

When considering whether or not to apply the BCMA system, it is worthwhile studying whether it is effective in the workflow. Tasi et al. (2010) found that the working time for oral medication administration reduced from 36.49s to 18.42s. They also found that the majority of nurses (66.7%) felt that the BCMA could reduce their oral drug administration time by 50%, and 93.5% of nurses also thought that the BCMA could enhance patient's oral medication safety and enhance the quality of oral medication. The following table provided in the study of Tsai et al. (2010) presents the results of comparing the average time for oral medication, order transcribing, verifying, administrating and renewals.

Table 3.5 Comparison of the average time for oral medication order transcribing, verifying, administrating and renew(s)

	BCMA group before BCMA after BCMA mean (SD)		Traditional group before and after BCMA mean (SD)	
Order transcription time	24.83 (21.93)	–	50.09 (30.61)	26.75(17.12)
Order verification time	5.42 (2.02)	–	3.72 (1.52)	7.92(10.46)
Giving oral medication time	6.24 (1.87)	18.42 (6.54)	9.08(2.35)	21.40 (6.41)
Subtotal	36.49	18.42	62.89	56.07
Order new time for each patient	259.72(93.85)	_	291.97(114.48)	284.54(168.06)

3.4.6 The effect of BCMA on injection medication

The study by Sakushima et al. (2015) found that the percentage of reported errors that related to the wrong patient and the wrong drug given for drug injections were 13% (208/1550) before BCMA (2003FY-2007FY) and 8% (99/1317) after (2008FY-2011FY). The mean of the wrong patient and drug errors/year (41.6) was reduced by 40% after the implementation of the BCMA system (24.8/year). Wrong patient errors reduced significantly after introducing BCMA (17.4/year vs 4.5 /year, $p<0.05$), even though wrong drug errors did not change significantly (24.2/year vs 20.3 /year, $p=0.33$).

A typical case of bedside error arises when a nurse takes two or more injection drugs for different patients to a multi-patient room and performs bar-code verification at the bedside. When injecting, it is possible that the wrong drug could be picked up and administered. In addition, in the case of preparing the wrong drug, this may occur because some drugs have similar names, such as Veen D®/Veen F® or Amigrand®/Aminofluid®.

3.5 Summary

To summarise, all of the studies confirmed that the Bar Code Medication Administration (BCMA) system has a positive impact on patient safety due to its ability to reduce either the rate of medication administration errors or the occurrence of adverse drug events. In addition, the BCMA technology outperforms the traditional medication administration system in all comparison studies.

However, some studies state that the BCMA did not show a significant change until time-errors were excluded. When the time-errors excluded, they point out a significant improvement. All of these findings are discussed further in the next chapter. The quality of the studies has been assessed using the JBI tool. Amongst all of the included studies, they scored between high and moderate in terms of quality.

Discussion:

4.1 Overview

This chapter will broadly discuss the selected studies, with a particular focus on the results of the review. In addition, the implications and recommendation for future research will be discussed.

Summary of Key Findings

This study contributes to the increasing focus on BCMA technology in policy and research literature. Therefore, this systematic review covers some projects and studies that have analysed BCMA technology, which has been developed to reduce medication errors (Staggers et al., 2015). Medication errors are the most dangerous issue that threatens patient safety, as classified by The Agency for Healthcare Research and Quality (Citty et al., 2017). The findings of this systematic review support the claim that BCMA technology can reduce medication errors and ADEs, which helps in improving patient safety and quality of healthcare, as is highlighted in the selected studies.

4.2 Discussion

This section has three main points of consideration: the effectiveness of observation as a data collection tool, the increase in wrong time medication administration errors, the effect of combining BCMA with eMAR and other systems, costs and staff commitment.

4.2.1 The effectiveness of observation as a data collection tool

Most of the ten studies used direct observational methodology to investigate the impact of BCMA in patient safety. According to the study by Thompson et al. (2018), medication administration errors reports reduced by 43.5%, with harmful medication errors rate reducing from 0.65/100,000 medications before the BMCA intervention to 0.29/100,000 medications after. They also pointed out that these reductions resulted in decrease in patient harm events by 55.4%. This result was similar to that presented by Poon et al. (2010). However, Sakushima et al. (2015) highlighted that the wrong drug errors did not change significantly (24.2/year vs 20.3 /year, $p=0.33$).

There is some question about how effective this methodology is in assessing BCMA effectiveness. For example, as people know that they are being watched, they will take extra care while doing their task, which is known as the Hawthorne effect (McCarney et al. 2007). According to a study about the BCMA and medication errors by Young, Slebodnik and Sands (2010), observation methodology is a limitation for this type of study. However, other researchers suggested that direct observation can be more accurate because unreported mistakes could be picked up as well (Black, 1996; Paoletti et al. 2007; Cronenwett et al. 2007; Flynn et al. 2002; Barker et al. 2002).

The study by Hardmeier et al.(2014) highlighted that this is the first direct observation that has assessed medication administration errors in a paediatric unit since BCMA implementation, and by using this methodology, they identified that the rate of medication administration errors lowered by 5% compared to other studies using other methods for recording medication errors. As a result, they combined observational data with incident reporting. They recommended that both methods should be used to classify medication administration errors. Conversely, Seibert et al. (2014) argued that direct observation is a scientifically effective technique for measuring medication errors because it provides an accurate report about how errors happened and how they can be prevented.

4.2.2 The efficiency of BCMA and the increase in wrong time errors

In Morriss et al.'s study (2011) of adverse drug events in neonates treated with opioids and the effect of a bar-code-assisted medication administration system, they highlighted that the BCMA technology could extend the period of ADEs for patients who treat with opioid medication from six days after hospitalisation to 13 days. This result raises questions, especially in terms of the number of medication errors that cause ADEs, which are considered as a proxy for medication errors.

However, it is important to bear in mind that not all medication errors cause ADEs (Aronson, 2009). Although some silent medication errors do not cause direct ADEs, in the future, silent medication errors are more likely to lead to

ADEs (Bates et al. 1995). Therefore, it is worth looking at the rate of medication errors in order to assess the benefit of the BCMA system.

Most of the included studies were interested in the medication errors related to the 'wrong time'. Siebert et al. pointed out that more medication errors have been identified following the implementation of BCMA because it has detected many wrong time errors. It should be mentioned that there is a lack of clarity in the literature about what constitutes a wrong time error. For example, is it considered an error if its seconds late, five minutes late or 30 minutes late?

Generally, the selected studies have concluded that BCMA technology is effective in reducing medication errors. However, the effectiveness of BCMA technology in wrong time error is not clinically significant (Shah et al. 2016). Interestingly, Seibert et al. (2014), concluded that while the accuracy rate significantly increased in both hospitals after the implementation of BCMA system, it improved more when wrong-time errors were excluded. Therefore, this means that the wrong time errors still occur frequently even with the presence of the BCMA system, which has the ability to prevent these kinds of errors (wrong patient, wrong drug, wrong dose and wrong route). However, this could be because nurses try to juggle many tasks, and they have set priorities, especially in the neonatal ICU, where the study took place. Douglas et al. (2013) made this clear when they analysed the duration and frequency of nursing tasks across a paediatric and adult ICU. Their findings showed that over 75% of ICU nurses' time was spent on patient care tasks, and 50% of this time was spent on direct patient care. Nevertheless, all the results of the included studies did show the BCMA system has the ability to reduce serious and non-timing medication errors. Thus, it seems that BCMA technology does eliminate human factor errors, but it does not prevent all medication administration errors.

4.2.3 The effect of combining BCMA with eMAR and other systems

The BCMA system combining with eMAR led to an effective result, which may be because the electronic medication administration provides a second check of the five medication rights (Jutila 2013). Siebert et al. (2014) analysed the impact of these two compounds together on medication administration accuracy rates.

Their study showed a positive result in terms of the BCMA-eMAR system, improving the accuracy rate of medication administration. Similarly, the experience of a small New England hospital reveals that BCMA technology worked well with other technologies and systems, when they added BCMA technology, after computerised prescriber order entry CPOE, to an established ADD system.

The findings showed that self-reported data provided by nurses showed a significant reduction in total medication errors, from 2.89 errors per 10 000 doses to 1.48 errors per 10,000 doses (Richardson et al. 2012).

4.2.4 BCMA costs and downsides

Despite all these positive results, there are some barriers to applying this kind of system. A study by Kohn et al. (2000) revealed that the preventable ADEs cost hospitals an estimated $2 billion. In 2003, the FDA estimated that the cost of BCMA implementation for 191 hospital beds would be $377,000 with annual maintenance costs of $315,000. But the worldwide spread of BCMA implementation can result in savings of $680 million from $3.9 billion (Cescon and Etchells 2008). BCMA can improve hospital efficiencies and add from $450 million to $720 million to $3.2 billion annual net benefits (Ibid). According to Maviglia et al. (2007), cost analyses focusing exclusively on the pharmacy dispensing processes have drawn the most attention because the BCMA system leads to fewer hospital costs due to preventing ADEs. There are no doubt the BCMA technology costs huge money, but it could save more than it costs.

Nonetheless, the BCMA cannot be effective if the nurses do not abide by it and integrate it into their daily nursing practice. A particularly good example is when St. Luke's Hospital implemented the BCMA system in 2003 to reduce medication administration errors; however, in 2009, the hospital noted a high number of medication errors in paediatric units because the nurses there were not committed to the BCMA system (Jutila 2013). Further research is needed to determine the specific implications of BCMA from this perspective.

Staff need to engage with BCMA for it to be effective, but this is not just with the technology; it also includes the inter-professional communication aspects of the system as well. One of the lessons learned from the implementation of BCMA technology in ICUs is that safe and effective barcode medication administration is not a non-participatory or mutually exclusive process. Clear communication between pharmacy and nursing staff is essential if the BCMA system is to work successfully (Wideman, Whittler and Anderson 2005). This can be seen, for example, when trying to solve an issue linked to pre- and post-surgical IV medication barcodes for coronary artery bypass surgery (CABG) patients. In this instance, it was discovered at a multidisciplinary meeting held with pharmacy, nursing and anaesthesia clinical staff that the anaesthesia team did not recognise the importance of the barcode labels, which had been applied to the outer wraps of the IV bags by the pharmacy staff. Once this issue was raised and resolved, the percentage of CABG patients who were admitted to the ICU after surgery with correctly barcoded IV bag labels rose by a significant degree (Ibid).

There is a limited number of studies discussing BCMA limitations, but one good example is Patterson, Cook and Render (2002)'s study, which identified five side effects of introducing the BCMA system. First, nurses were confused by the automated removal of medications by BCMA. The nurses noticed that the medications which had been automatically removed were, in fact, to be given, and administered to them in due course, but the mere fact that they were taken aback demonstrated that they were shocked that the medication was not displayed in BCMA, as they

had expected, and they pointed out that this design flaw could result in missed medications. The second side effect was the poor coordination between nurses and physicians. One result of replacing the paper medication administration record with the BCMA was that coordination between nurses and physicians started to suffer during observations, which would not have been the case if the paper- based system had been used. Before the BCMA, physicians were able to instantly bring themselves up to date concerning the patient's current medication administration information. Nurses could also quickly access information about pending and discontinued orders by looking at the medication administration record. It was estimated that the paper-based system at another hospital allowed patient medication orders to be scrutinised and assessed three times a week, on average. The third side effect involved nurses dropping activities to reduce their workload during busy periods. For example, the study found that rather than scanning the wristband code, nurses tended to type in at least one patient identification number. Additionally, all the nurses thought that typing in a seven- digit number was quicker than bringing a large medication cart into a room and scanning a wristband. The fourth side effect concerned the increased prioritisation of monitored activities during goal conflicts. Not long after BCMA was introduced, many nurses reported that medication administration was better timed and more of a priority. The final side effect was the decreased ability to deviate from routine sequences. Before the implementation of BCMA, one pharmacist stated that it took less than a minute to verify a taper dose order and to give nursing personnel a free-text note. Once BCMA was in place, the pharmacist had to breakdown a taper dose order into precise daily doses, which translated into 14 new orders, and to discontinue the original order—a process which took some 17 minutes.

In addition, technical issues could also happen, such as a wrong alert with a correct delivered care or barcode label issues, such as smudged barcode labels or ones that have not been updated (Franklin et al. 2007; Higgins et al. 2010). However, despite these negative effects, no study indicates that the BCMA system itself could cause medication errors. Furthermore, most of the previous BCMA limitations can be eliminated by best practice and good training (Wideman et al. 2005).

However, the results of all the included studies included in this review answer the research question by demonstrating the impact of BCMA on improving patient safety in different hospital settings. In addition, all these results reasonably agreed that the BCMA technology applies the 'five rights' of medication administration for inpatients. Compared to the conclusion of one other recent systematic review interested in the effectiveness of the BCMA system with computerised prescriber order entries and automated dispensing devices in patient safety, the findings of this review shows a similar result, which is that BCMA has a positive impact on patient safety by reducing medication administration harm.

4.3 Implications

The BCMA system has a great impact on reducing both medication errors and preventable ADEs, which endanger patient safetyas well as it is time-consuming for nurses as it indicated in a study by Tsai et al. (2010).Moreover, BCMA is cost- effective, which is another reason for hospitals to adopt it. However, BCMA efficiency can be affected by nurses' compliance.

4.3.1 Implications on evidence based practice

According to Melnyk and Fineout-Overholt (2011), evidence-based nursing is when a nursing practitioner uses the best available evidence from appropriate studies, patient values and preferences and use their own clinical expertise to make decisions regarding patient's care. This systematic review will serve as a piece of trustworthy evidence to refer and reform policy and practice on using the BCMA system in nursing practice. Also, the evidence that this review produces can help in revamping the current teaching around using BCMA system.

4.4 Evaluation of the systematic review

4.4.1 Strengths of the review

The strengths of the review lie in the large sample size of the combined studies; for instance, the study by Seibert et al. (2014) used two community hospitals totalling 644 beds, 22,807 annual patients, and the study by Morriss et al. (2009) had 92,398 doses for 958 subjects in neonatal ICUs. According to Schunemannet al. (2013), large sample sizes strengthen the trial. Also, this review followed a systematic review process, subject to a couple of modifications, and, finally, it achieved its aim and objectives.

4.4.2 Limitations of the review

One of the limitations of the studies was that only one person reviewed all papers to determine the quality of the studies. None of the studies was randomised control trials. According to Akobeng (2005), randomised control trials are the most reliable evidence for studying the effectiveness of an intervention. A meta- analysis was unable to be performed for this review, which was another limitation. Moreover, the evolving technology of BCMA technology means that the system used in earlier studies will be different from that used in later studies.

The review could have been improved by researching more studies that evaluated the BCMA system using different sorts of technology or systems. One example is BCMA technology combined with ADDs, as it would have been beneficial to compare the finding of the BCMA system with these other combinations. BCMA technology could also have been studied based on economic evaluations and forecasts. Another limitation is that the review did not evaluate the role of organisational culture in terms of the BCMA system. In addition, including only English studies is another limitation. Therefore, there are some possibilities of bias in this review regarding the positive impact of BCMA. Moreover, only one person reviewed all papers to determine which to include, and there was no independent quality appraisal of papers by two people.

4.5 Recommendations

The primary recommendation of this review for policy and practice is to apply the BCMA system to nursing practice in

hospitals to improve patient safety by reducing medication administration errors. Besides, healthcare staff members need to be educated and need to update their information regarding the BCMA system, as the system keeps updating. For future research, the concluded and analysed data from the selected studies could be used to generate different trends that could provide a more accurate evaluation of the BCMA system and its impact on patient safety. Moreover, future research should focus on the economic impact of using BCMA (for example, through a full cost-benefit analysis incorporating all direct, indirect and intangible costs and benefits). As well, additional studies are needed to determine the specific implications of BCMA for wrong-time types of error. Besides, more research is needed to be investigated and conducted in term of practitioners' commitment to the BCMA system.

4.6 Summary

This chapter discussed the key findings of the review as well as demonstrated that the findings of this review are supported by the wider literature.

Furthermore, it answered the research question and provided some recommendations for future research. Moreover, this chapter evaluated this systematic review by identifying its weaknesses and strengths. The next chapter presents the conclusion of this systematic review.

Conclusion:

This chapter presents the conclusion of the impact of BCMA on patient safety. The review was focused on different types of quantitative study designs, such as cross-sectional, non-randomised, prevalence and cohort designs. Equally, different sample types were included in this study in order to investigate the effect of BCMA.

Several studies were investigated and analysed in order to compare traditional medication administration systems with the BCMA system and its impact on patient harm. Essentially, all of the included studies demonstrated logical and reasonable results about the efficiency of the BCMA system on patient safety. BCMA systems enhance compliance with the five rights of medication administration. Moreover, BCMA reduces medication errors and preventable ADEs. However, although the BCMA system has a significant effect on non-timing medication administration errors, its effect on wrong time medication administration errors are limited. Yet some gaps that can be prevented have been identified. For example, the combination of BCMA-eMAR functions well. Also, although BCMA technology is initially costly, it saves more over time. The result of this systematic review answered the research question.

Acknowledgment:

First, I'd like to thank ALLAH for his endless grace and being able to complete this work with success. I am appreciative to my dissertation supervisor Mr. Philip Clissett for his support and guidance in all phases of this dissertation, and for keeping the opportunity for discussion open until I finished. Thanks to my parents for their ongoing prayers and unwavering support—thank you; it has been inspiring. Even in the hardest times you had, you still supported and encouraged me to continue my studying.

Indeed, I am grateful to the Higher Education Ministry of Saudi Arabia and the Ministry of Health for giving me this opportunity to study in the United Kingdom.

References:

1. AGRAWAL, A. and A .R. GLASSER. 2009. Barcode medication. Administration implementation in an acute care hospital and lessons learned. Journal of Healthcare Information Management, 2009, 23(4), 24-29.
2. AKOBENG, A .K. Understanding randomised controlled trials. Archives of Disease in Childhood, 2005, 90(8), 840-844.
3. ANDEL, C., S. L. DAVIDOW, M. HOLLANDER and D. A. MORENO The economics of health care quality and medical errors. Journal of Health Care Finance, 2012, 39(1), 39.
4. ARONSON, J. K. Medication errors: what they are, how they happen, and how to avoid them. QJM: An International Journal of Medicine, 2009, 102(8), 513-521.
5. AYDIN, C. E., L. B. BOLTON, N. DONALDSON, D. S. BROWN, M. BUFFUM, J. D. ELASHOFF and M. SANDHU. Creating and analyzing a statewide nursing quality measurement database. Journal of Nursing Scholarship, 2004, 36(4), 371-378.
6. BARKER, K. N., E. A. Flynn and G. A. PEPPER. Observation method of detecting medication errors. American Journal of Health-System Pharmacy, 2002, 59(23), 2314-2316.
7. BATES, D. W., D. L. BOYLE, M. B. VANDER VLIET, J. SCHNEIDER and L. LEAPE. Relationship between medication errors and adverse drug events. Journal of general internal medicine, 1995, 10(4), 199-205.
8. BATES, D.W., N. SPELL, D. J. CULLEN, E. BURDICK, N. LAIRD, L. A. PETERSEN, S. D. SMALL, B. J. SWEITZER and L. L. LEAPE. The costs of adverse drug events in hospitalized patients. Jama, 1997, 277(4), 307-311.
9. BATES, D. W. and A. A. GAWANDE. Improving safety with information technology. New England Journal of Medicine, 2003, 348(25), 2526-2534.
10. BECKER, G. Creating comparability among reliability coefficients: The case of Cronbach alpha and Cohen kappa. Psychological Reports, 2000, 87(3_suppl), 1171-1182E
11. BLACK, N., Why we need observational studies to evaluate the effectiveness of health care. BMJ, 1996, 312(7040), 1215-1218.
12. BLACKMAN, N. J. M., and J. J. KOVAL. Interval estimation for Cohen's kappa as a measure of agreement. Statistics in Medicine, 2000, 19(5), 723-741.
13. BROUSSARD, L.. Small size, big risk. Nursing for Women's Health, 2010, 14(5), 405-408.
14. CESCON, D. W., and E. ETCHELLS. Barcoded medication administration: A last line of defense. JAMA, 2008, 299(18), 2200-2202.
15. CHPSO A division of the hospital quality institute. 2014. Why Neither the 'Five Rights' Nor Bar Code Medication Administration Alone Will Prevent Medication Errors. [Online]. [Accessed 2 July 2019]. Available from: https://www.chpso.org/post/neither-five-rights-bar-code-medication- administration-alone-will-prevent-medication-errors.
16. CLANCY, M., and J. FURYK. Paediatric intramuscular injections for developing world settings: A review of the literature for best practices. Journal of Transcultural Nursing, 2012, 23(4), 406-409.
17. CLASSEN, D.C., S. L. PESTOTNIK, R. S. EVANS, J. F. LLOYD and J. P. BURKE. Adverse drug events in hospitalized patients: Excess length of stay, extra costs, and attributable mortality. JAMA, 1997, 277(4), 301-306.
18. CRONENWETT, L. R., J. L. BOOTMAN, J. WOLCOTT and P. ASPDEN, eds. Preventing Medication Errors. National Academies Press, 2007.
19. CUMMINGS, J., P. BUSH, D. SMITH and K. MATUSZEWSKI. Bar-coding medication administration overview and consensus recommendations. American Journal of Health-System Pharmacy, 2005, 62(24), 2626-2629.
20. Department of Veterans Affairs, 2004. Barcode Medication Administration (BCMA) Technical Manual/Security Guide, Version

3.0. VISTA (Veterans Health Information Systems & Technology Architecture) Health Systems Design & Development Documentation Library. Washington, DC: US Department of Veterans Affairs, 1, p.22.

21. DEYOUNG, J.L., M. E. VANDERKOOI and J. F. BARLETTA. Effect of bar-code-assisted medication administration on medication error rates in an adult medical intensive care unit. American Journal of Health-System Pharmacy, 2009, 66(12), pp.1110-1115.
22. DOUGLAS, S., R. CARTMILL, R. BROWN, P. HOONAKKER, J. SLAGLE, K. S. VAN ROY, J. M. WALKER, M. WEINGER, T. WETTERNECK and P. CARAYON. The work of adult and paediatric intensive care unit nurses. Nursing Research, 2013, 62(1), 50.
23. FITZHENRY, F., J. DORAN, B. LOBO, T. M. SULLIVAN, A. POTTS, C. C. FELDOTT, M. E. MATHENY, G. MCCULLOCH, S. DEPPEN and J. DOULIS. Medication-error alerts for warfarin orders detected by a bar-code-assisted medication administration system. American Journal of Health-System Pharmacy, 2011, 68(5), 434-441.
24. FLYNN, E. A., K. N. BARKER, G. A. PEPPER, D. W. BATES and R. L. MIKEAL.Comparison of methods for detecting medication errors in 36 hospitals and skilled-nursing facilities. American Journal of Health-System Pharmacy, 2002, 59(5), 436-446.
25. Fogg, B.J., Marshall, J., Laraki, O., Osipovich, A., Varma, C., Fang, N., Paul, J., Rangnekar, A., Shon, J., Swani, P. and Treinen, M., 2001, March. What makes Web sites credible?: a report on a large quantitative study. In Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 61-68). ACM.
26. FOOD AND DRUG ADMINISTRATION. FDA issues barcode regulation: Fact sheet. Washington, DC: FDA, 2004.
27. FOOTE, S, O., and J. R. COLEMAN. Medication administration: The implementation process of bar-coding for medication administration to enhance medication safety. Nursing Economics, 2008, 26(3), p.207.
28. FRANKLIN, B.D., K. O'GRADY, P. Donyai, A. Jacklin and N. Barber. The impact of a closed-loop electronic prescribing and administration system on prescribing errors, administration errors and staff time: A before-and-after study. BMJ Quality & Safety, 2007, 16(4), 279-284.
29. Gallagher P. Inews.co.uk (2018). NHS medication errors 'playing a role in 22,000 deaths a year'. [online] Available at: https://inews.co.uk/news/health/nhs- medication-errors-thousands-deaths-per- year-342620 [Accessed 20 Sep. 2019].
30. GREENGOLD, N. L., R. SHANE, P. SCHNEIDER, E. FLYNN, J. ELASHOFF, C. L. HOYING, K. BARKER and L. B. BOLTON. The impact of dedicated medication nurses on the medication administration error rate: A randomized controlled trial. Archives of Internal Medicine, 2003, 163(19), 2359-2367.
31. Greenway K. (2014) Rituals in nursing: intramuscular injection, Journal of ClinicalNursing, 23 (23-24): 3583–3588. DOI: 10.1111/jocn.12627.
32. GUMPPER, B. S., M. H. SISKA, B. S. PHARM, J. EVERSON and L. M. MAHANEY. Technology-enabled practice: A vision statement by the ASHP section of pharmacy informatics and technology. Am J Health Syst Pharm, 2009, 66,1573- 77
33. Guyatt, G., A. D. OXMAN, E. A. AKL, R. KUNZ, G. VIST, J. BROZEK, S. Norris, Y. FALCK-YTTER, P. GLASZIOU, H. DEBEER and R. JAESCHKE. GRADE guidelines: 1.
34. Introduction—GRADE evidence profiles and summary of findings tables. Journal of clinical epidemiology, 2011, 64(4), 383-394.
35. HANNEY, S.R., S. CASTLE-CLARKE, J. GRANT, S. GUTHRIE, C. HENSHALL, J. MESTRE-FERRANDIZ, M. PISTOLLATO, A. POLLITT, J. SUSSEX and S. WOODING. How long does biomedical research take? Studying the time taken between biomedical and health research and its translation into products, policy, and practice. Health Research Policy and Systems, 2015, 13(1), p.1.
36. HARDMEIER, A., C. TSOUROUNIS, M. MOORE, W. E. ABBOTT and B. J.GUGLIELMO. Pediatric medication administration errors and workflow following implementation of a bar code medication administration system. Journal for Healthcare Quality, 2014, 36(4), 54-63.
37. HELMONS, P. J., L. N. WARGEL and C. E. DANIELS. Effect of bar-code-assisted medication administration on medication administration errors and accuracy in multiple patient care areas. American Journal of Health-System Pharmacy, 2009, 66(13), 1202-1210.
38. HIGGINS, T., M. HEELON, B. SIANO, L. DOUGLASS, P. LIEBRO, B. SPATH, N. KUDLER and G. KERR. Medication safety improves after implementation of positive patient identification. Applied Clinical Informatics, 2010, 1(3), 213-220.
39. HOLDEN, R. J., A. J. RIVERA-RODRIGUEZ, H. FAYE, M. C. SCANLON and B. T. KARSH. Automation and adaptation: Nurses' problem-solving behavior following the implementation of bar-coded medication administration technology. Cognition, Technology & Work, 2013, 15(3), 283-296.
40. HUNTER J. Intramuscular injection techniques. Nursing Standard, 2008, 22(24): 35-40.
41. Hughes, R.G. and Blegen, M.A., 2008. Medication administration safety. In Patient safety and quality: An evidence-based handbook for nurses. Agency for Healthcare Research and Quality (US). JOHNSON, C .L., R. A. CARLSON, C. L. TUCKER and C WILLETTE. Using BCMA software to improve patient safety in Veterans Administration medical centers. JHIM, 2002, 16(1), 46-51.
42. JONES, S. W. Reducing medication administration errors in nursing practice. Nursing Standard, 2009, 23(50),
43. JUTILA, A., 2013. Optimizing the use of a bar code medication administration system for newborn patients using a lean methodological framework (Doctoral dissertation, The College of St. Scholastica). KARSH, B. T. Beyond usability: Designing effective technology implementation systems to promote patient safety. BMJ Quality & Safety, 2004, 13(5), 388-394.
44. KAUSHAL, R., K. N. BARKER and D. W. BATES. How can information technology improve patient safety and reduce medication errors in children's health care?. Archives of Pediatrics & Adolescent Medicine, 2001, 155(9), 1002-1007.
45. KEOHANE, C. A., A. D. BANE, E. FEATHERSTONE, J. HAYES, S. WOOLF, A.HURLEY, D. W. BATES, T. K. GANDHI and E. G. POON. Quantifying nursing workflow in medication administration. JONA: The Journal of Nursing Administration, 2008, 38(1), 19-26.
46. KIM, C. W., S. J. MYUNG, E. K. EO and Y. CHANG. Improving disclosure of medical error through educational program as a first step toward patient safety. BMC Medical Education, 2017, 17(1), 52.
47. KOHN L. T., J. M. CORRIGAN and M. S. DONALDSON, editors. To err is human: Building a safer health system. A report of the Committee on Quality of Health Care in America, Institute of Medicine. Washington, DC: National Academy Press, 2000.
48. KOPPEL, R., T. WETTERNECK, J. L. TELLES and B. T. KARSH. Workarounds to barcode medication administration systems: Their occurrences, causes, and threats to patient safety. Journal of the American Medical Informatics Association, 2008, 15(4), 408-423.
49. KORHONEN, A., T. HAKULINEN-VIITANEN, V. JYLHÄ and A. HOLOPAINEN. Meta-synthesis and evidence-based health care– a method for systematic review. Scandinavian Journal of Caring Sciences, 2013, 27(4), 1027-1034.
50. KRAINDLER, J., FIRTH, Z. AND CHARLESWORTH, A., 2018. False economy.
51. LEAPE, L. L., D. W. BATES, D. J. CULLEN, J. COOPER, H. J. DEMONACO, T. GALLIVAN, R. J. HALLISEY, J. IVES, N. LAIRD, G. LAFFELAND and R. NEMESKAL. Systems analysis of adverse drug events. JAMA, 1995, 274(1), 35-43.
52. LEWIN, S., C. GLENTON, H. MUNTHE-KAAS, B. CARLSEN, C. J. COLVIN, M. GULMEZOGLU, J. NOYES, A. BOOTH, R. GARSIDE and A. RASHIDIAN. Usingqualitative evidence in decision making for health and social interventions: An approach to assess confidence in findings from qualitative evidence syntheses (GRADE- CERQual). PLOS Medicine, 2015, 12(10), 1-18.
53. MARINI, S. D. AND HASMAN, A., 2009, June. Impact of BCMA on medication errors and patient safety: a summary. In Nursing Informatics (pp. 439-444).
54. MARINI, S. D., A. HASMAN, H. A. S. HUIJER and H. DIMASSI. Nurses' attitudestoward the use of the bar-coding medication

administration system. CIN: Computers, Informatics, Nursing, 2010, 28(2), 112-123.
55. MELNYK, B.M. AND FINEOUT-OVERHOLT, E. EDS., 2011. Evidence-Based Practice In Nursing & Healthcare: A Guide To Best Practice. Lippincott Williams & Wilkins. MAVIGLIA, S.M., J. Y. YOO, C. FRANZ, E. FEATHERSTONE, W. CHURCHILL, D. W. BATES, T. K. GANDHI and E. G. POON. Cost-benefit analysis of a hospital pharmacy bar code solution. Archives of Internal Medicine, 2007, 167(8), 788- 794.
56. MCCARNEY, R., J. WARNER, S. ILIFFE, R. VAN HASELEN, M, GRIFFIN and P. FISHER. The Hawthorne Effect: A randomised, controlled trial. BMC Medical Research Methodology, 2007, 7(1), 30.
57. MELINE, T. Selecting studies for systematic review: Inclusion and exclusion criteria. Contemporary Issues in Communication Science and Disorders, 2006, 33(21-27,
58. MILLS, P. D., J. NEILY, E. MIMS, M. E. BURKHARDT and J. BAGIAN. Improving the
59. bar-coded medication administration system at the Department of Veterans Affairs. American Journal of Health-System Pharmacy, 2006, 63(15), 1442-1447.
60. Montreuil, B., Y. Bendavid and J. Brophy. What is so odd about odds? Canadian Journal of Surgery, 2005, 48(5), 400.
61. MORRISS, Jr, F. H., P. ABRAMOWITZ, S. NELSON, G. MILAVETZ, S. MICHAEL, S. GORDON, J. PENDERGAST and F. COOK. Effectiveness of a barcode medication administration system in reducing preventable adverse drug events in a neonatal intensive care unit: a prospective cohort study. The Journal of Pediatrics,2009, 154(3), 363-368.
62. MORRISS, Jr, F.H., P. ABRAMOWITZ, S. NELSON, G. MILAVETZ, S. MICHAEL, andS. GORDON. Risk of adverse drug events in neonates treated with opioids and the effect of a bar-code-assisted medication administration system. American Journal of Health-System Pharmacy, 2011, 68(1), 57-62.
63. National Health Service (NHS). (2018) Never Events List 2018. [Online] Available: https://improvement.nhs.uk/documents/2266/Never_Events_list_2018_FINAL_v5pdf [Accessed 1/8/19].
64. PAOLETTI, R. D., T. M. SUESS, M. G. LESKO, A. A. FEROLI, J. A. KENNEL, J. M.MAHLER and T. Sauders. Using bar-code technology and medication observation methodology for safer medication administration. American Journal of Health- System Pharmacy, 2007, 64(5), 536-543.
65. PATTERSON, E. S., R. I. COOK and M. L. RENDER. Improving patient safety by identifying side effects from introducing bar coding in medication administration. Journal of the American Medical Informatics Association, 2002, 9(5), 540-553.
66. PATTERSON, E. S., M. L. ROGERS and M. L. RENDER. Fifteen best practice recommendations for bar-code medication administration in the Veterans Health Administration. The Joint Commission Journal on Quality and Safety, 2004, 30(7), 355-365.
67. PATTERSON, E. S., M. L. ROGERS, R. J. CHAPMAN and M. L. RENDER. Compliance with intended use of bar code medication administration in acute and long-term care: An observational study. Human Factors, 2006, 48(1), 15-22
68. RICHARDSON B., B. BROMIRSKI and A. HAYDEN. Implementing a safe and reliable, process for medication administration. Clin Nurse Speec, 2012, 26(3), 169-76.
69. SAKOWSKI, J. A., and A. KETCHEL. The cost of implementing inpatient bar code medication administration. The American Journal of Managed Care, 2013, 19(2), e38-45.
70. SAKUSHIMA, K., R. UMEKI, A. ENDOH, Y. M. ITO and Y. NASUHARA. Time trend of injection drug errors before and after implementation of bar-code verification system. Technology and Health Care, 2015, 23(3), 267-274.
71. SCHÜNEMANN, H., J. BROZEK, G. GUYATT and A. OXMAN. The GRADE handbook. Cochrane Collaboration, 2013.
72. SEIBERT, H. H., R. R. MADDOX, E. A. FLYNN and C. K. WILLIAMS. Effect ofbarcode technology with electronic medication administration record on medication accuracy rates. American Journal of Health-System Pharmacy, 2014, 71(3), 209-218.
73. SHAH, K., C. LO, M. BABICH, N. W. TSAO and N. J. BANSBACK. Bar code medication administration technology: a systematic review of impact on patient safety when used with computerized prescriber order entry and automated dispensing devices. The Canadian Journal of Hospital Pharmacy, 2016, 69(5), 394.
74. STAGGERS, N., S. IRIBARREN, J. W. GUO, and C. WEIR. Evaluation of a BCMA's electronic medication administration record. Western Journal of Nursing Research, 2015, 37(7), 899-921.
75. TAVAKOL, M., M. A. MOHAGHEGHI and R. DENNICK. Assessing the skills of surgical residents using simulation. Journal of Surgical Education, 2008, 65(2), pp.77-83.
76. TAVAKOL, M., and R. DENNICK. Making sense of Cronbach's alpha. InternationalJournal of Medical Education, 2011, 2, p.53.
77. TechTarget. 2014. Bar Coded Medication Administration (BCMA). 2015. [Online]. [Accessed 3 July 2019]. Available from: https://searchhealthit--com.cdn.ampproject.org/c/s/searchhealthit.techtarget.com/definition/Bar-Coded- Medication-Administration?amp=1.
78. THOMPSON, K.M., K. M. SWANSON, D. L. COX, R. B. KIRCHNER, J. J. RUSSELL,
79. R. A. WERMERS, C. B. STORLIE, M. G. JOHNSONAND and J. M. Naessens. Implementation of bar-code medication administration to reduce patient harm. Mayo Clinic Proceedings: Innovations, Quality & Outcomes, 2018, 2(4), 342-351.
80. TIAN, R., B. C. LEE, G. YUCEL, S. R. ABEL, K. E. HULTGREN and V. G. DUFFY.Evaluating bar coding-aided medication administration through identification of nursing work deficiencies. Human Factors and Ergonomics in Manufacturing & Service Industries, 2014, 24(4), 468-478.
81. TSAI, S.L., Y. C. SUN and F. M. TAUR. Comparing the working time between bar- code medication administration system and traditional medication administration system: An observational study. International Journal of Medical
82. Informatics, 2010, 79(10), 681-689.
83. WIDEMAN, M. V., M. E. WHITTLER and T. M. ANDERSON. Barcode medication administration: Lessons learned from an intensive care unit implementation. Rockville MD: Agency for Healthcare Research and Quality, 2005.
84. WILLIAMS, D. J. P.Medication errors. Journal-Royal College of Physicians of Edinburgh, 2007. 37(4), 343.
85. Wittich, C.M., Burkle, C.M. and Lanier, W.L., 2014, August. Medication errors: an overview for clinicians. In Mayo Clinic Proceedings (Vol. 89, No. 8, pp. 1116- 1125). Elsevier.
86. World Health Organization (WHO). (2016) What Is Patient Safety? [Online] Available from: https://www.who.int/patientsafety/education/curriculum/who_mc_topic-1.pdf [Accessed 1/8/19].
87. YOUNG, J., M. SLEBODNIK and L. SANDS. Bar code technology and medication administration error. Journal of Patient Safety, 2010, 6(2), 115-120.
88. YOSHII, A., D. A. PLAUT, K. A. MCGRAW, M. J. ANDERSON and K. E. WELLIK. Analysis of the reporting of search strategies in Cochrane systematic reviews. Journal of the Medical Library Association, 2009, 97(1), 21-29.